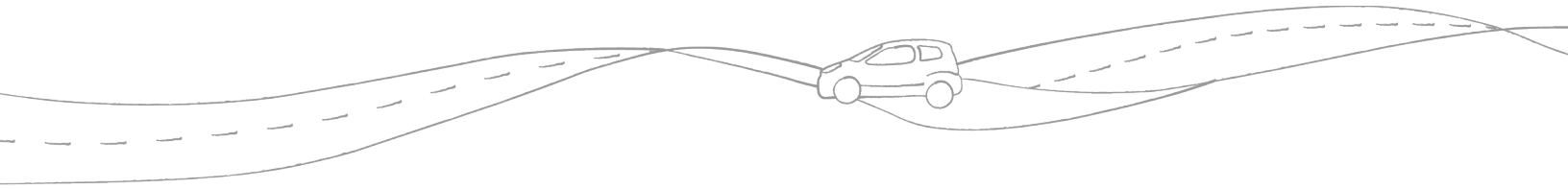

MACKENZIE VALLEY HIGHWAY PROJECT

DEVELOPER'S ASSESSMENT REPORT

Mandate commitment of the 19th Legislative Assembly

October 2023

VOLUME 3

Subjects of Note

Government of
Northwest Territories

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12.0 ASSESSMENT OF POTENTIAL EFFECTS ON AIR QUALITY

Air Quality has been selected as a Valued Component (VC), as it aligns with the Air Quality Subject of Note (SON) in the Terms of Reference (ToR) for the Developer's Assessment Report (DAR; Mackenzie Valley Environmental Impact Review Board [MVEIRB], 2015 [Public Registry {PR}#66]). The assessment of potential effects on air quality is valuable for its importance to the health and well-being of people, wildlife, vegetation, and other ecosystems biota. The assessment of potential effects on air quality considers criteria air contaminants (CAC) and greenhouse gases (GHG).

The CAC assessment considers risks from air contaminant emissions to human health and the environment. The assessed CACs are air pollutants that cause smog, acid rain and other health hazards, and can affect visibility by contributing to ice fog. They are typically products of fossil fuel combustion, and are emitted from many sources in industry, mining, transportation, electricity generation and agriculture. Project activities such as equipment operation, camp operations, borrow source and quarry development, and operations including blasting and crushing, dust control, and road traffic are expected to generate CACs.

The GHG assessment considers risks from air pollutant emissions associated with climate change, which has potential long-term ecological and socio-economic effects. As described by the Intergovernmental Panel on Climate Change (IPCC), GHGs are globally emitted from numerous natural sources, and human activities such as the combusting of fossil fuels (IPCC, 2013). Effects from GHG emissions are expected from the same project components as for CAC emissions, as well as the removal of forested areas, whose presence would remove the carbon dioxide (CO_2) from the atmosphere.

The assessment of potential effects on the Air Quality VC concludes that with the application of mitigation measures, residual effects resulting from the Project on air quality will be adverse. Residual effects and cumulative effects from the Project's GHG emissions are expected to exceed reporting thresholds; however, residual effects and cumulative effects from the Project's CAC emissions are not expected to exceed the Northwest Territories (NWT) 2018 to 2020 average facility CAC emissions. Therefore, residual effects and cumulative effects are predicted to be not significant.

12.1 Scope of Assessment

12.1.1 Regulatory and Policy Setting

The following regulations, programs, and protocols are used to quantify the CAC and GHG emission levels and establish thresholds to determine the effect of the air quality emissions on human health and the environment (especially wildlife and vegetation).

12.1.1.1 Change to Criteria Air Contaminants

The Environment and Climate Change Canada (ECCC) National Pollutant Release Inventory (NPRI) tracks the release of substances to the environment, including their disposal or their transfer for recycling (ECCC, 2022a). The program gives methods to quantify the contaminant emissions and lists threshold levels for each contaminant which, if exceeded, may pose a risk to the environment or to health. The Project's CAC emissions were estimated using the NPRI emission factors.

Although CAC concentration limits exist under different programs, such as the Government of the Northwest Territories (GNWT) Department of Environment and Climate Change (ECC) Guideline for Ambient Air Quality Standards in the Northwest Territories (GNWT, 2014), these limits are receptor-based, whereas NPRI is source-based. As NPRI does not specify source-based limits, the following thresholds are used to determine the potential effects from the Project's CAC emissions:

- NPRI reporting thresholds: The level at which the substances begin to pose a risk to the environment or to health. These reporting thresholds are obtained from the ECCC NPRI website (ECCC, 2022c).
- Average NWT facility emissions: The average facility CAC emissions are the average of each individual facility CAC emissions reported for the NWT for the past 3 years, from 2018 to 2020 (ECCC, 2022d). This gives an indication of where the Project's CAC emission levels stand in comparison to the existing CAC-emitting facilities in the NWT and is a better indicator of the potential effects from the CAC emissions. The rationale is that the Project's CAC emission levels are likely acceptable if they are within the range of the facilities' accepted emission levels existing within the NWT.

Table 12.1 lists the NPRI reporting thresholds for each project CAC emission.

Table 12.1 Criteria Air Contaminant Thresholds from NPRI

Substance	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$
Reporting Thresholds (t/year)	20.00	20.00	20.00	0.50	0.30
Average NWT Facility Emissions 2018 to 2020 (t/year)	176.82	258.55	69.23	24.26	8.75

Notes:
CO = carbon monoxide; NO_x = nitrogen oxide; SO_2 = sulphur dioxide; PM_{10} = coarse particulate matter; $PM_{2.5}$ = fine particulate matter

Dust includes the larger particles and smaller particles of PM_{10} and $PM_{2.5}$, as listed in Table 12.1. Since dust emissions other than PM_{10} and $PM_{2.5}$ are hard to quantify, they will be assessed qualitatively instead using general best-practice mitigation measures for highway projects to verify effects are within acceptable levels.

Ice fog affects visibility and will be assessed qualitatively.

12.1.1.2 Change to Greenhouse Gases

The NWT does not have a program that imposes limits on GHG emissions. Instead, the federal program from ECCC called Greenhouse Gas Reporting Program (GHGRP) will be used as guidance (ECCC, 2021a). Under the GHGRP, facilities that emit 10,000 tonnes of CO_2 equivalent (tCO_2e) per year must report their emissions to ECCC. This threshold will be used to assess the significance of the Project's GHG emissions.

The contribution of project GHG emissions will also be compared to the latest available NWT GHG emission total from the National Inventory Report (NIR), published by ECCC (ECCC, 2020), to quantify its contribution relative to the NWT total emissions.

12.1.1.3 Sahtu Land Use Plan

Specific to the areas to which the Sahtu Land Use Plan (SLUP) applies, the Project must meet the 13 general conformity requirements (CR) of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023). Conformity Requirement #2 requires that *"The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge."* Additionally, CR#14 requires that the Project be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 2023), including the following:

- Petiniʔah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)
- K'ąąlǫ Tué (Willow Lake Wetlands) SMZ (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

12.1.2 Influence of Engagement

The GNWT has engaged with Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapter 2 (Consultation and Engagement), Chapter 3 (Traditional Knowledge), and Chapter 11 (culture and traditional land Use). The GNWT has recently initiated Consultation with Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to air quality. This feedback has been considered and summarized in Table 12.2 and has been integrated into the assessment of potential effects on air quality that follows.

12.1.3 Potential Effects, Pathways, and Measurable Parameters

The potential effects, pathways, and measurable parameters for CACs and GHGs are described.

12.1.3.1 Change to Criteria Air Contaminants

The CACs are divided into the gaseous CACs and particulate CACs, all of which are quantified in tonnes per year. The gaseous CACs associated with the Project are nitrogen dioxide (NO_2), carbon monoxide (CO), and sulphur dioxide (SO_2). As described in Environment and Climate Change Canada's (ECCC) Greenhouse Gas Emissions Reporting Program (ECCC, 2022a), the gaseous CACs are described, along with their associated sources from the Project:

- Sulphur dioxide is formed from the sulphur contained in raw materials such as coal, oil, and metal-containing ores. The SO_2 gas, on its own or in its transformed state, can cause adverse effects on respiratory systems of humans and animals, and damage to vegetation. Sulphur dioxide emissions are expected mainly from blasting activities during the project construction phase.
- Carbon monoxide gas is colourless, odourless, tasteless, and poisonous. It is a product of incomplete combustion of hydrocarbon-based fuels and is emitted directly from automobile tailpipes. Other lesser but significant sources are the wood industry, residential wood heating, and forest fires. The CO gas can have a serious effect on human health. It enters the bloodstream through the lungs and affects the respiratory system. Carbon monoxide emissions are expected mainly from blasting activities during the project construction phase, and from road traffic during the operations and maintenance phase.
- Nitrogen dioxide gas is formed primarily from the liberation of nitrogen contained in fuel and in combustion air during combustion processes. It dissolves in water vapour in the air to form acids and interacts with other gases and particles in the air to form particles known as nitrates and other products that may be harmful to people and their environment. The NO_2 gas, on its own or in its transformed state, can cause adverse effects on respiratory systems of humans and animals, and damage to vegetation. Nitrogen dioxide emissions are expected mainly from heavy truck equipment during the project construction phase and heavy truck traffic during the operations and maintenance phase.

Table 12.2 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
CAC Effects Major habitat changes that have occurred in the Dehcho Region have been due to oil and gas development, introduction of bison, and forest fires, which may cause a disturbance in air quality from the smoke.	Dehcho First Nations, 2011	The GNWT has identified mitigation measures to reduce or eliminate the effects on air quality. Cumulative effects are addressed in Section 12.5.1. The presence of forest fires and dust as existing conditions is addressed in the Technical Data Report (TDR) for Air Quality, Greenhouse Gas and Climate Baseline (see Appendix 12A; K'alo-Stantec, 2022b) and summarized in Section 12.2.2 of this report. Dust and emissions resulting from project activities are addressed in Section 12.4.2. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning.	For mitigation measures to reduce or eliminate effects on air quality, see Table 12.7 See also: Section 12.2.2 (Overview) Section 12.4.2 (Change to Criteria Air Contaminants) Section 12.5.1 (Residual Effects Likely to Interact Cumulatively) Appendix 12A; K'alo-Stantec, 2022b
CAC Effects The community of Wrigley[1], expressed concerns about dust resulting from the project activities and pollution from the road operation.	Dessau, 2012 (Public Registry [PR]#13)		
CAC Effects Engagement participants expressed concerns about dust, including how far it will spread and whether there will be chemicals and carcinogens in the dust; they recommended appropriate dust suppressants and other control measures near water, including major creeks.	November to December 2022 Engagement		

[1] Wrigley (Pehdzéh Kį N'deh), hereafter referred to as Wrigley

Comment	Source	GNWT Response	Where Addressed
<u>GHG Effects</u> The Dehcho Region is reported to be getting warmer and wetter overall, with more rainfall in August and September and even into October.	Dehcho First Nations, 2011	The GNWT has identified mitigation measures to reduce or eliminate the effects on air quality. The historical and predicted change in climate is addressed in the TDR for Air Quality, Greenhouse Gas and Climate Baseline (see Appendix 12A; K'alo-Stantec, 2022b). The effect of climate on fish and wildlife is addressed in the TDR for Fish and Fish Habitat (see Appendix 17A; K'alo-Stantec, 2022c) and the TDR for Wildlife and Wildlife Habitat (see Appendix 19A; K'alo-Stantec, 2022d3), respectively. Food security is considered in Chapter 9 (Socio-Economic Impact Assessment). GHG emissions resulting from the project activities are addressed in Section 12.4.3. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning.	For mitigation measures to reduce or eliminate effects on air quality, see Table 12.7. See also: Section 12.4.3 (Change to Greenhouse Gas) Appendix 12A; K'alo-Stantec, 2022b Appendix 17A; K'alo-Stantec, 2022c Chapter 9 (Socio-economic Impact Assessment)
<u>GHG Effects</u> Community engagement participants from the Sahtu Region expressed concerns about warmer temperatures, thawing permafrost, erosion, slumping, and other environmental changes which negatively affect fish, wildlife, and food security.	November to December 2022 Engagement		

Particulate matter (PM) consists of airborne particles in solid or liquid form. Numerous studies have linked fine PM to aggravated cardiac and respiratory diseases, and to various forms of heart disease. PM can also have adverse effects on vegetation and structures and contributes to visibility deterioration and regional haze. The size of PM particles largely determines the extent of environmental and health damage. For this reason, ECCC identifies different sizes of PM. The PM CACs relevant to the Project are dust (total particulate matter or TPM), coarse particulate matter (PM_{10}), and fine particulate matter ($PM_{2.5}$). Each are described (ECCC, 2022b).

- Dust: Composed of solid particles that are present in the atmosphere and includes the larger particles (Total Suspended Particulate [TSP] or TPM) and smaller particles of PM_{10} and $PM_{2.5}$. The larger particles (TSP or TPM), with an upper size limit of approximately 100 micrometres (µm) in aerodynamic equivalent diameter, do not have the ability to penetrate to the lungs to potentially cause adverse health effects because they are captured in the oral and nasal passages. The TSP and TPM are most closely associated with concerns related to aesthetics and can be a source of nuisance (BC ENV, 2020). Note that since dust emissions other than PM_{10} and $PM_{2.5}$ are hard to quantify, they will be assessed qualitatively. Thus, dust in this report refers to the TSP and TPM only. Dust emissions from the Project are expected mainly from mobile equipment activities and blasting activities. Dust emissions are not expected to be a concern during winter because the frozen ground and snow cover during winter act as natural dust suppression.
- PM_{10}: Airborne particulate matter with a mass median diameter less than 10 µm. It is associated with dust and can be a nuisance. PM_{10} emissions are expected mainly from blasting activities during the project construction phase and road traffic during the operations and maintenance phase.
- $PM_{2.5}$: Airborne particulate matter with a mass median diameter less than 2.5 µm. It is known to have harmful effects on human health and the environment and contribute to visibility impairment and regional haze. $PM_{2.5}$ emissions are expected mainly from truck traffic during the project construction phase and operations and maintenance phase.

The CACs excluded from the assessment are listed along with the reason for their exclusion:

- Volatile Organic Compounds (VOCs): Chemical compounds whose composition makes it possible for them to evaporate under normal atmospheric conditions. They are produced by fossil fuel use and production, and the use of indoor products like solvents. Although they are part of the CAC list in the NPRI as detailed in Section 12.1.1.1, they are not part of the Northwest Territories (NWT) ambient air quality standards (GNWT, 2014) and the Project is not expected to generate substantial amounts of VOCs.

Like dust, fog may affect visibility. Ice fog forms in calm conditions when there is excess moisture in the air and conditions are cold enough for moisture to freeze; this is aggravated by local emission sources such as idling vehicles (IOL et al., 2004). Potential sources that increase fog are construction vehicles and road traffic.

Table 12.3 summarizes the effect parameters for the change to CACs.

Table 12.3 Potential Effects, Effects Pathways and Measurable Parameters for Air Quality and Greenhouse Gases

Potential Environmental Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change to CACs	Atmospheric release of air emissions from project equipment and activities during construction and operations and maintenance	• Emissions of gaseous CACs (NO_2, CO, and SO_2) in tonnes per year • Emissions of particulate CAC (PM_{10} and $PM_{2.5}$) in tonnes per year • Emissions of dust as a qualitative assessment • Emissions of ice fog as a qualitative assessment
Change to GHGs	Release of GHG emissions to the atmosphere from project equipment and activities during construction and operations and maintenance	• GHG emissions (CO_2, CH_4, and N_2O) in tCO_2e per year

12.1.3.2 Change to Greenhouse Gases

The GHGs associated with the Project are CO_2, methane (CH_4), and nitrous oxide (N_2O), all of which are quantified in tCO_2e per year. Each GHG is described below and further in (IPCC, 2013):

- Carbon dioxide is a naturally occurring gas and a by-product of burning fossil fuels from fossil carbon deposits (such as oil, gas, and coal), of burning biomass, of land use changes, and of industrial processes (e.g., cement production).
- Methane is the major component of natural gas and associated with all hydrocarbon fuels, animal husbandry, and agriculture.
- Nitrous oxide is naturally produced from a wide variety of biological sources in soil and water, particularly microbial action in wet tropical forests. There are many anthropogenic sources of N_2O, however the most abundant source is agriculture (e.g., soil and animal manure management). Other common sources of N_2O include sewage treatment, combustion of fossil fuel, and chemical and industrial processes.

Greenhouse gas emissions are expected mainly from heavy truck equipment during the project construction phase, and road traffic during the project operations and maintenance phase. The removal of forested area will also result in the effect of reduction of CO_2.

The GHGs excluded from the assessment are listed along with the reason for their exclusion:

- Sulphur hexafluoride (SF_6): This gas can be found in insulating gas used in electrical switch breakers. If the Project does use a SF_6 breaker, they are closed cycle and do not escape into the atmosphere. Therefore, the SF_6 gas is not expected to be released by the Project.

- Nitrogen trifluoride (NF_3): This gas is used in industrial processes related to semiconductors and liquid-crystal display panels. It also occurs in certain types of solar panels and chemical lasers. The NF_3 gas is not expected to be used or released by the Project.
- Hydrofluorocarbon (HFC) and Perfluorocarbon (PFC): These groups of gases are typically used as refrigerants in various applications. If the Project does use these gases, the systems would be designed so that there are no releases of these gases to the atmosphere. Therefore, HFCs and PFCs were not included in this assessment.

Table 12.3 summarizes the effect parameters for the change to GHGs.

12.1.4 Boundaries

The spatial and temporal boundaries for the CAC effect and the GHG effect are presented.

12.1.4.1 Spatial Boundaries

The spatial boundaries are described for the CAC effect and the GHG effect.

- **Project Development Area (PDA):** The area of direct project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 metres (m) wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sources with access roads on a 30 m ROW.
- **Local Assessment Area (LAA)**: The area within which measurable project-related effects (direct or indirect) are expected to occur. For the CAC effect the LAA is approximately a 1-kilometre (km) buffer around the PDA. This distance, estimated from professional experience, represents the distance at which the CACs emitted from construction and transportation sources disperse or settle. This is explained by the fact that construction and transportation sources are mostly mobile, intermittent, and the emissions intensity is relatively low compared to large stationary sources such as municipal or industrial diesel power plants. According to the United States Environmental Protection Agency (US EPA), dust particles are likely to settle within a few hundred feet (tens of metres) from the road (US EPA, 1995). For the GHG effect, since the effect affects the world climate independent of distance, the LAA does not apply.
- **Regional Assessment Area (RAA)**: The area that provides context for determining the significance of project effects and potential cumulative effects. The Project is located within the Dehcho Region (Dehcho) and Tulita District of the Sahtu Region. For the CAC effect, the RAA for the assessment of CAC effects was set as approximately a 15 km buffer around the PDA. This distance, estimated from professional experience, represents the distance at which the CACs emitted from large stationary sources may disperse or settle to baseline values. Physical activities located beyond the 15 km buffer are not expected to interact with project residual CAC effects due to air dispersion over distance. As cumulative effect of GHG emissions affects the world climate independent of distance, the RAA does not apply for the GHG effect.

Figure 12.1 shows a map of the Project's air quality LAA and RAA. The yellow squares in Figure 12.1 are the facilities within the air quality LAA and RAA that reported emission to the ECCC NPRI system during 2018 to 2020. These facilities are further discussed in Section 12.2.2.

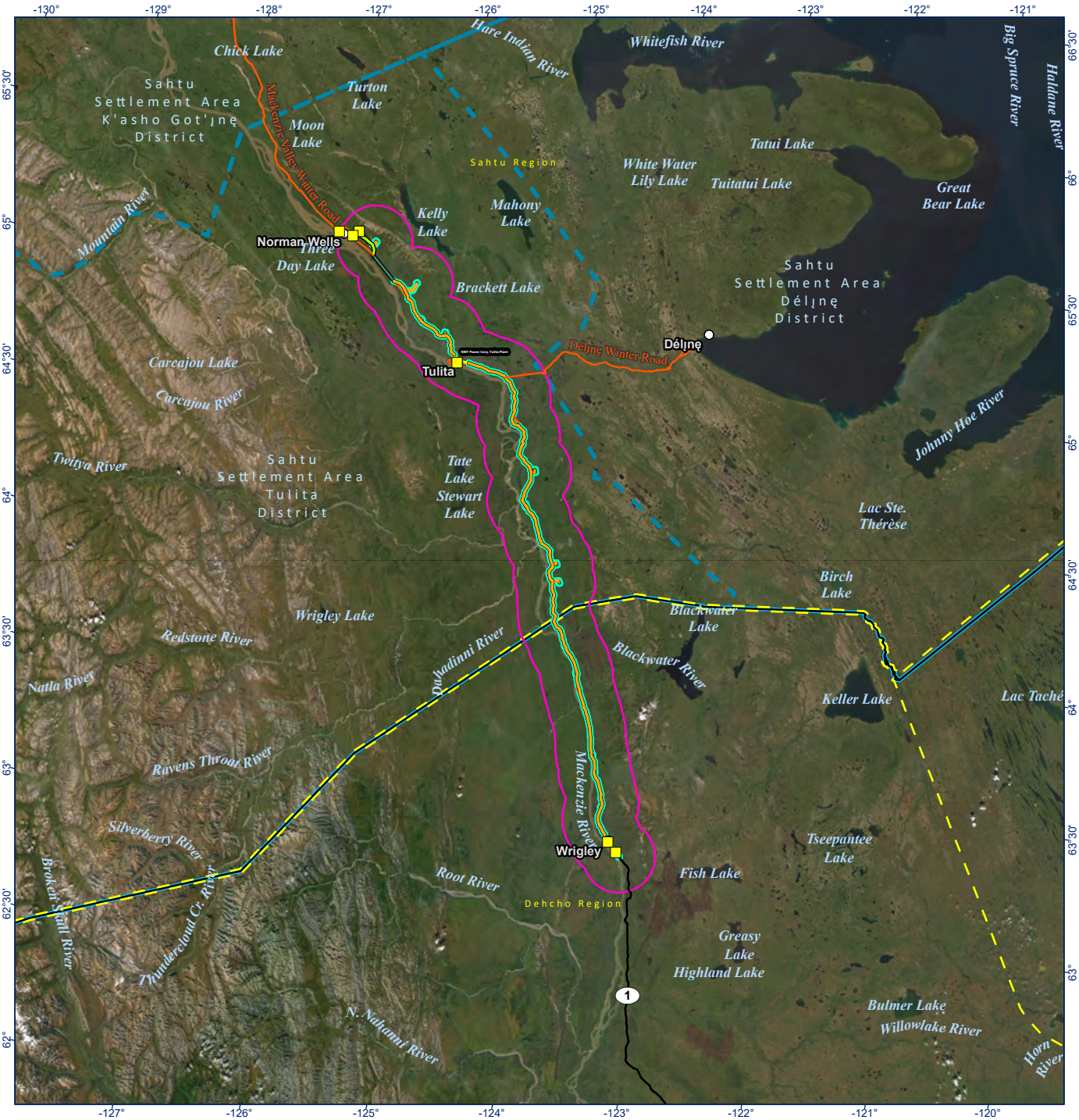
12.1.4.2 Temporal Boundaries

Since the assessment is based on yearly emissions and the project phases occur in separate years, the project activities have been separated into mobilization and demobilization activities of the construction phase, road construction activities of the construction phase, and the operations and maintenance phase.

- Construction phase:
  - The Project will take approximately 10 years to construct over a timeframe of up to 20 years. The conceptual schedule assumes the highway will be constructed in three consecutive segments, beginning in approximately 2026: Wrigley to the Dehcho–Sahtu border (102 km); Tulita[2] south to the Dehcho–Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells[3] sometime between 2041 and 2046.
  - Within the construction phase, mobilization and demobilization activities occur during the summer and/or winter season. The mobilization occurs prior to each of the three construction segments and the demobilization occurs at the end of each segment. The mobilization and demobilization activities are expected to have similar effects. Each segment is expected to take three to four years to construct, with approximately 300 workdays per year.
- Operations and maintenance phase: The operations and maintenance phase will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the highway is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, and borrow sources and quarries used only for construction are included within the construction phase.

[2] Tulita (Tulít'a), hereafter referred to as Tulita
[3] Norman Wells (Tłegǫ̀hłı), hereafter referred to as Norman Wells



- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Local Assessment Area
- Regional Assessment Area
- Community
- Existing Facility (within Regional Assessment Area)
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 25 50 Kilometres

(At original document size of 8.5x11)
1:2,500,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AJ on 8/2/2023
TR by CES on 8/2/2023

Client/Project
144903025-0113 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
12.1

Title
Air Quality Assessment Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS. Imagery date: 2021

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

12.1.5 Residual Effects Characterization

Air quality effects are assessed using the following characterizations: direction, magnitude, geographic extent, timing, duration, frequency, and reversibility. Each characterization is described, along with their respective possible outcome, in Table 12.4 and Table 12.5 for CAC and GHG, respectively.

The main characterization to determine significance is the magnitude of CAC and GHG emissions. Significance is further described in Section 12.1.6.

Table 12.4 Characterization of Residual Effects on Criteria Air Contaminants

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse –** a residual effect that moves measurable parameters of ambient air in a negative direction relative to baseline **Neutral –** no net change in measurable parameters for the air quality relative to baseline
Likelihood	The probability that the residual effect will occur	**Unlikely** – the residual effect is almost certainly not to occur **Possible** – the residual effect could occur **Certain –** the residual effect will certainly occur
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**No Measurable Change –** no measurable change in any of the CAC can be noted **Low –** measurable change in at least one CAC that is less than the NPRI reporting thresholds[1] and the 2018 to 2020 average facility emissions for the NWT[2] **Moderate –** measurable change in at least one CAC that exceeds the NPRI reporting thresholds but that is less than the NPRI 2018 to 2020 average facility emissions for the NWT **High –** measurable change in at least one CAC that exceeds both the NPRI reporting thresholds and the NPRI 2018 to 2020 average facility emissions for the NWT
Geographic Extent	The geographic area in which a residual effect occurs	**PDA –** residual effects are restricted to the PDA **LAA –** residual effects extend into the LAA **RAA –** residual effects interact with those of other projects in the RAA **Not Applicable** - the geographic extents do not apply to the residual effects

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Timing	Considers when the residual effect is expected to occur, where relevant to the VC.	**No sensitivity**– residual effect is unlikely to be influenced by seasonal aspects or time of day **Sensitive** – residual effect may be influenced by seasonal aspects or time of day
Duration	The time required until the measurable parameter or the VC returns to its existing condition, or the residual effect can no longer be measured	**Short-term –** the residual effect lasts 5 years or less, which approximately corresponds to the construction period for each highway segment **Long-term –** the residual effect lasts more than 5 years
Frequency	Identifies how often the residual effect occurs and how often during the Project or in a specific phase	**Single event –** residual effect occurs once **Multiple irregular event –** residual effect occurs at no set schedule **Multiple regular event –** residual effect occurs at regular intervals **Continuous –** residual effect occurs continuously
Reversibility	Pertains to whether a measurable parameter or the VC can return to its existing condition after the project activity ceases	**Reversible –** the residual effect is likely to be reversed after activity completion and reclamation **Irreversible –** the residual effect is unlikely to be reversed

Notes:

[1] The NPRI reporting thresholds are the level at which the substances begin to pose a risk to the environment or to health. See Section 12.1.1.1 for details.

[2] The average facility emissions for each CAC is obtained from the average of each individual facility reported for the NWT for the past 3 years, from 2018 to 2020. See Section 12.1.1.1 for details.

Table 12.5 Characterization of Residual Effects on Greenhouse Gases

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse –** a net increase in measurable parameters for the GHG emissions relative to baseline **Neutral –** no net change in measurable parameters for the GHG emissions relative to baseline
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**No Measurable Change –** no measurable change in GHG over the baseline **Low –** the Project's annual emissions are below 10,000 tCO_2e annually[1] **High –** the Project's annual emissions are above 10,000 tCO_2e annually
Geographic Extent	The geographic area in which a residual effect occurs	**PDA –** residual effects are restricted to the PDA **LAA –** residual effects extend into the LAA **RAA –** residual effects interact with those of other projects in the RAA
Timing	Considers when the residual effect is expected to occur, where relevant to the VC.	**Not Applicable** – residual effect is unlikely to be influenced by seasonal aspects or time of day **Applicable** – residual effect may be influenced by seasonal aspects or time of day
Duration	The time required until the measurable parameter or the VC returns to its existing condition, or the residual effect can no longer be measured	**Short-term –** the residual effect lasts 5 years or less, which approximately corresponds to the construction period for each highway segment **Long-term –** the residual effect lasts more than 5 years
Frequency	Identifies how often the residual effect occurs and how often during the Project or in a specific phase	**Single event** – residual effect occurs once **Multiple irregular event –** residual effect occurs at no set schedule **Multiple regular event –** residual effect occurs at regular intervals **Continuous –** residual effect occurs continuously
Reversibility	Pertains to whether a measurable parameter or the VC can return to its existing condition after the project activity ceases	**Reversible –** the residual effect is likely to be reversed after activity completion and reclamation **Irreversible –** the residual effect is unlikely to be reversed

Note:

[1] The 10,000 tCO_2e is the reporting threshold for the federal GHGRP under Section 46 of the *Canadian Environmental Protection Act* (CEPA).

12.1.6 Significance Definition

12.1.6.1 Change to Criteria Air Contaminants

The NPRI program, under which air emissions are source-based and not receptor-based, does not have specific thresholds or standards that could be used to determine significance when assessing the residual effects of the Project's CAC emissions. The report threshold is a good indicator of the magnitude of the potential effect, although it is not sufficient on its own to define a significant adverse effect, because the pathways and receptors also have to be considered.

Even though the pathways and receptors are not included, the Project's CAC emission levels are likely not significant if they are less than the 2018 to 2020 average of the facilities' accepted emission levels existing within the NWT.

Therefore, a significant adverse residual effect for CAC is one where the Project's CAC emissions are predicted to exceed the NWT 2018 to 2020 average facility CAC emissions, as described in Section 12.1.1.1.

12.1.6.2 Change to Greenhouse Gases

Territorial and federal policies and regulations do not identify specific thresholds or standards that could be used to determine significance when assessing the residual effects of the Project's GHG emissions. However, the federal GHGRP (ECCC, 2021a) has a minimum reporting threshold of 10,000 tCO_2e for annual emissions reporting. Therefore, a significant adverse residual effect for GHG is one where the Project's GHG emissions are predicted to exceed 10,000 tCO_2e per year.

12.2 Existing Conditions for Air Quality

The following sections summarize the baseline conditions for CAC emissions and GHG emissions as based on the TDR for Air Quality, Greenhouse Gas and Climate Baseline (Appendix 12A; K'alo-Stantec, 2022b).

12.2.1 Methods

The assessment considered the Traditional Knowledge, TLRU information, and community engagement feedback available from Indigenous Governments, Indigenous Organizations, and other affected parties. This included both project-specific TLRU studies and studies completed for previous projects. Following a review of each information source, air quality information was identified in the following reports and sources:

- Pehdzéh Kį N'deh Area (IMG-Golder Corporation, 2006)
- Dehcho Region (Dehcho First Nations, 2011; Dessau, 2012 [PR#13])
- Sahtu Region (McDonald, 2010; 5658 NWT Ltd. and GNWT, 2011 [PR#16]; Golder, 2015)
- Project-specific engagement program (2021-2023)

Other TLRU information did not report air quality related information.

The latest (2019 to 2021) existing conditions have been retrieved from publicly available data and reports from the following territorial and federal sources:

- ECCC National Air Pollution Surveillance (NAPS) Program: To obtain the CAC concentrations measured at stations near the project location, Norman Wells (Tłegǫ̀hłı̨), hereafter referred to as Norman Wells, and Fort Smith
- The GNWT-ECC and Canadian Council of Ministers of the Environment (CCME): To obtain the CAC concentration thresholds
- ECCC NPRI: To obtain the CAC emissions from NWT industrial sources
- ECCC NIR: To obtain the GHG emission levels from NWT industries

12.2.2 Overview

Based on feedback received through the community engagement program, TLRU studies, and Traditional Knowledge, these general concerns were expressed:

- Community engagement participants from the Sahtu Region expressed concerns about warmer temperatures, thawing permafrost, erosion, slumping, and other environmental changes which negatively affect fish, wildlife, and food security.
- Recent changes in climate include warmer temperatures, rain and freezing rain increase, and stronger winds. The Dehcho Region is reported to be getting warmer and wetter overall, with more rainfall in August and September and even into October (Dehcho First Nations, 2011).
- Increasing extremes may negatively affect the caribou.
- The community of Wrigley expressed concerns about dust resulting from the project activities and pollution from the road operation (Dessau, 2012 [PR#13]).

Based on the latest data from the air quality monitoring programs, the baseline case includes the following conditions in the Regional Study Area (RSA), as reported in Appendix 12A (K'alo-Stantec, 2022b):

- CAC concentrations in the RSA: All measured air contaminants, except the PM_{10} concentrations, are well below the applicable territorial and federal thresholds. The PM sources near the Norman Wells station include forest fire smoke as well as dust/sand from gravel and sand roads, which are exposed after being snow-covered during the winter months. There may also be sources of CAC emissions local to Norman Wells that were recorded during 2019.

- Existing CAC emissions from the NWT industries and municipal activities: There are no major industrial sources of air contaminants in the RSA, as confirmed by the latest available online NPRI inventory. There are, however, smaller industrial and municipal facilities in the RSA that release CAC emissions. As shown in Figure 12.1 (yellow squares), the nearest reporting municipal facilities to the project location are the Northwest Territories Power Corporation generating stations in Norman Wells, Tulita, and Wrigley. The nearest reporting industrial facilities are Enbridge Pipeline stations (near Norman Wells and Wrigley) and Imperial Oil Resources facility (near Norman Wells). Besides these industrial and municipal sources, other emission sources in the RSA include aviation, community activities (such as traffic and space heating), and natural sources such as regional wildfires that occur mainly during the summer months.
- Existing visibility conditions in the RSA: Atmospheric visibility can be affected by precipitation, fog, haze, or other suspended particles in the air such as snow, dust, or smoke from wildfires. High visibility (more than 9 km) occurs approximately 90% of year, predominantly during the summer months; and low visibility (less than 1 km) occurs approximately 1% of the year, mainly during the fall months.
- Existing GHG emissions in NWT: Emissions in NWT account for a small portion (about 0.2%) of the federal total. Changes in yearly emissions are mostly due to factors such as increasing or decreasing use of off-road diesel engines for large construction projects or the utilization of aviation fuel for mining exploration and fighting wildfires. Despite the NWT's low total GHG emissions, the emissions on a per capita basis are well above the national average. This is mainly due to a low population, long distances between communities, energy-intensive resource industry, and heating required during the long, cold winters.

12.3 Project Interactions with Air Quality

The assumed schedule of activities in the construction phase (which includes the mobilization activities, road construction activities, and demobilization activities) and operations and maintenance phase used in the assessment is summarized in Table 12.6. Emissions associated with multiple project activities include CAC and GHG emissions.

Generally, gaseous CAC emissions and $PM_{2.5}$ emissions are associated with combustion sources. In the Project, these include activities from construction equipment, maintenance vehicles, transportation equipment, road traffic vehicles, and camp facilities.

Table 12.6 Project-Environment Interactions with Air Quality

Physical Activities	Timing	Environmental Effects	
		Change to CAC	Change to GHG
Construction Phase			
Mobilization and demobilization activity			
Mobilization of equipment, materials, and fuel, resupply, and demobilization	Summer and winter	✓	✓
Construction activities			
Establishment and operation of camps	Year-round	✓	✓
Site preparation of ROW, access, and workspaces	Winter	✓	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	✓	✓
Material haul	Year-round	✓	✓
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓	✓
Culvert installations	Summer or winter	✓	✓
Road base placement, compaction, and surfacing	Summer	✓	✓
Water withdrawal to support construction activities	Year-round	✓	✓
Closure and reclamation of Mackenzie Valley Winter Road (MVWR) and temporary borrow sources/ quarries, camps, and workspaces	Summer	✓	✓
Employment and contracted goods and services[1]	Year-round	–	–
Operations and Maintenance Phase			
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	✓	✓
Material haul and stockpiling	Summer	✓	✓
Operation of, and activities at, maintenance yards	Year-round	✓	✓
Water withdrawal for dust control	Summer	✓	✓
Employment and contracted goods and services[1]	Year-round	–	–
Presence and use of the highway	Year-round	✓	✓
Highway and access road maintenance including snow clearing, repair, grading, dust control	Year-round	✓	✓
Vegetation control	Summer	✓	✓
Bridge and culvert maintenance	As needed	✓	✓

Notes:

✓ = Potential interaction

– = No interaction

[1] Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, "Employment and contracted good and services" have been introduced as an additional component under each project phase.

Particulate CAC emissions such as dust, PM_{10}, and $PM_{2.5}$ to a lesser extent, are associated with mechanical disturbance of rock and dirt surfaces, where the latter are commonly referred to as fugitive dust sources because they are not discharged to the environment in a combined flow stream through a stack or vent. In the Project, this includes sources from activities performed on the highway, on the access roads, and at the quarry/borrow source.

Project GHG emissions are associated with combustion sources, chemical processes, and indirectly by the removal of carbon sinks, which include the same activities listed for the gaseous CAC and $PM_{2.5}$ emissions, plus the removal of carbon sinks associated with clearing of forest for the highway and access roads ROWs and borrow sources and quarries.

12.4 Assessment of Residual Effects on Air Quality

Based on project interactions with the environment identified in Table 12.3, the Project may affect air quality. Potential effects, effect pathways, and mitigation measures that will reduce or eliminate the effects on air quality are summarized in Table 12.7. The mitigation measures are further described in the Section 12.4.2.2.

Table 12.7 Potential Effects and Mitigation Measures for Air Quality

Effect Name	Effect Pathway	Mitigation Measures
Change to CACs	• Release of CAC emissions to the atmosphere from project equipment and activities during the construction phase	• A dust control program will be implemented during construction, operations and maintenance. Where applicable, dust suppression will follow the GNWT Guideline for Dust Suppression. • Details of management and operation of incinerators will be included in the Waste Management Plan (WMP); see Volume 5. • Incinerators, if intended to be used by the contractor, will be operated in accordance with manufacturer's specifications and emissions will meet Canadian Council of Ministers of the Environment Canada Wide Standards for Dioxins & Furans and Mercury. • Vehicles and equipment will be maintained regularly. • Equipment idling will be discouraged or limited. • Vehicle speeds will be limited to 50 kilometres per hour (km/h) on unfinished project road surfaces. • Cold starts of equipment will be limited to the extent possible. • Efficient project planning will be used to reduce haul distances and the number of trips required to move road construction materials.

Effect Name	Effect Pathway	Mitigation Measures
Change to CACs (cont'd)		• Road surfaces will be repaired and maintained to reduce rolling resistance of vehicles. • The contractor will be encouraged to use passenger vehicles (e.g., passenger van or bus) to move crews. • Blast mats will be used when blasting near receptors sensitive to noise.
	• Release of CAC emissions to the atmosphere from project equipment and activities during the operations and maintenance phase	• A dust control program using water will be implemented during construction and operations and maintenance. • Dust suppression will be conducted as necessary to reduce dust and sediment from entering watercourses or waterbodies. • Where applicable, dust suppression will follow the GNWT Guideline for Dust Suppression. Vehicles and equipment will be maintained regularly. • Equipment idling will be discouraged or limited. • Vehicle speeds will be limited to 50 km/h on unfinished project road surfaces. • Cold starts of equipment will be limited to the extent possible.
Change to GHGs	• Release of GHG emissions to the atmosphere from project equipment and activities during the construction phase	The mitigation measures are the same as the ones listed for the incinerator and construction equipment, with the following additional measures: • The contractor will be encouraged to use modern construction equipment that has lower GHG emissions. • The area of direct ground disturbance will be limited by following the pre-existing MVWR road alignment to the extent possible. • The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical. • Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the ROW and approved access roads). • Closure and reclamation will promote natural re-establishment of vegetation. • Temporary access roads, quarries and workspaces not needed after construction will be closed and reclaimed.

Effect Name	Effect Pathway	Mitigation Measures
Change to GHGs	• Release of GHG emissions to the atmosphere from project equipment and activities during the operations and maintenance phase	The mitigation measures are the same as the ones listed for the incinerator, with the following additional measures: • The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical. • Closure and reclamation will promote natural re-establishment of vegetation. • Temporary access roads, quarries and workspaces not needed after construction will be closed and reclaimed.

12.4.1 Analytical Assessment Techniques

The CAC emissions were assessed quantitatively with the exception of dust emissions, which were assessed qualitatively. The GHG emissions were assessed quantitatively.

The CAC emission factors were obtained from the following programs and previous projects:

- ECCC NPRI Calculation Guidance (ECCC, 2022e)
- US EPA AP-42: Compilation of Air Emissions Factors (US EPA, 2022)
- Australian Government – Department of Agriculture, Water and the Environment: National Pollutant Inventory (NPI) – Emission estimation technique (EET) manuals (NPI, 2022)

Factors relevant to GHG emissions were obtained from the following programs and publicly available reports:

- ECCC National Inventory Report 1990-2019: Greenhouse Gas Sources and Sinks in Canada (ECCC, 2019)
- National Research Council of Canada (NRC) Research Press – Carbon in Canada's boreal forest — A synthesis (Kurtz et al., 2013)
- Rescan Environmental Services report: Application for an Environmental Assessment Certificate / Environmental Impact Statement for the KSM Gold/Copper Project (Rescan, 2013); to estimate the blasting emission factor
- Dyno Nobel- Blasting and Explosives - Quick Reference Guide 2010 (Dyno Nobel, 2010); to estimate the blasting powder factor

There are no specific NWT CAC emission factors; therefore, emission factors from guidance from ECCC, US EPA, and the Australian Government were used.

The methods followed to calculate the GHG emissions were the accounting and reporting principles of the GHG Protocol developed by the World Resource Institute (WRI) and the World Business Council for Sustainable Development (WRI, 2015). This protocol is an internationally accepted accounting and reporting standard for quantifying and reporting GHG emissions.

Since the assessment is based on yearly emissions and the project phases occur in separate years, the project activities have been separated in phases as described in Section 12.1.4.2.

The air quality emissions were quantified for each project activity for each phase and summed up for the period of one calendar year. The total yearly emissions for each phase were compared against the thresholds described in Section 12.1.1.

Mitigation measures are designed to reduce the emission levels below the thresholds, as practically and economically feasible.

12.4.2 Change to Criteria Air Contaminants

The potential effects of the Project on CAC emissions are discussed.

12.4.2.1 Effects Pathways

The CAC emissions from the various project activities are released to the atmosphere and increase the concentrations in ambient air. The atmospheric conditions at the time of the release of the CAC emissions determine how they are dispersed in the ambient air. The Project's CAC emissions were calculated for the following activities during the various project phases. The information comes from Chapter 5. The assumptions come from construction literature (FHWA, 2006), a Climate Lens Assessment report done for the Project (Appendix 24A; K'alo-Stantec, 2021), and professional experience.

Construction phase

- Construction mobilization and demobilization:
  - Trucks: up to 500 trucks during one year
  - Barges: up to 10 barges during one year
- Road construction equipment:
  - Excavators: up to 2 units on a single day, assumed to operate 40% of the daytime
  - Bulldozers: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Graders: up to 2 units on a single day, assumed to operate 40% of the daytime
  - Mulchers: up to 1 unit on a single day, assumed to operate 50% of the daytime
  - Tree harvesters: up to 1 unit on a single day, assumed to operate 50% of the daytime
  - Water trucks: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Vacuum trucks: up to 2 units on a single day, assumed to operate 40% of the daytime
  - Fuel trucks: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Mobile drills: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Loaders: up to 4 units on a single day, assumed to operate 40% of the daytime
  - Compaction equipment: up to 2 units on a single day, assumed to operate 20% of the daytime

- Transportation equipment:
  - Haul trucks: up to 10 trucks on a single day, travelling from the quarry/borrow source to the road construction site
  - Transport shuttles for workers: assuming 5 shuttles to transport 70 workers from the campsite to the road construction site each day
  - Resupply trucks: up to 100 trucks annually
  - Resupply barges: up to 10 barges annually
- Construction campsite equipment:
  - Vacuum truck: up to 1 truck on a single day
  - Generator: assumed to operate 50% of the daytime
  - Incinerators: up to 2 campsite incinerators, assumed to operate 2 hours per day
- Quarry/borrow source activities at 15 quarries and borrow sources:
  - Crushers: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Sorting and stockpiling: up to 10 rock trucks on a single day, assumed to operate 50% of the daytime
  - Blasting activities: ammonium nitrate fuel oil (ANFO) for blasting explosive; assumed to occur at most once per day per quarry/borrow source

Operations and maintenance phase

- Quarry/borrow source activities at 9 permanent quarries and borrow sources:
  - Crushers: assumed up to 1 unit on a single day, operating 50% of the daytime
  - Sorting and stockpiling: assumed up to 5 rock trucks on a single day, operating 50% of the daytime
  - Blasting activities: ANFO for blasting explosive; assumed to occur at most once every 10 days
- Highway traffic:
  - 50 vehicles per day, assuming 15% of vehicles are heavy trucks
- Snow clearing, grading and dust control:
  - Plow truck
  - Grader
  - Water truck
- Right of way vegetation control:
  - Mulcher: assumed to operate 12 hours a day, every day during September and October
- Culvert and bridge maintenance:
  - Light duty truck

The potentially CAC-emitting activities that have been excluded are listed, followed by the justification for their exclusion.

- Maintenance campsite equipment: No major air-emitting activities are expected in the maintenance campsites

12.4.2.2 Mitigation

The mitigation measures listed in Table 12.7 should be implemented to reduce the potential effects from the release of the CAC emissions. Key mitigation measures include:

- A dust control program using water will be implemented during construction and operations and maintenance.
- Where applicable, dust suppression will follow the GNWT Guideline for Dust Suppression (GNWT, 2013).
- Incinerators, if intended to be used by the contractor, will be operated in accordance with manufacturer's specifications and emissions will meet Canadian Council of Ministers of the Environment Canada Wide Standards for Dioxins & Furans and Mercury (ECCC, 2017).
- Vehicles and equipment will be maintained regularly.
- Equipment idling will be discouraged or limited.
- Vehicle speeds will be limited to 50 km/h on unfinished project road surfaces.
- Efficient project planning will be used to reduce haul distances and the number of trips required to move road construction materials.
- The contractor will be encouraged to use passenger vehicles (e.g., passenger van or bus) to move crews.
- Blast mats will be used when blasting near receptors sensitive to noise.

12.4.2.3 Residual Effects

Table 12.8 summarizes the results for the CAC emissions along with their respective threshold criteria, after the application of the mitigation measures described in Section 12.4.2.2. The calculations followed the methodologies from the programs listed in Section 12.4.1. Each CAC emission value is compared individually to its respective threshold.

As described in Section 12.1.4.2, the construction phase is subdivided into the mobilization and demobilization activities, and the road construction activities. Even though the operations and maintenance phase of a highway segment will begin right after the end of the construction phase for that segment, little to no traffic volume is expected before all highway segments are completed. As such, for the main assessment, the construction phase excludes the contribution of the operations and maintenance activities for the completed segments; and the operations and maintenance activities of the completed segments are included with the construction phase activities as a separate row below as a conservative estimate for informational purposes only.

Table 12.8 Criteria Air Contaminant Emission Calculation Results (Annual)

Project Phase or Activity	CAC Emissions (t/year)				
	CO	**NO_x**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**
Construction Phase					
Mobilization and Demobilization Activities	1.42	4.81	0.02	0.37	**0.35**
Road Construction Activities	**22.39**	**27.95**	0.45	**4.81**	**1.68**
Road Construction Activities + Operations and Maintenance Activities for two completed segments [1]	**28.08**	**34.52**	0.48	**5.78**	**2.42**
Operations and Maintenance Phase					
Operations and Maintenance Activities	8.93	10.31	0.05	**1.51**	**1.15**
CAC Thresholds from NPRI					
NPRI Reporting Thresholds [2]	20.00	20.00	20.00	0.50	0.30
2018 to 2020 Average NWT Facility Emissions [3]	176.82	258.55	69.23	24.26	8.75

Notes:

Bold values indicate that the emission level exceeds the reporting threshold.

1 The operations and maintenance activities of the completed segments are included with the construction phase activities as a conservative estimate for informational purposes only.

2 The level at which the substances begin to pose a risk to the environment or to health.

3 The average of each individual facility CAC emissions reported for the NWT for the past 3 years.

Mobilization and demobilization activities: The Project's CAC emissions are less than their NPRI reporting thresholds, except for $PM_{2.5}$. The dominant sources of $PM_{2.5}$ are the mobilization of trucks.

Road construction activities: The Project's CAC emissions are greater than their NPRI reporting thresholds, except for SO_2. The dominant source of CO is the blasting activity. The dominant sources of nitrogen oxide (NO_x) are the rock trucks, haul trucks, loaders, and the blasting explosives. The dominant source of PM_{10} is the blasting activity. The dominant sources of $PM_{2.5}$ are the rock trucks and haul trucks.

Operations and maintenance phase: The Project's CAC emissions are less than their NPRI reporting thresholds, except for PM_{10} and $PM_{2.5}$. The dominant sources of PM_{10} and $PM_{2.5}$ are the traffic vehicles (e.g., tailpipe emissions).

The Project's CAC emissions are less than the 2018 to 2020 average NWT facility emissions for both the construction phase and the operations and maintenance phase.

Dust emissions are not expected to affect human health or visibility after the application of the dust control program, as described in Section 12.4.2.2. Furthermore, they are not expected to affect terrestrial and aquatic environments. The dust mitigation methods for this Project are best management practices that have been implemented with successful outcomes for similar types of projects in different jurisdictions. The potential effects from the dust emissions are generally observed near the dust sources. There is a sufficient distance separating the dust sources from the nearby residential receptors that there is a low potential for adverse residual effects from the dust emissions.

12.4.2.3.1 Ice Fog

Though not a contaminant, potential increase in the extent or frequency of ice fog may occur during the construction phase when construction vehicles are operating in a specific location for a period of time, such as at the quarry/borrow source or the portion of the segment of the highway being constructed. By operating in one location, a build-up of emissions from construction vehicles may contribute to ice fog conditions; however, these effects are anticipated to be transient in nature, and its duration on the public would be the short time it takes for the MVWR traffic to pass by the activity. During the operations and maintenance phase, the number of vehicles anticipated to use the constructed highway is 50 vehicles per day. Vehicles will be traveling (not idling) on the highway, which would not lead to a build-up of emissions in one location.

12.4.3 Change to Greenhouse Gas

The potential effects of the Project on GHG emissions are discussed.

12.4.3.1 Effects Pathways

The GHG effect pathways will be all those described in Section 12.4.2.1 for the CAC effect, with the following additional pathways:

- Loss of carbon sink associated with boreal forest clearing areas from the highway right-of-way, temporary and permanent quarry/borrow source, and their access roads
- Construction campsite incinerator (if used) during the construction phase: up to 2 campsite incinerators, assumed to operate 2 hours per day

12.4.3.2 Mitigation

The mitigation measures to consider for GHG effects are the same as the ones listed in Section 12.4.2.2 for the CAC effects, with the following additional measures:

- The contractor will be encouraged to use modern construction equipment that has lower GHG emissions.

- The area of direct ground disturbance will be limited by following the pre-existing MVWR alignment to the extent possible.
- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical.
- Closure and reclamation will promote natural re-establishment of vegetation.
- Temporary access roads, quarries, and workspaces not needed after construction will be closed and reclaimed.

12.4.3.3 Residual Effects

Table 12.9 summarizes the GHG emission results for each project phase, along with their respective contribution relative to the NWT total emissions for 2020.

Table 12.9 GHG Emission Calculation Results

Project Phase	GHG Emissions (tCO_2e/year)	Contribution to the NWT Total Emissions [1]
Construction Phase		
Mobilization and Demobilization Activities	1,845	0.13%
Road Construction Activities	6,436	0.46%
Road Construction Activities + Operations and Maintenance Activities for two completed segments [2]	8,240	0.59%
Operations and Maintenance Phase		
Operations and Maintenance Activities	3,633	0.26%

Notes:

[1] Based on 2020 data (ECCC, 2020), the NWT total emissions for 2020 were 1,400,000 tCO_2e.

[2] The operations and maintenance activities of the completed segments are included with the construction phase activities as a conservative estimate for informational purposes only.

As described in Section 12.1.4.2, the construction phase is subdivided into the mobilization and demobilization task, and the road construction task. Even though the operations and maintenance phase of a highway segment will begin right after the end of the construction phase for that segment, little to no traffic volume is expected before all highway segments are completed. As such, for the main assessment, the construction phase excludes the contribution of the operations and maintenance activities for the completed segments. The operations and maintenance activities of the completed segments are included with the construction phase activities as a separate row below as a conservative estimate for informational purposes only.

The Project's annual emissions for all phases are below 10,000 tCO_2e annually, which is the reporting threshold for the federal GHGRP. For the mobilization and demobilization activities, the dominant source is the mobilization trucks. For the road construction activities, the dominant source is the rock trucks. For the operations and maintenance phase, the dominant sources are the traffic vehicles (e.g., tailpipe emissions).

The NWT total emissions for 2020 were 1,400,000 tCO_2e (ECCC, 2020). The Project's annual GHG emissions for each of the project phases and activities range between 0.13% and 0.46% of the NWT total GHG emissions for 2020.

12.4.4 Summary of Residual Effects

12.4.4.1 Change to Criteria Air Contaminants

Table 12.10 summarizes the residual effects for the CAC effect, based on the characterizations as described in Section 12.1.5.

- Direction: The direction of change in CAC emissions during both project phases is rated adverse (A) because the phases result in a predicted increase of ambient concentrations compared to baseline conditions.
- Likelihood: The likelihood for change in CAC during all the project phases is rated certain (CE) because the activities from all the project phases emit CACs.
- Magnitude: The magnitude for change in air quality during both project phases is rated moderate (M) because for each phase, at least one of the CACs is greater than the NPRI reporting threshold, but no CAC is over the 2018 to 2020 average NWT facility emissions.
- Geographic Extent: The geographic extent for change in CAC emissions is expected to be limited to the LAA for each phase of the Project because the LAA was set at the maximum geographic extent to which the air emissions, mostly fugitive dust, from the project highway traffic is expected to disperse until the concentrations are undiscernible from the background PM concentrations.
- Timing: Seasonality is applicable (A) to the CAC emissions because during summer there are higher PM emissions, especially from the fugitive dust sources such as unpaved roads, compared to winter when the ground is frozen and sometimes covered in snow.
- Duration: The duration for change in CAC emissions during the construction phase is short-term (ST) because the construction activities do not extend past the construction period for each highway segment which is predicted to be 5 years or less. The duration for change in CAC emissions during the operations and maintenance phase is long-term (LT) because the operation activities extend through the duration of the operations and maintenance phase which is longer than 5 years.

- Frequency: The frequency for change in CAC emissions during the construction phase is rated regular event (R) because the CAC emissions from the construction activities are scheduled at times during the daytime and are not assumed to occur during the nighttime. The frequency for change in CAC emissions during the operations and maintenance phase is rated continuous (C) because the road will be open on a continuous basis for travel by vehicles.
- Reversibility: The reversibility for change in air quality during the construction phase is rated reversible (R) because the predicted increase in ambient CAC concentrations and dust due to the project activity would return to baseline conditions after the end of the activity. The reversibility for change in air quality during the operations and maintenance phase is rated Irreversible (I) because even though the predicted increase in ambient CAC concentrations and dust due to the phase activities would return to baseline condition after the end of the activity, the phase is indeterminate.

Table 12.10 Residual Effects on CAC Emissions

Residual Effect	Residual Effects Characterization*							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in CAC - Construction Phase	A	CE	M	LAA	A	ST	R	R
Change in CAC - Operations and Maintenance Phase	A	CE	M	LAA	A	LT	C	I

KEY

*See Table 12.4 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMC: No Measurable Change
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NA: Not Applicable
A: Applicable

N/A: Not applicable

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

12.4.4.2 Change to Greenhouse Gases

Table 12.11 summarizes the residual effects for the GHG effect, based on the characterizations as described in Section 12.1.4.2.

- Direction: The direction for change in GHG during both Project phases is rated adverse (A) because the phases result in a predicted increase of GHG emissions compared to baseline conditions.
- Likelihood: The likelihood for change in GHG during all the project phases is rated certain (CE) because the activities from all the project phases emit GHGs.
- Magnitude: The magnitude for change in GHG during both project phases is rated low (L) because the emission levels are below the threshold of 10,000 tCO_2e annually.
- Geographic Extent: The geographic extent for change in GHG during operation is not applicable (NA) because the effect is determined at the territorial, national, and global scales.
- Timing: Seasonality is not applicable (NA) to change in GHG because emissions are released across all seasons.
- Duration: The duration for change in GHG is long-term (LT) because effects related to the release of GHG emissions will contribute to climate change for the long-term.
- Frequency: The frequency for change in GHG during the construction phase is rated regular event (R) because the GHG emissions from the construction activities are scheduled at times during the daytime and do not occur during the nighttime. The frequency for change in GHG during the operations and maintenance phase is rated continuous (C) because the road will be open on a continuous basis for travel by vehicles.
- Reversibility: The reversibility for change in GHGs during the construction phase is rated reversible (R) because the predicted increase in yearly emissions due to the project activity would return to baseline conditions after the end of the activity. The reversibility for change in GHGs during the operations and maintenance phase is rated Irreversible (I) because the duration of the phase is indeterminate.

Table 12.11 Residual Effects on GHG Emissions

Residual Effect	Residual Effects Characterization*							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in GHG - Construction Phase	A	CE	L	NA	NA	LT	R	R
Change in GHG - Operations and Maintenance Phase	A	CE	L	NA	NA	LT	C	I

KEY

*See Table 12.4 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMC: No Measurable Change
L: Low
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area
NA: Not Applicable

Timing
NA: Not Applicable
A: Applicable

N/A: Not applicable

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

12.4.4.3 Sahtu Land Use Plan

With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirement consideration of engagement input and incorporation of Traditional Knowledge.

Mitigation measures for reducing effects of the Project on air quality respect the values of the Petiniɂah (Bear Rock) CZ, Mio Lake CZ, Norman Range SMZ, K'ąąlǫ Tué (Willow Lake Wetlands) SMZ, and Deh Cho (Mackenzie River) SMZ as areas with important ecological habitats, and take into account traditional and community use of these areas.

12.5 Assessment of Cumulative Effects on Air Quality

12.5.1 Residual Effects Likely to Interact Cumulatively

The project and physical activities inclusion list, in Chapter 4, identifies other projects and physical activities that have the potential to act cumulatively with residual effects of the Project on air quality.

For the GHG effect, as GHG emissions have a global effect and not any effect localized to the RAA, cumulative interaction between the project activities and any specific activities in the RAA is not expected other than immeasurably within the global climate change phenomena.

For the CAC effect, projects and physical activities have the potential to act cumulatively with the Project if all the following conditions apply:

- The activity period overlaps with the project activity period, because CAC effects have a short duration before settling to the ground or dispersing in the atmosphere and returning to the baseline ambient concentration levels.
- The activity is within the RAA, that is, 15 km from the PDA, which represents the distance at which the CACs emitted from large stationary sources may disperse or settle and return to baseline values.
- The activity, to be considered CAC-emitting, includes combustion emission sources and mechanical disturbance of rock and dirt surfaces.

Where residual effects from the Project act cumulatively with residual effects from other projects and physical activities, as listed in Table 12.12, a cumulative effects assessment is undertaken to determine their significance. For each air quality effect identified in Table 12.12 that is marked as not likely to interact cumulatively with residual effects of other projects and physical activities (no check mark) a justification is given, and a cumulative effects assessment is not warranted.

Table 12.12 Projects with the Potential to Contribute to Cumulative Effects in the RAA

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects	
	Change in CAC	Change in GHG
Past and Present Physical Activities and Resource Use (Base Case)		
Geotechnical	-	-
Oil, Gas & Seismic*	-	-
Infrastructure		
MVWR, including bridges and bridge-sized culverts	✓	-
Mackenzie Highway #1 Operation and Maintenance	✓	-
Délı̨nę Winter Road	✓	-
Prohibition Creek Access Road	✓	-
Norman Wells Pipeline	✓	-
Quarries and Borrow Sources	-	-
Mining & Exploration	-	-
Municipal Operations, including water, waste, power, and community development		
Wrigley Municipal Activities	✓	-
Tulita Municipal Activities	✓	-
Norman Wells Municipal Activities	✓	-
Project-Related Physical Activities (Project Case)		
Mackenzie Valley Highway Project	✓	✓
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)		
Quarries		
Dhu-1 Quarry	✓	-
Infrastructure		
Great Bear River Bridge	✓	-
Oil and Gas		
Enbridge Maintenance Camp	✓	-

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with Project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = Includes support activities such as production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas.

For the CAC effect, the following Infrastructure activities are expected to interact cumulatively with the project activities. The assessment of cumulative effects is provided in the next section.

- Highway #1: The highway is open to all-season traffic. It overlaps with the RAA near Wrigley.
- The MVWR: Is open to traffic every winter and runs along the same corridor as the project highway corridor.
- The Délı̨nę Winter Road is open to traffic every winter and overlaps a portion of the RAA south of Tulita.
- Prohibition Creek Access Road (PCAR): This road connects to the northernmost segment of the Project and is partly in the RAA. The maintenance and use of the PCAR will overlap temporally with the construction of the Tulita to Norman Wells segment.
- Dhu-1 Quarry: The development of this quarry in the RAA could overlap temporally with the construction of the Tulita to Norman Wells segment.
- Proposed Great Bear River Bridge: The construction of a permanent bridge spanning the Great Bear River north of Tulita is planned between 2024 and 2027. This activity is within the project RAA, approximately 2 km south of the Project Tulita North highway segment, and may overlap temporally during the project construction phase.
- Enbridge Pipelines stations: permanent surface pipeline terminal stations located within the RAA in Norman Wells and Wrigley.

The following infrastructure activities located within the RAA currently exist or may occur during the project period; the magnitude of the cumulative effect on air quality from the interaction of these activities with the project activities is expected to be low or unmeasurable, as explained below:

- Highway #1 south of the project PDA ends at the community of Wrigley, where the PDA begins, and has traffic activities year-round. The area of overlap of the two activities, between Wrigley and the Project's southernmost quarry/borrow source, is a highway portion of approximately 10 km in length. The Highway No.1 has approximately 60 to 70 vehicles per day, as obtained from the nearest traffic count location at Mackenzie River Ferry (GNWT, 2020) located approximately 130 km south of Wrigley. If the CAC emissions from the Highway No.1 activities were estimated to be equal to the emissions from the Project traffic activities, this would be equivalent to adding 10 km to the existing 281 km of Project traffic activity, or less than 4% of the Project traffic emissions, which is low or unmeasurable. Thus the contribution of the Highway No.1 activities to cumulative effects is expected to be low or unmeasurable.

- The Délı̨nę Winter Road is built every winter and allows traffic between Tulita and Délı̨nę, located approximately 105 km east of Tulita. This road is connected to the MVWR in the PDA which will become the Project, approximately 20 km southeast of Tulita. A small overlap area of activities of 2 km is expected every winter at the connection of the two roads, and the construction duration in the overlapping area is expected to be short. The Délı̨nę Winter Road has approximately 40 vehicles per day (GNWT, 2020) which is less than the expected traffic from the project operations. If the CAC emissions from the Délı̨nę Winter Road activities were conservatively estimated to be equal to the emissions from the Project activities, this would be equivalent to adding 2 km to the existing 281 km of Project activity, or less than 1% of the Project emissions, which is low or unmeasurable. Thus the contribution of the Délı̨nę Winter Road activities to cumulative effects is expected to be low or unmeasurable.

Three municipal activities located within the RAA currently exist; one oil and gas activity is reasonably foreseeable. The cumulative effect on air quality from the interaction of these activities with the project activities is not expected to be measurable, as explained:

- Power Generation by the Northwest Territories Power Corporation at Wrigley, Tulita, and Norman Wells: Although there would be a temporal overlap and a possible spatial overlap due to the CAC emission plumes from these municipal power generation activities and the project activities, since the project sources are intermittent and transient, the cumulative effect is not expected to be measurable on an annual basis. The same is expected for the fog emissions.
- A camp site in support of Enbridge Line 21 is expected to be built at an unknown date in the future and will be located approximately 9 km away from the Project's temporary quarry/borrow source called Edie Lake near Norman Wells. The camp will have a 300-kW generator as part of its CAC emitting equipment (Mackenzie Valley Land and Water Board, 2023). The Edie Lake quarry/borrow source is temporary and will be active for only 3 years between 2027 and 2029; after which, the camp will no longer be within the project RAA. Based on professional experience, the magnitude of CAC effect 9 km away from a generator is not expected to be measurable on an annual basis. Thus, the magnitude of the cumulative effect from the interaction of the camp activities and the project activities on air quality is not expected to be measurable on an annual basis.

The following Oil, Gas & Seismic, Infrastructure, and Municipal activities that were identified in Section 12.2.2 from the TDR for Air Quality, Greenhouse Gas and Climate Baseline (Appendix 12A; K'alo-Stantec, 2022b) are not expected to interact cumulatively with the project activities, as listed along with an explanation:

- Oil, Gas & Seismic activities:
  - Imperial Oil Resources Ltd. activities (near Norman Wells): All Imperial Oil activities ended in 2020, and as the initial project construction phase is planned for 2026, there is no temporal overlap.

No other surrounding projects or activities are expected to interact cumulatively with the Project, as explained:

- No Mining & Exploration activities, Remediation activities, or Staging Area activities are planned to occur during the time of the Project (i.e., no activity period overlap).
- No Geotechnical or Quarrying activities are planned to occur during the time of the project activities for the segments at the same location.

12.5.2 Mackenzie Valley Winter Road, Great Bear River Bridge, and Norman Wells Pipeline Criteria Air Contaminants Effect

12.5.2.1 Cumulative Effects Pathways

For the CAC effect, three Infrastructure activities are expected to interact cumulatively with the project activities: the MVWR, the proposed Great Bear River Bridge, and the Norman Wells Pipeline.

The MVWR is built every winter and runs along the same corridor as the project highway corridor. It provides winter access to Sahtu communities north of Wrigley, including Tulita, Norman Wells, Fort Good Hope (K'asho Got'ine), Délı̨nę and Colville Lake. The Project will share the ROW of the MVWR in places, and construction of the Project will be ongoing when the MVWR is open to public traffic. Based on the DAR Detailed Project Description (see Chapter 5), public access along the MVWR will be maintained during project construction, including portions of the MVWR that need to be operated until the full highway is connected from end to end.

Change in CACs is expected from the annual road construction and traffic activities during the winter season. The following information on the infrastructure comes from the DAR Detailed Project Description (see Chapter 5) and Climate Lens Assessment report (K'alo-Stantec, 2021):

- The road is open to traffic annually from December 25 to April 1 on average
- The average annual daily traffic volume is estimated to be 50 vehicles per day, assuming 15% of vehicles are heavy trucks
- The construction equipment includes one grader, one plow truck, and one water truck

The construction of the Great Bear River Bridge, a permanent bridge spanning the Great Bear River in Tulita, is planned between 2024 and 2027. This activity is within the project RAA, between the Tulita to Prohibition Creek highway segment, and Tulita to Dehcho/Sahtu border segment. The projects may overlap temporally during the project construction phase, if the segment of the highway from Tulita to the Dehcho/Sahtu border is constructed first.

Changes in CACs are expected from the construction activities during its four-year construction period. Similar to the project construction activities, the Great Bear River Bridge construction activity CAC emissions are not expected to disperse past 1 km, and thus the spatial overlap is small. As the construction activities for the Great Bear River Bridge are similar to those of the project (including road construction) CAC emissions are conservatively estimated to be equivalent to the project annual construction activities emissions.

The Norman Wells Pipeline includes stations near Norman Wells and Wrigley. According to the NPRI website, the Norman Wells and the Wrigley pipeline stations reported CAC emissions from 2018 to 2020 (ECCC, 2022c). Other CAC effects expected from the Norman Wells pipeline maintenance activities include maintenance of cleared fireguard areas, roads, camp sites and seasonal trails. Since these activities and their resulting CAC emissions are intermittent, transient, and generally low intensity, the cumulative effect from these activities is not expected to be measurable on an annual basis.

12.5.2.2 Mitigation for Cumulative Effects

The mitigation measures used to mitigate the effects on air quality for the annual building of the MVWR, the construction of the Great Bear River Bridge, and the Norman Wells Pipeline stations are assumed to be the same as those planned for the project construction phase listed in Table 12.7, as applicable.

12.5.2.3 Cumulative Effects

Table 12.13 summarizes the results of the cumulative CAC effect of the Project, MVWR, the Great Bear River Bridge, and the Norman Wells Pipeline. Each CAC emission value is compared individually to its respective threshold.

The Project will replace the MVWR and will incorporate the Great Bear River Bridge during the operations and maintenance phase once all segments are completed, and thus the MVWR and Great Bear River Bridge activities will interact cumulatively with the project activities only during the construction phase. Furthermore, Great Bear River Bridge activities will only interact cumulatively with the project activities if construction of both projects within the RAA occurs at the same time.

The Norman Wells Pipeline stations are expected to operate permanently, and as such, their activities will interact cumulatively with the Project activities during both the construction phase and the operations and maintenance phase of the Project.

Note that, since the MVWR runs along the same corridor as the project highway corridor, the three other infrastructure activities that interact with the project activities as described in Section 12.5.1 will also interact with the MVWR. However, as explained in Section 12.5.1, the emissions from these activities are expected to be low or unmeasurable; and thus their contribution to cumulative effects is expected to be low or unmeasurable and are not included in this cumulative effects assessment.

As described in Section 12.1.4.2, the construction phase is subdivided into the mobilization and demobilization activities, and the road construction activities. Even though the operations and maintenance phase of a highway segment will begin right after the end of the construction phase for that segment, little to no traffic volume is expected before all highway segments are completed. As such, for the main assessment, the construction phase excludes the contribution of the operations and maintenance activities for the completed segments; and the operations and maintenance activities of the completed segments are included with the construction phase activities as a separate row below as a conservative estimate for informational purposes only.

Table 12.13 Cumulative CAC Emission Calculation Results (Annual)

Activity	CAC Emissions (t/year)				
	CO	**NO_x**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**
MVWR Activities	2.28	2.86	0.00	0.37	**0.35**
Great Bear River Bridge Activities	**22.39**	**27.95**	0.45	**4.81**	**1.68**
Norman Wells Pipeline Activities	-	**28.61**	-	**0.59**	**0.59**
Cumulative Effects During Construction Phase Activities [1]					
Mobilization and Demobilization Activities	**26.09**	**64.23**	0.48	**6.14**	**2.97**
Road Construction Activities	**47.06**	**87.37**	0.91	**10.59**	**4.31**
Road Construction Activities + Operations and Maintenance Activities for two completed segments [2]	**52.75**	**93.94**	0.94	**11.55**	**5.04**
Cumulative Effects during Operations and Maintenance Phase Activities [1]					
Operations and Maintenance Phase Activities	8.93	**38.92**	0.05	**2.10**	**1.74**
CAC Thresholds from NPRI					
NPRI Reporting Thresholds [3]	20.00	20.00	20.00	0.50	0.30
2018 to 2020 Average NWT Facility Emissions [4]	176.82	258.55	69.23	24.26	8.75

Notes:
Bold values indicate that the emission level exceeds the reporting threshold.

1 The project activity CAC emissions are found in Table 12.8.

2 The operations and maintenance activities of the completed segments are included with the construction phase activities as a conservative estimate for informational purposes only.

3 The level at which the substances begin to pose a risk to the environment or to health.

4 The average of each individual facility CAC emissions reported for the NWT for the past 3 years.

Cumulative effects during the mobilization and demobilization activities of the construction phase: The cumulative CAC emissions are greater than their NPRI reporting thresholds, except for SO_2.

Cumulative effects during the road construction activities of the construction phase: The cumulative CAC emissions are greater than their NPRI reporting thresholds, except for SO_2.

Cumulative effects during the operations and maintenance phase: The cumulative CAC emissions are greater than their NPRI reporting thresholds, except for CO and SO_2.

The cumulative CAC emissions are less than the 2018 to 2020 average NWT facility emissions for both the construction phase, and the operations and maintenance phase of the Project.

Dust emissions, as described in Section 12.4.2.3, are not expected to affect human health or visibility after the application of the dust control program as described in Section 12.4.2.2. Furthermore, dust emissions from the MVWR activities are not expected to be measurable during the winter when the ground is frozen and sometimes covered in snow.

Ice fog, as described in Section 12.4.2.3, is not expected to have a measurable effect on the public.

As GHG emissions only have a global effect and not any effect localized to the RAA, cumulative interaction between the project activities and the MVWR and Great Bear River Bridge activities is not expected other than immeasurably within the global climate change phenomena.

12.5.3 Summary of Cumulative Effects

Table 12.14 summarizes the cumulative CAC effect from the MVWR, the Great Bear River Bridge, the Norman Wells Pipeline, and the project activities, based on the characterizations as described in Section 12.1.5.

- Direction: The direction of change in cumulative CAC emissions is rated adverse (A) during both the construction phase and the operations and maintenance phase of the Project because the cumulative effect results in a predicted increase of CAC concentrations compared to baseline conditions.
- Likelihood: The likelihood for change in cumulative CAC is rated certain (CE) during both the construction phase and the operations and maintenance phase because the activities from the MVWR, the Great Bear River Bridge, the Norman Wells Pipeline and the Project emit CACs.
- Magnitude: The magnitude for change in cumulative CAC is rated moderate (M) during both the construction phase and the operations and maintenance phase of the Project because at least one of the CACs is greater than the NPRI reporting threshold, but no CAC is over the 2018 to 2020 average NWT facility emissions.
- Geographic Extent: The geographic extent for change in cumulative CAC emissions is expected to be the RAA during both the construction phase and the operations and maintenance phase of the Project, because the RAA was set at a 15 km buffer around the PDA, which is the maximum geographic extent to which the air emissions from the project activities is expected to disperse until the concentrations are undiscernible from the background PM concentrations, and the MVWR, the Great Bear River Bridge and the Norman Wells Pipeline are located within 15 km of the project highway corridor.
- Timing: Seasonality is applicable (A) to the CAC emissions during both the construction phase and the operations and maintenance phase of the Project because during summer there are higher PM emissions, especially from the fugitive dust sources such as unpaved roads, compared to winter when the ground is frozen and sometimes covered in snow.
- Duration: The duration for change in cumulative CAC emissions during the construction phase of the Project is short-term (ST) because the project construction activities do not extend past the construction period for each highway segment which is predicted to be 5 years or less. The duration for change in cumulative CAC emissions during the operations and maintenance phase of the Project is long-term (LT) because the both the Norman Wells Pipeline activities and the Project operations and maintenance phase activities are expected to last more than 5 years.

- Frequency: The frequency for change in cumulative CAC emissions of the Project is rated regular event (R) during both the construction phase and the operations and maintenance phase of the Project because even though the MVWR and the Norman Wells Pipeline stations operations are expected to be continuous, the construction activities from the Great Bear River Bridge and the Project are assumed to be scheduled at times during the daytime and not during the nighttime.
- Reversibility: The reversibility for change in air quality during the construction phase of the Project is rated reversible (R) because the predicted cumulative increase in CAC concentrations due to the MVWR activity, the Great Bear River Bridge activity, and the project construction activity would return to baseline conditions after the end of the activity. The reversibility for change in air quality during the operations and maintenance phase of the Project is rated irreversible (I) because the predicted cumulative increase in CAC concentrations due to the Norman Wells Pipeline activity and the project operations and maintenance activity are permanent.

Table 12.14 Residual Effects on CAC Emissions

Residual Effect	Residual Effects Characterization*							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in CAC - Construction Phase	A	CE	M	RAA	A	ST	R	R
Change in CAC - Operations and Maintenance Phase	A	CE	M	RAA	A	LT	R	I

KEY

* See Table 12.4 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMC: No Measurable Change
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NA: Not Applicable
A: Applicable

N/A: Not applicable

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

As GHG emissions only have a global effect and not any effect localized to the RAA, cumulative interaction between the project activities and the MVWR activity is not expected other than immeasurably within the global climate change phenomena.

12.6 Determination of Significance

12.6.1 Significance of Residual Effects

The criteria that determine the effect significance are described in Section 12.1.6. Project activities have been grouped into the construction phase (which includes the mobilization activities, road construction activities, and demobilization activities) and operations and maintenance phase.

The change in CAC are not significant. As detailed in Section 12.4.2.3, the predicted annual CAC emissions are below the 2018 to 2020 average NWT facility emissions for each of the CACs assessed and for all phases of the Project.

The change in GHG is not significant. As detailed in Section 12.4.3.3, the annual GHG emissions are below the federal GHGRP annual reporting threshold of 10,000 tCO_2e, for all phases of the Project.

12.6.2 Significance of Cumulative Effects

The cumulative CAC effects are not significant. As described in Section 12.5, the MVWR, the Great Bear River Bridge, and the Norman Wells Pipeline are the only activities whose effect magnitude from the cumulative interaction with the Project is expected to be medium to high. As described in Section 12.5.2.3, the cumulative annual CAC emissions from the MVWR activity, the Great Bear River Bridge activity, the Norman Wells Pipeline activity, and the project activities are below the 2018 to 2020 average NWT facility emissions for each of the CACs assessed.

As GHG emissions only have a global effect and not any effect localized to the RAA, cumulative interaction between the project activities and any specific activities in the RAA is not expected.

12.6.3 Project Contribution to Cumulative Effects

Since the Project's CAC effects on their own are not significant, as explained in Section 12.6.1, and the cumulative CAC emissions of the Project's activities and the other existing activities are below the 2018 to 2020 Average NWT Facility Emissions threshold, as described in Section 12.5.2.3, the Project's contribution to cumulative CAC effect is not significant. Since the project CAC effects are expected to settle or disperse within a 1 km distance, as described in Section 12.1.4.1, the overall regional effects are not expected to be measurable.

Since there are no measurable cumulative effects as a result of the residual effects of the Project in combination with the effects of other emission sources for GHG, the determination of significance from the Project's contribution to cumulative GHG effect does not apply.

12.7 Prediction Confidence

The prediction confidence for residual effects and cumulative effects for air quality is moderate and is based on the accuracy of the project design information, emission source data, and accuracy of the emission factors.

Calculations can be revised, if necessary, when final design information on equipment and activities is available. Conservative assumptions were used, as described in the next section.

Emission factors are based on the latest available data from the various air emissions monitoring programs, which update the values from time to time. Calculations can be revised, if necessary, before the start of the project construction phase if the programs revise their emission factors.

12.7.1 Assumptions

The following assumptions have been made to estimate the air quality effects:

Blasting activities

- The blasting depth does not exceed 21 m. This pertains to the calculation formula used.
- Based on a previous road construction project, it is expected that if and when blasting is required, it will only occur once daily per quarry/borrow source (Stantec, 2016).
- Based on the estimated amount of rock material needed yearly during the operations and maintenance phase (30,000 to 50,000 m^3) and the estimated amount needed during the whole construction period (14.7 million m^3) reported in the DAR Detailed Project Description (see Chapter 5), the blasting frequency for the operations and maintenance phase is conservatively estimated to be 10% of the frequency for the construction phase.
- Based on uniform use, approximately 50,000 cubic metres (m^3) of blasted rock is assumed to be required for every 13 km of the Project. The weight of the rock is assumed to average 2.3 tonnes per cubic metre (t/m^3), based on professional experience.

Construction equipment

- The daily frequency of activities was obtained from construction literature for similar equipment (FHWA, 2006).
- The annual work hours of each construction equipment unit is estimated based on the maximum number of units in a day.
- Transport shuttles for workers have an estimated capacity of 14 passengers per vehicle, based on research on typical transport shuttles in Canada (Alberta Transportation, 2016).
- Based on the quarry and campsite locations relative to the proposed highway location, the average daily round trip for workers transport shuttles is estimated to be 40 km.

- Off-road and on-road equipment is assumed to be powered with diesel fuel, as described in the Climate Lens Assessment done for the Project (K'alo-Stantec, 2021).
- Fuel consumption rates (litres/hour) are based on the GNWT experience with construction projects, and various information sources including NRCan (2019 and 2020) and Generator Source (2020).

Operations and maintenance

- Average annual daily highway traffic volume is 50 vehicles per day, assuming 15% of vehicles are heavy trucks, based on the DAR Detailed Project Description (see Chapter 5).
- The maintenance equipment operation time was obtained from the Climate Lens Assessment done for the Project (K'alo-Stantec, 2021) and pro-rated per km for use in the calculations.
- Based on the estimated amount of rock material needed yearly during the operations and maintenance phase (30,000 to 50,000 m^3) and the estimated amount needed during the whole construction period (14.7 million m^3) reported in the DAR Detailed Project Description (see Chapter 5), the activity frequency at the quarry/borrow sources during the operations and maintenance phase is conservatively estimated to be 10% of the frequency at the quarry/borrow sources during the construction phase.
- Where data was unavailable for an activity such as equipment load factor or fuel consumption, the reasonable worst-case values were selected.

Loss of Carbon Sink

- The construction and presence of the highway could result in changes to permafrost, resulting in the release of CH_4. Due to limited data on the correlation between road construction and a measurable release of GHG emissions from permafrost decay in the NWT, the release of CH_4 from permafrost decay was not factored into the analysis. See the Climate Lens Assessment report (K'alo-Stantec, 2021) for more information about permafrost thaw.

MVWR

- The traffic volume is estimated to be 50 vehicles per day, assuming 15% of vehicles are heavy trucks, as described in the Climate Lens Assessment done for the Project (K'alo-Stantec, 2021).

Great Bear River Bridge

- The activity CAC emissions are assumed to be equivalent to the project annual construction activities emissions. Since the Great Bear River Bridge construction footprint area is smaller than the Project PDA, this assumption is conservative.

12.7.2 Gaps and Uncertainties

Gaps that may affect the air quality effects are listed:

- Detailed data on blasting activities is unavailable currently. Conservative assumptions were made based on a previous road construction project (Stantec, 2016). Blasting activities is a dominant source of CAC emissions for the construction phase.

Uncertainties in the calculations are listed:

- Emission factors get updated by the air quality programs from time to time. Calculations can be revised, if necessary, before the start of the project construction phase if the programs revise the emission factors.

12.8 Follow-up and Monitoring

As part of an adaptive management plan for follow-up and monitoring, mitigation measures will be regularly reviewed and updated by the GNWT to verify and enhance their effectiveness. In the event that an unexpected deterioration of the environment is observed as part of follow-up and/or monitoring, intervention mechanisms will apply the adaptive management process.

Regular monitoring of climate data, such as snowfall accumulation and rainfall, will be undertaken as part of terrain, soils and permafrost monitoring to better correlate the changes in the highway with climate-related parameters.

Monitoring will also be initiated on a case-by-case basis should any complaints related to air quality occur from Indigenous Governments, Indigenous Organizations or other affected parties as a result of project activities.

12.9 References

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13.0 ASSESSMENT OF POTENTIAL EFFECTS ON NOISE

Noise has been selected as a valued component (VC) because changes in noise levels have potential effects on communities, which may lead to adverse effects such as annoyance and interference with speech comprehension. It may also result in changes to wildlife and wildlife habitat.

The Mackenzie Valley Highway Project (the "Project") has the potential to change noise levels in the environment from activities during the construction phase and the operations and maintenance phase. Noise emissions from road projects are generally associated with the mechanical movement of construction equipment and vehicle traffic.

The effects of noise on wildlife are assessed in Chapter 10 (caribou and moose), and Chapter 19 (wildlife and wildlife habitat). The assessment of potential effects of the Project on noise focuses on the effects on communities and other human receptor locations. Receptor locations are locations where human noise sensitive receptors are present, based on the Health Canada Noise Guidance 2017 recommendations (Health Canada, 2017). In this assessment, it includes permanent and seasonal residences.

The assessment of potential effects on noise concludes that with the application of mitigation measures, residual effects resulting from the Project on noise will be adverse. Residual effects and cumulative effects will be of magnitude, duration, frequency and timing such that they will be below criteria required to be considered significant as defined in Section 13.1.6. Predicted residual effects and cumulative effects of the Project on noise are predicted to be not significant.

13.1 Scope of Assessment

13.1.1 Regulatory and Policy Setting

The Government of the Northwest Territories (GNWT) has developed guidelines that, along with legislation, regulations, and policies, help manage the environment in the Northwest Territories (NWT). However, there is no dedicated territorial regulation or guideline that regulates the acoustic environment. In the absence of territorial noise regulations, the following regulations are used as guidelines.

13.1.1.1 Health Canada Noise Guidance

Health Canada - Guidance for Evaluating Human Health Impacts in Environmental Assessment: Noise (Health Canada, 2017): The Health Canada Noise Guidance concerns the assessment of health risks associated with noise and types of sound predicted in federal environmental assessments of proposed major resource and infrastructure projects. The thresholds for the parameters relevant to the Project are listed below. See Section 13.1.3 for a description of those parameters.

- Long-Term Community Annoyance: If change in percent highly annoyed (%HA) between baseline and application case exceeds 6.5%, then the project-related noise effect is considered “severe” and noise mitigation measures should be considered.
- Short-Term Community Annoyance: If a noise level exceeds the Mitigation Noise Level (MNL) of 47 A-weighted decibels (dBA) day-night sound level (L_{dn}), then adverse noise effects are likely and noise mitigations are warranted.
- Low-Frequency Noise: If a noise level exceeds 70 Z-weighted or unweighted decibels (dBZ) equivalent sound level (L_{eq}) (which translates to daytime sound level [L_d] in the Project) for the energy summation of the 16 Hertz (Hz), 31.5 Hz, and 63 Hz bands, then the activities would be expected to cause additional annoyance by creating a "rattle" noise in the environment.
- Speech Comprehension: If noise level exceeds 55 dBA L_{eq} (which translates to L_d in the Project), then the activities would be expected to interfere with speech comprehension outdoors.

13.1.1.2 Alberta Transportation

Alberta Transportation - Noise Attenuation Guidelines for Provincial Highways Under Provincial Jurisdiction Within Cities and Urban Areas (Alberta Transportation, 2002): Determines when noise mitigation measures such as noise barriers or berms are warranted near residences due to highway traffic noise levels. If the noise effect from highway traffic exceeds the threshold of 65 dBA 24-hour equivalent sound level ($L_{eq\text{-}24hr}$), then noise control such as noise barriers or berms would be warranted to attenuate the traffic noise.

13.1.1.3 Sahtu Land Use Plan

Specific to the areas to which the Sahtu Land Use Plan (SLUP) applies, the Project must meet the 13 general conformity requirements (CR) of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023). Conformity Requirement #2 requires that *"The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge."* Additionally, CR#14 requires that the Project be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 2023), including the following:

- Petiniɂah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)
- K'ąąlǫ Tué (Willow Lake Wetlands) SMZ (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

13.1.2 Influence of Engagement

The GNWT has engaged with Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapter 2 (Consultation and Engagement), Chapter 3 (Traditional Knowledge), and Chapter 11 (culture and traditional land use). The GNWT has recently initiated Consultation with Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, and through a review of publicly available TLRU information, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to noise. This feedback has been considered and summarized in Table 13.1 and has been integrated into the assessment of potential effects of noise on wildlife and wildlife resources that follows.

Table 13.1 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
Norman Wells Renewable Resources Council (NWRRC) TLRU study participants reported that muskox generally avoid noise and activity, however, they are not as sensitive as caribou to sensory disturbance.	NWRRC, 2023	The GNWT has identified mitigation measures to reduce noise levels resulting from project activities. The effects of the Project on caribou, moose and other wildlife from changes in noise are assessed in Chapters 10, 19, and 20. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning. The GNWT will engage with communities to inform them of the activities and the noise sources that will occur prior to construction	For mitigation measures to reduce or eliminate effects on noise levels, see Table 13.5. The effects of the Project on wildlife from changes in noise are assessed in Section 10.5.2 (caribou and moose change in habitat); Section 19.4.2 (wildlife change in habitat).
Indigenous Governments, Indigenous Organizations, and other affected parties (Sahtu Dene and Métis, Pehdzéh Kį N'deh community members and Dehcho First Nations, NWRRC and Tulita Renewable Resources Council [TRRC] study participants) have also advised that boreal caribou avoid the winter roads due to sensory disturbance (i.e., noise, pollution), and concerns have been raised about the effects of future road construction and operations and the potential to affect the availability and accessibility of caribou for cultural use within proximity of the highway.	Auld and Kershaw, 2005; Dehcho First Nations, 2011; IMG-Golder Corporation, 2006; TRRC, 2022		
Participants of the NWRRC study explained that the intensity of noise can affect the level of response in wildlife, particularly moose. While most wildlife would be disturbed by most noise, NWRRC study participants reported that moose are relatively unbothered by noise unless it is loud or more disturbing, citing ground disturbance as a problem.	NWRRC, 2023		

Comment	Source	GNWT Response	Where Addressed
Participants of the NWRRC study reported that previous road construction and operation have affected migratory patterns and calving locations of wildlife around the Mackenzie Valley Winter Road (MVWR).	NWRRC, 2023		
Participants of the NWRRC study expressed concern that potential project effects to wildlife, including increased traffic and noise along the MVWR may compound existing effects on wildlife identified by NWRRC, including effects related to noise and vehicle traffic.	NWRRC, 2023		
Sahtu Region reported that boreal caribou are particularly sensitive to sensory disturbance; noise disturbance was identified as a major factor that affects boreal woodland caribou.	McDonald et. al., 2010		
Community engagement participants expressed concern about noise and vibration, including from blasting and traffic.	November to December 2022 Engagement		

13.1.3 Potential Effects, Pathways, and Measurable Parameters

Based on Health Canada noise guidance and Alberta Transportation noise guideline, the following noise effects are assessed quantitatively:

- Long-term community annoyance: Some of the project noise-emitting activities are long-term, (i.e., last more than one year), such as traffic on the completed highway.
- Short-term community annoyance: Even though the construction phase is expected to last several years, the construction activities at particular locations are expected to be short-term (i.e., last less than one year).
- Low-frequency noise: Annoyance related to noise is greater when low-frequency noise is present (International Organization for Standardization [ISO] 1996-1:2003). Some of the Project activities, such as heavy truck operations, have the potential to emit low-frequency (below 100 to 200 Hz) noise.
- Interference with Speech Comprehension: Project noise levels may occasionally affect speech comprehension.
- Traffic Noise: Once the highway is open for operation, the main source of noise will be from the daily traffic.

Listed below are other types of effects that are excluded from this assessment, along with a justification for their exclusion:

- Sleep disturbance: Nighttime sleep disturbance assessment does not apply for the construction and maintenance activities as the work is planned to be conducted on a day shift only. Nighttime traffic during operation is not expected to reach noise levels close to the sleep disturbance threshold.
- Noise-Induced Hearing Loss: Project noise levels are not expected to be close to the hearing loss threshold.
- Effect on Wildlife: This is assessed as part of the assessment of potential effects on caribou and moose (Chapter 10), and wildlife and wildlife habitat (Chapter 19).

Table 13.2 summarizes the effects included in the assessment. The project life cycle is divided into two phases: the construction phase, and the operations and maintenance phase. The construction phase has been further divided into tasks: a construction mobilization task and a road construction task are part of the construction phase and are assessed separately for this VC because they occur during separate time periods. Note that the construction demobilization task planned at the end of each road segment is expected to have similar effects as the construction mobilization task, and thus is not assessed separately.

Table 13.2 Potential Effects, Effects Pathways, and Measurable Parameters for Noise

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in noise level	Noise effects during the mobilization activity of the construction phase, due to the transportation of equipment	• Short-Term Construction day-night sound level (L_{dn}), measured in dBA • Daytime sound level (L_d), measured in dBZ, for low frequency noise analysis • Interference with Speech Comprehension noise effect daytime sound level (L_d), measured in dBA
	Noise effects during the road construction activity of the construction phase, due to the mobile equipment along different highway segments and stationary noise sources at the quarries and borrow sources (e.g., blasting, excavating, crushing)	• Short-Term Construction day-night sound level (L_{dn}), measured in dBA • Daytime sound level (L_d), measured in dBZ, for low frequency noise analysis • Interference with Speech Comprehension noise effect daytime sound level (L_d), measured in dBA
	Noise effects during the operations and maintenance phase, due to the traffic vehicles and maintenance activities on the completed highway, and stationary noise sources at the quarries and borrow sources	• Long-Term High Annoyance, measured in change in percent highly annoyed (%HA) between baseline and Application case, for longer term community annoyance • Daytime sound level (L_d), measured in dBZ, for low frequency noise analysis • 24-hour equivalent sound level ($L_{eq-24hr}$), measured in dBA, for traffic noise analysis

13.1.4 Boundaries

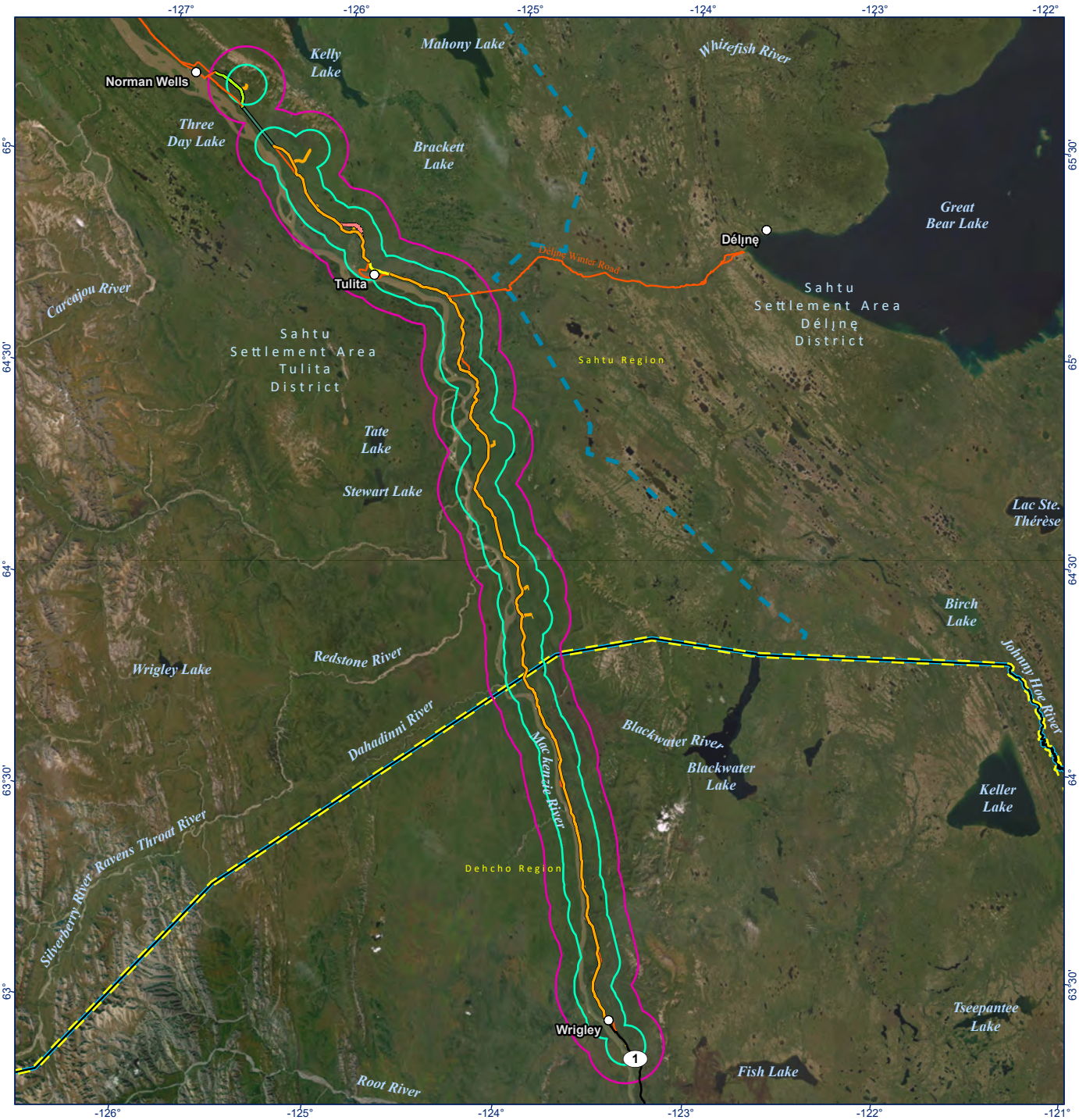
13.1.4.1 Spatial Boundaries

This section provides the rationale and a description of the three study areas:

- **Project Development Area (PDA):** The area of direct Project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 metres (m) wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sites with access roads on a 30 m ROW.
- **Local Assessment Area (LAA)**: The area within which measurable project-related effects (direct or indirect) are expected to occur. This assessment considers receptors located within the LAA, which is defined as an approximately 5 kilometre (km) buffer around the PDA. Further than 5 km, the project noise effects are expected to attenuate well below the baseline sound level due to natural atmospheric attenuation and ground absorption over distance.
- **Regional Assessment Area (RAA)**: The area that provides context for determining significance of Project effects and potential cumulative effects. The RAA for the assessment of effects on acoustic environment was set as an approximately 10 km (double of LAA) buffer around the PDA. The RAA is to account for other existing and future physical activities that may act cumulatively with the Project. Physical activities located beyond the 10 km buffer are not expected to interact with Project residual acoustic effects due to natural atmospheric attenuation and ground absorption.

Figure 13.1 shows a map of the Project's location, LAA, and RAA. Figure 13.2 to Figure 13.4 show the presence of receptors in the communities of Wrigley, Tulita, and Norman Wells, respectively.

Receptor areas are the boundaries within which human receptors are present. As shown in Figure 13.2 to Figure 13.4, the receptor areas in the community of Wrigley are located within the LAA and are the closest areas to the PDA due to their proximity to the road alignment route and borrow source 10.043 (approximately 350 m away), and therefore the residences within these areas are expected to be the most affected by the project's noise effects. The receptor area in the community of Tulita is also located within the LAA, but it is not as close to the PDA (approximately 2.5 km away) as the receptor areas in the community of Wrigley, and thus, the Tulita residences are not expected to be as affected by the Project's noise effects as the Wrigley residences. The receptor areas in the community of Norman Wells are outside of the LAA (approximately 5.7 km from the PDA), which means these receptors are not expected to be substantially affected by the Project's noise effects.



Notes

1. Coordinate System: NAD 1983 Northwest Territories Lambert

2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, Northwest Territories Cumulative Impact Monitoring Program (CIMP), GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, d. Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd. 2015-2016

3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 7/28/2023
TR by AJ on 7/28/2023

Client/Project
144903025-0089 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
13.1

Title
Project Location, Local Assessment Area and Regional Assessment Area

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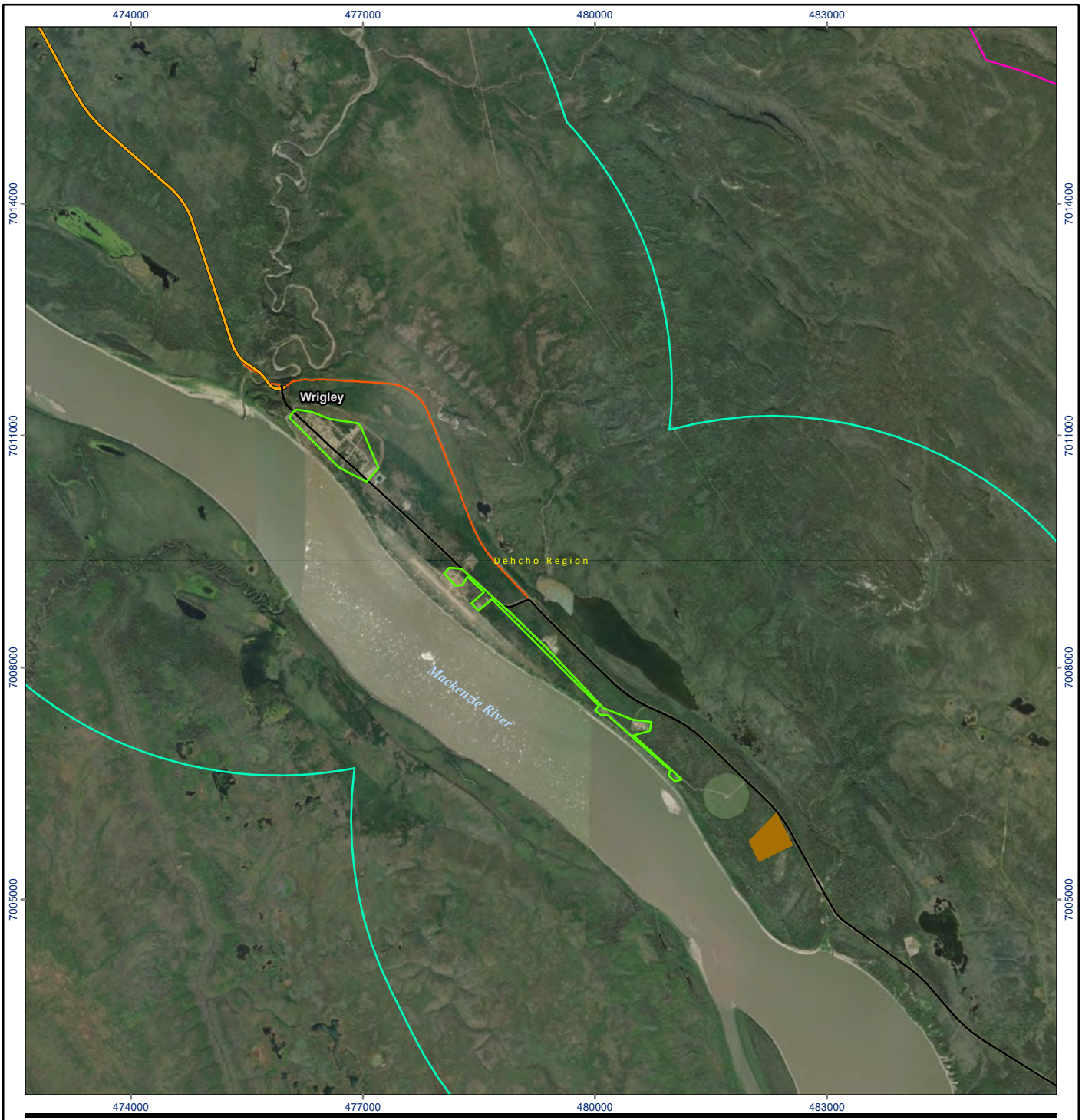

- Wrigley Receptor Area
- Proposed Mackenzie Valley Highway Project Route
- Proposed Borrow / Rock Quarry Site and Access
- Local Assessment Area
- Regional Assessment Area
- Winter Road
- Northwest Territories Highway

0 1 2 Kilometres
(At original document size of 8.5x11)
1:75,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 8/1/2023
TR by AJ on 8/1/2023

Client/Project
144903025-0090 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
13.2

Title
Receptor Area in the Community of Wrigley

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd. 2015-2016
3. Background: World Imagery: Earthstar Geographics
World Topographic Map: Esri, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
World Hillshade: Esri, USGS
Imagery date: 2021

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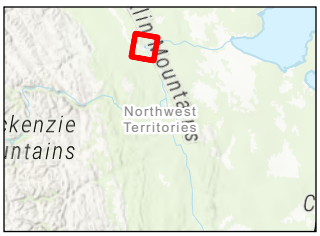

- Tulita Receptor Area
- Proposed Mackenzie Valley Highway Project Route
- Proposed Great Bear River Bridge
- Proposed Bear Rock Alignment Option
- Proposed Borrow / Rock Quarry Site and Access
- Local Assessment Area
- Regional Assessment Area
- Winter Road
- Northwest Territories Highway

0 1.5 3 Kilometres

(At original document size of 8.5x11)
1:150,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 8/1/2023
TR by AJ on 8/1/2023

Client/Project
Government of the Northwest Territories
Mackenzie Valley Highway Project

144903025-0091 REVA

Figure No.
13.3

Title
Receptor Area in the Community of Tulita

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd. 2015-2016
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
Imagery date: 2021

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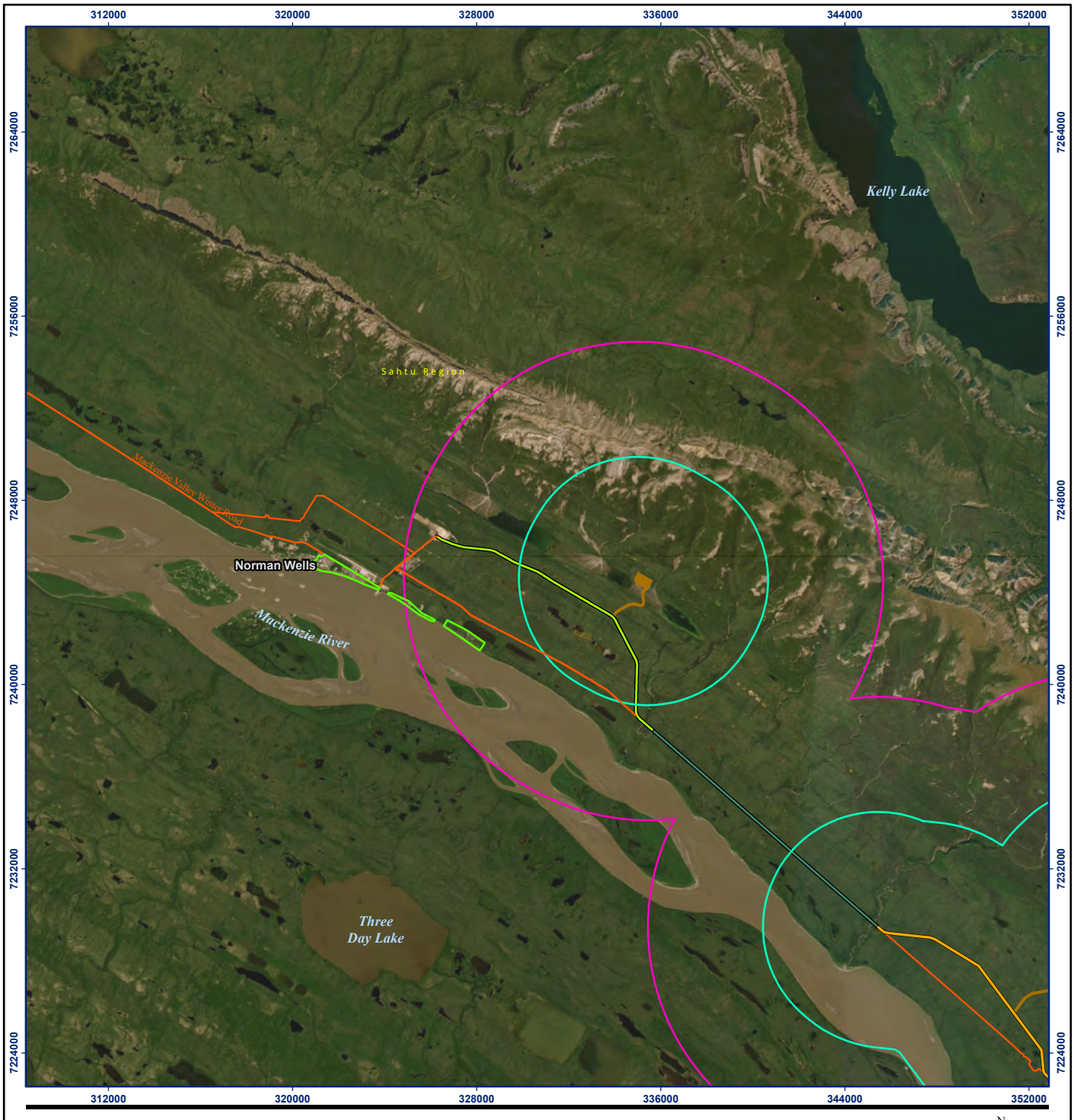

- Norman Wells Receptor Area
- Proposed Mackenzie Valley Highway Project Route
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Borrow / Rock Quarry Site and Access
- Local Assessment Area
- Regional Assessment Area
- Winter Road
- Northwest Territories Highway

0 2.5 5 Kilometres

(At original document size of 8.5x11)
1:250,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 8/1/2023
TR by AJ on 8/1/2023

Client/Project
144903025-0092 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
13.4

Title
Receptor Area in the Community of Norman Wells

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd. 2015-2016
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
Imagery date: 2021

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13.1.4.2 Temporal Boundaries

The Project will take approximately 10 years to construct over a timeframe of up to 20 years. The conceptual schedule assumes the highway will be constructed in three consecutive segments, beginning in approximately 2026: Wrigley to the Dehcho–Sahtu border (102 km); Tulita south to the Dehcho–Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells sometime between 2041 and 2046.

The project temporal boundaries include the construction phase and operations and maintenance phase. The construction phase has been further divided into the construction mobilization and activity, and road construction activities, because these activities generally occur at different times and their noise effects differ.

- Construction phase:
  - Construction mobilization and demobilization activity: The mobilization occurs prior to each of the three construction segments; and the demobilization occurs at the end of each segment. Each mobilization activity is expected to last approximately eight months, and may be in summer or winter. Equipment will be mobilized to and from sites within the PDA via barges and the MVWR as applicable.
  - Road construction activities: These include activities associated with road construction, such as site preparation, camp operations, quarry and borrow source development, embankment construction and culvert installations.
- Operations and maintenance phase: Operations and maintenance will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the Project is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, and borrow sources and quarries used only for construction are included within the construction phase.

13.1.5 Residual Effects Characterization

Noise effects are assessed using the following characterizations: direction, magnitude, geographic extent, timing, duration, frequency, and reversibility. Table 13.3 provides the definition of residual effects characterizations.

The main characterization to determine significance is the magnitude of noise effect. Significance is further described in Section 13.1.6.

Table 13.3 Characterization of Residual Effects on Noise

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse –** a residual effect that moves measurable parameters of noise in a negative direction relative to baseline **Neutral –** no net change in measurable parameters for noise relative to baseline
Likelihood	The probability that the residual effect will occur	**Unlikely –** the residual effect is almost certainly not to occur **Possible –** the residual effect could occur **Certain –** the residual effect will certainly occur
Magnitude	The amount of change in noise level relative to existing conditions	**Low** - Project noise effect is 10 decibels (dB)[1] below the baseline sound level or lower, as applicable **Moderate** - Project noise effect is below the noise thresholds[2] **High** - Project noise effect exceeds the noise thresholds[2]
Geographic Extent	The geographic area in which noise effect occurs	**PDA –** residual effects are restricted to the PDA **LAA –** residual effects extend into the LAA **RAA –** residual effects interact with those of other projects in the RAA
Timing	Considers when the noise effect is expected to occur.	**Not Sensitive -** Effect occurs outside of the period of receptor occupancy or timing does not change the effect **Moderate Sensitivity -** Effect occurs during the daytime period when people are generally less sensitive to noise **High Sensitivity -** Effect occurs during the nighttime period, when people are generally more sensitive to noise than during the daytime period
Duration	The time required until noise effect returns to its existing condition, or the noise effect can no longer be measured	**Short-term -** the residual effect lasts less than 1 year **Long-term -** the residual effect lasts more than 1 year
Frequency	Identifies how often the noise effect occurs and how often during the project or in a specific phase	**Single event** **Multiple irregular event –** occurs at no set schedule **Multiple regular event –** occurs at regular intervals **Continuous –** occurs continuously

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Reversibility	Pertains to whether the noise effect can return to its existing condition after the project activity ceases	**Reversible –** the residual effect is likely to be reversed after activity completion and reclamation **Irreversible –** the residual effect is unlikely to be reversed

Notes:

1 A 10 dB margin is a typical safety margin because in logarithmic arithmetic, adding a noise source that is 10 dB below the existing levels results in less than a 1 dB cumulative increase. Note that baseline levels do not apply to all parameters.

2 See Section 13.1.1 for a description of the Health Canada Noise Guidance thresholds for Long-Term, Short-Term Construction Noise Exposure, Long-Term Annoyance, Low-Frequency Noise, Speech Comprehension, and Alberta Transportation Traffic Noise Level.

13.1.6 Significance Definition

A project's noise effect is considered significant if all of the following criteria are met for a majority of the noise sensitive receptors:

- High-magnitude
- Duration of more than two months: the Health Canada noise guidance recommends higher noise thresholds for short-term community annoyance if the activity duration is less than two months (Health Canada, 2017)
- Moderate or high sensitivity timing
- Continuous, multiple irregular, or multiple regular event frequency

13.2 Existing Conditions for Noise

13.2.1 Methods

The assessment considered the Traditional Knowledge, TLRU information, and community engagement feedback available from Indigenous Governments, Indigenous Organizations, and other affected parties. This included both project-specific TLRU studies and studies completed for previous projects. Following a review of each information source, information related to noise was identified in the following reports and sources:

- Auld, J. and R. Kershaw. 2005. The Sahtú Atlas
- Dehcho First Nations. 2011. Traditional Knowledge Assessment of Boreal Caribou (Mbedzih) in the Dehcho Region
- IMG-Golder Corporation. 2006. Draft Report on Renewable Resource Assessment of the Pehdzéh Kį N'deh Area of Interest

- McDonald et al. 2010. Boreal Caribou Traditional Knowledge Collection Study: The Sahtu Settlement Area
- NWRRC TLRU Study (NWRRC, 2023)
- Project-specific engagement program (2021-2023)
- TRRC TLRU Study (TRRC, 2022)

The following guidance documents and baseline noise study were used to obtain information on estimation of baseline levels based on project activity duration, characteristics of activity, and characteristics of the receptors.

- Alberta Energy Regulator (AER), 2007: Noise Control
- Alberta Utilities Commission (AUC), 2021: Noise Control
- British Columbia Oil and Gas Commission (BC OGC), 2021: British Columbia Noise Control Best Practices Guideline
- Health Canada - Guidance for Evaluating Human Health Impacts in Environmental Assessment: Noise (Health Canada, 2017)
- Imperial Oil Resources Ventures Limited (IOL), 2004. Mackenzie Gas Project Environmental Impact Statement Volume 3: Biophysical Baseline Part A Environmental Setting, Air Quality and Noise
- Enbridge Pipelines (NW) Inc., 2018. Environmental Noise Impact Assessment For The Line 21 Segment Replacement Project

13.2.2 Overview

Based on feedback received through the public engagement program, TLRU studies, and publicly available literature, concerns were expressed regarding the effect of noise on wildlife. These potential effects are assessed in Chapter 10 (for caribou and moose), and Chapter 19 (for wildlife).

The Acoustic Environment Baseline Technical Data Report (Appendix 13A; K'alo-Stantec, 2022b) provides findings from the review of noise guidance documents and baseline noise study. The baseline sound levels for the Project are assumed to be 38 dBA L_{dn}, based on the 34 dBA daytime sound level (L_d) and 31 dBA nighttime sound level (L_n). These assumed levels are based on the average measurement results from the Mackenzie Gas Project and Norman Wells Pipeline project. The project baseline noise levels are assumed the same for the PDA along the proposed highway route and near the proposed quarry/borrow sources.

13.3 Project Interactions with Noise

The assumed schedule of activities in the construction phase (which includes the mobilization activities and road construction activities) and operations and maintenance phase used in the assessment is summarized in Table 13.4. Noise emissions are associated with multiple project activities.

Table 13.4 Project-Environment Interactions with Noise

Physical Activities	Timing	Environmental Effect Change in Noise Level
Construction Phase		
Mobilization of equipment, materials and fuel, resupply, and demobilization	Summer and winter	✓
Establishment and operation of camps	Year-round	✓
Site preparation of ROW, access, and workspaces	Winter	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	✓
Material haul	Year-round	✓
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓
Culvert installations	Summer or winter	✓
Road base placement, compaction, and surfacing	Summer	✓
Water withdrawal to support construction activities	Year-round	✓
Closure and reclamation of Mackenzie Valley Winter Road (MVWR) and temporary borrow sources quarries, camps, and workspaces	Summer	✓
Employment and contracted goods and services[1]	Year-round	–
Operations and Maintenance Phase		
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	✓
Material haul and stockpiling	Summer	✓
Operation of, and activities at, maintenance yards	Year-round	✓
Water withdrawal for dust control	Summer	✓
Employment and contracted goods and services[1]	Year-round	–
Presence and use of the highway	Year-round	✓
Highway and access road maintenance, including snow clearing, repair, grading, dust control	Year-round	✓
Vegetation control	Summer	✓
Bridge and culvert maintenance	As needed	✓

Notes:

✓ = Potential interaction

– = No interaction

[1] Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, "Employment and contracted goods and services" have been introduced as an additional component under each project phase.

Generally, noise emissions are associated with the activities from stationery and mobile equipment. In the Project, this includes activities from construction equipment, maintenance vehicles, off-road transportation equipment, borrow sources operation, campsite equipment, and road traffic vehicles.

13.4 Assessment of Residual Effects on Noise

Based on project interactions with the environment identified in Table 13.2, the Project may affect the noise levels. Potential effects, effect pathways, and mitigation measures that will reduce or eliminate the effects on noise levels are summarized in Table 13.5. The mitigation measures are further described in the Section 13.4.2.2.

Table 13.5 Potential Effects and Mitigation Measures for Noise

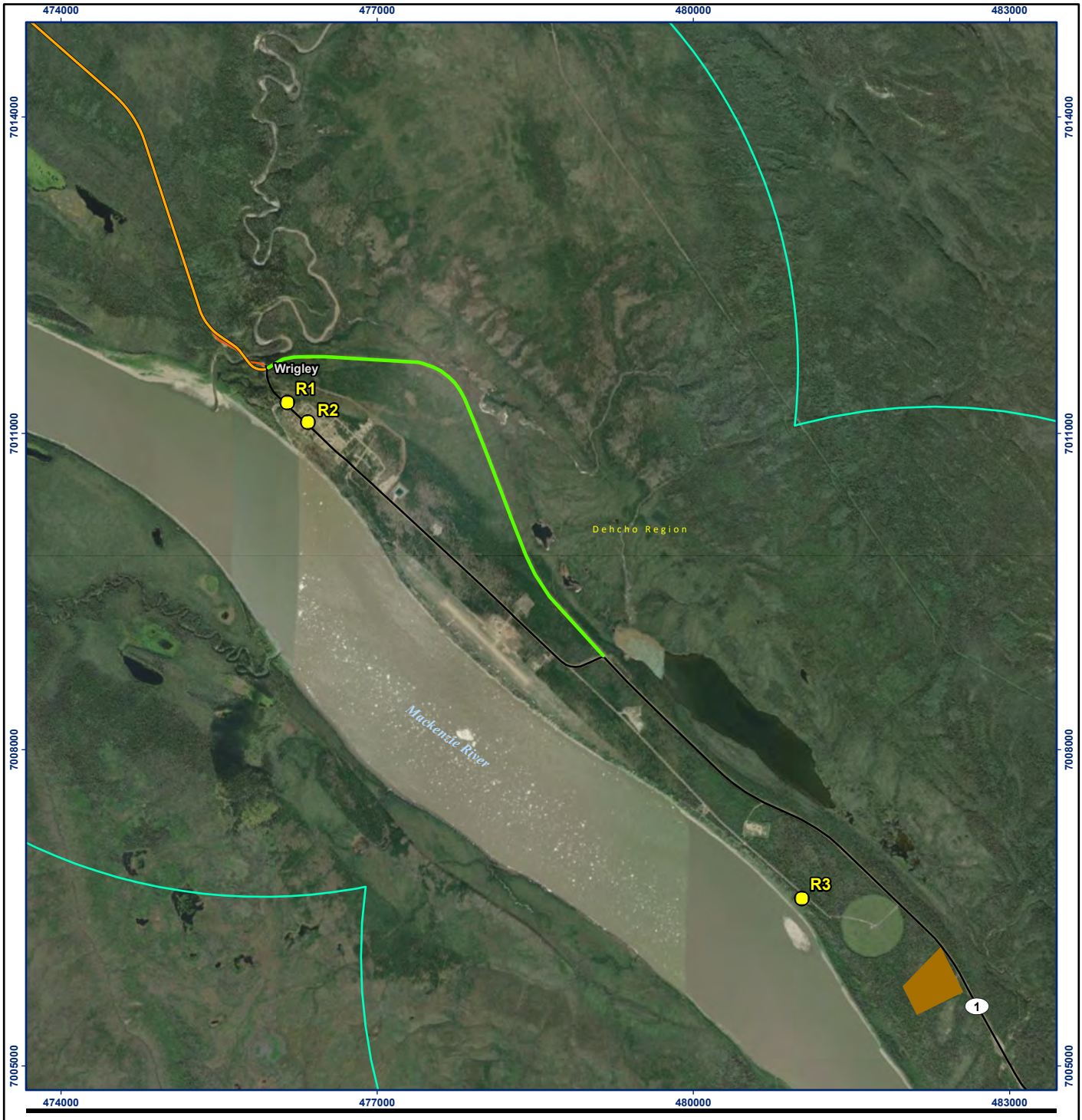
Effect Name	Effect Pathway	Mitigation Measures
Change in noise levels	Noise effects during the construction phase due to the mobile equipment along different highway segments and stationary noise sources at the borrow sources	• The GNWT will engage with communities to inform them of the activities and the noise sources that will occur prior to construction. • Blasting activities: – Blasting activities will be limited to daytime hours to the extent practical. – Methods to reduce the powder factor will be considered (e.g., through a combination of increased hole spacing, decreased column height of explosives, increased depth of stemming material in the blasthole, variable diameter blastholes) to reduce blasting effects. – The use of modified blasting techniques will be considered to reduce blasting effects, including use of electronic detonation instead of explosive detonation cord; use of air decking, which involves the use of an inverted cone in the blasthole to constrain energy within the rock mass; timing sequence to develop an echelon effect; and coordinating blast patterns towards a partially open face. – Blast mats will be used when blasting near receptors sensitive to blasting effects, including residences within 5 km. • Use of residential roads: – Use of residential roads by construction equipment will be limited, where possible. – Project vehicles will avoid the use of residential roads, where possible. • Communities will be informed of time periods and characteristics of noise that may exceed the recommended noise threshold. • Vehicles and equipment will be equipped with manufacturer-recommended noise muffling equipment. • Construction equipment will be regularly maintained. • The GNWT will develop a system to track complaints and responses to manage and mitigate feedback from the public regarding noise concerns.
	Noise effects during the operations and maintenance phase, due to the traffic vehicles and maintenance vehicles on the completed highway, and stationary noise sources at the borrow sources	

Effect Name	Effect Pathway	Mitigation Measures
Change in noise levels (cont'd)		• Transportation of construction materials and equipment via barge will be used to reduce the number of trucks for construction resupply along the Mackenzie Highway (Highway No. 1). Efficient project planning will be used to reduce haul distances and the number of trips required to move road construction materials.

13.4.1 Analytical Assessment Techniques

The following list presents the methodology used to predict and assess the project noise levels:

- The noise emission from each noise source is quantified using samples found in acoustical literature (Department for Environmental Food and Rural Affairs [DEFRA], 2005, 2008; Federal Highway Administration [FHWA], 2006; Federal Transit Administration [FTA], 2018) and previous studies done on similar equipment.
- Receptors of concern include human occupancies such as permanent residences, campgrounds, cabins and work camps used for the Project. Known receptors in the LAA were identified from area maps and satellite images and engagement input. Based on the best available information at the time, the main receptors within the study area are located in the communities of Wrigley, Tulita, and Norman Wells, where there are permanently occupied residences. Work camps have been excluded because these are expected to be occupied during the nighttime only when no project noise activities take place. Receptors for wildlife are assessed in the Wildlife and Wildlife Habitat VC (see Chapter 19). Figure 13.2 to Figure 13.4 show maps of the areas with the presence of receptors in the communities of Wrigley, Tulita, and Norman Wells, respectively. As described in Section 13.1.4.1, the residences in the receptor areas in the communities of Tulita and Norman Wells are expected to be less affected by the Project's noise effects than the residences in the community of Wrigley, due to their distances to the PDA. Figure 13.5 shows the location of the most affected receptors in the LAA, which are also all located in the community of Wrigley. These receptors represent the residences that are closest to the project activities as described below:
  - R1 represents the receptor that is closest to the road construction site
  - R2 represents the receptor that is closest to the path of the mobilization equipment
  - R3 represents the receptor that is closest to the borrow sources
- Each effect parameter is quantitatively assessed using the noise modelling software CadnaA (DataKustik, 2021). The model predicts the sound levels (e.g., L_d, L_n, L_{dn}) received at the receptors by considering parameters such as noise source acoustic factors and location, receptor location, and ground acoustic factors.
- The resulting sound levels are compared to their respective noise level threshold as described in Section 13.1.1 to determine its magnitude.
- Mitigation measures are designed to reduce the noise effect levels to below the thresholds, as feasible.



- Most Impacted Receptor
- Wrigley Winter Bypass Road
- Proposed Mackenzie Valley Highway Project Route
- Proposed Borrow Source
- Local Assessment Area
- Winter Road
- Northwest Territories Highway

0 0.5 1 Kilometres

(At original document size of 8.5x11)
1:55,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 8/1/2023
TR by AJ on 8/1/2023

Client/Project
144903025-0093 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
13.5

Title
Most Impacted Receptors in the Community of Wrigley

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd. 2015-2016
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
Imagery date: 2021

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13.4.2 Noise Effect

13.4.2.1 Effects Pathways

Increase in noise level is a potential effect associated with each of the project phases, notably via the following major noise effect pathways. The information comes from Chapter 5 (Detailed Project Description). The assumptions come from acoustic literature (FHWA, 2006), a Climate Lens Assessment completed for the Project (Appendix 24A; K'alo-Stantec, 2021), and consulting experience.

Mobilization activity of the construction phase:

- Trucks: up to 500 trucks for each construction segment, assuming up to 5 trucks on a single day
- Barges: up to 10 barges for each construction segment, assuming up to 1 barge on a single day

Road construction activities of the construction phase:

- Road construction equipment
  - Excavators: up to 2 units on a single day, assumed to operate 40% of the daytime
  - Bulldozers: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Graders: up to 2 units on a single day, assumed to operate 40% of the daytime
  - Mulchers: up to 1 unit on a single day, assumed to operate 50% of the daytime
  - Tree harvesters: up to 1 unit on a single day, assumed to operate 50% of the daytime
  - Water trucks: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Vacuum trucks: up to 2 units on a single day, assumed to operate 40% of the daytime
  - Fuel trucks: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Mobile drills: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Loaders: up to 4 units on a single day, assumed to operate 40% of the daytime
  - Compaction equipment: up to 2 units on a single day, assumed to operate 20% of the daytime
- Transportation equipment
  - Haul trucks: up to 10 trucks on a single day, travelling from the borrow sources to the road construction site
  - Transport shuttles for workers: assuming 5 shuttles to transport 70 workers from the campsite to the road construction site each day
  - Resupply trucks: up to 100 trucks; assuming up to 1 truck on a single day
  - Resupply barges: up to 10 barges annually; assuming up to 1 barge on a single day

- Construction campsite equipment
  - Vacuum truck: up to 1 truck on a single day
  - Generator: assumed equipped with typical noise suppression, operating 50% of the daytime
  - Incinerator: blower noise, assuming ≤85 dBA at 1 m, operating 50% of the daytime
- Borrow source activities
  - Crushers: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Sorting and Stockpiling: up to 10 rock trucks on a single day, assumed to operate 50% of the daytime

Operations and maintenance phase:

- Highway traffic
  - 50 vehicles per day, assuming 15% of vehicles are heavy trucks (K'alo-Stantec, 2021) and 10% of the volume is during the nighttime

The potentially noise-emitting activities that have been excluded are listed, followed by the justification for their exclusion.

- Maintenance yards: Intermittent and infrequent noise-emitting activities such as gravel loading are expected in the maintenance yards.
- Maintenance activities and vegetation control: Includes snow clearing, grading and dust control, ROW vegetation control, and culvert and bridge maintenance. These activities are considered to have negligible noise effects due to the following reasons:
  - Infrequent and seasonal nature of the activities
  - Expected to occur during the daytime period only and for a short period of time
  - Culvert and bridge maintenance equipment in most cases will be limited to a light pickup truck with negligible noise level
- Blasting events at quarries and road cuts: The blasting activities are designed to meet the Health Canada Noise Guidance threshold below which "little or no public annoyance is expected" (Health Canada, 2017) from the blasting effect, once the mitigation measures described in Section 13.4.2.2 are implemented. Due to its unique noise characteristic (Health Canada, 2017), blasting effects are not expected to act cumulatively with other noise effects of the Project, irrespective of their activity type.
- Activities at permanent quarries/borrow sources during the operations and maintenance phase: The nearest permanent proposed quarry/borrow source to the residences is located approximately 11 km away (north of Tulita), which is beyond the 5 km study area limit (note that R3 is assessed relative to a temporary borrow source, which will not require blasting activity).
- Demobilization equipment: As this task is expected to have similar effects as the mobilization task, it is not assessed separately.

13.4.2.2 Mitigation

Table 13.5 lists all mitigation measures that will reduce effects of the Project on noise. The following are key mitigation measures to be implemented to reduce noise effects:

- Blasting activities will be limited to daytime hours to the extent practical.
- Project vehicles will avoid the use of residential roads, where possible.
- Methods to reduce the powder factor will be considered (e.g., through a combination of increased hole spacing, decreased column height of explosives, increased depth of stemming material in the blasthole, variable diameter blastholes) to reduce blasting effects.
- The use of modified blasting techniques will be considered to reduce blasting effects, including use of electronic detonation instead of explosive detonation cord; use of air decking, which involves the use of an inverted cone in the blasthole to constrain energy within the rock mass; timing sequence to develop an echelon effect; and coordinating blast patterns towards a partially open face.
- Blast mats will be used when blasting near receptors sensitive to blasting effects (VC chapter), including residences within 5 km.
- Construction equipment and project vehicles will avoid the use of residential roads, where possible.
- In winter, haul trucks will use the Wrigley Winter Bypass road, shown in Figure 13.5, instead of passing through the community, if possible.
- Communities will be informed of time periods and characteristics of noise that may exceed the recommended noise threshold.
- Transportation of construction materials and equipment via barge will be used to reduce the number of trucks for construction resupply along the Mackenzie Highway (Highway #1).

The following general best practice mitigation measures will be considered:

- The GNWT will engage with communities to inform them of the activities and the noise sources that will occur prior to construction.
- The GNWT will develop a system to track complaints and responses to manage and mitigate feedback from the public regarding noise concerns.

13.4.2.3 Residual Effects

Table 13.6 summarizes the results for each of the effect parameters along with their respective threshold criteria, after the application of the mitigation measures described in Section 13.4.2.2. The calculations of these parameters follow the methodology from the Health Canada Noise Guidance (Health Canada, 2017) and Alberta Transportation Guidelines (Alberta Transportation, 2002). See Figure 13.5 for the location of the most affected receptors. Only the single most affected receptor out of the three most affected receptors identified in Section 13.4.1 is shown in the table.

Appendix 13B shows figures with the noise projection of the maximum predicted effect for the Short-Term Community Annoyance levels (L_{dn}) and Traffic Noise levels ($L_{eq\text{-}24hr}$) for each project phase.

Table 13.6 Summary of Effect Parameter Results

Project Phase	Effect Parameter	Most Affected Receptor [1]	Predicted Noise Effects at the Most Affected Receptor	Threshold Criteria [2]
Construction Phase – Construction Mobilization	Short-Term Community Annoyance (L_{dn})	R2	46 dBA	47 dBA
	Low-Frequency Noise (L_d)	R2	55 dBZ	70 dBZ
	Speech Comprehension (L_d)	R2	48 dBA	55 dBA
Construction Phase - Road Construction	Short-Term Community Annoyance (L_{dn})	R1 R3	**56 dBA** [3] 47 dBA [4]	47 dBA
	Low-Frequency Noise (L_d)	R1	**71 dBZ** [3]	70 dBZ
	Speech Comprehension (L_d)	R1	**58 dBA** [3]	55 dBA
Operations and Maintenance Phase	Long-Term Community Annoyance (%HA)	R1	0.0%	6.5%
	Low-Frequency Noise (L_d)	R1	33 dBZ	70 dBZ
	Traffic Noise ($L_{eq\text{-}24hr}$)	R1	19 dBA	65 dBA

Notes:

Bold values indicate that the noise level exceeds the threshold.

1 See Figure 13.5 for the receptor location.

2 The threshold criteria are described in Section 13.1.1.

3 The exceedances are expected to last 11 days for the short-term community annoyance parameter, and 3 days for the low-frequency noise and speech comprehension parameters.

4 Once the road construction site has moved away from Wrigley after 11 days, the most affected receptor is expected to be R3, due to its proximity to the south borrow source.

Mobilization and demobilization task of the construction phase:

- Short-Term Community Annoyance (L_{dn}): The predicted noise level at a Wrigley residential receptor closest to the construction activities, 46 dBA, is below the threshold limit of 47 dBA L_{dn}. The most affected receptors are the ones located along the path of the mobilization vehicles. The main source of noise is the mobilization trucks travelling on the highway during the summer season before each construction segment.
- Low-Frequency Noise (L_d): The predicted level, 55 dBZ, is below the threshold of 70 dBZ. Mobilization activities are not expected to cause low frequency "rattle" noise annoyance.
- Speech Comprehension (L_d): The maximum level, 48 dBA, is below the threshold of 55 dBA, indicating that mobilization activities are not expected to interfere with speech comprehension.

Road construction task of the construction phase:

- Short-Term Community Annoyance (L_{dn}): The highest predicted noise level, 56 dBA L_{dn}, is over the MNL threshold of 47 dBA L_{dn}. The most affected receptors are the ones located within 1 km of the road construction activity. The noise levels are expected to exceed the threshold for approximately 11 days while the construction activities are in proximity to Wrigley, which is below the two-month duration in the significance determination as described in Section 13.1.6. This 11-day period is estimated based on the distance to attenuate the sound propagation to below the threshold criteria at the receptors (approximately 1,200 m) and the predicted development rate as the construction activities progress north along the highway alignment (approximately 115 m per day). Afterwards, the construction activities will be further from the town (over 1 km north) for the noise levels to drop down to the threshold limit (47 dBA L_{dn}) or below, and the most affected receptors become the ones closest to the south borrow source.
- Low-Frequency Noise (L_d): The predicted noise level, 71 dBZ, is marginally over the threshold of 70 dBZ. Construction activities may result in low frequency "rattle" noise. The most affected receptors are the ones located within 450 m of the road construction activity. This effect is expected to last for approximately three days while the road construction activity is in proximity to the town of Wrigley.
- Speech Comprehension (L_d): The maximum level, 58 dBA L_d, is over the threshold limit of 55 dBA L_d. This means the construction activities are expected to interfere with speech comprehension, both indoor and outdoor. The affected receptors are the residences located within 450 m the road construction activity. This effect is expected to last for approximately three days while the road construction activity is in proximity to the town of Wrigley, which is below the two-month duration in the significance determination as described in Section 13.1.6. This three-day period is estimated based on the distance to attenuate the sound propagation to below the threshold criteria at the receptors (approximately 340 m) and the predicted development rate as the construction activities progress north along the highway alignment (approximately 115 m per day).

Operations and maintenance phase:

- Long-Term Community Annoyance (%HA): The highest predicted change in %HA result, 0.0%, is below the threshold of 6.5%. The result indicates that operations and maintenance activities are not expected to cause long-term community annoyance.
- Low-Frequency Noise (L_d): The predicted noise level, 33 dBZ L_d, is below the threshold of 70 dBZ L_d. Operations and maintenance activities are not predicted to result in low frequency "rattle" noise.
- Traffic Noise ($L_{eq\text{-}24hr}$): The highest predicted level at the closest receptor, 19 dBA $L_{eq\text{-}24hr}$, is below the threshold of 65 dBA $L_{eq\text{-}24hr}$.

13.4.3 Summary of Residual Effects

Table 13.7 summarizes the residual effects based on the characterizations described in Section 13.1.5.

- Direction: The direction for change in noise levels during all the project phases is rated adverse (A) because the phases result in a predicted increase in noise level compared to baseline conditions.
- Likelihood: The likelihood for change in noise levels during all the project phases is rated certain (CE) because the activities from all the project phases have noise-emitting sources.
- Magnitude: The magnitude for change in noise level during the construction phase is rated high (H) because the levels are expected to exceed the noise thresholds, although these high magnitudes are expected to last up to 11 days, after which the noise effect magnitude are expected to be moderate (M) because the noise levels are expected to drop below the thresholds. The magnitude during the operations and maintenance phase is rated low (L) for all parameters except Low-Frequency Noise because the levels are expected to stay within the noise thresholds and are at least 10 dB below the baseline sound levels. The magnitude is rated moderate (M) for the Low-Frequency Noise parameter because the levels are expected to stay within the noise threshold, and the baseline criteria for a low magnitude is not applicable for this parameter.
- Geographic Extent: The geographic extent for change in noise levels is expected to be limited to the LAA for each phase of the Project because beyond the LAA buffer limit of 5 km the project noise effects are expected to attenuate well below the baseline sound level due to natural atmospheric attenuation and ground absorption over distance.
- Timing: The timing in noise effect is rated as moderated sensitivity (MS) during the construction phase activities because these activities occur during the daytime period only, when people are generally less sensitive to noise. The timing in noise effect is rated as high sensitivity (HS) during the operations and maintenance phase activities because these activities also occur during the nighttime period, when people are generally more sensitive to noise than during the daytime period.

- Duration: The duration for change in noise levels during the construction phase is short-term (ST) because the construction activities at any specific location are expected to last less than one year. The duration for change in noise levels during the operations and maintenance phase is long-term (LT) because these activities will last more than one year.
- Frequency: The frequency for change in noise levels during the construction phase for most parameters, except for the speech comprehension parameter, are rated regular event (R) because the construction activities occurs at regular intervals (i.e., 12 hours during the daytime). The speech comprehension is rated irregular event (IR) because this parameter is only mainly affected by noise sources in close proximity to the receptor, which is not expected to occur regularly. The frequency for change in noise levels for the operations and maintenance phase is rated continuous (C) because the activities for this phase will occur continuously.
- Reversibility: The reversibility for change in noise levels during the construction phase is rated reversible (R) because the activities from this phase are temporary and the predicted increase in noise levels would return to baseline conditions at the end of these activities. The reversibility for change in noise levels during the operations and maintenance phase is rated irreversible (I) because the activities from this phase will continue for an indeterminate time.

For the road construction task, the high magnitude noise effects are expected to last 11 days for the short-term community annoyance, and three days for the low-frequency noise and speech comprehension as described in Section 13.4.2.3, both of which are below the two-month duration in the significance determination described in Section 13.1.6. After that, the noise effect magnitude is expected to be moderate.

With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirement consideration of engagement input and incorporation of Traditional Knowledge.

Mitigation measures for reducing effects of the Project on noise respect the values of the Petiniʔah (Bear Rock) CZ, Mio Lake CZ, Norman Range SMZ, K'ąąlǫ Tué (Willow Lake Wetlands) SMZ, and Deh Cho (Mackenzie River) SMZ as areas with important ecological habitats, and take into account traditional and community use of these areas. Although the noise assessment was based on proximity to permanent residences, the findings can be applied to temporary occupations such as cabins and campsites which may occur within the LAA.

Table 13.7 Residual Effects on Noise

Residual Effect	Residual Effects Characterization*							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Construction Phase								
Short-Term Construction Noise Exposure	A	CE	H	LAA	MS	ST	R	R
Low-Frequency Noise	A	CE	H	LAA	MS	ST	R	R
Speech Comprehension	A	CE	H	LAA	MS	ST	IR	R
Operations and Maintenance Phase								
Long-Term High Annoyance	A	CE	L	LAA	HS	LT	C	I
Low-Frequency Noise	A	CE	M	LAA	HS	LT	C	I
Traffic Noise Level	A	CE	L	LAA	HS	LT	C	I

KEY

*See Table 13.3 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMC: No Measurable Change
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

N/A: Not applicable

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

13.5 Assessment of Cumulative Effects on Noise

13.5.1 Residual Effects Likely to Interact Cumulatively

The project and physical activities inclusion list, shown in Table 4.2, identifies other projects and physical activities within the largest of the RAAs (wildlife).

Projects and physical activities have the potential to affect the cumulative sound levels if all the following conditions apply:

- The activity period overlaps with the project activity period
- Residences exist within 5 km of both the Project activities and the other activity
- The activity, to be considered noise-emitting, includes activities from stationery and mobile equipment

Where residual effects from the Project act cumulatively with residual effects from other projects and physical activities, as listed in Table 13.8, a cumulative effects assessment is undertaken to determine their significance. For each project and physical activity identified in Table 13.8 that is marked as not likely to interact cumulatively with the Project (without a check mark), a justification is provided and a cumulative effects assessment is not warranted.

The following activities are expected to interact cumulatively with the Project activities. The cumulative effects assessment for these activities is described in the next section.

- Mackenzie Highway #1
- Mackenzie Valley Winter Road (MVWR) and Délı̨nę Winter Road
- Wrigley Power Generation facility
- Tulita Power Generation facility
- Great Bear River Bridge project

No other surrounding projects or activities are expected to interact cumulatively with the Project, as explained below:

- One infrastructure activity overlaps spatially with the Project, the Enbridge Pipeline terminal station at Norman Wells, but no residences exists within the overlapping area.
- Other infrastructure, such as the Prohibition Creek Access Road and Dhu-1 Quarry are within the RAA but more than 5 km from residences, and therefore will not contribute cumulatively to noise effects.
- No oil and gas activities, mining and exploration activities, remediation activities, or staging activities are planned to occur during the time period of any of the project phases.

- A camp activity is expected at an unknown date in the future and is located within 5 km of residences in Norman Wells; however, these residences are located more than 9 km away from the nearest project activity, and thus the project effects are not expected to be cumulative at these residences.
- No geotechnical or quarrying activities are planned to occur during the time period of any of the phases of the Project. One geotechnical activity overlaps spatially with the Project, but that activity will end before the project construction phase begins near that location.

Table 13.8 Projects with the Potential to Contribute to Cumulative Effects in the RAA

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects
	Change in Noise Level
Past and Present Physical Activities and Resource Use (Base Case)	
Geotechnical	-
Oil, Gas & Seismic*	-
Infrastructure	
Mackenzie Valley Winter Road	✓
Mackenzie Highway #1	✓
Délı̨nę Winter Road	✓
Quarries and Borrow Sources	-
Mining & Exploration	-
Municipal Operations, including water, waste, power, and community development	
Wrigley Municipal Activities	✓
Tulita Municipal Activities	✓
Project-Related Physical Activities (Project Case)	
Mackenzie Valley Highway Project	✓
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)	
Quarries	-
Infrastructure	
Great Bear River Bridge	✓
Oil and Gas	-

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with Project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = Includes support activities such as production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas.

The ongoing operations and maintenance activities associated with the Mackenzie Highway #1 will continue to occur during the period of the project construction and operations and maintenance phases. Residences exist within 5 km of this activity and the Project activities. Highway #1 has traffic activities year-round and ends at the community of Wrigley, where the PDA begins. The traffic volume is estimated to be 60 to 70 vehicles per day or less, as obtained from the nearest traffic count location at the Mackenzie River Ferry (GNWT, 2020). Given the low traffic volume, the cumulative noise effect from the interaction of Highway #1 with the project activities is expected to be low.

The MVWR is built every winter and runs along the same corridor as the project highway corridor. The traffic volume, is estimated to be 50 vehicles per day, based on traffic volumes recorded at the turnoff to the Délı̨nę Winter Road (GNWT, 2020)). As this road will be replaced by the project highway, the temporal overlap will be only during the project construction phase and only during the winter. Given its low traffic volume and short temporal overlap with the Project, the cumulative noise effect from the interaction of MVWR with the project activities is expected to be low. The Délı̨nę Winter Road will continue to operate once the Project is completed, but is not expected to add traffic (i.e., traffic reflects combined use of both roadways).

The Great Bear River Bridge project within the municipal boundary of Tulita is scheduled to be completed in 2027. As such, there is a short temporal overlap with the Project. Depending on the sequence of construction of Project highway segments, there may or may not be spatial overlap with the Project's residual effects on noise. If Project construction activities within 5 km of the Hamlet of Tulita occur at the same time as the construction of the Great Bear River Bridge, cumulative effects on noise are likely to occur. These will also combine with the effects of the Tulita Power Generation Facility. There is no overlap between the Great Bear River Bridge and the Project during the operations and maintenance phase, as the bridge will become part of the highway and is assessed as such.

13.5.2 Power Generation Facility Noise Effect

13.5.2.1 Cumulative Effects Pathways

Noise effects from the Wrigley and Tulita Power Generation facilities are expected to occur from the continuous operation of the facility generators. The following information on the facilities come from the Northwest Territories Power Corporation website (NWT Power Corporation, 2022):

- Wrigley Power Generation Facility:
  - Power is supplied by three diesel generating units with a total output of 781 kilowatts (kW)
  - The solar power systems of 10 kW capacity are expected to have negligible noise emissions

- Tulita Power Generation Facility:
  - Equipped with three diesel engines with a total installed capacity of 1.1 megawatts (MW)
- Both facilities are expected to run continuously during both the daytime and nighttime

13.5.2.2 Mitigation Measures for Cumulative Effects

The following typical noise mitigation measures are assumed to be present at the Power Generation facilities:

- The generators are enclosed in typical acoustical metal buildings with doors closed year-round
- Generator cooler fans are designed to emit 85 dBA or less at 1 m
- Generator exhausts are equipped with typical hospital-grade silencers or equivalent

13.5.2.3 Residual Cumulative Effects

Among the measurable parameters listed in Table 13.2, only the long-term community annoyance parameter applies to cumulative effects assessments, because this parameter considers baseline levels as part of its calculation, for which the noise contribution from existing adjacent sources applies. The other parameters, short-term community annoyance, low-frequency noise, speech comprehension, and traffic noise, do not consider baseline levels as part of their calculations, and as such, the noise contribution from existing adjacent sources does not apply. Since the long-term community annoyance parameter only applies to the Project's operations and maintenance phase, only this phase is assessed.

Table 13.9 summarizes the results of the cumulative noise effect on long-term community annoyance along with their respective threshold criteria for the receptors that are most affected by the project activities, R1, R2 and R3 in the community of Wrigley, as identified in Section 13.4.1. Since the residences in the community of Tulita are located farther away from the project activities than the most affected receptors assessed, the Project's contribution to the cumulative effects is expected to be less for the Tulita residences, and thus these residences do not need to be assessed separately.

The highest change in %HA, 0.0%, is below the threshold of 6.5%. The result indicates that the cumulative interaction of the Wrigley Power Generation activity with the project operations and maintenance activities are not expected to cause long-term community annoyance.

Since the Project's contribution to the baseline results is a negligible change in %HA, the Project's contribution to the cumulative effect is not noted. Since the Project noise effects are expected to attenuate well below the baseline sound level beyond a 5 km distance, as described in Section 13.1.4.1, the overall regional effects are not expected to be substantial.

Table 13.9 Cumulative Effect Results on Long-Term Community Annoyance

Receptor	Baseline %HA [1]	Cumulative %HA [2]	Change in %HA [3]	Threshold Criteria for %HA
R1	1.4	1.4	0.0%	6.5%
R2	2.4	2.4	0.0%	6.5%
R3	0.6	0.6	0.0%	6.5%

Notes:

The percent highly annoyed (%HA) is determined as per Appendix F1 of the Health Canada Noise Guidance (Health Canada, 2017).

1 The %HA for the baseline condition includes the contribution of the assumed baseline sound level for the region of 38 dBA L_{dn} as described in Section 13.2.2, and the Power Generation facility sound level.

2 The %HA for the cumulative condition includes the baseline condition and the project contribution.

3 The difference between the Baseline %HA and the Cumulative %HA.

13.5.3 Great Bear River Bridge Noise Effect

13.5.3.1 Cumulative Effects Pathways

Noise effects from the Great Bear River Bridge are expected to occur from the construction of access roads, piers and bridge superstructure. The construction activities are expected to take approximately 4 years, and will be located approximately 800 m from the nearest Tulita residence. In contrast, the nearest Project segment, on the south end of the Tulita North segment, is located approximately 2,500 m northwest of the nearest Tulita residence.

The noise effects from the Great Bear River Bridge activities are assumed to be similar to the effects from the Project's construction activities (Section 13.4.2.1), and the cumulative noise effects include the following parameters:

- Short-Term Community Annoyance
- Long-Term Community Annoyance
- Low-Frequency Noise
- Speech Comprehension

13.5.3.2 Mitigation Measures for Cumulative Effects

The principal mitigation measure for cumulative effects on noise from construction of the Great Bear River Bridge project within 5 km of the Project and within the Hamlet of Tulita is to apply the mitigation measures as identified in Section 13.4, and to plan Project activities such that they do not occur at the same time as the Great Bear River Bridge Project within 5 km of Tulita, if possible.

13.5.3.3 Residual Cumulative Effects

Under the assumption that the noise effect from the construction activities of the Great Bear River Bridge project are equivalent to the Project construction activities, the noise effects from the Great Bear River Bridge activities are expected to exceed the Short-Term Community Annoyance noise threshold criteria (per Health Canada, 2017) on their own. Consequently, the cumulative effect from the Great Bear River Bridge project activities and the Project activities, where and if ,they overlap in time and space, are expected to exceed some the noise threshold criteria for the construction phase of the Project. All the noise threshold criteria are expected to be met for the operations and maintenance phase of the Project.

13.5.4 Summary of Cumulative Effects

Table 13.10 summarizes the cumulative noise effect from the power generation facility activities, the Great Bear River Bridge activities, and the project activities based on the characterizations described in Section 13.1.5.

- Direction: For the power generation facility activities, the direction for change in noise levels is rated neutral (N) because the cumulative effect results in a no-net change in measurable in noise level compared to baseline conditions. For the Great Bear River Bridge activities, the direction for change in noise levels during the construction phase of the Project is rated adverse (A) because the cumulative effect results in a negative direction in noise effect compared to baseline conditions.
- Likelihood: For the power generation facility activities, the likelihood for change in noise levels is rated certain (CE) because the activities from the power generation facilities and the Project have noise-emitting sources. For the Great Bear River Bridge activities, the likelihood is rated possible (P) for the construction phase because the Great Bear River Bridge activities may not overlap in time with the Project activities, and the magnitude of its construction activity noise effects are not certain.
- Magnitude: For the power generation facility activities, the magnitude for change in noise level is rated low (L) because the levels are expected to stay within the noise thresholds and are at least 10 dB below the baseline sound levels. For the Great Bear River Bridge activities during the construction phase of the Project, the magnitude is rated high (H) because the Great Bear River Bridge activities are expected to exceed some of the noise thresholds.
- Geographic Extent: For both the power generation facility activities and the Great Bear River Bridge activities, the geographic extent for change in noise levels is expected to be limited to the LAA because, beyond the LAA buffer limit of 5 km, the activity noise effects are expected to attenuate well below the baseline sound level due to natural atmospheric attenuation and ground absorption over distance.

- Timing: For the power generation facility activities, the timing in noise effect is rated as high sensitivity (HS) because the activities also occur during the nighttime period, when people are generally more sensitive to noise than during the daytime period. For the Great Bear River Bridge activities, the timing is rated moderate sensitivity (MS) because the Great Bear River Bridge activities are expected to occur only during the daytime period when people are generally less sensitive to noise.
- Duration: For the Great Bear River Bridge activities during the construction phase of the Project, the duration for change in noise levels is short-term (ST) because the cumulative effect from these activities and the Project activities will last less than one year. For the power generation facility activities during the operations and maintenance phase of the Project, the duration for change in noise levels is long-term (LT) because the cumulative effect from these activities and the Project activities will last more than one year.
- Frequency: For the power generation facility activities, the frequency for change in noise levels is rated continuous (C) because the activities will occur continuously. For the Great Bear River Bridge activities, the frequency is rated regular event (R) because the construction activities occur at regular intervals (i.e., expected to occur 12 hours during the daytime).
- Reversibility: For the power generation facility activities, the reversibility for change in noise levels is rated irreversible (I) because the activities will continue for an indeterminate time. For the Great Bear River Bridge activities, the reversibility is rated reversible (R) because the activities are temporary and the predicted increase in noise levels would return to baseline conditions at the end of these activities.

Table 13.10 Residual Effects on Noise

Residual Effect	Residual Effects Characterization*							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Project Construction Phase								
Great Bear River Bridge with Project	A	P	H	LAA	MS	ST	R	R
Project Operations and Maintenance Phase								
Power Generation Facility with Project	N	CE	L	LAA	HS	LT	C	I

KEY

*See Table 13.3 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMC: No Measurable Change
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

N/A: Not applicable

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

13.6 Determination of Significance

13.6.1 Significance of Residual Effects

The criteria that determine the effect significance is described in Section 13.1.6. Project activities have been grouped into the construction mobilization activity, the road construction activity, and the operations and maintenance phase.

During the construction mobilization activities and the operations and maintenance phase, the magnitude, duration, sensitivity, and frequency at all receptors do not meet the significance criteria. During the road construction activities, the duration, sensitivity, and frequency at all receptors do not meet the significance criteria. However, the magnitude classification at R1 (see Figure 13.5) is high for a period of 11 days which is below the two-month criteria for duration; and otherwise, the magnitude classification at all receptors is predicted to be moderate or low for the remaining time period. In consideration of the residual effect classifications, no receptor meets all the criteria of magnitude, duration, sensitivity, and frequency, for significance as defined in Section 13.1.6; therefore, the project noise effect is not significant.

13.6.2 Significance of Cumulative Effects

As described in Section 13.5, the Wrigley and Tulita Power Generation facility activities and the Great Bear River Bridge activities are the only two project and physical activities that are expected to interact cumulatively with the Project in a potentially moderate or high magnitude. As described in Section 13.5.2.3, the cumulative interaction of the Power Generation facility activities with the Project activities are not expected to cause long-term community annoyance at any receptor. As described in Section 13.5.3.3, the cumulative interaction of the Great Bear River Bridge construction activities with the Project activities are expected to exceed some the noise threshold criteria at the nearest residences in the community of Tulita, if this project occurs at the same time as the Project. Therefore, the cumulative effects are significant.

13.6.3 Project Contribution to Cumulative Effects

Since the Project's effects on noise on their own are not significant, as explained in Section 13.6.1, and the Project's noise levels result in a negligible change in percent highly annoyed over the baseline condition as described in Section 13.5.2.3, the Project's contribution to cumulative noise effect is not significant.

13.7 Prediction Confidence

The predication confidence for residual effects and cumulative effects for acoustic is moderate and is based on the accuracy of the project design information, noise source data, and sound propagation algorithm.

- Acoustic models can be revised, if necessary, when final design information is available. Conservative assumptions were used, as described in the next section.
- The various sound power levels of noise sources were established with field measurements of similar equipment, or acoustic literature. For most data samples, upper percentiles were used to be conservative.
- The Cadna/A model predicts outdoor noise in accordance with ISO 9613. The ISO 9613 sound propagation algorithms have a published accuracy of ±3 dB over source receiver distances between 100 m and 1,000 m. The accuracy for distances up to or over 1.5 km is not stated. The ISO 9613 model also produces results representative of meteorological conditions enhancing sound propagation (e.g., downwind and temperature inversion conditions). These conditions do not occur all the time; therefore, model predictions are expected to be conservative.

13.7.1 Assumptions

The following assumptions have been made to estimate the noise effects:

- The frequency of activities were obtained from acoustical literature for similar equipment (FHWA, 2006).
- The traffic speed limit is conservatively assumed to be up to 50 kilometres per hour (km/h) in communities such as Wrigley, though local by-laws will apply. This is based on vehicle speeds to be limited to 50 km/h on all unfinished project road surfaces.
- The Wrigley Winter Bypass Road is assumed to be operational during the winter season from December to March.
- The development rate of the highway sections is assumed to be evenly distributed throughout the construction period.
- The terrain within 5 km from the highway is conservatively assumed to be flat, such that there are no natural barriers between the noise source and the receptor to attenuate the sound.
- Transport shuttles for workers have a capacity of 14 passengers per vehicle.
- Highway traffic volume is 50 vehicles per day, assuming 15% of vehicles are heavy trucks (K'alo-Stantec, 2021) and 10% of the volume is during the nighttime.
- The list of maintenance equipment was obtained from the Climate Lens Assessment for the Project (K'alo-Stantec, 2021).

- Borrow source material will be transported from the borrow source that is nearest to the road construction site.
- The mobilization vehicles operate 50% of the days and the trips are evenly spread out throughout the mobilization period.
- Downwind conditions exist 100% of the time, which is more conservative than upwind or crosswind conditions.
- All operating equipment was modelled at 100% capacity even though the capacity might be less throughout the activity period.
- A ground factor of 0.7 is used in the noise model, which conservatively represents uncultivated land for both summer and winter seasons.
- The method for calculating the Power Generation facility generators sound level emissions comes from Engineering Noise Control (Bies and Hanson, 2009).
- The noise effects from the Great Bear River Bridge activities are assumed to be similar to the effects from the Project's construction activities.

13.7.2 Gaps and Uncertainties

A gap that may affect the assessment of potential effects on noise are listed below:

- No receptors (permanent residences) outside of municipalities were identified, based on the best available information at the time.

Uncertainties in the calculations are listed below:

- Sound level emissions for the noise sources have been quantified using samples found in acoustical literature (DEFRA, 2005, 2008; FHWA, 2006; FTA, 2018) and previous studies done by Stantec on similar equipment. Final values were processed as a percentile of the sample. Uncertainties are present due to the variance in the sample values.
- The sound propagation method used in the model has an uncertainty of ±3 dB at a distance between 100 m and 1,000 m. The accuracy for distances up to or over 1.5 km is not stated (ISO 9613-2).

13.8 Follow-up and Monitoring

No specific noise monitoring is proposed. Noise levels at assessed receptor locations are anticipated to be highest during the construction phase, but will be short-term. Noise monitoring is not likely to be able to lead to a timely response, and additional reasonable noise mitigation measures may not be available. The GNWT will develop a system to track complaints and responses to manage and mitigate feedback from the public regarding noise concerns. Noise monitoring may be initiated on a case-by-case basis, if required.

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14.0 ASSESSMENT OF POTENTIAL EFFECTS ON TERRAIN, SOILS AND PERMAFROST

Terrain, Soils and Permafrost were selected as a Valued Component (VC) as these interrelated elements together support ecosystem functions and provide foundations to biophysical components. The VC aligns with the Subject of Note (SON) Terrain, Soils and Permafrost in the Terms of Reference (ToR; Mackenzie Valley Environmental Impact Review Board [MVEIRB], 2015 [Public Registry {PR}#66]). The term "terrain" refers to characteristics of surficial materials and landforms (or surface expressions) and the geomorphological processes which result in the modification of surface materials and their surface expressions. These characteristics, alongside the development of soils (i.e., the uppermost unconsolidated layer of mineral and organic material) and the availability of surface water, are the foundation of northern ecosystems. Permafrost also has a fundamental importance to northern ecosystems by stabilizing certain terrain and modifying the hydrological cycle. Permafrost ecosystems, therefore, help keep ecological balance by supporting unique habitats for animal and plants.

The Mackenzie Valley Highway Project (the Project) has the potential to affect terrain, soils, and permafrost during the construction and operations and maintenance phases of the Project through pathways such as land clearing, ground disturbance and its effects on terrain, soils, physical and thermal stability, and alteration of surface and sub-surface water flow paths.

Changes to terrain, soils, and permafrost conditions may trigger changes to the surface water quantity (see Chapter 15), vegetation (see Chapter 18) fish and fish habitat (see Chapter 17), wildlife and wildlife habitat (see Chapter 19), and traditional land and resource use (see Chapter 11). These changes may occur due to specific project activities and/or from naturally occurring processes (e.g., climate change or forest fires) over the life of the Project.

The assessment of potential effects on the Terrain, Soils and Permafrost VC concludes that with the application of mitigation measures, residual effects resulting from the Project on terrain, soils, and permafrost will be adverse. Residual effects and cumulative effects are not expected to threaten the stability of local terrain, soil development, and/or soil capability, or physical and thermal stability of permafrost and therefore are predicted to be not significant.

14.1 Scope of Assessment

14.1.1 Regulatory and Policy Setting

The assessment of potential project-related effects on terrain, soils, and permafrost is guided by the ToR (MVEIRB, 2015 [PR#66]), federal and territorial guidance and, where applicable, the Sahtu Land Use Plan (SLUP).

14.1.1.1 Federal and Territorial Guidelines

The following notable federal and territorial guidance applies:

- The Government of the Northwest Territories (GNWT) Land Use Guidelines for Camp and Support facilities (GNWT, 2015a)
- The GNWT Land Use Guidelines Pits and Quarries (GNWT, 2015b)
- The GNWT Land Use Guidelines Access: Roads and Trails (GNWT, 2015c)
- Guidelines for Development and Management of Transportation Infrastructure in Permafrost Regions by the Transportation Association of Canada (TAC, 2010)
- National Guide to Erosion and Sediment Control on Roadways Projects (TAC, 2005)
- The GNWT Erosion and Sediment Control Manual (GNWT, 2013)
- General guidance for various soils parameters is provided via the Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME, 2007)
- Quarry Development Plan Template (GNWT, 2021)

14.1.1.2 Sahtu Land Use Plan

Specific to the areas to which the SLUP applies, the Project must meet the 13 general conformity requirements (CR) of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023). Specific to permafrost, CR#10 requires that *"Any land use activity requiring a land use permit or water license must be designed and carried out in a manner that prevents and/or mitigates adverse environmental impacts resulting from the degradation or aggradation of permafrost*." Conformity Requirement #2 requires that "*The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge."*

Additionally, CR #14 requires that the Project be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 2023), including the following:

- Petiniʔah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)

- K'ąąlǫ Tué (Willow Lake Wetlands) SMZ (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

14.1.2 Influence of Engagement

The GNWT has engaged with Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapters 2 (Consultation and Engagement), 3 (Traditional Knowledge), and 11 (Culture and Traditional Land Use) of this Developer's Assessment Report (DAR). The GNWT has recently initiated Consultation Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, and through a review of publicly available TLRU information, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to terrain, soils, and permafrost. This feedback has been considered and summarized in Table 14.1 and has been integrated into the assessment of potential effects to terrain, soil, and permafrost and associated effects on valued resources including wildlife, vegetation, and water that follows.

14.1.3 Potential Effects, Pathways, and Measurable Parameters

Potential effects on terrain, soils, and permafrost could occur wherever project activities interact with the ground surface. For this reason, one of the key ways to address changes to terrain, soils, and permafrost is to limit ground disturbance during the Project.

The ground surface, either the organic/mineral topsoil or overall surficial materials and underlying permafrost, could be affected by several activities during the construction and operations and maintenance of the highway. Changes to terrain or soil conditions may occur due to clearing activities, set up and operation of access roads and camps, excavation of borrow materials, quarrying, excavation of road cuts, and construction of the embankment. All of these activities require travel across the ground, either along the alignment, along access roads, or working in areas of open cut in borrow sources or quarries, therefore presenting a potential effect pathway on terrain, soils, and permafrost.

To mitigate potential effects on terrain, soils, and permafrost, the construction and operation activities will be limited, to the extent possible, to within the planned footprint of the Project.

The potential effects on terrain, soils, and permafrost considered in this DAR include:

- Change in terrain conditions (including potential erosion, modification of local drainage patterns, and slope stability)
- Change in soils conditions (including physical, chemical, and biological properties)
- Change in permafrost conditions (including loss of permafrost, either from degradation of physical or thermal properties)

Table 14.1 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
Sahtu Dene and Métis expressed concerns that thawing permafrost will increase turbidity and solids in local streams, affecting water quality and quantity.	SRRB, 2016	The GNWT has identified mitigation measures to reduce effects on terrain, soils, and permafrost. Project design will avoid ice-rich areas where possible. Steep grades where subsidence may occur as a result of permafrost thaw will be avoided, where possible. A fill-only construction approach will be used, except at specific locations of road cuts. A project-specific Erosion and Sedimentation Control Plan (ESCP), Quarry Development Plan (QDP), and Permafrost Protection Plan (PPP) will be developed and implemented. Best management practices for erosion control will be implemented according to the Erosion and Sedimentation Control Plan. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning.	For mitigation measures to reduce effects of the Project on terrain, soils, and permafrost, see Table 14.5. See also: Section 14.4.2 (Change in Terrain Conditions) Section 14.4.3 (Change in Soils Conditions) Section 14.4.4 (Change in Permafrost Conditions) Chapter 5 Table 5.2 Summary of Consideration of Community Input on Design Chapter 10 (caribou and moose) Chapter 11 (culture and traditional land use) Chapter 15 (water quantity) Chapter 16 (water and sediment quality) Volume 5 for management plans.
Elders in the K'ásho Got'ı̨nę and Tulita regions expressed concerns about potential project effects associated with land clearing, including increased rates of thawing permafrost, leading to problems with vegetation establishment, erosion and slumping on the banks of the Sahtu waterbodies, which has previously been linked to erosion in Great Bear River and other waterbodies in the area.	Auld and Kershaw, 2005; Golder, 2015		
Sahtu Region residents expressed concerns about potential project effects thawing permafrost (erosion, flooding, scouring, reduced land subsistence), which also can affect ground water and surface water; and effects to Norman Wells water quality.	SRRB, 2016		
Sahtu Dene and Métis reported concern that thawing permafrost will increase turbidity and solids in local streams, affecting water quality.	SRRB, 2016		
Dehcho First Nations reported increased temperatures and precipitation, changes to snow and vegetation, and effects on lake and river ice and boat access. They stated that warmer temperatures, thawing permafrost, and other environmental changes create concerns related to the environment, including the thawing of permafrost which harbors and protects lichens and reduces the availability of lichen-rich habitats important for caribou. Additionally, forest fires are burning the moss, which leaves the permafrost poorly insulated.	Dehcho First Nations, 2011; Golder, 2015		

Comment	Source	GNWT Response	Where Addressed
Local knowledge provided by Tulita Renewable Resources Council (TRRC) and Norman Wells Renewable Resources Council (NWRRC) TLRU study participants explained that thawing permafrost creates wetter, boggier areas where the ground was previously hard, which makes traversing the landscape to practice TLRU more difficult.	NWRRC, 2023; TRRC, 2022		
NWRRC study participants observed that weather in the TLRU study area has changed over the last few years, attributed to cumulative effects and warming temperatures, which affects the land and the permafrost and can influence the flow of creeks.	NWRRC, 2023		
TRRC study participants reported increase erosion resulting from road construction and operation along the Mackenzie Valley Winter Road (MVWR).	TRRC, 2022		
Community engagement participants stated there are increased landslides and sloughing and permafrost thawing, accelerated by climate change. Warmer temperatures, thawing permafrost, and other environmental changes create concerns related to the environment (EBA, 2011). Sahtu Dene and Métis reported that thawing permafrost, slumping ground, and shoreline erosion, effects of climate change pose additional safety risks to infrastructure, including roads, and buildings, as well as risks to traditional economies, and TLRU.	SLUPB, 2022; EBA, 2011); April to July 2022 Engagement		

Comment	Source	GNWT Response	Where Addressed
Community engagement participants expressed concern about erosion and the steepness of the MVWR. They identified Seagrams Creek, Blackwater Creek, Strawberry Creek, Gotcha Creek, the Délı̨nę Winter Road turnoff, and the area north of Big Smith Creek as specific areas of concern.	August 2021 Engagement; April to July 2022 Engagement; November to December 2022 Engagement; November 2022 to February 2023 Engagement		

Table 14.2 summarizes the potential effects of the Project on terrain, soils, and permafrost; the pathways by which they may trigger changes in terrain, soils, and permafrost conditions; and the measurable parameters for evaluating these effects. Potential effects and measurable parameters were selected based on professional judgment, recent environmental assessments for road projects in the Northwest Territories (NWT), and lessons learned from other similar projects. Where potential effects are not able to be measured quantitatively, visual observations serve as a trigger to undertaking further investigation, which may include site-specific collection of quantitative data.

Table 14.2 Potential Effects, Effects Pathways, and Measurable Parameters for Terrain, Soils, and Permafrost

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in terrain conditions (including potential erosion, modification of local drainage patterns, and slope stability)	• Terrain stability issues resulting from ground disturbance (e.g., at locations of road cuts, borrow sources and quarries) • Potential water erosion and sediment delivery following vegetation clearing and exposure of surficial materials to erosive factors	• Ground surface elevation (metres [m]) • Visible changes in sediment loads in streams, turbidity (nephelometric turbidity units) • Visual observations of changes to terrain conditions, including seepage, erosion and/or ponding, mass movement features and processes (e.g., cracks, flow features, slumping) • Site-specific survey of extents and elevations
Change in soils conditions, capability (including physical, chemical, and biological properties)	• Loss of soils from road construction • Change in soil reclamation suitability from construction activities and reclamation activities at borrow sources and quarries • Soil compaction, rutting, and pulverization from vehicle/equipment traffic during mobilization/ demobilization, site clearing, and/or construction-related activities along the right-of-way (ROW) at borrow sources and quarries • Potential soil contamination due to accidental spills (detailed in accidents and malfunctions, Chapter 25)	• Loss of soils from road construction (volume in cubic metres [m^3]) • Soil reclamation suitability, such as coarse fragment content or soil organic matter on reclaimed borrow sources and quarries • Visual observations of rutting or compaction including mixing of soil horizons, excessive build-up of mud on vehicle tires, formation of puddles, excessive tracking of mud during stripping and reclamation activities of borrow sources and quarries • Visual observations of soil pulverization during stripping and reclamation activities at borrow sources and quarries • Analytical testing of soil contamination

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in permafrost conditions (physical and thermal properties)	• Permafrost thaw resulting from vehicle traffic and clearing during construction • Permafrost thaw resulting from construction-related activities (including granular extraction, excavation of road cuts, and construction of embankment and culverts) • Permafrost thaw resulting from changes to local drainage pattern, erosion and/or ponding along the embankment during construction, operations and maintenance activities (including effects of snow distribution on ground thermal regime)	• Active layer depths (centimetres [cm]) • Air and ground temperature (degrees Celsius [°C]) • Ground surface elevation (m) • Visual observations of thaw settlement, ponding, vegetation change, or thermokarst (i.e., the process by which characteristic landforms result from the thawing of ice-rich permafrost)

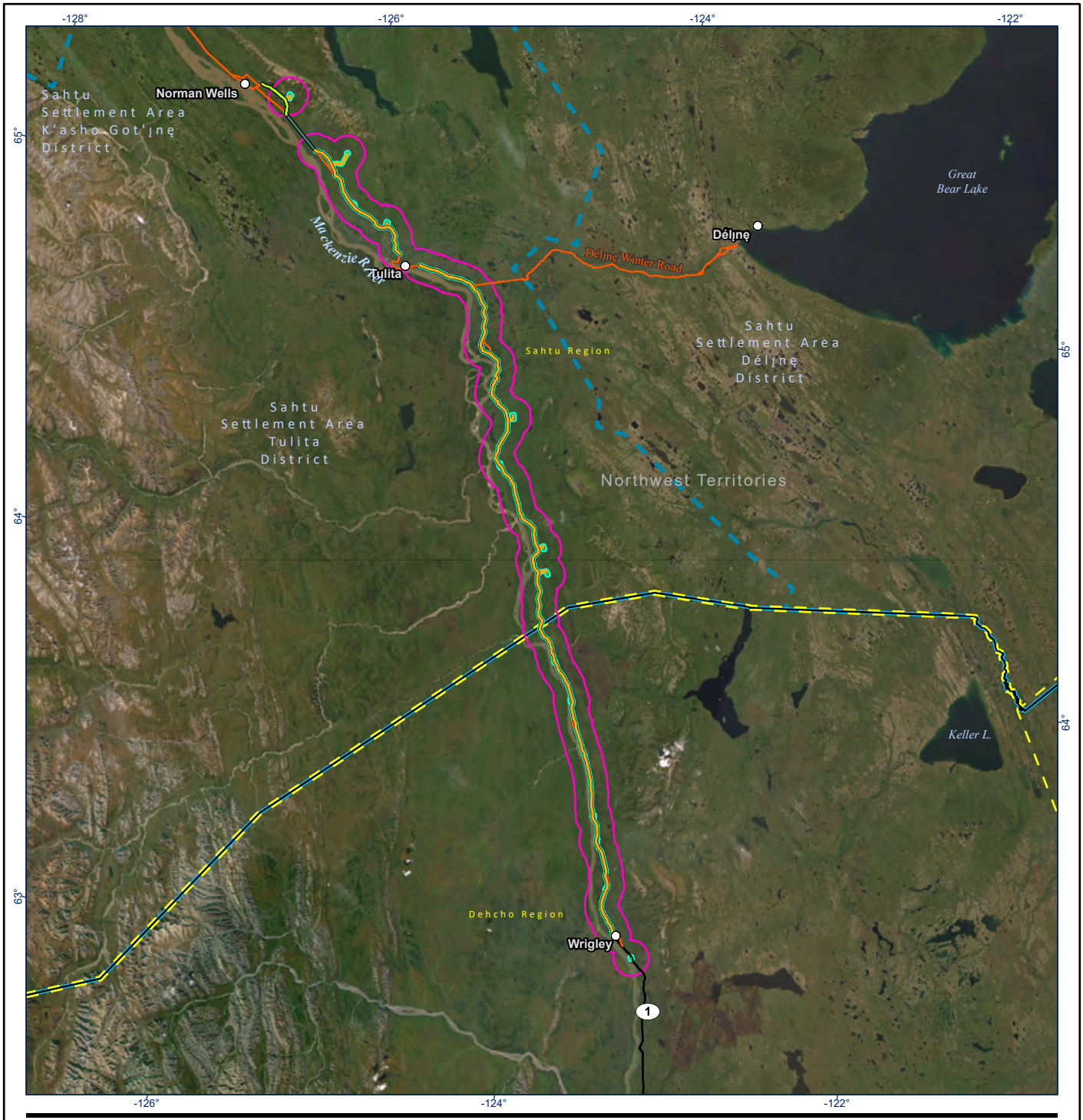
14.1.4 Boundaries

The spatial and temporal boundaries used to assess potential effects on terrain, soils, and permafrost are described in Sections 14.1.4.1 and 14.1.4.2, respectively.

14.1.4.1 Spatial Boundaries

The Project development area (PDA), local assessment area (LAA), and regional assessment area (RAA) for the assessment of effects on terrain, soils, and permafrost are shown on the Project Overview map (see Figure 14.1). These spatial boundaries are used to assess Project effects, including residual and cumulative effects, on terrain, soils, and permafrost within a representative region surrounding the Project.

- **Project Development Area (PDA):** The area of direct project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 m wide highway ROW, laydown and staging areas, maintenance yards, construction camps, and borrow sources and quarries sites with access roads with a 30 m ROW.
- **Local Assessment Area (LAA)**: The area within which measurable project-related effects on terrain, soils and permafrost (direct or indirect) are expected to occur. The LAA for terrain, soils, and permafrost is a 0.5 kilometre (km) buffer on either side of the proposed road alignment route centerline, access roads, and quarry and borrow source extents (Figure 14.1).
- **Regional Assessment Area (RAA)**: The area that provides context for determining significance of project effects and cumulative effects. The RAA is an approximate 5 km buffer around the PDA (Figure 14.1). This buffer is used to capture regional scale landscapes that could potentially be affected cumulatively by the Project and other past, present, and reasonably foreseeable projects.



- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Local Assessment Area
- Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Territorial Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,750,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 8/3/2023
TR by OP on 8/3/2023

Client/Project
Government of the Northwest Territories
Mackenzie Valley Highway Project

144903025-0143 REVA

Figure No.
14.1

Title
Terrain, Soils and Permafrost Assessment Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
Imagery date: 2021

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

14.1.4.2 Temporal Boundaries

Effect on terrain, soils, and permafrost will be evaluated in relation to specific project phases and activities. The temporal boundaries for this assessment include:

- **Construction phase:** The Project will take approximately 10 years to construct over a timeframe of up to 20 years. The conceptual schedule assumes the alignment will be constructed in three consecutive segments, beginning in approximately 2026: Wrigley to the Dehcho–Sahtu border (102 km); Tulita south to the Dehcho–Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells sometime between 2041 and 2046.
- **Operations and maintenance phase**: The operations and maintenance phase will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the highway is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, and borrow sources and quarries used only for construction are included within the construction phase.

14.1.5 Residual Effects Characterization

Potential residual effects of the Project on terrain, soils, and permafrost are characterized in terms of direction, likelihood, magnitude, geographic extent, timing, duration, frequency, and reversibility (as defined in Table 14.3). The criteria describe the potential residual effects that remain after mitigation measures have been implemented.

Table 14.3 Characterization of Residual Effects on Terrain, Soils and Permafrost

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse –** a residual effect that moves measurable parameters of terrain, soils, and permafrost in a negative direction relative to baseline **Neutral –** no net change in measurable parameters for the terrain, soils, and permafrost relative to baseline
Likelihood	The probability that the residual effect will occur	**Unlikely –** the residual effect is almost certainly not to occur **Possible –** the residual effect could occur **Certain –** the residual effect will certainly occur

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**No measurable or observable change –** no qualitative or quantitative change in the effect can be noted **Low –** effect slightly exceeds baseline conditions but has no effect on ecological function **Moderate –** effect exceeds baseline conditions and has some effect on ecological function **High –** effect exceeds baseline conditions and may cause a loss of ecological function
Geographic Extent	The geographic area in which a residual effect occurs	**PDA –** residual effects are restricted to the PDA **LAA –** residual effects extend into the LAA **RAA –** residual effects interact with those of other projects in the RAA
Timing[1]	Considers when the residual effect is expected to occur, where relevant to the VC.	**No sensitivity** - effect does not occur during a sensitive time for soils (e.g., effect occurs during wintertime when soils are frozen) **Moderate sensitivity -** effect may occur during a somewhat sensitive period (e.g., during early spring or late fall when soils are still snow covered and/or frozen or partially frozen) **High sensitivity -** effect occurs during a highly sensitive period (e.g., during the summer period when terrain, soils, and permafrost are the most susceptible to ground disturbance)
Duration	The time required until the measurable parameter or the VC returns to its existing condition, or the residual effect can no longer be measured	**Short-term –** the residual effect is restricted to one year in duration or less **Medium-term –** the residual effect extends through the construction of the Project (may be up to 20 years) **Long-term –** the residual effect extends beyond the construction of the Project (greater than 20 years)
Frequency	Identifies how often the residual effect occurs and how often during the Project or in a specific phase	**Single event** – occurs as a single occurrence **Multiple irregular event** – occurs at no set schedule **Multiple regular event** – occurs at regular intervals **Continuous** – occurs continuously
Reversibility	Pertains to whether a measurable parameter or the VC can return to its existing condition after the project activity ceases	**Reversible –** the residual effect is likely to be reversed after activity completion and reclamation **Irreversible –** the residual effect is unlikely to be reversed

Note:

[1] Sensitive times are mainly related to seasonality (with respect to air and ground thermal conditions) rather than the timing of the different phases of the Project. For example, potential residual effects on terrain, soils, and permafrost are more likely to occur (or have an increased significance and lead on to other effects) during thawing season than during the winter.

14.1.6 Significance Definition

A significant residual effect on terrain, soils, and permafrost is one that, following the application of avoidance and mitigation measures, threatens the stability of local terrain, soil development, and/or soil capability, as well as physical and thermal stability of permafrost.

14.2 Existing Conditions for Terrain, Soils and Permafrost

Existing conditions for terrain, soils, and permafrost within the LAA and RAA have been detailed in the Terrain, Soils and Permafrost Technical Data Report (TDR; Appendix 14A; K'alo-Stantec, 2023). This report was developed with the objective of presenting baseline information, as well as providing a basis for the suitable design and construction of the highway. Key subjects covered in the TDR include:

- Regional overview (physiography and bedrock geology)
- Surficial materials and landforms
- Soil types, including great group or subgroup
- Permafrost, ground thermal conditions, and ground ice conditions (including climate change considerations)
- Geomorphological processes and geological hazards

The TDR also provides information for the proposed and alternate borrow sources and quarries locations (including land ownership), proposed access routes, overall terrain conditions, and expected material quality, as well as the presence/absence of terrain-related constraints and geological hazards.

14.2.1 Methods

Baseline conditions for terrain, soils, and permafrost were obtained from three sources: a compilation and review of existing data, terrain mapping, and a reconnaissance site visit (specific to conditions at the borrow and quarry sources).

Information sources consulted as part of the data review included the following (see Appendix 14A [K'alo-Stantec, 2023] for complete source information):

- Project Description Reports (PDRs) completed for the Sahtu Region and Dehcho Region
- TLRU and Traditional Knowledge information
- Existing soils and surficial geology mapping
- Open-source borehole database
- Geotechnical investigation reports conducted for the 1970s roadway alignment
- Granular material inventory reports completed for the local communities and surrounding lands

- Geotechnical pipeline route investigations completed for private industry
- Reports from recent geotechnical investigations conducted in support of the Mount Gaudet Access Road (MGAR; kilometre markers [KM] 695 to 711) near Wrigley and Prohibition Creek Access Road (PCAR)
- Scientific literature, publications, and data relevant to terrain, soils, and permafrost conditions in the Mackenzie Valley

Terrain mapping was completed at a 1:10,000 scale in the LAA. Mapping was conducted in the ArcGIS platform using aerial photography, ortho-imagery, and light detection and ranging (LiDAR) data available for the Project. A map book presenting the terrain mapping is included in Appendix 14A (K'alo-Stantec, 2023). As part of the mapping, relatively homogeneous terrain units (or polygons) were delineated based on:

- Surficial materials (e.g., till, glaciolacustrine)
- Surface expression (e.g., hummocky, fan)
- Depth to bedrock (e.g., veneer, blanket) or stratigraphic composition (i.e., identifying the expected subsurface material)
- Slopes and geomorphological processes (e.g., groundwater seepage, mass wasting)

The reconnaissance site visit focused on collecting information at prospective borrow sources and quarries to inform recommendations concerning future detailed investigations required for advancing the project design. Information gathered as part of the visit included descriptions of topographic site conditions, rock and material types, soil drainage conditions, permafrost, presence of environmental constraints, and overall accessibility of the sites for future development. These visual observations were supplemented by limited water and rock sampling for screening of metal leaching and acid rock drainage potential, and limited soil and rock sampling for the assessment of the overall material suitability for borrow source development.

14.2.2 Overview

14.2.2.1 Regional Overview

From north to south, the Project spans the Taiga Plains Low Subarctic, Taiga Cordillera Low Subarctic, and Boreal Cordillera Level III ecoregions, each distinguished by different landscapes and degrees of climatic factors. The area is separated into two main physiographic regions consisting of the Mackenzie Plain and the Franklin Mountains.

The dominant geological units consist of Devonian-aged sedimentary bedrock, predominantly sandstone, shale, limestone, and dolostone (Okulitch and Irwin, 2014). Exposed rocks and rugged bedrock-controlled terrain are generally limited to the easternmost section of the RAA (i.e., towards the west flank of the Franklin Mountains), with most of the LAA overlaid by a thick mantle of surficial material. There are a few exceptions, including shallow bedrock at river crossings and shallow or exposed bedrock alongside Mount Gaudet north of Wrigley, and Bear Rock (Petınızah) across from Tulita.

14.2.2.2 Surficial Materials and Landforms

Published surficial geology mapping identifies glaciolacustrine materials, till (moraine), colluvium, alluvial materials, glaciofluvial materials, eolian materials, bedrock, and organic materials within the RAA (Duk-Rodkin, 2002; Duk-Rodkin and Couch, 2004; Duk-Rodkin and Huntley, 2009; Côté et al., 2013; GSC, 2019a, 2019b). The Mackenzie Plain, which covers most of the area immediately east from the Mackenzie River (Deh Cho), hereafter referred to as Mackenzie River, is primarily covered by a thick sequence of morainal and glaciofluvial deposits, in several areas overlaid by a veneer (<1 m) to a blanket (>1 m) of glaciolacustrine sediments. Following glacial retreat these deposits have been modified by geomorphic processes, including the development of recent drainage features (from tributary rivers to gully systems and seepage flow paths), the slow and/or rapid downslope movements of materials (e.g., soil creep and landslides), and the reworking of fine-grained surficial deposits by eolian activity. Organic soils are present throughout the RAA, especially above poorly to very poorly drained fine-grained soils.

The landscape is more rugged along the Franklin Mountains (i.e., eastern most portion of the RAA, above the Mackenzie Plain), where the weathering of bedrock-controlled terrain (mainly limestone and dolomite) has contributed to the accumulation of a mantle of colluvial materials along the base of major slopes. Large fluvial fans, characteristically poorly drained and marked by seasonal seepage following snowmelt, are commonly found along the tributary streams or large gully systems.

14.2.2.3 Soils

Two soil orders, Cryosols and Brunisols, are present in the PDA, LAA and RAA. Cryosols are mineral or organic materials that have perennially frozen material (permafrost) within 1 m of the surface, while Brunisols are mainly associated with coarse-textured and/or well-drained surficial materials absent of permafrost.

14.2.2.4 Permafrost

Permafrost is defined as ground (soil or rock) that remains at or below zero degree Celsius (0 °C) for at least two years (Harris et al., 1988). The Project spans the extensive discontinuous permafrost (predominantly near Norman Wells), intermediate discontinuous permafrost (e.g., Mackenzie Plain area), and sporadic discontinuous permafrost (area surrounding Wrigley) zones (Heginbottom et al., 1995; Heginbottom, 2000). Climate is the predominant element controlling this broad distribution of permafrost along the Project, followed by other factors such as topography, soils characteristics, vegetation, snow cover, and surface water.

Permafrost may be absent or found at greater depth beneath large bodies of water (including rivers and lakes). Discontinuous permafrost is associated with warm ground temperatures and thermally sensitive permafrost conditions. The distribution of permafrost within both the RAA and LAA is difficult to predict as it is dependent on multiple variables, including topography, soil and vegetation characteristics, snow cover, and geothermal gradient. Along the PDA and LAA, permafrost is expected to be more predominant in low-lying, often imperfect to poorly drained,

fine-grained soils (e.g., glaciolacustrine sediments, clay till) than in areas of well-drained, often coarse-grained soils (e.g., glaciofluvial deposits). These terrain types were mapped and described in Appendix 14A (K'alo-Stantec, 2023). Similarly, permafrost is more likely to be present in forests with high canopy closure, elevated peat plateaus, and in soils with thick organic horizons.

Permafrost can be classified into two types based on the relative amount of ice within the ground: ice-rich (thaw-sensitive) and ice-poor (thaw-stable). The type of permafrost that is of interest when constructing infrastructure is ground that is ice-rich (thaw-sensitive). Fine-grained soils (predominantly silt and clay) that contain visible ice are considered thaw-sensitive. Coarse-grained soils (predominantly sand and gravel) and bedrock that do not contain excess ice are considered thaw-stable.

Warming in the North has triggered changes that are affecting both infrastructure and the livelihood of communities. Terrain hazards, especially permafrost degradation, are anticipated to be exacerbated by the effects of climate change. The progressive increase in mean annual temperatures is expected to accelerate the thawing of permafrost. Along a transportation corridor like the Mackenzie Valley Highway, permafrost degradations could lead to the increased occurrence of soil instability and ground movements (e.g., heaving, thawing, sinkholes, potholes, and settlement issues).

Local knowledge provided by TRRC and NWRRC study participants explained that thawing permafrost creates wetter, boggier areas where the ground was previously hard, which makes traversing the landscape to practice TLRU more difficult (NWRRC, 2023; TRRC, 2022). NWRRC study participants observed that weather in the Sahtu Area has changed over the last few years, attributed to cumulative effects and warming temperatures, which affects the land and the permafrost and can influence the flow of creeks (NWRRC, 2023). Dehcho First Nations identified warmer temperatures, thawing permafrost, and other environmental changes create concerns related to the environment, including the thawing of frost which harbors and protects lichens and reduces the availability of lichen-rich habitats important for caribou (Dehcho First Nations, 2011). Sahtu Dene and Métis reported that thawing permafrost will increase turbidity and solids in local streams, affecting water quality (NWRRC, 2023; SRRB, 2016). Additionally, Sahtu Dene and Métis reported concerns about potential project effects exacerbating permafrost thawing, slumping ground, and shoreline erosion; in conjunction with effects of climate change potential project effects can pose additional safety risks to infrastructure, including roads, and buildings, as well as risks to traditional economies, and TLRU (SLUPB, 2022). Elders in the K'ásho Got'ıné and Tulita regions also noted concerns about potential project effects associated with land clearing, including increased rates of thawing permafrost, leading to problems with vegetation establishment, erosion and slumping on the banks of the Sahtu waterbodies, which has previously been linked to erosion in Great Bear River and other waterbodies in the area (Auld and Kershaw, 2005; Golder, 2015).

14.3 Project Interactions with Terrain, Soils and Permafrost

Table 14.4 identifies, for each potential effect, the physical activities and components of the Project that have the potential to interact with terrain, soils, and permafrost. Interactions that have the potential to result in effects on terrain, soils, and/or permafrost within the LAA or RAA are indicated by a check mark. These interactions are discussed in detail in Section 14.4, in the context of effects pathways, standard and project-specific mitigation, and residual effects. A justification for activities not expected to interact with terrain, soils, and/or permafrost is provided following the table.

Project schedules and activities for the construction phase and the operations and maintenance phase are described in detail in Sections 5.4 and 5.5, respectively. Project-related accidents and malfunctions are described in Chapter 25.

Table 14.4 Project-Environment Interactions with Terrain, Soils and Permafrost

Physical Activities	Timing	Environmental Effects		
		Change in Terrain Conditions	Change in Soils Conditions	Change in Permafrost Conditions
Construction Phase				
Mobilization of equipment, materials, and fuel, resupply, and demobilization	Summer and winter	–	–	–
Establishment and operation of camps	Year-round	–	✓	✓
Site preparation of ROW, access, and workspaces	Winter	–	✓	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	✓	✓	✓
Material haul	Year-round	–	–	–
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓	✓	✓
Culvert installations	Summer or winter	✓	✓	✓
Road base placement, compaction, and surfacing	Summer	–	–	–
Water withdrawal to support construction activities	Year-round	–	–	–
Closure and reclamation of MVWR and temporary borrow sources/quarries, camps, and workspaces	Summer	✓	✓	✓
Employment and contracted goods and services[1]	Year-round	–	–	–

Physical Activities	Timing	Environmental Effects		
		Change in Terrain Conditions	Change in Soils Conditions	Change in Permafrost Conditions
Operations and Maintenance Phase				
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	✓	✓	✓
Material haul and stockpiling	Summer	–	–	–
Operation of, and activities at, maintenance yards	Year-round	–	–	✓
Water withdrawal for dust control	Summer	–	–	–
Employment and contracted goods and services[1]	Year-round	–	–	–
Presence and public use of the highway	Year-round	✓	✓	✓
Highway and access road maintenance, including snow clearing, repair, grading, dust control	Year-round	–	–	✓
Vegetation control	Summer	–	–	–
Bridge and culvert maintenance	As needed	–	–	–

Notes:

✓ = Potential interaction

– = No interaction

[1] Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, "Employment and contracted goods and services" have been introduced as an additional component under each project phase.

The potential interactions between project activities and the environment were considered for the construction phase and the operations and maintenance phase of the Project. The identification of project activities and their potential interactions was based on engagement with Indigenous Governments, Indigenous Organizations, and other affected parties, the professional judgment of technical specialists involved in the assessment, and a review of known existing conditions. The selection of interactions is also informed by the potential effects and effects pathways for each VC as described in Section 14.1.3.

Mobilization and demobilization of project equipment is not expected to interact with terrain, soils, and permafrost as equipment will be transported by barge on the Mackenzie River during the open-water season, the Mackenzie Highway #1, or by the MVWR in the winter to designated staging areas, as well as along the existing disturbances and infrastructure (i.e., including newly built embankment as it is being constructed). Aside from the clearing and grubbing (where needed) of the ROW in winter, there will be no mobilization or demobilization of equipment across undisturbed terrain as part of the construction, operation, and maintenance of the Project.

The placement of road base, compaction and surfacing, as well as hauling of waste, water, or borrow material (either granular or crushed rock), is not expected to interact with terrain, soils, and permafrost because these activities will be undertaken on already constructed embankment or workspaces.

During operations and maintenance, water withdrawal for dust control activities is not anticipated to result in interactions with terrain, soils, and permafrost as this will occur intermittently and will not cause ground disturbance. Likewise, activities associated with culvert and bridge maintenance are likely to occur on previously constructed embankment without disturbance to surrounding areas.

Employment and contracted goods and services activities are not expected to result in a change in terrain, soils, and permafrost for the lifetime of the Project as there is no pathway for these activities to interact with terrain, soils, and permafrost.

14.4 Assessment of Residual Effects on Terrain, Soils and Permafrost

This section discusses the interaction pathways for the project activities identified in Table 14.4 (Section 14.3) that have the potential to affect a change in terrain, soils, or permafrost conditions. Potential effects, effect pathways, and mitigation measures that will reduce or eliminate the effects on terrain, soils, and permafrost are identified in Table 14.5. These residual effects and associated analytical assessment techniques are described.

Table 14.5 Potential Effects and Mitigation Measures for Terrain, Soils and Permafrost

Effect Name	Effect Pathway	Mitigation Measures
Change in Terrain Conditions	• Terrain stability issues resulting from ground disturbance (e.g., at locations of road cuts)	• The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent possible. • Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the ROW and approved access roads). Project vehicles will be confined to existing roads and trails to avoid disturbing vegetated areas. • A fill-only construction approach will be used, except at specific locations of road cuts. • To promote the stability of cuts and fills on slopes, fill material will be compacted and the tops of cut slopes will be rounded. • The slope of the cut or fill will have a horizontal to vertical ratio accounting for the geotechnical properties of the materials.
	• Potential water erosion and sediment delivery following vegetation clearing and exposure of surficial materials to erosive factors	• A Project-specific ESCP will be developed and implemented. Erosion and drainage patterns will be observed and documented per the Erosion and Sedimentation Control Plan. • Best management practices for erosion control will be implemented according to the Erosion and Sedimentation Control Plan • Erosion and sedimentation control measures will be regularly inspected and maintained. Erosion and sedimentation control measures and structures will be repaired if damage occurs. • Sedimentation and erosion control measures will be regularly inspected to confirm they are performing as intended. These measures will be maintained until disturbed areas are revegetated or until such areas have been permanently stabilized by other effective measures. • Runoff control methods will be used to protect permafrost soils, including but not limited to: the diversion of water entering the site, modification of slope surfaces, reduction of slope gradients, controlling flow velocity, providing adequate or increased drainage, and diverting flows away from exposed soil areas for mitigating permafrost degradation. • Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns. • Clearing will not be conducted during high rainfall or runoff events.

Effect Name	Effect Pathway	Mitigation Measures
Change in Soil Conditions (including physical, chemical and biological properties)	• Loss of soils from road construction	• The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent possible. • Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the ROW and approved access roads). • Tree roots will be grubbed only in areas required for construction or stripping. • Organic topsoil will be left in place to retain a protective layer during the construction of the road to limit permafrost degradation and protect the soils from erosive factors of water.
	• Changes to soil structure, porosity, organic matter, and reclamation suitability resulting from soil compaction, rutting, and pulverization from vehicle/equipment traffic, site clearing, and/or construction-related activities on borrow areas	• Construction on cleared ground will be conducted during dry or frozen conditions, or will use rig matting to reduce soil compaction, rutting, and erosion. • Organic material and topsoil will be set aside for use during reclamation, to the extent possible. • If surface organic material must be removed for construction, it will be stockpiled and re-applied where possible. • Undisturbed areas will be avoided until they are scheduled for clearing/stripping to limit unnecessary soil degradation and compaction. • Soil stripping operations in borrow areas will be conducted under the guidance of a qualified person. • Closure and reclamation will promote re-establishment of vegetation ground cover. • Site grading at closure will approximate pre-development conditions. • Soil stripping will be postponed on borrow areas during wet weather or thawing conditions to reduce deterioration in soil conditions. • Soils stripping will be postponed on borrow areas on coarse textured soil during windy conditions to reduce deterioration of soil conditions.

Effect Name	Effect Pathway	Mitigation Measures
Change in permafrost conditions (physical and thermal properties)	• Permafrost thaw resulting from vehicle traffic and site clearing during construction	• The Project will follow measures in the PPP. • The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent possible. • Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the ROW and approved access roads). • A fill-only construction approach will be used, except at specific locations of road cuts. • Erosion control products and methods will be used to limit erosion of fine-grained soils per the GNWT Erosion and Sediment Control Manual (GNWT, 2013). • Project vehicles will be confined to existing roads and trails to avoid disturbing vegetated areas. • To promote the stability of cuts and fills on slopes, fill material will be compacted and the tops of cut slopes will be rounded. • The slope of the cut or fill will have a horizontal to vertical ratio accounting for the geotechnical properties of the materials. • Clearing of new areas will be completed when the ground is frozen to limit disturbance to soils and permafrost. • Clearing will be completed by hand, where required, to prevent damage to the ground. • A minimum of 10 cm of packed snow or ice will be used on winter access roads. • Construction equipment will be operated on designated winter roads or constructed embankment only. • During spring, summer, and fall, suitable equipment will be used to prevent effects on sensitive terrain. • Ice-rich soils or materials that are susceptible to physical erosion encountered during excavation will be covered to reduce permafrost degradation. • Where possible, cleared material will be mulched and spread over cleared areas within the project footprint to protect the soil and permafrost. • Organic topsoil will be left in place to retain a protective layer during the construction of the road to reduce permafrost degradation and protect the soils from erosive factors of water. • If surface organic material must be removed for construction, it will be stockpiled and re-applied where possible.

Effect Name	Effect Pathway	Mitigation Measures
Change in permafrost conditions (physical and thermal properties) (cont'd)	• Permafrost thaw resulting from construction-related activities (including granular extraction, excavation of road cuts, and construction of embankment)	• The Project will follow measures in the QDP to reduce ponding, erosion, and damage to permafrost during quarry operations and closure. • The Project will follow measures in the PPP to reduce ponding, erosion and damage to permafrost. • The stability of permafrost over time will be monitored. • The pit floor of borrow areas/quarries will be sloped to reduce ponding of water. • Excavations and developed borrow sources will be visually monitored throughout the summer and fall to observe for physical erosion resulting from the degradation of permafrost. If ice-rich permafrost is identified during excavation activities, suitable measures will be taken to protect permafrost and ground ice encountered during material extraction activities. • Excavations will be contoured prior to closure to reduce steep slopes. • Project design will avoid ice-rich areas where possible. • If ice-rich permafrost is identified during excavation activities, suitable measures will be taken to protect permafrost and ground ice encountered during material extraction activities. • Construction equipment will be operated on designated winter roads or constructed embankment. • Geotextile and embankment placement will be completed in the winter to limit disturbance to soils and permafrost. • Placement of embankment will occur primarily during winter (December 15 to April 1), during frozen conditions. If work is to be completed under non-frozen conditions, equipment will be equipped with mushroom shoes. • During spring, summer, and fall, suitable equipment will be used to prevent effects on sensitive terrain. • The area of direct ground disturbance will be minimized by following the pre-existing winter road alignment to the extent possible. • Organic topsoil will be left in place to retain a protective layer during the construction of the road to limit permafrost degradation and protect the soils from erosive factors of water. • The embankment will be constructed predominantly using a "fill approach" with minimal disruption to the subgrade rather than a "cut and fill" approach; however, road cuts will be needed where grades at a steep valley approach can be reduced by cutting into the hill slope. • During spring, summer, and fall, suitable equipment will be used to prevent effects on sensitive terrain.

Effect Name	Effect Pathway	Mitigation Measures
Change in permafrost conditions (physical and thermal properties) (cont'd)	*See above*	• Use of equipment on highly saturated soil will be avoided, where possible. • Steep grades where subsidence may occur as a result of permafrost thaw will be avoided, where possible.
	• Permafrost thaw resulting from changes to local drainage pattern, erosion, and/or ponding along the embankment (including effects of snow distribution on ground thermal regime)	• Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns. • Culvert design will include requirements for bedding materials and geotextile to protect surrounding permafrost from thaw. Rip rap will be incorporated into culvert design to avoid erosion around each culvert. • Snow accumulation and runoff alongside the highway will be monitored visually. Snow removal methods will be modified if needed in areas presenting excessive snow accumulation/runoff. • Accumulated snow may be dispersed (e.g., snow drifts flattened and/or plowed) to reduce potential long-term effects on permafrost. In areas where snow drifting becomes a reoccurring issue, strategies such as snow fencing will be considered to keep snow drifts off the road surface and away from drainage ditches.
	• Permafrost thaw resulting from natural conditions and geoprocesses (e.g., forest fires, climate change)	• A project-specific PPP will be developed and implemented to monitor the stability of the permafrost over time.

14.4.1 Analytical Assessment Techniques

Potential effects on terrain, soils, and permafrost were assessed by comparing existing baseline conditions in the LAA and RAA (as summarized in Section 14.2 and described in detail in the TDR [Appendix 14A; K'alo-Stantec, 2023]) to conditions anticipated to occur with construction of the Project. Existing baseline conditions were obtained from reviewing data obtained from a literature review (i.e., including reports, maps, and available relevant databases) as well as from the terrain mapping conducted for the project LAA. These are considered the most important data sources from which potential effects, and the success of mitigation measures, can be assessed.

The terrain mapping completed for the LAA uses a formal classification system that uses expert judgement, experience, and training in the identification and delineation of geomorphological landforms and processes visible on the Earth's surface to interpret and classify a landscape (Resources Inventory Committee, 1996; Howes and Kenk, 1997). Although focusing on surficial geology, landforms, and geoprocesses, this data often forms the basis to the interpretation of soil and permafrost properties (including their expected distribution). This information forms the basis for many derivative assessments and analyses that in turn can inform the expected performance or effects of the Project on the environment.

Effects on terrain, soil conditions, and permafrost were assessed by comparing baseline conditions to the expected conditions resulting directly from road construction and indirectly from changes in drainage and reclamation activities. Potential effects were also assessed by reviewing similar assessments conducted for other all-season highway projects in the NWT (e.g., Tłı̨chǫ Highway [MVEIRB, 2018], Prairie Creek All Season Road [CZC, 2015], Inuvik to Tuktoyaktuk Highway [Kiggiak EBA, 2011]). Changes in soil conditions were qualitatively assessed based on professional judgement on soil reclamation suitability, compaction, rutting, pulverization, and contamination processes. Changes in permafrost conditions were also qualitatively assessed based on professional judgement and available data obtained as part of the description of baseline conditions.

The assessment of potential effects on terrain, soils, and permafrost does not include a failure modes analysis. The potential failure modes associated with a highway built over permafrost may include (but are not limited to) differential thaw settlement, loss of soil strength and localized slumping. These are expected to be closely related to the local distribution of ground ice, and will be further influenced by the locations of ground disturbances, such as those associated with road cuts. As the design does not yet incorporate site-specific geotechnical information, the assessment of effects is based on best available information. Additional geotechnical information to inform design will be collected once there is certainty of the alignment routing corridor (upon completion of the environmental assessment).

14.4.2 Change in Terrain Conditions

14.4.2.1 Effects Pathways

Project activities could result in changes in terrain conditions, both during the construction and operations and maintenance of the infrastructure. The project construction will require that all equipment, materials, fuel, camps, and other supplies be mobilized to designated construction start locations. Although the mobilization of equipment itself is not expected to generate effects on the local terrain due to the use of existing roads (both all-season and winter roads), activities such as clearing of the ROW, workspaces, borrow sources, and quarries has the potential to interact with terrain conditions. The same applies to excavation at borrow sources, quarries, or road cuts, embankment construction, and culvert installation. In this context, ground disturbance is a direct effect which results in the alteration or displacement of soils, and therefore also changing terrain conditions.

Indirect effects on terrain conditions may also occur, mainly through alteration to the movement of surface water. For example, the newly built embankment can form a barrier to the movement of unchannelized surface water. The modified topography will create new preferential paths for surface water drainage that often do not match with the natural surface water drainage pattern. Water running along the uphill toe of the road for some distance (i.e., instead of across it) could generate physical and thermal erosion. Locations where the water is finally directly downslope can also be affected, in some cases potentially triggering changes in material strength and leading slope instabilities. Aside from a change in hydrology and surface water runoff, an increased erosion potential could be linked to changes in vegetation conditions, change in topography or slopes, a change in material strength, or a change in ground thermal regime (discussed under permafrost). Localized erosion may occur along the road embankment, at the stream crossings or other areas where the erosive action of water (including along poorly-define flow paths identified as part of the TDR terrain mapping) may take place.

Knowing that the PDA, in some areas, crosses terrain susceptible to mass movement (landslides), the Project has the potential to reactivate old landslides or to initiate new ones. Although such features can reactivate on their own, ground disturbance can increase the likelihood of landslide reactivation. Grading, excavation, or removal of surface vegetation can trigger landslides. Alteration of natural flow paths can also lead to landslides; for example, if the road reroutes surface water drainage into a marginally stable area, slope instabilities could result. Similarly, if natural slopes are altered or if a section of the road cuts into the supporting toe of an old landslide, that cut could result in the slide reactivating, even if it is not a slope in permafrost soils.

14.4.2.2 Mitigation

Standards, best management practices, and mitigation measures are expected to prevent or reduce changes in terrain conditions resulting from the Project. Potential effects will be mitigated through management practices applied during design, construction, operations, and reclamation, while site-specific mitigation may be required in certain circumstances. The mitigation strategy will overlap across several interrelated VCs for which the effect pathways are similar (e.g., mitigation of soil surface erosion addresses effects on vegetation, soils, permafrost, surface water, and sediment quality). Following construction, the need for additional mitigation will be determined by monitoring.

Refer to Table 14.5 for a list of mitigation measures that will address effects on terrain, soils, and permafrost. Key mitigation measures to prevent or reduce changes to terrain conditions include the following:

- The Project will follow measures in the PPP (see Volume 5).
- The Project will follow measures in the ESCP. Sediment and erosion control measures will be regularly inspected to confirm they are performing as intended (see Volume 5).
- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical.
- Clearing of new areas will be completed when the ground is frozen. Clearing will be completed by hand, where required, to prevent damage to the ground.
- Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns. Modification to the location or number of drainage culverts will be determined in consultation with the Engineer as based on observed site conditions.
- A fill-only construction approach will be used, except at specific locations of road cuts.

14.4.2.3 Residual Effects on Terrain Conditions

Potential residual effects of the Project on terrain conditions were characterized in terms of direction, likelihood, magnitude, geographic extent, timing, duration, frequency, and reversibility (see Table 14.6).

Based on the implementation of best practices, as well as adherence to the standards, mitigations, and procedures outlined in the ESCP, the effects on terrain conditions are expected to be restricted to the footprint of the road and borrow areas. Because of the construction of permanent access roads, borrow sources, quarries, and of the highway itself, the effects on terrain are expected to be long term and irreversible.

14.4.3 Change in Soils Conditions

Road construction can negatively affect physical and chemical properties of soil due to the direct loss of soil from road and permanent borrow/quarry construction and changes soil conditions such as structure, porosity, permeability, organic matter content, and chemical conditions resulting from soil stripping, stockpiling, and replacement on areas designated for closure and reclamation.

Construction and operations and maintenance can negatively affect physical and chemical properties of soils due to contamination resulting from accidental spills.

The effect of accidental spills and releases on soils is addressed in Chapter 25, Accidents and Malfunctions.

14.4.3.1 Effects Pathways

Road construction will entail clearing of the ROW and access roads and placing woven geotextile, 300 millimetres (mm) blast rock, and 50 mm and 20 mm granular rock over native soils. Construction will require the development of both temporary and permanent quarries/borrow as a source of crush rock and granular material and temporary support infrastructure and workspaces, including camps, maintenance yards, laydown and staging areas, fuel storage areas, and in places, a winter travel lane.

Construction, operations and maintenance, and reclamation activities from the Project could affect soil conditions in the following ways:

- Clearing and grubbing of the ROW, as well as road and permanent quarry/borrow construction, will result in the direct loss of soils
- Temporary borrow/quarry and workspace development, including land clearing, soil salvage, storage, and replacement could result in changes to soil structure, porosity, organic matter, and reclamation suitability from admixing, soil compaction, rutting, and pulverization

14.4.3.2 Mitigation

Best practices and avoidance measures identified in the ESCP, as well as soil-specific mitigation measures, will be implemented during construction and operation of the Project to lessen the effects of the Project on soil conditions.

Refer to Table 14.5 for a list of mitigation measures that will address effects on terrain, soils, and permafrost. Key mitigation measures that will prevent or reduce changes to soils conditions include the following:

Loss of Soil from Road Construction and Permanent Borrow Sources and Quarries

- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical.
- Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the ROW and approved access roads).
- Project vehicles will be confined to existing roads and trails to avoid disturbing vegetated areas.
- Tree roots will be grubbed only in areas required for construction or stripping. Grubbing will preserve soil surface organic material.

Soil Admixing, Compaction, Rutting, Pulverization, and Reclamation Suitability

- Clearing of new areas will be completed when the ground is frozen.
- Clearing will not be conducted during high rainfall or runoff events.
- Clearing will be completed by hand, where required, to prevent damage to the ground.
- Organic material and topsoil will be set aside for use during reclamation, to the extent possible.
- Undisturbed areas will be avoided until they are scheduled for stripping to limit unnecessary soil degradation and compaction.
- Soil salvage will be postponed during wet weather or high winds to prevent erosion and/or damage to the soil structure.
- Soil stripping operations in borrow areas will be conducted under the guidance of a qualified person.

14.4.3.3 Residual Effect on Soils Conditions

Road construction and the ancillary development of permanent borrow sources and quarries will result in the direct loss of soil even if the Project will largely follow the existing MVWR. The use of existing borrow sources and quarries (where applicable) will, however, reduce the need for disturbing new ground. Effects of direct loss of soil are restricted to the PDA, long-term, and irreversible.

Development of temporary quarries/borrow and temporary workspace will result in soil disturbance and possible changes to soil structure, porosity, organic matter, and soil reclamation suitability. The progressive reclamation of these access road and temporary borrow sources, however, will make those effects on soils to be reversible. Effects are expected to be restricted to the PDA, short-term, and reversible with implementation of mitigations.

14.4.4 Change in Permafrost Conditions

14.4.4.1 Effects Pathways

Permafrost, especially that which is ice-rich, is highly sensitive to ground disturbance and changes in ground temperature. This is particularly true of the warm discontinuous permafrost found within the PDA, although the extent of localized permafrost degradation is difficult to predict as it is dependent on multiple variables including surface temperature, soil properties, and the initial permafrost temperature conditions.

Permafrost is vulnerable to both thermal erosion and physical erosion of surficial materials (i.e., including both organic and mineral soils).

- Physical erosion is characterized as the mobilization of soil particles by water flow and subsequent deposition as sediment. Vulnerability to physical erosion is similar in permafrost and non-permafrost areas.
- Thermal erosion is characterized as the thawing of permafrost or seasonally frozen ground. Frozen ground containing ice will thaw and settle and the discharge water will flow over saturated soil.

Although thermal erosion may or may not result in physical erosion, physical erosion generally increases the vulnerability to thermal erosion.

Within the PDA, LAA, and RAA, the terrain, soils, and permafrost are in their most vulnerable state in the spring, summer, and fall when the air/surface temperature are high and the active layer is thawing or thawed. Travel over ground when the ground is in this vulnerable state can damage the soil and vegetative surface and cause deformation of the ground surface (particularly in areas of soft, fine-grained soils and peat). This can then lead to compaction and rutting of organic layers and topsoils, and creation of uneven topography favorable to the collection of surface water.

Physical changes caused from ground disturbance could result in an increase in ground surface temperature and a corresponding increase in the depth of the active layer and subsequent thawing of ice-rich soil, slope and soil instability, erosion/sedimentation, and subsidence of the ground surface. Earthwork activities in thaw-sensitive permafrost may require the removal of the organic layer and cutting into the ground (e.g., during borrow extraction or excavation of road cuts). These activities may potentially expose permafrost, which in areas of ice-rich permafrost could cause subsidence and water ponding, excessive erosion and sedimentation, thawing, and settlement. These changes may affect terrain stability and cause mass movements alongside the highway (either slow and progressive or rapid).

Once constructed, the highway surface and embankment slopes will have a lower albedo (i.e., lower reflection of solar radiation) when compared to the natural undisturbed and vegetated ground surface. In a similar way, the slope and orientation characteristics of the embankment could be influential on the amount of energy that the future road will receive from the sun. This increased absorption of solar radiation could lead to modification of the thermal balance of the underlying

permafrost over time. In warm permafrost, the edges of the embankment tend to allow the permafrost beneath to thaw, sometime causing ponding along the embankment toe (especially where seepage may occur), while in the middle of the embankment the permafrost may be preserved or even grow (i.e., permafrost aggradation into the embankment). The newly built embankment also may affect local thermal balance of the permafrost by allowing snow drift buildup. The increased snow accumulation can have many effects, including an effect on ground temperatures (i.e., due to the thermal insulation of the snow cover, which reduces heat loss in the embankment shoulders and toes), an increase of the active layer thickness and surface subsidence, increase of soils water content, and ultimately a modification of local vegetation communities alongside the embankment (de Grandpré et al., 2012).

14.4.4.2 Mitigation

The Project will follow measures in the PPP and ESCP. Permafrost and sedimentation and erosion control measures will be regularly inspected to confirm they are performing as intended (see Volume 5). The ESCP incorporates standards, best management practices, and mitigation measures to prevent or reduce potential changes to permafrost conditions, and will be guided by the following resources:

- Northern Land Use Guidelines: Roads and Trails (GNWT, 2015d)
- The GNWT, Department of Transportation – Erosion and Sediment Control Manual (GNWT, 2013)
- Guidelines for Development and Management of Transportation Infrastructure in Permafrost Regions (TAC, 2010)

Refer to Table 14.5 for a list of mitigation measures that will address effects on terrain, soils, and permafrost. Key mitigation measures that will prevent or reduce permafrost degradation include the following:

- The embankment will be constructed predominantly using a “fill approach” with minimal disruption to the subgrade rather than a “cut and fill” approach; however, road cuts will be needed where grades at a steep valley approach can be reduced by cutting into the hill slope.
- Erosion control products and methods will be used to limit erosion of fine-grained soils per the GNWT Erosion and Sediment Control Manual (GNWT, 2013).
- Where possible, cleared material will be mulched and spread over cleared areas within the Project footprint to protect the soil and permafrost.
- Project design will avoid ice-rich areas where possible.
- Steep grades where subsidence may occur as a result of permafrost thaw will be avoided, where possible.
- Positive drainage will be maintained within quarry floors.
- If ice-rich permafrost is identified during excavation activities, suitable measures will be taken to protect permafrost and ground ice.

14.4.4.3 Residual Effect on Permafrost Conditions

One of the key goals of the project design is to develop permanent infrastructure that reduces potential negative effects on the environment and that is resilient to climate change. This requires understanding the local terrain, soils, and permafrost conditions and selecting a final highway alignment that follows competent and least-sensitive ground available along the route. However, to some degree, building on permafrost is unavoidable, and some localized permafrost degradation is inevitable (e.g., in sensitive terrain where ice-rich soils might be present) due to the change in thermal regime resulting from ground disturbance and ongoing effects of climate change. Effects are therefore expected to be long-term as the road will be permanent, and irreversible as a return to baseline conditions will not be achievable.

With the implementation of best practices, as well as adherence to the mitigations, procedures, and strategies outlined in the ESCP and PPP, however, adverse effects of the Project onto the permafrost are anticipated to be limited geographically (e.g., areas of ice-rich, thaw-sensitive permafrost).

14.4.5 Summary of Residual Effects on Terrain, Soils and Permafrost

Residual effects resulting from the Project on terrain, soils, and permafrost conditions after mitigation are implemented will certainly occur. These effects are predicted to be adverse (e.g., changes in drainage conditions, loss of soils from road construction, localized modification of the ground thermal regime); however, with an overall magnitude expected to vary from low to moderate (i.e., depending on the effect pathway). The geographic extent of direct effects will be the PDA for terrain and soil conditions and the PDA and LAA for permafrost conditions. Effects will be ongoing during construction and operations and maintenance and are assumed irreversible in relation to expected changes in permafrost conditions due to the indefinite duration of operation of the Project.

With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirement related to permafrost, and consideration of engagement input and incorporation of Traditional Knowledge.

The design of the Project and mitigation measures for protection of soils, terrain and permafrost will protect the rock formation of the Petiniʔah (Bear Rock) CZ, and are intended to respect the values of the Petiniʔah (Bear Rock) CZ, Mio Lake CZ, Norman Range SMZ, K’ąąlǫ Tué (Willow Lake Wetlands) SMZ, and Deh Cho (Mackenzie River) SMZ as areas with important ecological habitats.

Table 14.6 Residual Effects on Terrain, Soils and Permafrost

Residual Effect	Residual Effects Characterization*							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in Terrain conditions	A	C	L	PDA	NS[1]	LT	IR	I
Change in Soils conditions	A	C	M	PDA	NS[1]	LT[2]	IR	I[3]
Change in Permafrost conditions	A	C	M	LAA	MS-HS	LT	C	I

KEY

***** See Table 14.3 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMOC: No Measurable or Observable Change
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: Low sensitivity
MS: Moderate sensitivity
HS: High sensitivity

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

N/A: Not applicable

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

Notes:

1 Assumes that activities such as vegetation clearing and/or soil stripping do not occur at a sensitive period (e.g., thawing or wet soil conditions).

2 Short-term for construction at any one point. Effects of soil contamination could be long-term.

3 Loss of soil under constructed road and permanent quarries/borrow sources will be irreversible, while the effects of soil contamination may be reversible. Changes to soil conditions from admixing, compaction, rutting, pulverization, and reclamation suitability that may occur and during the stripping and reclamation activities of temporary quarries and borrow areas is reversible.

14.5 Assessment of Cumulative Effects on Terrain, Soils and Permafrost

14.5.1 Residual Effects Likely to Interact Cumulatively

Existing environmental conditions reflect cumulative effects on terrain, soils, and permafrost from past and present projects and physical activities. Past and present projects and physical activities that have been or are being carried out have influenced the existing conditions for terrain, soils, and permafrost (Section 14.4). The assessment of cumulative effects focuses on the same three interconnected adverse residual project effects, as previously assessed. They consist of a change in terrain conditions, a change in soils conditions, and a change in permafrost conditions.

Table 14.7 presents project and physical activity inclusion lists, which identify other past, present, and reasonably foreseeable projects and physical activities within the RAA.

Where adverse residual effects from the Project act cumulatively with those from other past, present, or reasonably foreseeable projects and physical activities, a cumulative effects assessment is undertaken to determine their significance.

Table 14.7 Projects with the Potential to Contribute to Cumulative Effects

Other Projects and Physical Activities with Potential for Cumulative Effects on Soils, Terrain and Permafrost	Environmental Effects		
	Change in Terrain Conditions	Change in Soils Conditions	Change in Permafrost Conditions
Past and Present Physical Activities and Resource Use (Base Case)			
Geotechnical	–	–	–
Oil, Gas & Seismic*	–	–	–
Infrastructure			
Mackenzie Valley Winter Road, including bridges and bridge-sized culverts	✓	✓	✓
Canyon Creek All Season Access Road	✓	✓	✓
Prohibition Creek Access Road	✓	✓	✓
Norman Wells Pipeline	–	✓	✓
Mackenzie Valley Fibre Link	–	✓	✓
Délı̨nę Winter Road	✓	✓	✓
Mackenzie Highway #1	✓	✓	✓
Quarries and Borrow Sources			
HRN Quarry	✓	✓	✓
Little Bear River Quarry			

Other Projects and Physical Activities with Potential for Cumulative Effects on Soils, Terrain and Permafrost	Environmental Effects		
	Change in Terrain Conditions	Change in Soils Conditions	Change in Permafrost Conditions
Mining & Exploration	–	–	–
Municipal Operations, including water, waste, power, and community development			
Wrigley Municipal Activities	–	–	–
Tulita Municipal Activities	–	–	–
Norman Wells Municipal Activities	–	–	–
Project-Related Physical Activities (Project Case)			
Mackenzie Valley Highway Project	✓	✓	✓
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)			
Quarries			
Dhu-1 Quarry	✓	✓	✓
Infrastructure			
Great Bear River Bridge	✓	✓	✓
Oil and Gas			
Enbridge Maintenance Camp	–	–	–

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = includes support activities such as production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas.

Similar to the Project, interactions between other projects and physical activities with terrain, soils and permafrost are anticipated where there will be physical disturbance of vegetation or ground surface. Checkmarks are given for those other projects and activities.

In some cases, the effects of other projects and physical activities are anticipated to affect only soils and permafrost, but not terrain (e.g., the Mackenzie Valley Fibre Link and Norman Wells Pipeline). For some other projects and physical activities, such as municipal operations, works have been developed in consideration of geotechnical conditions to reduce long-term effects on terrain, soils and permafrost, and take into account municipal plans.

Oil, gas and seismic projects, past and present geotechnical projects, as well as mining and exploration projects are not expected to interact with terrain, soils and permafrost as their footprint, timing, and/or location is generally different from the current project. Whenever, their footprint overlaps (i.e., whenever other projects footprints overlap the PDA or LAA, their respective activities are likely to occur on previously constructed embankment without disturbance to surrounding areas, therefore not contributing to residual effects.

14.5.2 Change in Terrain Conditions

14.5.2.1 Cumulative Effects Pathways

Potential cumulative effects on terrain conditions arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project (see Section 14.4.2.1). Those include potential ground stability issues resulting from activities involving ground disturbance, as well as potential water erosion and sediment delivery following vegetation clearing and exposure of surficial materials to erosive factors.

14.5.2.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects on terrain conditions are the same as those presented in Table 14.5 and Section 14.4.2.2.

14.5.2.3 Cumulative Effects

The effect on terrain conditions from all projects and physical activities in the RAA is considered low and limited to the immediate area of ground disturbance of each project. Many projects and associated activities have the potential for both direct and indirect effects and the effects are expected to be long-term as most projects and activities will be long-term or permanent. However, there will be few adverse cumulative effects on terrain conditions in the RAA.

14.5.3 Change in Soil Conditions

14.5.3.1 Cumulative Effects Pathways

Potential cumulative effects on soil conditions arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project, including the direct loss of soil and changes in soil structure, porosity, organic matter, or reclamation suitability as discussed in Section 14.4.3.1.

14.5.3.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects on soil conditions are the same as those presented in Table 14.5 and Section 14.4.3.2.

14.5.3.3 Cumulative Effects

Cumulative effects on changes to soil conditions arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways.

The effect on soil conditions from all projects and physical activities in the RAA is considered low. Many projects and associated activities have the potential for both direct and indirect effects and the effects are expected to be long-term as most projects and activities will be long-term or permanent. However, there will be few adverse cumulative effects on the overall distribution of soil or the soil landscape in the RAA.

14.5.4 Change in Permafrost

14.5.4.1 Cumulative Effects Pathways

Potential cumulative effects on changes in permafrost arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project, including permafrost thaw from vehicle traffic, site clearing, construction-related activities, and changes to ground surface conditions including local drainage patterns, erosion, and/or ponding, as discussed in Section 14.4.4.1.

14.5.4.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects on permafrost thaw are the same as those presented in Table 14.5 and Section 14.4.4.2.

14.5.4.3 Cumulative Effects

Cumulative effects on changes to permafrost conditions arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways. Lessons learned from previous linear projects are well-documented. Essentially, ground disturbance which involved eliminating or greatly reducing plant growth or affecting the organic topsoil generally resulted in increased permafrost thaw. Once the vegetative cover is physically damaged and/or the mineral soil is exposed, the increased thaw is often accompanied by erosion. The application of design and construction standards, best management practices, and mitigation measures to prevent or reduce changes in permafrost conditions, however, can greatly limit potential negative effects.

The effect on permafrost conditions from all projects and physical activities in the RAA is considered low. Many projects and associated activities have the potential for both direct and indirect effects and the effects are expected to be long-term as most projects and activities will be long-term or permanent. However, there will be few adverse effects on the abundance and distribution of permafrost in the RAA.

14.5.5 Summary of Cumulative Effects

Cumulative effects on terrain, soils, and permafrost from past, present, and reasonably foreseeable projects and activities will certainly occur. These effects are predicted to be adverse in direction and low in magnitude. The geographic extent of direct effects will be the PDA.

Effects for many projects and activities will persist for the long-term due to the long operating life of many projects and activities. For many of these project and activities, effects will be ongoing during construction and operation and may be reversible or irreversible. The timing of potential residual cumulative effects on permafrost is considered highly sensitive as they are assumed more likely to occur during a specific portion of the year (e.g., during the thawing season).

Table 14.8 Summary of Cumulative Effects

Residual Cumulative Effect	Residual Cumulative Effects Characterization							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in Terrain Conditions	A	C	L	RAA	MS	LT	IR	I
Contribution from the Project to the residual cumulative effect	The Project will have a low magnitude contribution to cumulative effects on changes to terrain conditions at the RAA level.							
Change in Soil Conditions	A	C	L	RAA	MS	LT	IR	I
Contribution from the Project to the residual cumulative effect	The Project will have a low magnitude contribution to cumulative effects on changes to soil conditions at the RAA level.							
Change in Permafrost Conditions	A	C	L	RAA	HS	LT	C	I
Contribution from the Project to the residual cumulative effect	The Project will have a low magnitude contribution to cumulative effects on changes to permafrost conditions at the RAA level.							

KEY

***** See Table 14.3 for detailed definitions

Project Phase

C: Construction

O: Operations and maintenance

Direction:

A: Adverse

N: Neutral

Likelihood:

U: Unlikely

P: Possible

CE: Certain

Magnitude:

NMOC: No Measurable or Observable Change

L: Low

M: Moderate

H: High

Geographic Extent:

PDA: Project Development Area

LAA: Local Assessment Area

RAA: Regional Assessment Area

Timing

NS: Low sensitivity

MS: Moderate sensitivity

HS: High sensitivity

N/A: Not applicable

Duration:

ST: Short-term

MT: Medium-term

LT: Long-term

Frequency:

S: Single event

IR: Irregular event

R: Regular event

C: Continuous

Reversibility:

R: Reversible

I: Irreversible

14.6 Determination of Significance

14.6.1 Significance of Residual Effects

A significant adverse residual effect on terrain, soils and permafrost is one that, following the application of avoidance and mitigation measures, threatens the long-term stability of terrain and permafrost, as well as the ability of soils to support the vegetation. To some degree, effects such as thermal erosion or the thawing of permafrost is inevitable due to the change in thermal equilibrium that will be triggered by the construction. These effects, wherever they occur, are expected to be localized and of low magnitude. The extent of localized changes to terrain, soils and permafrost is difficult to predict, however, most likely to correspond to areas where surface disturbance will occur (i.e., PDA). Far from all areas of surface disturbance are likely to be prone to residual effects. Activities to be undertaken on already disturbed terrain, for examples, are not expected to be affected.

When accounting for the methods, strategies, and monitoring efforts aimed at preventing or mitigating negative impacts due to the disturbance of permafrost, the effects on terrain, soils, and permafrost are considered not significant.

14.6.2 Significance of Cumulative Effects

A significant adverse cumulative effect on terrain, soils, and permafrost is defined the same as for residual effects. Many past, present, and reasonably foreseeable projects and activities will have adverse effects on changes to terrain, soils, and permafrost conditions. However, a large amount of the area in the RAA will not be affected and the cumulative effects on terrain, soils, and permafrost are predicted to be not significant.

14.6.3 Project Contribution to Cumulative Effects

The Project is predicted to make a low contribution to cumulative effects on changes to terrain, soils, and permafrost.

14.7 Prediction Confidence

Based on professional judgement, the overall quality of publicly available and project data, and the experience learned from similar projects, as well as the expected effectiveness of mitigation measures, the prediction confidence in assessing potential effects for terrain, soils, and permafrost is considered to range from moderate to high.

This mainly is because it is difficult to accurately determine the magnitude of potential effects due to the overall limited measurable criteria and indicators of changes. The potential localized variability of permafrost conditions is a good example (e.g., presence/absence of permafrost, localized occurrence of ice-rich permafrost). Nevertheless, the data gathered to describe baseline conditions are considered sufficient to support the statement that cumulative effects on terrain, soils, and permafrost are predicted to be not significant.

14.7.1 Assumptions

It is assumed that the construction of the embankment will be conducted using a "fill approach" with minimal disruption to the subgrade rather than a "cut and fill" approach. This excludes a few locations where road cuts may be needed to reduce the grades by cutting into the hill slope (e.g., at a steep valley approach). This key assumption is important to the evaluation of potential effects on terrain, soils, and permafrost as the ground disturbance associated with road cuts is often a source of instabilities. The potential failure modes associated with a highway built over permafrost are therefore expected to be closely related to the local distribution of ground ice. Such failure modes may include (but not limited to) differential thaw settlement, loss of soil strength and localized slumping.

The prediction confidence is also based on the highway design/construction approach, as well as implementation of best practices and adherence to mitigations, procedures, and strategies outlined in the ESCP and PPP. Data used to assess and evaluate the presence of thaw-sensitive terrain is typically acquired through geotechnical field investigations (e.g., through installation and monitoring of ground thermistors). Such instrumentation exists along the project, with data updates expected to be obtained on an annual basis. This information will be incorporated into the final design to minimize potential effects to the permafrost. It is as part of future design activities that the final construction methodology and timing will be established and that the final contingency plans to the potential degradation of local permafrost will be established.

The overall limited availability of site-specific geotechnical data relevant to the distribution of ground ice along the PDA is not influencing the prediction confidence as conservative assumptions on the potential presence of permafrost were taken in the assessment of potential residual effects.

14.7.2 Gaps and Uncertainties

Aside from the terrain mapping conducted for the LAA, a literature review was used to establish baseline conditions for terrain, soils, and permafrost. Several distinct data sources were consulted, including documents and reports, open-source databases, and existing regional mapping data. A reference list of reviewed literature is included in Section 7.1 of the Terrain, Soils and Permafrost TDR (Appendix 14A; K'alo-Stantec, 2023).

Potential gaps in the availability of site-specific subsurface information are expected to be addressed as part of future geotechnical field investigation and follow-up highway design activities to be undertaken within the alignment routing corridor.

14.8 Follow-up and Monitoring

Monitoring is the continuation of observation, measurement, or assessment of environmental conditions at and surrounding the Project and its components or activities. Objectives of permafrost monitoring may include:

- Verify compliance with terms and conditions of authorizations
- Verify embankment integrity and performance
- Identify areas where snow accumulation may be contributing permafrost degradation
- Verify effectiveness of permafrost protection measures
- Identify areas of terrain instability in the PDA
- Evaluate stability of terrain and permafrost over time

Components to be monitored have been determined based on regulatory requirements, environmental importance, sensitivity and vulnerability, and past experience.

Monitoring plans included in the ESCP and PPP (see Volume 5) will describe sampling, observation and measurement schedule, locations and procedures, quality control, and reporting requirements, where applicable. The plans will also provide details on the location, design, methods (e.g., parameters to be measured), applicable regulatory instruments, and schedule.

Examples of monitoring activity conducted to identify changes in terrain, soils, and/or permafrost conditions include the following:

- Visual observations of embankment performance (e.g., signs of cracking, sloughing) and the effectiveness of roadway design and mitigation measures with regard to modification of drainage conditions (e.g., presence of ponding water or winter icings)
- Visual observations of the effectiveness of soil stripping and reclamation strategies specific to quarries and borrow areas
- Where permafrost is encountered and where practicable, monitoring of the thermal regimes to assess if the embankment performs as designed.

See Section 9 of the draft PPP in Volume 5. Additional monitoring requirements, if identified as part of the project approval and permitting, will be incorporated into the PPP.

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15.0 ASSESSMENT OF POTENTIAL EFFECTS ON WATER QUANTITY

Project construction, operation, and maintenance activities have the potential to affect water quantity. In recognition of this interaction, and the water quality and quantity Subject of Note in the Terms of Reference (ToR; Mackenzie Valley Environmental Impact Review Board [MVEIRB], 2015 [Public Registry {PR}#66]), Water Quantity was selected as a Valued Component (VC). Potential effects on water quantity may affect (or be affected by) other VCs, including water and sediment quality (see Chapter 16), fish and fish habitat (see Chapter 17), vegetation and wetlands (see Chapter 18), and terrain, soils, and permafrost (see Chapter 14).

The assessment of potential effects on water quantity concludes that with the application of mitigation measures, residual effects resulting from the Mackenzie Valley Highway (the Project) on water quantity will be adverse. Based on the predicted magnitude and geographic extent of residual effects, and the experience and judgement of qualified professionals, residual effects and cumulative effects on water quantity are predicted to be not significant.

15.1 Scope of Assessment

15.1.1 Regulatory and Policy Setting

The assessment of potential project-related environmental effects on water quantity is guided by the ToR (MVEIRB, 2015 [PR#66]), federal regulations and guidelines, and the Sahtu Land Use Plan (SLUP).

15.1.1.1 Federal and Territorial Legislation and Guidelines

The Northwest Territories *Waters Act* and regulations apply to the Project. The Mackenzie Valley Land and Water Board (MVLWB) regulates the use of water (including groundwater) and disposal of waste into watercourses through the issuance of water licences. The Sahtu Land and Water Board (SLWB) will be responsible for issuing the water licence for any segment of the Project wholly within the Sahtu Region. Water licensing criteria are set out in the Waters Regulations and include the following licensing requirements for direct water use (including groundwater):

1. Water use under 100 cubic metres (m^3) per day: licence not required
2. Water use between 100 m^3 and 300 m^3 per day: Type “B” licence required
3. Water use greater than 300 m^3 per day: Type “A” licence required

The Waters Regulations also require a Type "B" licence to be obtained for watercourse training, which includes culvert installations over watercourses greater than 5 metres (m) in width.

There is no groundwater use planned for the Project. However, groundwater withdrawal (use) may be required if borrow source or quarry excavations extend below the groundwater table. In this case, a water licence associated with this groundwater use may be required.

Federal and territorial guidance documents most pertinent to water quantity are:

- Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada (Fisheries and Oceans Canada [DFO], 2013):
- Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut (DFO, 2010):
- Northern Land Use Guidelines - Pits and Quarries (GNWT, 2015)

15.1.1.2 Sahtu Land Use Plan

Specific to the areas to which the SLUP applies, the Project must meet the 13 general conformity requirements of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023). The SLUP's conformity requirements include consideration of watershed management in CR#5:

> *"The SLWB and/or MVLWB must ensure that the Project:*
>
> *a) does not substantially alter quality, quantity, or rate of flow for waters that flow on, through, or adjacent to Sahtu Settlement Lands; and*
>
> *b) is subject to mitigation measures to minimize potential impacts on surface and groundwater that flow into CZs [Conservation Zones], SMZs [Special Management Zones], or PCI [Proposed Conservation Initiatives]."*

Conformity Requirement #2 requires that *"The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge."*, and CR#14 requires that the Project be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 20213), including the following:

- Petiniʔah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)
- K'ąąlǫ Tué (Willow Lake Wetlands) SMZ (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

15.1.2 Influence of Engagement

The Government of the Northwest Territories (GNWT) has engaged with Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapter 2 (consultation and engagement), Chapter 3 (Traditional Knowledge), and Chapter 11 (culture and traditional land use). The GNWT has recently initiated Consultation with Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, and through a review of publicly available TLRU information, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to water quantity and water resources. This feedback has been considered and summarized in Table 15.1 and has been integrated into the assessment of potential effects on water quantity that follows. Drinking water is considered within the assessment of potential effects on water and sediment quality in Chapter 16.

Table 15.1 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
Participants of the Norman Wells Renewable Resources Council (NWRRC) TLRU study reported that the water quantity (levels) at Canyon Creek, Prohibition Creek and Vermilion Creek has been lower in recent years and study participants are concerned about cumulative effects to creeks if water is taken from those areas for project construction, and operations and maintenance. The NWRRC study participants reported that Canyon Creek previously contained several small ponds and was an ideal location for camping, however, the area has completely dried up.	NWRRC, 2023	The GNWT has identified mitigation measures to reduce the effects of the Project on water quantity. Water withdrawal will be within the limits of water licences and in accordance with the DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013), which is generally limited to less than 10% of the available flow or volume for all users. Monitoring will be undertaken to confirm the Project is meeting licence conditions. The Project will follow measures in the Permafrost Protection Plan (PPP) to reduce ponding, erosion, and damage to permafrost. Erosion and drainage patterns will be observed and documented in support of the Erosion and Sedimentation Control Plan (ESCP).	For mitigation measures to reduce effects of the Project on water quantity see Table 15.8 See also: Section 15.4.2 (Changes in Streamflows) Section 15.4.3 (Changes in Lake Volumes) Section 15.4.4 (Change in Groundwater Quantity) Chapter 10 (caribou and moose) Chapter 17 (fish and fish habitat) Chapter 19 (wildlife and wildlife habitat) Chapter 20 (birds and bird habitat) Volume 5 for management plans
Dehcho First Nations reported many factors influencing water quantity in the Dehcho Region, noting that the region is getting warmer and wetter overall, with more rainfall in August and September and even into October, resulting in higher water levels on smaller rivers and streams.	Dehcho First Nations, 2011		
Sahtu Elders have linked decreasing water levels to a reduction in fish and wildlife habitat, as well as creating additional challenges for water navigation, travel, and fishing, and expressed concerns about potential project effects to water quality and quantity in the Sahtu Region including contamination, which could be far reaching due to the speed at which surface and groundwater flows; patterns of surface water flow and potential groundwater changes; increased sediment from vegetation clearing along waterbodies from effects of blasting, runoff and thawing permafrost (erosion, flooding, scouring, reduced land subsistence), which also can affect groundwater and surface water. Change in water quantity could also affect the conditions for current use, potentially resulting in avoidance by Indigenous harvesters.	Dessau, 2012 (PR#13); Golder, 2015		
Community engagement participants reported that water levels in Mackenzie River (Deh Cho) change depending on ice levels and driftwood build-up in Mackenzie Mountains.	August 2021 Engagement		

Comment	Source	GNWT Response	Where Addressed
Sahtu land users have observed that declining water levels have reduced fish and wildlife habitat, and has created additional challenges for water navigation, travel and fishing due to drying of water bodies (e.g., Moose Lake[1]).	Golder, 2015	*(cont'd from above)* The Project does not propose to take water from lakes on the west side of Mackenzie River (Deh Cho). The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning.	*See above*
Community members in the Sahtu Region have expressed concerns for water operation withdrawals from lakes near *Dehdéleı̨ǫ Tué* (Sucker Lake/Three Day Lake) as lakes in the area are shallow.	Golder, 2015		
Community engagement participants expressed concern about water sources used during project construction maintenance because they provide habitat for wildlife and fish. Participants identified locations of suitable water sources for the Project.	April to July 2022 Engagement; November to December 2022 Engagement; November 2022 to February 2023 Engagement		
Sahtu harvesters reported powerful ice breaks during the spring break around the area of the proposed Great Bear River Bridge site that influence surface water quantity in the Sahtu Region; however, NWRRC study participants reported that large chunks of ice are no longer carried down the rivers because the water has been too low to move.	Golder, 2015; NWRRC, 2023; TRRC, 2022		

Note:

[1] The location of Moose Lake was not disclosed in the report.

15.1.3 Potential Effects, Pathways and Measurable Parameters

The Project has the potential to cause changes in streamflows, lake volumes, and groundwater quantity (Table 15.2). Streamflow is measurable with parameters such as the mean monthly and annual flow rate, and annual peak and low flows. Potential changes in streamflow may occur through changes to surface drainage patterns (either directly [e.g., by blocking natural streams] or indirectly through project interaction with terrain, soils, and permafrost, including borrow extraction and changes to snow distribution); erosion and sediment deposition; potential glaciation and icings at watercourse crossings; or water withdrawals during construction and operations and maintenance (Table 15.2).

Table 15.2 Potential Effects, Effects Pathways and Measurable Parameters for Water Quantity

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in streamflows	• Changes to surface drainage patterns either directly (e.g., blocking natural streams) or indirectly through project interaction with terrain, soils, and permafrost (including borrow extraction and changes to snow distribution) • Erosion and sediment deposition • Potential for glaciation and icings at watercourse crossings • Water withdrawals	Mean monthly and annual flow rates; annual peak and low flows (cubic metres per second [m^3/s])
Change in lake volumes	• Water withdrawals	Volume of lakes (m^3) or lake levels (m)
Change in groundwater quantity	• **Excavation:** Excavation of a borrow source, quarry, or road cut may result in a change in groundwater levels (direct effect) and a change in groundwater discharge to streams, lakes, or wetlands (indirect effect) • **Ground Disturbance:** The construction of the highway may alter ground surface characteristics such that the groundwater recharge rate over disturbed areas may change (direct effect) • **Permafrost Degradation:** The construction of the highway will alter ground surface characteristics that may result in permafrost degradation (direct effect), a change in active layer thickness or increased connection to sub-permafrost groundwater systems (indirect effects), and a change in groundwater flow to or from streams, lakes, or wetlands (indirect effects)	Groundwater levels measured as elevation in metres above sea level (m asl)

Potential changes in lake volumes may occur as a direct effect of water withdrawals during construction and operations and maintenance (Table 15.2). The pathways for potential changes in streamflows may also indirectly affect lake volumes through the change in streamflows.

Changes to groundwater quantity refer to a change in groundwater flow rate or direction, which can be measured indirectly by a change in groundwater levels from existing conditions. A change in groundwater quantity may be caused by excavations, or by ground disturbance during clearing site activities, borrow source and quarry development, embankment construction, and the presence of the highway. These activities can also cause permafrost degradation that in turn would cause a change in groundwater flow.

These potential effects, corresponding effects pathways, and measurable parameters for water quantity are summarized in Table 15.2.

15.1.4 Boundaries

15.1.4.1 Spatial Boundaries

Potential project-related changes to surface water quantity are assessed relative to the following areas:

- **Project Development Area (PDA):** The area of direct project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 m wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sites with access roads on a 30 m ROW.
- **Local Assessment Area (LAA)**: The area within which measurable project-related effects (direct or indirect) are expected to occur (Figure 15.1). The water quantity LAA is the area within a 1 kilometre (km) buffer of the preliminary alignment route centerline, quarries and borrow sources and associated access roads. The buffer was extended to the west to include the mainstem of Mackenzie River (Deh Cho) and potential water sources for construction of the Mackenzie Valley Winter Road (MVWR). The LAA is divided into a northern section (i.e., Tulita to the northern most extent of the Project) and a southern section (i.e., Wrigley to Tulita). The northern and southern sections of the LAA are separated by a 10 km break in the project alignment at the Hamlet of Tulita to account for the Great Bear River Bridge (not part of the Project).
- **Regional Assessment Area (RAA)**: The area that provides context for determining significance of project effects and potential cumulative effects. The surface water quantity RAA is defined as the area within approximately 15 km of the PDA (Figure 15.1).

- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Surface Water Local Assessment Area
- Surface Water Regional Assessment Area
- Groundwater Local Assessment Area
- Groundwater Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Mackenzie River Sub-Basin

0 10 20 Kilometres
(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 8/7/2023
TR by CS on 8/7/2023

Client/Project
144903025-0139 REVA
Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
15.1

Title
Water Quantity Assessment Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
Imagery date: 2021

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

Potential project-related changes to groundwater quantity are assessed relative to the following areas:

- **Project Development Area (PDA):** The area of direct project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 m wide highway ROW, laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sites with access roads on a 30 m ROW.
- **Local Assessment Area (LAA)**: The area within which measurable project-related effects (direct or indirect) are expected to occur. The groundwater quantity LAA is a 0.5 km buffer of the preliminary alignment route centerline, quarries and borrow sources and associated access roads (Figure 15.1). The LAA is divided into a northern section (i.e., Tulita to the northern most extent of the Project) and a southern section (i.e., Wrigley to Tulita). The northern and southern sections of the LAA are separated by a 10 km break in the project highway alignment at the Hamlet of Tulita to account for the Great Bear River Bridge (not part of the Project).
- **Regional Assessment Area (RAA)**: The area that provides context for determining significance of project effects and potential cumulative effects. The groundwater quantity RAA is the area within approximately 5 km of the PDA or the mainstem of the Mackenzie River (Deh Cho), whichever is closer (Figure 15.1). The Mackenzie River (Deh Cho) is a regional groundwater flow divide (K'alo-Stantec, 2022b) that will limit the influence of project activities on one side of the river to groundwater on the other.

15.1.4.2 Temporal Boundaries

The temporal boundaries for the Project consist of the following phases:

- **Construction phase:** The Project will take approximately 10 years to construct, over a timeframe of up to 20 years. The conceptual schedule assumes the highway will be constructed in three consecutive segments: Wrigley to the Dehcho/Sahtu border (102 km); Tulita south to the Dehcho/Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (PCAR) (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells sometime between 2041 and 2046.
- **Operations and maintenance phase:** Operations and maintenance will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the highway is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, quarries and borrow sources not needed for operations and maintenance will occur during the construction phase.

15.1.5 Residual Effects Characterization

Potential residual effects of the Project on water quantity are characterized in terms of direction, likelihood, magnitude, geographic extent, timing, duration, frequency, and reversibility (as defined in Table 15.3). Likewise, quantitative measures or, where applicable, descriptions of qualitative measures, are provided in Table 15.3.

Table 15.3 Characterization of Residual Effects on Water Quantity

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse –** A residual effect that moves measurable parameters of water quantity in a negative direction relative to baseline **Neutral –** No net change in measurable parameters for water quantity relative to baseline
Likelihood	The probability that the residual effect will occur	**Unlikely –** The residual effect is almost certainly not to occur. **Possible –** The residual effect could occur. **Certain –** The residual effect will certainly occur.
Magnitude[1,2]	The amount of change in measurable parameters or the valued component (VC) relative to existing conditions	**Surface Water Quantity** **No Measurable Change –** Changes in streamflow compared to existing conditions (i.e., streamflow without project effects) are less than 5% (i.e., changes are within the range of uncertainty in hydrologic data measurement and analysis). For lake volumes, water withdrawals within the limit of existing licences are considered to have no measurable change. **Low (<10%) –** Changes in streamflow or lake volume are greater than the "no measurable change" threshold, but less than 10% compared to existing conditions (within the natural variability of existing conditions). **Moderate (10-20%) –** Changes in streamflow or lake volume compared to existing conditions are between 10% and up to 20%. **High (>20%) –** Changes in streamflow or lake volume compared to existing conditions are greater than 20%.

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Magnitude[1,2] (cont'd)		**Groundwater Quantity** **No Measurable Change –** Seasonal groundwater levels are consistent with baseline conditions (i.e., they are within the range of potential inter-annual groundwater level variations). **Low –** Seasonal groundwater levels deviate from the range of potential inter-annual groundwater level variations by less than 1 m. **Moderate –** Seasonal groundwater levels deviate from the range of potential inter-annual groundwater level variations by 1 – 2 m. **High –** Seasonal groundwater levels deviate from the range of potential inter-annual groundwater level variations by greater than 2 m
Geographic Extent	The geographic area in which a residual effect occurs	**PDA –** Residual effects are restricted to the PDA. **LAA –** Residual effects extend into the LAA. **RAA –** Residual effects interact with those of other projects within the RAA.
Timing	Considers when the residual effect is expected to occur, where relevant to the VC	**No Sensitivity –** Seasonal aspects are unlikely to affect water quantity. **Low sensitivity** - Effect does not occur during a sensitive time for surface water or groundwater. **High sensitivity -** Effect occurs during a highly sensitive period. For surface water, the highly sensitive period is during winter (from freeze-up to spring-thaw) when streamflows are low. For groundwater, the highly sensitive period is from spring thaw to autumn freeze-up, when terrain, soils, and permafrost are the most susceptible to ground disturbance).
Duration	The time required until the measurable parameter or the VC returns to its existing condition, or the residual effect can no longer be measured	**Short-term –** The residual effect is restricted to one year in duration or less. **Medium-term –**The residual effect extends through the construction of the Project (20 years). **Long-term –** The residual effect extends beyond the construction of the Project and/or during operations (greater than 20 years).
Frequency	Identifies how often the residual effect occurs and how often during the project or in a specific phase	**Single event** – The residual effect occurs once. **Multiple irregular event –** The residual effect occurs at no set schedule. **Multiple regular event –** The residual effect occurs at regular intervals. **Continuous –** The residual effect occurs continuously.

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Reversibility	Pertains to whether a measurable parameter or the VC can return to its existing condition after the project activity ceases	**Reversible –** The residual effect is likely to be reversed after activity completion and reclamation. **Irreversible –** The residual effect is unlikely to be reversed.

Notes:

1 The 5% uncertainty in hydrologic data measurement and analysis is based on professional judgment. The 10% threshold for the (low) magnitude of potential changes in streamflows and lake volumes are informed by guidance documents (e.g., DFO, 2010, 2013) and professional judgement. The 20% threshold for the (high) magnitude changes in streamflows and lake volumes is based on professional judgment.

2 For example, at the time of water withdrawal, if existing streamflow (i.e., measured steamflow just upstream of a withdrawal point) is 1 cubic metre per second (m^3/s), water withdrawals of less than 0.1 m^3/s will be considered low magnitude (i.e., the change is less than 10%).

15.1.6 Significance Definition

For surface water quantity, the significance of residual effects is determined by the qualified professionals based on their experience and professional judgment, as well as the characterization of residual effects as described in Table 15.3. The following general considerations (along with professional judgement) are applied in determining significance:

- If the magnitude of the effect is low (<10%), the effect is not significant.
- For moderate (10-20%) magnitude effects, if the geographic extent of the effect is confined to the PDA or LAA, the effect is likely to be not significant.
- For high (>20%) magnitude effects, significance evaluation will be based on geographic extent, duration, frequency, and reversibility.

Consideration of these attributes for the evaluation of a significant, or not significant effect relies heavily on professional judgement.

For groundwater quantity, the significance of potential residual effects will be determined based on the characterization of residual effects as outlined in Table 15.3 using the following criteria:

- If the magnitude of the effect is no measurable change or low, the effect is not significant.
- If the magnitude of the effect is moderate and the geographic extent of the effect is confined to the PDA or LAA, the effect is not significant.
- If the magnitude of the effect is moderate and the geographic extent of the effect extends to the RAA, the effect is significant.
- If the magnitude of the effect is high, the significance evaluation of the effect will be based on the characterization of the effect's geographic extent, duration, and reversibility.

Consideration of these attributes for the evaluation of a significant, or not significant effect relies heavily on professional judgement.

The preceding definition of significance applies to groundwater quantity as a resource. Indirect effects from a change in groundwater quantity on other VCs are not evaluated in this chapter.

15.2 Existing Conditions for Water Quantity

To support the assessment of effects of the Project on surface water quantity, existing information within the LAA and RAA has been described and evaluated in the Surface Water Quantity technical data report ([TDR]; Appendix 15A; K'alo-Stantec, 2022a).

The TDR includes 27 local watersheds that had been identified as watersheds of interest in previous surface water quantity studies (Golder, 2015; IORVL, 2004). From those 27 watersheds (i.e., tributaries of the Mackenzie River [Deh Cho] which the Project will cross), 13 watersheds can be identified as major drainages based on the criterion of watershed area being greater than 100 square kilometres (km^2; Golder, 2015). However, the TDR describes all those 27 previously identified watersheds of interest.

Existing conditions for groundwater quantity within the LAA and RAA have been detailed in the Hydrogeology Technical Data Report ([TDR]; Appendix 15B; K'alo-Stantec, 2022b). This report presents the groundwater system existing conditions and provides a conceptual model of local and regional groundwater flow systems to use in the evaluation of potential project effects. Key subjects covered in the Hydrogeology TDR include:

- Permafrost influence on groundwater flow (Section 4.2.3)
- Surficial geology hydrostratigraphy (Section 4.3)
- Bedrock geology hydrostratigraphy (Section 4.4)
- Groundwater as a resource (Section 4.6)
- Conceptual model of the groundwater flow system (Section 5)

15.2.1 Methods

Existing data were collected from Water Survey of Canada (WSC) hydrometric stations in the region, and previously published documents were reviewed (including documented Traditional Knowledge [TK]). K'alo-Stantec (2022a; Appendix 15A) characterized hydrologic indices (i.e., mean annual runoff [MAR], monthly distribution of annual runoff, peak flows, and low flows) for the watersheds of interest identified within a study area, which is the same as the RAA. Further, K'alo-Stantec (2023a, 2022c; Appendix 15C and Appendix 15D) provided a preliminary water availability assessment for 23 streams and 24 water bodies (i.e., lakes, ponds, basins) in the LAA. Methods used for these preliminary estimates are described in K'alo-Stantec (2023a, 2022c; Appendix 15C and Appendix 15D).

In addition, existing TK and TLRU (e.g., TRRC, 2022) was reviewed, and a literature review of water quantity-related information to characterize existing hydrological and hydrogeological conditions within the LAA and RAA (Appendix 15A and Appendix 15B [K'alo-Stantec, 2022a, 2022b]).

Based on the data compiled during the TK, TLRU, and literature review, K'alo-Stantec completed hydrostratigraphic interpretations of soils and bedrock geological units intersected by the Project and developed regional and local conceptual models of the groundwater flow system in the vicinity of the Project (a conceptual hydrogeological model).

15.2.2 Summary of Flows in Major Streams Intersected by the Project

The MAR identified in the TDR ranges from 151 millimetres (mm) to 220 mm (Appendix 15A; K'alo-Stantec, 2022a). Likewise, although it is assumed that major drainages with watershed area of greater than 100 km^2 are perennial, it is not known with certainty what drainages with watershed areas of less than 100 km^2 are perennial and which ones are seasonal.

A summary of annual flow estimates in 23 major streams intersected by the PDA is provided in Table 15.4. Location of these streams and detailed, preliminary month-by-month flow and water availability predictions are provided in Appendix 15C and Appendix 15D (K'alo-Stantec, 2023a, 2022c).

Data presented in the TDR are intended to be used for environmental assessment and do not provide engineering design parameters. Engineering design and analysis of crossings (e.g., conveyance capacity and channel stability) requires a study tailored for such purposes. Additional data will need to be collected to support applications for authorization to use water sources for withdrawal to demonstrate availability of water at time of withdrawal in accordance with applicable guidelines (e.g., DFO, 2010, 2013).

Sahtu Region land users have observed that declining water levels have reduced fish and wildlife habitat, and has created additional challenges for water navigation, travel and fishing due to drying of water bodies (Golder, 2015). NWRRC TLRU study participants reported that Canyon Creek previously contained several small ponds and was an ideal location for camping; however, the area has completely dried up (NWRRC, 2023).

Participants of the NWRRC TLRU study reported the water in Canyon Creek, Prohibition Creek, and Vermilion Creek is shallower in recent years, and concern were raised about potential cumulative effects to creeks if water is taken from those areas for project construction and operations and maintenance (NWRRC, 2023). Dehcho First Nations have also indicated many factors influencing water quantity in the Dehcho Region, noting that the region is getting warmer and wetter overall, with more rainfall in August, September, and October, resulting in higher water levels on smaller rivers and streams (Decho First Nations, 2011).

Table 15.4 Summary of Preliminary Flow Estimates in Major Streams Assessed for Water Availability (K'alo-Stantec, 2023a, 2022c)

Watercourse Location [1]	Location Alignment (KM)	Watershed Area (km^2)	Mean Annual Discharge (m^3/s)	Maximum Monthly Discharge[2] (m^3/s)
Hodgson Creek Bridge	695.6	358	2.04	9.6
Ochre River Bridge	725.7	1,207	9.71	49.6
Whitesand Creek Bridge	733.8	346	1.64	8.8
Big Strawberry Creek Culvert	748.5	59	0.30	1.9
Small Strawberry Creek Culvert	748.6	49	0.25	1.6
Vermillion Creek South Bridge	752.3	68	0.34	2.2
Bob's Canyon Creek Culvert	755.3	9	0.06	0.4
Dam Creek Bridge	764.8	110	0.54	3.3
Blackwater Bridge	785.3	10,716	62.8	230
Steep Creek Bridge	816.5	154	0.75	4.4
Devil's Canyon Bridge	828.4	21	0.12	0.8
Saline River Bridge	831.9	317	1.51	8.1
Seagrams Creek Bridge	844.3	57	0.29	1.9
Little Smith Creek Bridge	852.3	439	2.08	10.8
Big Smith Creek Bridge	872.1	1,076	6.38	33.7
Gotcha Creek Bridge	912.7	155	0.75	4.4
Twelve Mile Creek Bridge	922.0	42	0.22	1.4
Four Mile Creek Culvert	931.5	17	0.10	0.7
Great Bear River at Tulita[3]	937.2	158,400	584	682
Jungle Ridge Creek Bridge	967.8	60	0.33	2.1
Notta Creek Bridge	971.5	65	0.33	2.1
Vermillion Creek North Bridge	973.4	92	0.46	2.8
Prohibition Creek Bridge	984.0	86	0.45	2.76

Notes:

1 Locations are shown in Figure 1.2 of K'alo-Stantec (2023a; Appendix 15C).

2 Maximum Monthly Discharge typically occurs in May (the exception is Blackwater River where maximum monthly discharge occurs in June; K'alo-Stantec, 2023a; Appendix 15C).

3 The Great Bear River is not in the LAA; however, the Great Bear River was assessed in K'alo-Stantec (2023a; Appendix 15C).

15.2.3 Summary of Available Under-Ice Lake Water Volumes

Available information was compiled from a preliminary assessment of lakes potentially to be used for water withdrawal within the LAA. For the purposes of preliminary water availability calculations, all waterbodies with open water maximum depths greater than 1.5 m (the maximum ice depth in the region; DFO, 2010) are considered potential fish habitat. Lakes shallower than this would freeze to the lakebed in winter.

Maximum ice thickness in the LAA is expected to be about 1.5 m (DFO, 2010). Given this expected maximum thickness, DFO winter withdrawal guidance is summarized in Table 15.5. To apply these criteria, maximum lake depth and lake volume are needed.

Table 15.5 Fisheries and Oceans Canada (DFO) Winter Water Withdrawal Guidance for Ice-Covered Waterbodies Applied to Lakes in the LAA

Maximum Open Water Depth	DFO Protocol Guidance (applies to ice-covered waterbodies)
Shallower than 1.5 m	"exempt from 10% maximum withdrawal limit" Interpreted as withdrawals cannot occur when ice is at its maximum thickness, and withdrawals may occur based on site-specific conditions when ice thickness is less than its annual maximum.
Deeper than 1.5 m, and shallower than 3.0 m	Waterbodies are "particularly vulnerable to the effects of water withdrawal" Interpreted as withdrawals should not occur.
Deeper than 3.0 m	"total water withdrawal… is not to exceed 10% of the available water volume"

Note:
Guidance is from DFO, 2010.

Volume estimates were based on actual surveyed results (if available). Although the MVLWB's method for small-scale projects (MVLWB, 2021) applies to small-scale projects, for reference, estimations were also made using this method. Results are summarized in Table 15.6. Additional study, such as bathymetric survey, will be required to be completed to support licencing of water sources selected for construction and/or operations and maintenance where volume is currently noted as "unknown." For location of these waterbodies and detailed results of these preliminary estimates, refer to Appendix 15C (K'alo-Stantec, 2023a).

Table 15.6 Summary of Estimates for Available Under-Ice Volume of Lakes Preliminarily Assessed for Water Withdrawal (K'alo-Stantec, 2023a)

Name[1]	Alignment (KM)[2]	Max Depth (m)		Volume Available for Withdrawal based on DFO, 2010[4]	Volume Available for Withdrawal Estimated from Surface Area (MVLWB, 2021)[5]	Comment
		Surveyed	Coarse[3]			
WS Wrigley	686.5	-	-	-	90,207	Volume unknown
WR2	702.2	5.1	-	4,277	36,496	-
WR3	718.8	-	2.9	-	53,383	Volume unknown
WR4	721.8	-	2.9	-	3,640	Volume unknown
WS791	791	-	-	-	3,639	Volume unknown
WR5	798.8	2.1	-	-	20,017	Too shallow to withdraw
WR6	804	3.4	-	682	79,647	-
WR7	810.1	-	1.5	-	20,726	Too shallow to withdraw
WR8	820	15.2	-	126,553[f]	25,174	-
WR9	826.6	2.2	-	-	1,962	Too shallow to withdraw
WR10	835	15.1	-	3,084[f]	1,316	-
WR11	839.5	1.9	-	-	4,365	Too shallow to withdraw
WR12	863	2.3	-	-	743,243	Too shallow to withdraw
WR13	876.3	1.7	-	-	71,477	Too shallow to withdraw
WR16	882.5	4.9	-	4,899[f]	5,663	-
WR18	892	9.3	-	22,937[f]	138,544	-
WR893	893	-	-	-	19,009	Volume unknown
WR19	903	3.8	-	1,181[f]	3,595	-
WR20	908.9	2.6	-	-	359,597	Too shallow to withdraw

Name[1]	Alignment (KM)[2]	Max Depth (m)		Volume Available for Withdrawal based on DFO, 2010[4]	Volume Available for Withdrawal Estimated from Surface Area (MVLWB, 2021)[5]	Comment
		Surveyed	Coarse[3]			
WR22	916	-	3.4	-	225,436	Volume unknown
WR21	921.3	-	5.2	-	3,061	Volume unknown
WR948	948.4	-	-	-	1,646	Volume unknown
WR25	944.6	21.7	-	316,381[6]	46,113	-
WR28	950.4	14.8	-	74,686	20,449	-

Notes:

1 Locations are shown in Figure 1.3 of K'alo-Stantec (2023a; Appendix 15C)

2 Approximate mid-point of each lake along the project alignment (kilometre marker)

3 From Golder (2006). These are lakes where full bathymetric surveys have not been conducted and may not represent the true maximum lake depth.

4 10% of under ice water volume calculated assuming 1.5 m thick ice.

5 10 centimetre drawdown of lake based on waterbody surface area

6 from Golder (2008)

"-" Data not available

15.2.4 Conceptual Hydrogeological Model

Groundwater flow systems are generally conceptualized as nested regional, intermediate, and local scale systems (Toth, 1963). Regional groundwater flow systems develop from large-scale topographic, physiographic, and geologic features (such as the Central Mackenzie Valley [CMV], larger than the RAA). Local groundwater flow systems develop from smaller-scale variation of topography and geologic features and local flow (i.e., within the PDA and/or LAA) is often dominated by one component of the regional flow system (Freeze and Cherry, 1979). The predominant features of the conceptual groundwater model of the CMV and the PDA, as it traverses the Mackenzie Plain from Wrigley to Norman Wells, include the following (K'alo-Stantec, 2022b):

- The PDA is largely within the discharge zone of regional groundwater flow-paths that extend from recharge areas beyond the RAA within the Franklin and McConnell Mountain Ranges.

- Surficial geology within the RAA is predominately low permeability glaciolacustrine (43.0%) and till (21.3%) with smaller fractions of moderate to high permeability alluvial (15.3%), colluvium 9.4%), and glaciofluvial (5.9%) sediments and other (5.1%) materials.
- Surficial geology within the LAA includes low permeability till (23.3%) and glaciolacustrine (20.6%) materials, moderate to high permeability organic (15.3%), glaciofluvial (14.1%), colluvium (11.0%), eolian (6.1%), and fluvial (4.9%) materials, and (4.2%) other materials.
- Surficial geology along the PDA includes low permeability glaciolactustrine (25.8%) and till (21.3%) materials, moderate to high permeability glaciofluvial (19.5%), organic (12.7%), eolian (7.6%), fluvial (6.4%), and colluvium (5.8%) materials, and (0.9%) other materials.
- Low permeability glaciolacustrine and till deposits, if present, will act as a barrier to local and regional groundwater discharge and artesian (above ground surface) pressure conditions have the potential to develop in underlying stratigraphy.
- Permafrost, where it exists, is expected to be a barrier to groundwater flow and will separate the groundwater flow system into shallow, seasonal, supra-permafrost flow within the active layer and deeper, perennial sub-permafrost flow components. The degree to which this separation exists is expected to increase north along the PDA as the presence of permafrost increases from sporadic discontinuous (10-35% of land area) near Wrigley, through intermediate discontinuous (35% to 65% of land area), to extensive discontinuous (65% to 90% of land area) permafrost near Norman Wells.
- Where extensive discontinuous permafrost is present, interaction between supra-permafrost and sub-permafrost groundwater flow systems may be limited to taliks, regions of thawed strata that allow fluid flow. Taliks within the CMV may be concentrated along regional fault trace and fracture systems where regional flow gradients prevent permafrost from becoming established, and beneath large lakes and streams. Regional groundwater discharge likely occurs predominately through these perennial conduits.
- Permafrost, where it exists, will limit the volume of local groundwater recharge (i.e., occurring within the RAA, LAA, and/or PDA) that reaches the sub-permafrost groundwater system. The limitation will be greater along northern portions of the PDA than southern portions due to the increased presence of permafrost.
- Permafrost, where it exists, limits groundwater flow within the RAA to the shallow supra-permafrost flow component. The limitation will be greater along northern portions of the PDA than southern portions due to the increased presence of permafrost. Groundwater flow limited to the supra-permafrost component limits overall groundwater storage and results in rapid groundwater discharge to surface following spring melt or precipitation events.
- Borrow source excavations target glaciofluvial and fluvial materials for construction fill that also tend to be high permeability and well drained. These characteristics limit the formation of ground ice and may reduce the compartmentalizing effect of permafrost where present in these materials.

15.3 Project Interactions with Water Quantity

Project schedules and activities for the construction phase and the operations and maintenance phase are described in detail in Sections 5.4 and 5.5, respectively. Project-related accidents and malfunctions are not considered project interactions and are described in Chapter 25.

Project activities that have the potential to interact with water quantity are identified with a check mark in Table 15.7.

Table 15.7 Project-Environment Interactions with Water Quantity

Physical Activities	Timing	Environmental Effects		
		Change in Streamflows	Change in Lake Volumes	Change in Groundwater Quantity
Construction Phase				
Mobilization of equipment, materials, and fuel, resupply, and demobilization	Summer and winter	–	–	–
Establishment and operation of camps	Year-round	✓	✓	–
Site preparation of ROW, access, and workspaces	Winter	✓	✓	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	✓	–	✓
Material haul	Year-round	✓	✓	–
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓	✓	✓
Culvert installations	Summer or winter	✓	–	–
Road base placement, compaction, and surfacing	Summer	✓	✓	–
Water withdrawal for construction activities	Year-round	✓	✓	–
Closure and reclamation of MVWR and temporary borrow sources/quarries, camps, and workspaces	Summer	✓	–	✓
Employment and contracted goods and services[1]	Year-round	–	–	–

Physical Activities	Timing	Environmental Effects		
		Change in Streamflows	Change in Lake Volumes	Change in Groundwater Quantity
Operations and Maintenance Phase				
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	✓	✓	✓
Material haul and stockpiling	Summer	✓	–	–
Operation of, and activities at, maintenance yards	Year-round	✓	✓	–
Water withdrawal for dust control	Summer	✓	✓	–
Employment and contracted goods and services[1]	Year-round	–	–	–
Presence and use of the highway	Year-round	✓	–	✓
Highway and access road maintenance including snow clearing, repair, grading, dust control	Year-round	✓	✓	–
Vegetation control	Summer	✓	✓	–
Bridge and culvert maintenance	As needed	✓	✓	–

Notes:

✓ = Potential interaction

– = No interaction

[1] Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, "Employment and contracted goods and services" have been introduced as an additional component under each project phase.

The activities listed below were excluded, and the reasons for such exclusions are provided:

- Mobilization of equipment, materials, and fuel, resupply and demobilization: These activities will use established transportation systems and constructed roads. No water use or water diversion will be required.
- Employment and contracted goods and service: These activities do not have a physical interaction with water quantity.
- Activities involving water withdrawal, such as camp operations, embankment construction, and dust control, will not interact with groundwater quantity as groundwater will not be sourced for water uses.

Activities that disturb the land cover and terrain and require excavation (e.g., site preparation activities, borrow source and quarry development, embankment and quarry access road construction, and road cuts) have the potential to affect surface drainage patterns and groundwater quantity and cause erosion and sedimentation, thereby potentially also affecting streamflow and/or lake volume. Similarly, closure and reclamation of MVWR and temporary borrow sources/quarries, camps, and workspaces include alteration of land cover (i.e., vegetation) which may affect the surface drainage pattern and groundwater quantity and cause erosion and sediment deposition.

Culvert installation and the presence of the highway can lead to an alteration of the natural surface drainage pattern and affect streamflow if conveyance capacity of a culvert is not sufficient, or the culvert is installed incorrectly. Potential glaciation and icings can reduce the conveyance capacity of the culverts during spring and lead to changes in surface drainage patterns. Likewise, culverts may alter the hydraulics, and thereby the erosion and sediment deposition processes of a stream.

Changes in streamflow and/or lake volume may occur as a result of activities which require water withdrawal for consumption or use. These activities include:

- Establishment and operation of camps
- Site preparation of ROW, access, and workspaces
- Material haul, which requires water for dust suppression
- Water withdrawal for construction activities
- Water withdrawal for dust control

Project activities that may indirectly affect groundwater quantity through permafrost degradation include those activities requiring excavation and ground disturbances, when they occur in areas underlain by permafrost, and by the presence of the highway itself.

15.4 Assessment of Residual Effects on Water Quantity

Based on project interactions with the environment identified in Table 15.7, the Project may affect water quantity. Potential effects, effect pathways, and mitigation measures that will reduce or eliminate the effects on surface water quantity are identified in Table 15.8.

Potential residual effects that may persist after application of mitigation measures, as well as the qualitative assessment techniques used to evaluate these effects, are described in the subsections.

Table 15.8 Potential Effects and Mitigation Measures for Water Quantity

Potential Effect	Effect Pathway	Mitigation Measures
Change in streamflows	• Changes to surface drainage patterns either directly (e.g., blocking natural streams) or indirectly through project interaction with terrain, soils, and permafrost (including borrow extraction and changes to snow distribution) • Erosion and sediment deposition • Potential for glaciation and icings at watercourse crossings • Water withdrawals	• Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns (i.e., limit inter-watershed water routing). • Accumulated snow may be dispersed (e.g., snow drifts flattened and/or plowed) to reduce potential long-term effects on permafrost. In areas where snow drifting becomes a reoccurring issue, strategies such as snow fencing will be considered to keep snow drifts off the road surface and away from drainage ditches. • The Project will follow measures in the PPP to reduce ponding, erosion, and damage to permafrost. Detailed mitigation measures to reduce the effects on terrain, soil, and permafrost are described in Chapter 14 (terrain, soils and permafrost). • Erosion and drainage patterns will be observed and documented in support of the ESCP. • Sediment control measures will be implemented per the GNWT Erosion and Sediment Control Manual (GNWT, 2013) and will be in place prior to construction activities and before the spring melt/freshet. • Culverts will be designed and constructed to maintain water flow and fish passage. Drainage culverts will be installed according to specifications to accommodate storm events and maintain drainage patterns and in consideration of site-specific icing/glaciation effects. • Ice in culverts will be thawed by steaming, where needed to maintain flow. • Culvert design will include requirements for bedding materials and geotextile to protect surrounding permafrost from thaw. Rip rap will be incorporated into culvert design to avoid erosion around each culvert. • Water withdrawal will be within the limits of water licences and in accordance with the DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013).

Potential Effect	Effect Pathway	Mitigation Measures
Change in lake volumes	Water withdrawals	• Water withdrawal will be within the limits of water licences and in accordance with the DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013).
Change in Groundwater Quantity	**Excavation:** Excavation of a borrow source, quarry, or road cut may cause the following: a decline in groundwater levels (direct effect) and a reduction in groundwater discharge to streams, lakes, or wetlands (indirect effect).	• A fill-only construction approach will be used except at specific locations of road cuts. • Borrow sources will not be located in areas where there is a high groundwater table. • Borrow source floors will be sloped to reduce ponding of water. • Quarry operations will be located a minimum of 100 m from the ordinary high-water mark of any waterbody. • Excavations will be contoured prior to closure to reduce steep slopes. • Positive drainage will be maintained within quarry floors. • Measures to manage borrow source water will be included in the Quarry Development Plan (QDP). • The QDP will include measures to assess and mitigate, if needed, potential effects of excavation on groundwater quantity for each borrow source and quarry site. These plans will outline required actions should groundwater withdrawal and subsequent discharge begin to affect groundwater quantity. • Use mitigation measures listed under Ground Disturbance as applicable.
	Ground Disturbance: The construction of the highway will alter ground surface characteristics such that the groundwater recharge rate over affected areas may change (direct effect).	• The Project will use previously disturbed areas for project activities and infrastructure and workspaces, to the extent practical. • The area of direct ground disturbance will be limited by following the pre-existing MVWR to the extent possible. Clearing will be limited to areas required for construction and safe operations. • A fill-only construction approach will be used except at specific locations of road cuts. • Steep grades where subsidence may occur as a result of permafrost thaw will be avoided, where possible. • Clearing will be completed by hand in sensitive areas (e.g., in riparian areas), where required, to prevent damage to the ground.

Potential Effect	Effect Pathway	Mitigation Measures
Change in Groundwater Quantity (cont'd)		• Clearing of new areas will be completed when the ground is frozen to limit disturbance to soils and permafrost. • Travel of vehicles will be confined to existing roads and trails as much as possible to avoid disturbing vegetated areas. • Organic topsoil will be left in place to retain a protective layer during the construction of the road to limit permafrost degradation and protect the soils from erosive factors of water. • If surface organic material must be removed for construction, it will be stockpiled and re-applied where possible. • Removal of vegetation will be limited to the ROW and workspaces.
	Permafrost Degradation: The construction of the highway will alter ground surface characteristics that may result in permafrost degradation (direct effect), a change in active layer thickness or increased connection to sub-permafrost groundwater systems (indirect effects), and a change in groundwater flow to or from streams, lakes, or wetlands (indirect effects).	• Geotextile and embankment placement will be completed in the winter to limit disturbance to soils and permafrost. • Disturbance of the active layer during construction and maintenance activities will be avoided where possible. • Construction equipment will be operated on designated winter roads or constructed embankment only. • Clearing of new areas will be completed when the ground is frozen. • Placement of embankment will occur primarily during winter (December 15 to April 1), during frozen conditions. If work is to be completed under non-frozen conditions, equipment will be equipped with mushroom shoes. • The Project will follow measures in the PPP to reduce ponding, erosion, and damage to permafrost. • Ice-rich soils or materials that are susceptible to physical erosion will be covered to reduce permafrost degradation. • Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns.

Potential Effect	Effect Pathway	Mitigation Measures
Change in Groundwater Quantity (cont'd)		• Runoff control methods will be used to protect permafrost soils, including diversion of water entering the site; the modification of slope surfaces, the reduction of slope gradients, controlling flow velocity, providing adequate or increased drainage, and diverting flows away from exposed soil areas for mitigating permafrost degradation. • Modification to the location or number of drainage culverts will be determined in consultation with the Engineer as based on observed site conditions. • Excavations and developed borrow sources will be visually monitored throughout the summer and fall to confirm there is no physical erosion resulting from the degradation of permafrost. • If ice-rich permafrost is identified during quarrying activities, suitable measures will be taken to protect permafrost and ground ice encountered during material extraction activities as per quarry operations plans. • Use mitigation measures listed under Excavation and Ground Disturbance, as applicable.

15.4.1 Analytical Assessment Techniques

Potential project-related effects were evaluated with consideration of the following:

- The anticipated success of mitigation measures
- The level of sensitivity of surface water quantity (at the watershed scale) to potential effects
- A review of surface water effects assessments for similar all-season highway projects in the NWT (i.e., Tłı̨chǫ Highway [GNWT, 2016], Prairie Creek All Season Road [Canadian Zinc Co., 2015], and Inuvik to Tuktoyaktuk Highway [Kiggiak-EBA, 2011])

The hydrogeological conceptual model (Section 15.2.4) was a fundamental tool used to assess the effect of project activities upon groundwater quantity.

This assessment of residual effects follows a qualitative approach that relies on professional judgement to evaluate potential project-related changes to water quantity. Additional considerations in the evaluation of potential residual effects included the anticipated success of mitigation measures which are designed to be protective of the environment.

15.4.2 Changes in Streamflows

15.4.2.1 Effects Pathways

The pathway mechanisms through which residual effects on streamflows may occur are summarized in Table 15.2 and Table 15.8 and described:

- Changes to surface drainage patterns may be either due to the highway blocking natural streams, or an indirect result of project interaction with terrain, soils, and permafrost (including borrow extraction and changes to snow distribution). Project interactions with terrain, soils, and permafrost are described and assessed in detail in Chapter 14.
- Erosion and sediment deposition has the potential to affect the capacity of streams to convey streamflow. Erosion effects are described and assessed in detail in Chapter 16.
- Glaciation and icings at watercourse crossings have the potential to reduce their capacity to convey peak flows and cause ponding upstream of the road.
- Water withdrawals during construction and operations and maintenance reduce natural streamflow in streams.

15.4.2.2 Mitigation

Design-based mitigation to reduce or eliminate changes in streamflow are summarized in Table 15.8. In this section, mitigation measures are organized according to the effect pathway they target.

Water withdrawal will be within the limits of water licences and in accordance with the DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013). This mitigation measure will target the water withdrawals pathway. Particularly, DFO (2013) guidance is:

- Cumulative flow alterations of less than +/- 10% of the magnitude of actual (instantaneous) flow in the river relative to a natural flow regime have a low probability of detectable negative effects on ecosystems.
- "Cumulative flow alterations that result in instantaneous flows less than 30% of the Mean Annual Discharge (MAD) have a heightened risk of effects on ecosystems that support fisheries." Periods below 30% MAD were identified as 'highest risk'.

These mitigation measures for water withdrawal are considered effective at reducing potential effects on water quantity from changes in streamflow.

Multiple design mitigation measures will be in place to avoid changes to surface drainage patterns. In particular, mitigation measures that are anticipated to be successful in eliminating the potential measurable changes in streamflow at the watershed scale include the following:

- Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns (i.e., limit inter-watershed water routing).

- Accumulated snow may be dispersed (e.g., snow drifts flattened and/or plowed) to reduce potential long-term effects on permafrost. In areas where snow drifting becomes a reoccurring issue, strategies such as snow fencing will be considered to keep snow drifts off the road surface and away from drainage ditches.
- The Project will follow measures in the PPP to reduce ponding, erosion, and damage to permafrost. Detailed mitigation measures to reduce the effects on terrain, soil, and permafrost are described in Chapter 14 (terrain, soils and permafrost).

Culverts will be designed and constructed to maintain water flow and fish passage. Design mitigation measures for the erosion and sediment deposition pathway are anticipated to be successful in eliminating the potential measurable changes in streamflow at the watershed scale due to the erosion and sediment deposition pathway. These measures are as follows:

- Erosion and drainage patterns will be observed and documented in support of the ESCP.
- Sediment control measures will be implemented per the GNWT Erosion and Sediment Control Manual (GNWT, 2013) and will be in place prior to construction activities and before the spring melt/freshet.
- Culvert design will include requirements for bedding materials and geotextile to protect surrounding permafrost from thaw. Rip rap will be incorporated into culvert design to avoid erosion around each culvert.

To eliminate the potential effect of glaciation and icings pathway on conveyance capacity of the culverts, and thereby on streamflow:

- Drainage culverts will be installed according to specifications to accommodate storm events and maintain drainage patterns and in consideration of site-specific icing/glaciation effects.
- Ice in culverts will be thawed by steaming, where needed to maintain flow.

15.4.2.3 Residual Effects

After the application of mitigation measures, the Project is anticipated to have residual effects on streamflows as a result of water withdrawals; however, the mitigation measures are anticipated to eliminate the effects of other pathways to streamflows beyond practically measurable thresholds at the watershed scale.

With the implementation of mitigation measures, the residual effects on streamflows during the construction and operations and maintenance phases are predicted to be low (<10%) magnitude and limited to the LAA. That is, the magnitude of change in discharge rates of the Mackenzie River (Deh Cho) downstream of the LAA is not predicted to be measurable (i.e., not >5% of natural flow as per Table 15.3).

Timing of water withdrawals and their potential effect on streamflows can be sensitive, particularly if water withdrawals occur when streamflows are decreasing near the 30% of mean annual discharge threshold guided by DFO (2010), or during the freeze-up or thaw seasons, which may have icing implications.

Water withdrawals and water use occur for multiple project activities as described in Section 15.3. As such, the effects on streamflow are considered long-term (although water use volumes will be reduced after the construction phase; Section 5.4.11) and the frequency is categorized as multiple irregular events. Effects are predicted to be reversible following cessation of water withdrawal activities.

15.4.3 Changes in Lake Volumes

15.4.3.1 Effects Pathways

Water withdrawals from lakes during construction and operations and maintenance have the potential to reduce the volume of lakes (Table 15.2 and Table 15.8).

15.4.3.2 Mitigation

Water withdrawal from lakes will be within the limits of water licences and in accordance with DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013). MVLWB (2021) is not directly applicable because it only relates to small-scale projects.

15.4.3.3 Residual Effects

After the application of mitigation measures, water withdrawal pathway is still anticipated to have residual effects on lake volumes. However, given compliance with DFO measures, changes in lake volumes are predicted to remain under 10% and protective of littoral habitat, and therefore the residual effects on lake volumes during the construction and operations and maintenance phases are predicted to be of low magnitude. The geographic extent of residual effects on lake volumes are limited to the LAA (i.e., the volumes of lakes outside the LAA are not anticipated to be affected by the Project).

Timing of water withdrawals and their potential effect on lake volumes can be sensitive, particularly if water withdrawals occur during winter (November to April when lake volumes are reduced due to ice cover).

Water withdrawals and water use occur for multiple project activities, as described in Section 15.3. As such, the effects on lake volumes are considered long-term (although water use volumes will be reduced after the construction phase; Section 5.4.11) and the frequency is categorized as multiple irregular events. However, residual effects are predicted to be reversible following cessation of water withdrawal activities, which may be seasonal or localized to the area of construction.

15.4.4 Change in Groundwater Quantity

15.4.4.1 Effects Pathways

Potential project effects on groundwater quantity, resulting from applicable effect pathways (i.e., excavation, ground disturbance, and permafrost degradation), depend on the hydrogeological characteristics of the area where the effect occurs.

15.4.4.1.1 Excavation

Excavations, if they advance below the groundwater table in permafrost-free areas, will result in the flow of groundwater into the excavation that must be removed (e.g., pumped out). If personnel will be working within the excavation (i.e., as could be expected in a borrow source or quarry), additional pumping must occur to lower the groundwater level below the floor of the excavation to have safe working conditions. As a result, groundwater levels near the excavation will decline and the excavation will become a local sink for groundwater flow.

The groundwater level change will be greatest at the excavation and will logarithmically decline as distance from the excavation increases. The area of the groundwater system affected by the groundwater level change is the excavation's cone of depression. Groundwater discharge to wetlands, streams, or lakes within the cone of depression may begin to decrease, or water from these environments may begin to infiltrate to ground, as a result of groundwater withdrawal.

Excavations, if they do not advance below the groundwater table, will result in a topographic depression to which surface flow and runoff may be directed. As a result, ground recharge may increase in the vicinity of the excavation and, where permafrost exists, permafrost degradation may occur.

15.4.4.1.2 Ground Disturbance

Ground disturbance activities may alter the characteristics of the ground surface such that the rate of incident precipitation or melt water that infiltrates to the groundwater system (recharge) may change. In permafrost-free areas, ground disturbance activities can be expected to increase groundwater recharge by decreasing water loss from evapotranspiration. The magnitude of the increase will depend, in part, on the permeability of local sediments. Approximately 47% of the PDA is underlain by low-permeability glaciomarine and till deposits (Section 15.2), and a potential increase in recharge from ground disturbance may be limited by the presence of these sediments. Conversely, ground disturbance in areas underlain by moderate to high permeability glaciofluvial, organic, eolian, fluvial, and colluvium materials (approximately 52% of the PDA, Section 15.2) may experience increased recharge.

15.4.4.1.3 Permafrost Degradation

Project activities that may affect groundwater quantity through permafrost degradation may occur along the entire PDA, but effects are more likely to occur where permafrost is classified as extensive continuous (65% to 90% of the land area; i.e., primarily in the northern half of the PDA [K'alo-Stantec, 2023b]).

Excavation, where permafrost exists, will remove ground cover and sediment layers, expose previously insulated stratigraphy to thaw-freeze conditions, and create a local topographic low. These changes may increase the thickness of the active layer near the excavation and/or promote ponding, which may cause additional permafrost degradation and an increased connection between supra- and sub-permafrost groundwater systems.

Vegetation and topsoil act as a thermal buffer that reduces ground surface heat loss in the winter and radiative heat penetration in the summer (Burgess and Smith, 2000). Ground disturbance where permafrost exists, as presented in Chapter 14 (terrain, soils and permafrost), will remove this buffer and increase the depth that seasonal thaw-freeze fluctuations penetrate. Thermokarst landforms, drainage pattern alteration, and an increase in the thickness of the active layer may result.

The presence of the road embankment may cause permafrost degradation by impeding slope drainage. The proposed road embankment will intersect westward-flowing drainage systems that ultimately discharge into the Mackenzie River (Deh Cho) (TRRC, 2022). Snowmelt and the seasonal thaw of the active layer result in considerable runoff that may encounter the upgradient side of the embankment. If the embankment is not adequately designed to allow water to pass, ponding may occur along its upgradient edge.

Ponded surface water will thaw underlying permafrost and thaw ground ice if these are present, which may cause thermokarst subsidence, create a topographic low, and in turn promote further ponding. The end effect on groundwater quantity of sustained ponding is the degradation of underlying permafrost and ground ice such that a hydraulic connection between supra- and sub-permafrost groundwater systems (Section 15.2) may be formed.

15.4.4.2 Mitigation Measures

Design-based mitigation measures to reduce or eliminate adverse effects on groundwater quantity are summarized in Table 15.8, organized according to the effect pathway the mitigation targets (i.e., excavation, ground disturbance, and permafrost degradation).

Additional mitigation measures to limit ground disturbance activities, such as the removal of vegetation and/or topsoil for road construction, are provided in the ESCP (see Volume 5). Additional detail on mitigation measures to limit the degradation of permafrost are provided in the PPP (see Volume 5).

15.4.4.3 Residual Effect on Groundwater Quantity

With the application of mitigation measures summarized in Table 15.8, the Project is likely to result in a change in groundwater quantity (i.e., a residual effect).

Project-related activities that change the conditions of the existing groundwater flow system (Table 15.7) will have an effect on groundwater quantity and on hydraulically connected surface water environments. Since these environments exist in balance with the recharge and discharge components of the existing groundwater flow system, there are no scenarios in which a project activity causes a positive or neutral effect on unaffected, existing groundwater conditions. Therefore, the characterization of the type of residual effect on groundwater quantity is defined as 'adverse' (Table 15.3).

Other residual effect characterizations defined for a change in groundwater quantity (Table 15.3) are discussed in terms of the pathway that cause the effect.

15.4.4.3.1 Excavation

The magnitude of groundwater level change associated with an excavation depends on the final depth of the excavation, whether the excavation extends below the groundwater table, and whether the excavation occurs where permafrost exists. Since the depth of the excavations anticipated by the Project are unknown, the magnitude of groundwater level change and the size of the associated cone of depression are uncertain. However, avoiding borrow material where groundwater levels are close to ground surface (Table 15.8) will reduce excavation below the groundwater table and reduce the magnitude of groundwater level decline. Additionally, planning for water management, as part of each site-specific QDP (Table 15.8), will provide a framework to manage and mitigate groundwater inflow and discharge to the environment should an excavation proceed beneath the groundwater table.

While a regional distribution of permafrost is available for the Project (K'alo-Stantec, 2022b), the distribution of permafrost at specific borrow source or quarry targets is unclear. However, where excavations proceed in permafrost, the low-permeability and confining nature of permafrost can be expected to reduce the development of a large cone of depression.

The magnitude of groundwater level change occurring from project excavations is expected to range from low to moderate within the PDA, no measurable change to low within the LAA, and no measurable change within the RAA. These expectations are consistent with a logarithmic reduction in groundwater level change as distance from the excavation increases (Section 15.4.4). Residual effects from excavation are not anticipated to extend beyond the LAA (i.e., 500 m) because excavation for borrow source, quarry, and road cut activities, based on past project experience and professional judgement, are generally too shallow to result in a cone of depression extending more than 500 m. The likelihood of a large cone of depression developing from excavations for this Project is further reduced since excavations may not extend below the groundwater table (no cone of depression) or they may occur in permafrost (limited cone of depression).

Residual effects associated with excavations are not expected to be sensitive to timing since borrow source, quarry, and road cut excavations will operate year-round and result in permanent changes in topography. As a result, the duration, frequency, and reversibility of associated residual effects are expected to be long-term, continuous, and irreversible, respectively.

15.4.4.3.2 Ground Disturbance

The magnitude of groundwater level change associated with ground disturbance will depend on the area affected. If the mitigation measures listed in Table 15.8 are employed, such as limiting project work to the PDA and limiting the removal of vegetation to the width of the ROW, ground disturbance will be locally limited to the PDA, which is a small fraction of the ground surface area within the LAA and RAA. The affected area will be further reduced since 47% of the PDA is underlain by low-permeability glaciomarine and till deposits that can be expected to restrict recharge (Section 15.2.4). As a result, the magnitude of the groundwater level change associated with project ground disturbance activities is anticipated to be no measurable change to low.

The residual effects from project activities with a ground disturbance pathway that can be remediated (e.g., temporary camp locations) are expected to be medium-term (e.g., during the construction phase), continuous, and reversible. Effects related to ground disturbance caused by permanent changes, such as the presence of the highway, are expected to be long-term, continuous, and irreversible.

Residual effects associated with ground disturbance activities are not expected to be sensitive to timing as a result of mitigation measures taken to reduce effects on groundwater quantity that specifically address sensitive timing (e.g., new areas will be cleared when the ground is frozen, Table 15.8).

15.4.4.3.3 Permafrost Degradation

The magnitude of groundwater level change associated with permafrost degradation (indirect effect) is difficult to predict but will depend, in part, on the effectiveness of the PPP and the mitigation measures contained therein. A key component of the PPP will be adequate drainage culverts or other design infrastructure used to convey surface runoff and supra-permafrost (active layer) groundwater flow through the embankment and reduce ponding on the upgradient edge.

The magnitude will also depend on the permeability of the underlying sediments. Low permeability glaciomarine and till deposits (approximately 47% of the PDA) will continue to act as confining layers, in the absence of permafrost, by resisting recharge and encouraging surface runoff. Where the PDA intersects moderate to high permeability alluvial, colluvium, or glaciofluvial materials (approximately 52% of the PDA) containing permafrost and ground ice, there is greater potential for these materials to drain or store water that previously flowed as surface runoff.

If the PPP is used effectively, the magnitude of the groundwater level change associated with permafrost degradation for the Project is anticipated to be low to moderate, moderate being consistent with the residual effect of the Project on permafrost degradation (direct effect) discussed in Chapter 18 (terrain, soils and permafrost).

Permafrost degradation is expected to be limited to the PDA and LAA. Southern areas of the PDA are less likely to be affected than northern areas. Because the road embankment is intended to be a permanent infrastructure feature, residual effects from associated permafrost degradation are long-term, continuous, and irreversible.

Residual effects from activities associated with the permafrost degradation pathway are not expected to be sensitive to timing as mitigation measures taken to reduce effects on groundwater quantity specifically address sensitive timing (e.g., new areas will be cleared when the ground is frozen, Table 15.8).

15.4.5 Summary of Residual Effects

With mitigation measures in place, residual effects from the Project on water quantity are anticipated to occur in the form of changes in streamflows, changes in lake volumes, and changes in groundwater quantity. These residual effects are predicted to be adverse in direction. Adverse effects on streamflows and lake volumes are predicted to be of low (<10%) magnitude and occur within the LAA with a long-term duration (i.e., the construction and operations and maintenance phases). Timing of the effects can be sensitive, and effects can be irregular, but they are reversible.

Residual effects resulting from the Project on groundwater quantity after mitigation is implemented will occur and these effects are predicted to be adverse in direction. The magnitude and geographic extent of residual effects depend on the pathway mechanism that causes the effect as follows:

- Residual effects on groundwater quantity from excavations are expected to have magnitudes that range from low to moderate within the PDA and no measurable change to low within the LAA. These effects are expected to be continuous and irreversible but geographically limited to the LAA.
- Residual effects of the Project from ground disturbance include no measurable change to low magnitude, continuous, and reversible and irreversible changes to groundwater quantity that are geographically limited to the PDA.
- Residual effects of the Project from permafrost degradation include low to moderate magnitude and irreversible changes to groundwater quantity that are geographically limited to the LAA.

A summary of residual effects on water quantity is provided in Table 15.9. With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirement related to watershed management, and consideration of engagement input and incorporation of Traditional Knowledge.

The design of the Project and mitigation measures for reducing effects on water quantity respects the values of the Petiniɂah (Bear Rock) CZ, Mio Lake CZ, Norman Range SMZ, K'ąąlǫ Tué (Willow Lake Wetlands) SMZ, and Deh Cho (Mackenzie River) as areas with important ecological habitats, and takes into account the Project's location within Tulita's community drinking water source catchment.

Table 15.9 Residual Effects on Water Quantity

Residual Effect	Residual Effects Characterization*								
	Project Phase	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Changes in Streamflows	C/O	A	P	L	LAA	HS	LT	IR	R
Changes in Lake Volumes	C/O	A	P	L	LAA	HS	LT	IR	R
Change in Groundwater Quantity	C/O	A	P	NMC[1,2] L[1,2,3] M[1,3]	PDA[1,2,3] LAA[1,3]	NS	MT[2] LT[1,2,3]	C	R[2], I[1,2,3]

KEY

*See Table 15.3 for detailed definitions

Project Phase:
C: Construction
O: Operations and Maintenance

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMC: No Measurable Change
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
LS: Low sensitivity
HS: High sensitivity

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

Notes:

1 Applies to the excavation effects pathway (Section 15.4.4.1)

2 Applies to the ground disturbance effects pathway (Section 15.4.4.1)

3 Applies to the permafrost degradation effect pathway (Section 15.4.4.1)

15.5 Assessment of Cumulative Effects on Water Quantity

15.5.1 Residual Effects Likely to Interact Cumulatively

Other projects and activities within the RAA may interact with the Project and cumulatively affect water quantity. A project inclusion list of such past, present, and foreseeable projects and activities is provided in Table 15.10 and shown in Figures 4.1 and 4.2.

Where adverse residual effects from the Project on water quantity have the potential to act cumulatively with those from other projects and physical activities, this potential has been identified with check marks in Table 15.10. The projects and activities listed below were excluded from cumulative effects assessment:

- Geotechnical assessment activities within the Hamlet of Tulita, upstream of confluence with Great Bear River, are not anticipated to have measurable effects on the Mackenzie River (Deh Cho) streamflows or interact with effects of the Project on groundwater.
- Existing quarries and borrow sources (i.e., Little Bear River Quarry and Sand Bar Quarrying) are on the west side of the Mackenzie River (Deh Cho), and therefore will not interact with the Project to affect surface water or groundwater quantity.
- Mining exploration and oil and gas projects located on the west side of the Mackenzie River (Deh Cho) are excluded from the cumulative effects assessment as their effects will not interact with residual effects on water quantity.

Other past, present, and foreseeable projects and activities in Table 15.10 have the potential to interact with the project activities and cumulatively affect streamflows and groundwater quantity. These include the oil, gas and seismic projects east of the Mackenzie River (Deh Cho); MVWR; Canyon Creek All Season Access Road; municipal operations at Wrigley, Tulita, and Norman Wells; Dhu-1 Quarry; Great Bear River Bridge; and Prohibition Creek Access Road. Only the municipal activities and Dhu-1 Quarry have potential to also affect lake volumes, as the other projects do not use lakes as water withdrawal sources.

These projects and activities have the potential to interact with water quantity through surface drainage pattern, erosion and sediment deposition, excavation, terrain disturbance, glaciation and icings, and water withdrawal pathways.

Table 15.10 Projects with the Potential to Contribute to Cumulative Effects in the RAA

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects		
	Change in Streamflows	Change in Lake Volumes	Change in Groundwater Quantity
Past and Present Physical Activities and Resource Use (Base Case)			
Geotechnical	–	–	–
Oil, Gas & Seismic*			
Tulita 2D Seismic Program	✓	✓	–
Windy Island Drilling Program	✓	–	–
Infrastructure			
MVWR, including bridges and bridge-sized culverts	✓	✓	✓
Canyon Creek All Season Access Road	✓	–	✓
Norman Wells Pipeline	–	–	✓
Mackenzie Valley Fibre Link	–	–	✓
Prohibition Creek Access Road	✓	–	✓
Quarries and Borrow Sources			
HRN Quarry	–	–	✓
Mining & Exploration	–	–	–
Municipal Operations, including water, waste, power and community development			
Wrigley Municipal Activities	✓	✓	–
Tulita Municipal Activities	✓	✓	–
Norman Wells Municipal Activities	✓	✓	–
Project-Related Physical Activities (Project Case)			
Mackenzie Valley Highway Project	✓	✓	–
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)			
Quarries			
Dhu-1 Quarry	✓	✓	✓
Infrastructure			
Great Bear River Bridge	✓	–	✓

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects		
	Change in Streamflows	Change in Lake Volumes	Change in Groundwater Quantity
Oil and Gas			
Enbridge Maintenance Camp	✓	–	–

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with Project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = Includes support activities such as production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas.

15.5.2 Changes in Streamflows

15.5.2.1 Cumulative Effects Pathways

Similar to effects pathways of the Project (see Section 15.4.2.1), the pathway mechanisms through which residual cumulative effects on streamflows may occur are described:

- Changes to surface drainage patterns may be either due to directly blocking natural streams, or an indirect result of project interaction with terrain, soils, and permafrost (including borrow extraction and changes to snow distribution).
- Erosion and sediment deposition has the potential to affect the capacity of streams to convey streamflow.
- Glaciation and icings at watercourse crossings have the potential to reduce their capacity to convey peak flows and cause ponding upstream of the road. The icings could impact watercourse crossings if the water source producing the icing is contributing continuously. Furthermore, ponding that may result upstream of the road could cause permafrost degradation and localized thermokarst subsidence.
- Water withdrawals reduce natural streamflow in streams.

15.5.2.2 Mitigation for Cumulative Effects

No additional mitigation measures are recommended to reduce or eliminate cumulative effects on streamflow beyond those measures presented in Section 15.4.2.2 and Table 15.8, namely that cumulative changes to streamflows will not exceed 10% of the flow. It is assumed that water withdrawals associated with future projects and activities would obtain the necessary approvals and adhere to applicable DFO guidelines.

15.5.2.3 Cumulative Effects

Similar to the residual effects of the Project (see Section 15.4.2.3), it is anticipated that after the application of mitigation measures, cumulative effects on streamflows due to potential changes in surface drainage patterns, erosion and sediment deposition, and/or glaciation and icings at watercourse crossings will be negligible. However, even with application of mitigation measures, cumulative effects associated with water withdrawal will remain.

These cumulative residual effects on streamflows during the construction and operations and maintenance phases are predicted to be of low (<10%) magnitude. Within the LAA, the relative contribution from the Project to the cumulative residual effect cannot be quantified because quantified magnitudes of change in streamflows due to the Project and other projects are not known. However, such a quantified relative contribution within the LAA will not be relevant if the magnitude of cumulative effects is low (i.e., as long as the MVWLB considers cumulative withdrawal of less than 10% when assessing the water licence applications).

The geographic extent of these cumulative effects on streamflows is limited to the LAA. That is, the magnitude of change in discharge rates of the Mackenzie River (Deh Cho) downstream of the LAA is not predicted to be measurable (i.e., not >5% of natural flow as per Table 15.3).

Timing of water withdrawals and their potential effect on streamflows can be sensitive, particularly if water withdrawals occur during winter (i.e., under ice conditions) or during the freeze-up or thaw seasons, which may have icing implications.

The effects on streamflow are considered long-term and the frequency is categorized as multiple irregular events. Cumulative effects are predicted to be reversible following cessation of water withdrawal activities.

15.5.3 Changes in Lake Volumes

15.5.3.1 Cumulative Effects Pathways

Similar to that assessed for project effects, it is assumed that the mechanism for cumulative changes in lake volumes is through water withdrawals.

15.5.3.2 Mitigation for Cumulative Effects

No additional mitigation measures are recommended to reduce or eliminate cumulative effects on lake volumes beyond those measures presented in Section 15.4.2.2 and Table 15.8, namely that cumulative water withdrawal will not exceed 10% of the under-ice volume. It is assumed that water withdrawals associated with future projects and activities would obtain the necessary approvals and adhere to applicable DFO guidelines.

15.5.3.3 Cumulative Effects

The cumulative residual effects on lake volumes during the construction and operations and maintenance phases are predicted to be of low (<10%) magnitude. Within the LAA, contribution from the Project to the cumulative residual effect cannot be quantified because quantified magnitudes of change in lake volumes due to the Project and other projects are not known. However, such a quantified relative contribution within the LAA will not be relevant if the magnitude of cumulative effects is low (i.e., as long as the MVLWB considers cumulative withdrawal of less than 10% when assessing the water licence applications).

The geographic extent of these cumulative effects on lake volumes is limited to the LAA. That is, the volume of lakes outside the LAA are not anticipated to be affected by the Project, and therefore the Project will not have cumulative effects on lake volumes outside the LAA.

Timing of water withdrawals and their potential cumulative effect on lake volumes can be sensitive, particularly if water withdrawals occur during winter (i.e., under ice conditions when lake volumes are reduced).

The effects on lake volumes are considered long-term and the frequency is categorized as multiple irregular events. Cumulative effects are predicted to be reversible following cessation of water withdrawal activities.

15.5.4 Change in Groundwater Quantity

15.5.4.1 Cumulative Effects Pathways

Residual effects on groundwater quantity arising from past, present, and reasonably foreseeable future projects and physical activities include the same effects pathways as those resulting from the Project (Section 15.4.4); ground disturbance and permafrost degradation. Effects occurring through these pathways will only act cumulatively with the residual effects of the Project if they extend into the project LAA, since project effects are not anticipated to extend beyond the LAA.

15.5.4.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects on groundwater quantity from excavation, ground disturbance, and permafrost degradation pathways include those presented in Table 15.8. No additional mitigation measures are recommended to reduce or eliminate the cumulative effects on groundwater quantity beyond those measures presented. It is assumed that other projects and activities have or would apply similar mitigation measures to those presented in Table 15.8.

15.5.4.3 Cumulative Effects

Residual effects from the Project to groundwater quantity are not anticipated to extend to the RAA and therefore are not expected to contribute to cumulative effects within the RAA.

The residual effects of other past or present projects on baseline groundwater quantity conditions with the Project LAA are difficult to determine. Existing groundwater quantity data (groundwater levels) was lacking at a level of detail required to characterize baseline conditions beyond general statements on regional and local groundwater flow systems (Section 15.2).

Reasonably foreseeable projects and developments include the Dhu-1 Quarry, the Great Bear River Bridge, and the Prohibition Creek Access Road.

The Dhu-1 Quarry is a permitted quarry source 1.6 km from the project PDA and the Dhu-2 quarry is a proposed alternate quarry source 3.1 km from the PDA (Chapter 5). The quarries are located approximately 2 km from one another. Residual effects on groundwater quantity, should quarry excavation at these two sources extend below the groundwater table, are expected to be similar to the residual effects of other excavations (Section 15.4.4). The maximum extent of groundwater level change is expected to be 500 m or less (Section 15.4.4.3), and residual effects from the quarries are not expected to act cumulatively.

The Great Bear River Bridge and Prohibition Creek Access Road projects are either outside the LAA or the continuation of the same overall linear infrastructure as the Project, to the extent they will be designed to the same highway standard (Section 5.3.2). As a result, residual effects from these projects are not expected to act cumulatively with the Project.

Therefore, the magnitude of cumulative effects are expected to range from no measurable change to moderate within the LAA, consistent with the assessment completed for residual effects. Likelihood, sensitivity, timing, duration, frequency, and reversibility are expected to be possible, not sensitive, long-term, continuous, and irreversible, respectively.

15.5.5 Summary of Cumulative Effects

With mitigation measures in place, cumulative residual effects on water quantity are anticipated to occur in the form of change in streamflows, change in lake volumes, and change in groundwater quantity (Table 15.11).

Cumulative effects on surface water quantity are predicted to be adverse and of low (<10%) magnitude. The effects are anticipated to occur within the LAA with a long-term duration (i.e., the construction and operations and maintenance phases). Timing of the effects can be sensitive, and effects can be irregular, but they are reversible.

Cumulative effects on groundwater quantity are predicted to be adverse in direction and range from no measurable change to moderate in magnitude. Cumulative effects will occur in the LAA and persist for the long term due to the long operational period and permanent changes to the environment imposed by of many of these projects. For many of these project and activities, cumulative effects will likely be irreversible.

Table 15.11 summarizes the Project cumulative effects on water quantity.

Table 15.11 Summary of Cumulative Effects on Water Quantity

Residual Cumulative Effect	Residual Cumulative Effects Characterization							
	Direction	**Likelihood**	**Magnitude**	**Geographic Extent**	**Timing**	**Duration**	**Frequency**	**Reversibility**
Residual Cumulative Change in Streamflows	A	P	L	LAA	HS	LT	IR	R
Contribution from the Project to the residual cumulative effect	Within the LAA, contribution from the Project to the cumulative residual effect cannot be quantified (see Section 15.5.2.3). Outside the LAA (within the RAA), the Project does not contribute to cumulative residual effects.							
Residual Cumulative Change in Lake Volumes	A	P	L	LAA	HS	LT	IR	R
Contribution from the Project to the residual cumulative effect	Within the LAA, contribution from the Project to the cumulative residual effect cannot be quantified (see Section 15.5.3.3). Outside the LAA (within the RAA), the Project does not contribute to cumulative residual effects.							
Change in Groundwater Quantity	A	P.	NMC[1], L[1,2,3], M[2,3]	PDA[1,2], LAA[2,3],	NS	LT	C	I
Contribution from the Project to the residual cumulative effect	The Project contribution to cumulative effects on changes to groundwater quantity is expected to be no measurable change at the RAA level.							

KEY

*See Table 15.3 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMC: No Measurable Change
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
LS: Low sensitivity
HS: High sensitivity

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

N/A: Not applicable

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

Notes:

1 Applies to the ground disturbance effects pathway (Section 16.4.3.1)

2 Applies to the excavation effects pathway (Section 16.4.3.1)

3 Applies to the permafrost degradation effect pathway (Section 16.4.3.1)

15.6 Determination of Significance

15.6.1 Significance of Residual Effects

Residual effects of the Project on surface water quantity include low magnitude, reversible changes in streamflows and lake volumes that are geographically limited to the LAA (Table 15.9).

Based on these characterizations, as well as the significance definition in Section 15.1.6, residual effects on surface water quantity are predicted to be not significant.

Based on the characterizations of residual effects outlined in Table 15.11 and summarized in Section 15.4.4, and the significance definition in Section 15.1.6, residual effects on groundwater quantity are predicted to be not significant.

15.6.2 Significance of Cumulative Effects

Cumulative residual effects on surface water quantity include low magnitude, reversible changes in streamflows and lake volumes that are geographically limited to the LAA. Based on these characterizations, as well as the significance definition in Section 15.1.6, these cumulative residual effects on surface water quantity are predicted to be not significant.

Cumulative residual effects on groundwater quantity range from no measurable change to moderate effects geographically limited to the LAA, Cumulative residual effects on groundwater quantity are possible, and expected to be long-term, continuous, and irreversible. Based on these characterizations, as well as the significance definition in Section 15.1.6, cumulative effects on groundwater quantity are predicted to be not significant.

15.6.3 Project Contribution to Cumulative Effects

Within the LAA, contribution from the Project to the cumulative residual effect on surface water quantity cannot be quantified because quantified magnitudes of change in lake volumes due to the Project and other projects are not known. However, such a quantified relative contribution within the LAA will not be relevant if the magnitude of cumulative effects is low (i.e., as long as the MVWLB considers cumulative withdrawal of less than 10% when assessing the water licence applications).

Outside the LAA (within the RAA), the Project does not contribute to cumulative residual effects.

The contribution of residual effects of the Project to cumulative effects on groundwater quantity within the LAA are expected to range from no measurable change to moderate in magnitude, consistent with the assessment of residual effects (Section 15.4.4).

The Project is not expected to contribute measurably to cumulative effects within the RAA since residual effects of the Project are anticipated to be limited to the LAA.

15.7 Prediction Confidence

For surface water quantity, if it is confirmed that the design of the Project will apply the mitigation measures for water quantity (particularly those listed in the assumptions, Section 15.7.1), the prediction confidence will be moderate. If such a confirmation cannot be provided, the prediction confidence will be low. Additional confirmation of lake volumes will improve confidence in residual effects predictions and field data will be required to be collected to support construction licence applications.

For groundwater quantity, confidence in the assessment of potential residual effects is increased by considering that the Project will not use groundwater for water supply and does not require excavations that extend far below the groundwater table. As a result, many common pathways to significant residual changes in groundwater quantity are not present.

Confidence in the assessment of potential effects on groundwater quantity is reduced based on the following:

- A lack of existing conditions groundwater quantity data from which to characterize potential residual effects.
- The long, linear disturbance nature of the Project results in the project PDA crossing a variety of conceptual groundwater flow systems, the variability of which limits the potential to describe or define these systems in detail.

In summary, the prediction confidence in assessing potential project effects on groundwater quantity is low to moderate based on this discussion and reliance on professional judgement.

15.7.1 Assumptions

Results of this effects assessment are dependent on effective implementation of mitigation measures, described in Section 15.4 and summarized in Table 15.8. Particularly, successful implementation the following mitigation measures are critical to the validity of these effects assessment results:

- Water withdrawal will be within the limits of water licences that will be in accordance with the DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013).
- There will be sufficient drainage culverts installed along the roadway to facilitate water movement and maintain drainage patterns (i.e., limit inter-watershed water routing).
- Culverts will be designed and installed as per hydrotechnical recommendations to maintain flow and fish passage, and as based on observing performance during construction.
- Culvert design will include requirements for bedding materials and geotextile to protect surrounding permafrost from thaw. Rip rap will be incorporated into culvert design to avoid erosion around each culvert.

- Drainage culverts will be installed according to specifications to accommodate storm events and maintain drainage patterns, and in consideration of site-specific icing/glaciation effects.
- The Project will follow measures in the PPP to reduce ponding, erosion, and damage to permafrost.
- Erosion and drainage patterns will be observed and documented in support of the ESCP.
- Sediment control measures will be in place prior to construction activities and before the spring melt/freshet.

15.7.2 Gaps and Uncertainties

Some existing condition data requirements of the ToR (MVEIRB, 2015) were not available for this assessment. These include:

- The extent of connectivity of existing water resources to adjacent watercourses, including any potential seasonal variation: This would be a potential issue where the drainage divide between two flat catchments is not well defined. However, the Project interacts with streams at the lowest end of their catchments where the flow is well channelized and natural inter-catchment flow is less common. Therefore, it is reasonable that such inter-catchment flows were not documented in the literature reviewed, and such flows would not be relevant to this effects assessment.
- A description of ephemeral streams located within or near the boundaries of the study area(s): It is not known with certainty what drainages with watershed areas of less than 100 km^2 are perennial and which ones are seasonal/ephemeral. Additional data will need to be collected to support applications for authorization to use water sources for withdrawal to demonstrate availability of water in accordance with applicable guidelines (e.g., DFO, 2010, 2013). Winter flow measurements are required to be collected from streams and winter under-ice volume will need to be determined for lakes.
- A description of naturally occurring icings: A key design-based mitigation measure is the installation of drainage culverts according to specifications to accommodate storm events and maintain drainage patterns and in consideration of site-specific icing/glaciation effects. To implement this mitigation, further project design will need to consider naturally occurring icings and the uncertainty in their magnitude of effect.
- A description of channel and bed morphology and stability, and a description of bank stability and areas of erosion for major drainages: The hydrotechnical assessment and fish and fish habitat assessment reports (see Appendix 22A; K'alo-Stantec, 2022d; Tetra Tech, 2021, 2022) provide this information for minor crossings where the Project will construct new crossing structures. These assessment reports did not include major drainages because these major drainages have existing bridges and will not be altered or replaced as part of the Project.

- For major drainages, a description of sediment load (suspended and bed load): As mentioned, the Project does not include alteration of existing bridges on major drainages. At minor drainages, although sediment loads have not been directly discussed, channel assessment has been conducted in the hydrotechnical assessment and fish and fish habitat assessment reports (see Appendix 22A; K'alo-Stantec, 2022d; Tetra Tech, 2021, 2022). In addition, potential effects of the Project on sediment quality have been assessed in Chapter 16.
- For major drainages, a description of active and historical floodplains: As mentioned, the Project does not include alteration of existing bridges on major drainages.
- Existing groundwater quantity data (groundwater levels) to characterize baseline conditions such that neither quantitative nor qualitative definitions of residual effects characterizations (Table 15.3) for groundwater quantity could be confidently developed.

As explained, data gaps (compared to the ToR [MVEIRB, 2015] requirements) do not materially change this effects assessment if the mitigation measures are effectively implemented as assumed in Section 15.7.1.

Uncertainties in input data that feed into the design can cause uncertainty in effectiveness of the design-based mitigation measures. Hydrologic input data with uncertainty include:

- Existing monthly streamflows, peak flows, and lake volumes (Appendix 15A and Appendix 15C [K'alo-Stantec, 2022a, 2023a] are based on estimates)
- Channel bed material and bank stability near crossings
- Effects of icing on conveyance capacity of culverts

While the abovementioned hydrologic input data are uncertain under existing conditions, such uncertainties are likely more considerable for future conditions with potential changes to climate, land cover, and drainage.

In addition, the dimensions and depths of the borrow source and quarry excavations are currently unknown. These variables will affect the effect pathway and the magnitude, geographic extent, duration, and reversibility of the residual effect on the groundwater quantity in the vicinity of the excavation. If borrow source, quarry, or road cut excavations extend below the groundwater table (uncertainty), a water licence to permit groundwater withdrawal may be required (GNWT, 2015).

15.8 Follow-up and Monitoring

Streamflow and lake level monitoring programs will be undertaken to confirm the low (<10%) effect of water withdrawals on streamflows and lake volumes. Likewise, existing winter under-ice volume will need to be determined for lakes. The need for monitoring programs, as well as their details (e.g., location, frequency, and parameters of measurement) will be determined during the water licence application process.

The monitoring programs should verify the effectiveness of design-based mitigation measures (e.g., culverts accommodating storm events with icing effects) both for existing and future conditions (i.e., with potential climate and land cover changes).

Monitoring plans for ground disturbance and permafrost degradation are included in the ESCP and the PPP that will describe sampling procedures, quality control and assurance programs, laboratory methods and protocols, laboratory accreditations, and reporting requirements, where applicable. The plans will also provide details on the location, design, methods (e.g., parameters to be measured), applicable regulatory instruments, and schedule for the follow-up and monitoring programs.

Management plans will be developed to assess and mitigate potential residual effects of excavation on groundwater quantity for each borrow source and quarry site, as required by the GNWT (2015). These plans will provide an adaptive management framework that outline required actions should groundwater withdrawal and subsequent discharge begin to affect groundwater quantity or other VCs.

15.9 References

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16.0 ASSESSMENT OF POTENTIAL EFFECTS ON WATER AND SEDIMENT QUALITY

The Mackenzie Valley Highway Project (the Project) has the potential to affect water and sediment quality in watercourses (e.g., streams, rivers, muskeg, and lakes) and groundwater quality during the construction, and operations and maintenance phases of the Project. Water resources that may be affected by the Project include those which will be downstream or downgradient of (or in proximity to) project components such as quarries, borrow sources, construction camps, and the highway itself.

Water and Sediment Quality was selected as a Valued Component (VC) because of its importance in supporting aquatic life, wildlife, human health, and community well-being. Changes in water or sediment quality can have negative effects on aquatic habitat and drinking water quality and may adversely affect the quantity and/or quality of food for wildlife and humans. The assessment of water and sediment quality contributes to the Subject of Note water quality and quantity as identified in the Terms of Reference ([ToR]; Mackenzie Valley Environmental Impact Review Board [MVEIRB], 2015 [PR#66]).

Protection of water quality in the Mackenzie Valley is of high cultural importance. Watercourses intersected by the Project are traditionally used as sources of sustenance, including drinking water and for harvesting of fish. Groundwater is valued as a potential source of water for human consumption and for its intrinsic links with aquatic environments.

This chapter assesses the potential effects of the Project on surface water quality, groundwater quality and on sediment quality in the aquatic environment. The potential for project-related changes in water and/or sediment quality to cause adverse effects on ecological receptors, human health, traditional land use, and community well-being is assessed separately for other VCs: Chapter 9 (human health and community wellness; non-traditional land and resource use), Chapter 10 (caribou and moose), Chapter 11 (cultural use), Chapter 17 (fish and fish habitat), and Chapter 19 (wildlife and wildlife habitat).

The assessment of potential effects on water and sediment quality concludes that with the application of mitigation measures, residual effects resulting from the Project on water and sediment quality will be adverse. Residual effects will not result in a persistent measurable change in surface water quality and sediment parameters that adversely affect ecological and/or human receptors. Changes to groundwater quality are predicted to be low in magnitude. The assessment concludes that residual effects and cumulative effects on water and sediment quality are predicted to be not significant.

16.1 Scope of Assessment

16.1.1 Regulatory and Policy Setting

The regulatory requirements associated with water quality include federal and territorial laws and policies, as well as water quality guidelines. Additionally, specific to the areas to which the Sahtu Land Use Plan (SLUP) applies, the Project must meet the conformity requirements (CR) of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023).

16.1.1.1 Federal and Territorial Legislation and Guidelines

The federal *Fisheries Act*, in particular Sections 34 through 42, regulates fisheries and addresses water pollution. Section 36 prohibits the deposit of deleterious substances into waters frequented by fish, unless authorized under regulations. As defined in Section 34(1)(a) of the *Fisheries Act*, a deleterious substance is "*any substance that, if added to any water, would degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water*."

The Government of the Northwest Territories (GNWT) is responsible for managing water resources in the Mackenzie Valley through the administration of the *Waters Act* and regulations. The territorial *Waters Act* is administered by the Department of Environment and Climate Change and regulates water quality through water usage and disposal of waste in water bodies. Within the Mackenzie Valley and Sahtu Region, water quality regulation is shared by the Mackenzie Valley Land and Water Board (MVLWB) and the Sahtu Land and Water Board (SLWB), for projects where a water licence is required. There are no regulations under the *Waters Act* prescribing water quality standards. Therefore, the following water quality guidelines (standards) are applied to surface water and groundwater quality:

- Canadian Council of Ministers of the Environment (CCME) Guidelines for the protection of Freshwater Aquatic Life (CWQG-FAL) (CCME, 2022)
- Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (CSQG-FAL; CCME, 2022)
- Federal Environmental Quality Guidelines (FEQGs) for the protection of aquatic life in fresh water and sediment (CCME, 2022; Environment and Climate Change Canada [ECCC], 2022a)
- The Alberta Environment and Parks (AEP) Environment and Sustainable Resource Development (ESRD) Tier 1 Groundwater Remediation Guidelines (AEP, 2022).
- Health Canada's Drinking Water Quality Guidelines (HC DWQG) and Recreational Water Quality Guidelines (HC RWQG) apply to potable water and recreational waters (Health Canada, 2012, 2020)

The intent of these guidelines and standards is to protect freshwater aquatic life and human health by providing concentrations of substances (e.g., metals, nutrients, major anions) below which adverse effects are generally not expected to occur. Because guidelines for the protection of

freshwater aquatic life are more stringent than water quality guidelines for the protection of wildlife, they are also considered protective of wildlife receptors. However, these guidelines and standards are generic and applied across Canada (or in the case of the Tier 1 guidelines, Alberta). Therefore, site-specific conditions that can influence the bioavailability and/or toxicity of a substance to ecological or human receptors (e.g., water chemistry or the sensitivity of specific biological receptors to the substance) aren't always adequately represented in a generic guideline. In some cases, site-specific water quality objectives are developed to more appropriately assess the potential for adverse effects than generic guidelines.

16.1.1.2 Sahtu Land Use Plan

The SLUP's CRs include consideration of:

- Community engagement and Traditional Knowledge (CR#2): *"2) The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge."*
- Watershed management (CR#5): The SLWB and/or MVLWB must ensure that the Project: *"a) does not substantially alter quality, quantity, or rate of flow for waters that flow on, through, or adjacent to Sahtu Settlement Lands; and b) is subject to mitigation measures to minimize potential impacts on surface and groundwater that flow into CZs [Conservation Zones], SMZs [Special management Zones], PCI [Proposed Conservation Initiatives] and EPAs [Established Protected Areas]."*
- Drinking water (CR#6): *"1) Any land use activity that would result in the contamination of surface or groundwater within community catchments is prohibited; 2) Where there is reasonable potential for any land use activity to affect a downstream drinking water source: a) the affected community must be informed and engaged with respect to potential impacts, the design of mitigation measures and monitoring programs; b) baseline water quality data must be collected from the drinking water source prior to the start of any activity; and c) regular water quality testing of the source watershed must be conducted to monitor potential impacts."* (SLUPB, 2023).

Additionally, CR#14 requires that the Project be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 2023), including the following:

- Petiniɂah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)
- K'ąąlǫ Tué (Willow Lake Wetlands) SMZ (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

16.1.2 Influence of Engagement

The GNWT has engaged with Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapters 2 (consultation and engagement), 3 (Traditional Knowledge), and 11 (culture and traditional land use). The GNWT has recently initiated Consultation with Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, and through a review of publicly available TLRU information, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to water and sediment quality and drinking water resources. This feedback has been considered and summarized in Table 16.1 and has been integrated into the assessment of potential effects on water and sediment quality and drinking water resources that follows.

Table 16.1 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
Engaged Indigenous Governments, Indigenous Organizations and other affected parties identified locations of water resources important for drinking water near the Project.	Golder, 2015; Norman Wells Renewable Resources Council (NWRRC), 2023; Tulita Renewable Resources Council (TRRC), 2022	The GNWT has considered this information in the selection of water sources to be considered for the Project. For example, owing to concerns raised, Trout Lake near Bear Rock (Petınıʔah) has been removed as a water source. Water withdrawal will be within the limits of water licences and in accordance with the Fisheries and Oceans Canada (DFO) measures to protect fish and fish habitat (e.g., DFO, 2010, 2013) and other applicable guidance. The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent practical, to limit new disturbances. Water quality will be monitored during culvert installation in accordance with the Fish and Fish Habitat Protection Plan (FFHPP). The GNWT has reviewed and considered the species of importance and important habitats identified by Indigenous Governments, Indigenous Organizations, and other affected parties. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning.	For information about drinking water sources identified by engaged Indigenous Governments and Indigenous Organizations, and other affect parties, see Section 16.2.2 (Table 16.4) See also: Section 5.4.11 Section 11.2.3.8 for additional information about water sources Chapter 17 (fish and fish habitat) Volume 5 (management plans)
Engagement participants recommended using silty water sources for road maintenance to avoid drinking water sources; sourcing water should also not affect fish and fish habitat.	April to July 2022 Engagement		

Comment	Source	GNWT Response	Where Addressed
Sahtu Region residents have expressed concerns about potential project effects on water quality and quantity in the Sahtu Region including contamination, which could be far reaching due to the speed at which surface and groundwater flows; patterns of surface water flow and potential groundwater changes; increased sediment from vegetation clearing along waterbodies from effects of blasting, runoff and thawing permafrost (erosion, flooding, scouring, reduced land subsistence), which also can affect groundwater and surface water; and can potentially effect surface water in Norman Wells.	Dessau, 2012 (Public Registry [PR]#13); Golder, 2015	The GNWT has identified mitigation measures to reduce the effects of the Project on water quality. The Project will follow mitigation measures in the Erosion and Sedimentation Control Plan (ESCP) to reduce potential effects on water quality. This includes applying best management practices (BMPs) according to the GNWT's Erosion and Sediment Control Manual (GNWT, 2013a). The Project will follow mitigation measures in the Permafrost Protection Plan (PPP) to reduce ponding, erosion, and damage to permafrost. Water quality will be monitored during culvert installation in accordance with the FFHPP. The Project will implement the Spill Contingency Plan (SCP) to reduce the potential for effects on water quality from unplanned releases. The Project will follow measures in the Quarry Development Plans (QDP) for each quarry and borrow source to reduce potential effects on water quality. Water only will be used for dust suppression, except as provided for in the GNWT Guideline for Dust Suppression.	For mitigation measures to reduce effects of the Project on water quality, see Table 16.6. See also: Section 16.4.2 Section 16.4.3 Chapter 25 (Assessment of Potential Accidents or Malfunctions) Volume 5 (management plans)
Community engagement participants explained that the water is changing, attributed to sedimentation. Participants also noted that the water is getting warmer and explained that there is radium in Great Bear River.	August 2021, Engagement; April to July 2022 Engagement		
Participants of the NWRRC TLRU study raised concerns regarding the quality of water in Fort Good Hope and reported that the water along the shoreline appears to have an oily sheen (While Fort Good Hope is not located near the Project, NWRRC study participants shared concerns about previous developments, in the TLRU study area, specifically oil drilling that occurred at Bluefish Creek, which study participants have attributed to be the cause of water quality decline in the TLRU study area leading down to Fort Good Hope).	NWRRC, 2023		

Comment	Source	GNWT Response	Where Addressed
Participants of the NWRRC TLRU study reported that Prohibition Creek has been known to contain too many minerals at times for drinking.	NWRRC, 2023	*(cont'd from above)* The GNWT has reviewed and considered the species of importance and important habitats identified by Indigenous Governments, Indigenous Organizations, and other affected parties. The GNWT will work with Sahtu Renewable Resources Board (SRRB) and other resource managers to address uncertainty regarding the effects of increased access created by the Project on harvested resources in the study areas. This would include monitoring of harvest that can be used to identify the need for management actions to be taken by the appropriate resource management organization.	
Participants of the NWRRC TLRU study reported concerns from local Sahtu harvesters about potential project effects on open-water sources from vehicle breakdown, specifically near Bear Rock (Petınıʔah), which have potential to cause contamination, or affect the flow of water in Great Bear River.	TRRC, 2022		
Participants of the NWRRC TLRU study discussed experiences of environmental contamination from vehicle fluid leaks and spills that have occurred along the MVWR in the TLRU study area and raised concerns about potential project effects from vehicle operations and mechanical equipment contaminating open water resources during construction and operation of the Project.	NWRRC, 2023		
Community engagement participants expressed concern about blasting, which may contaminate water and affect food sources and food chains. Some land users stated that they will no longer eat fish from Mackenzie River (Deh Cho) because of oil and gas activity in the area.	November to December 2022 Engagement		

Comment	Source	GNWT Response	Where Addressed
Elders, land users and community members in the Sahtu Region previously expressed concern about potential project effects on human health through water and air quality, and consequently the health of the region's wildlife, fish, and vegetation.	Golder, 2015		
A number of drinking water resources relative to the Project that have been identified Sahtu Dene and Métis by through a review of publicly available literature, and project-specific TLRU studies in the PDA, LAA, and RAA.	Golder, 2015; NWRRC, 2023; TRRC, 2022		
Participants of the NWRRC TLRU study reported that the water quantity (levels) at Canyon Creek is too low to use as a drinking water source, however Canyon Creek used to be a good source of drinking water.	NWRRC, 2023		

16.1.3 Potential Effects, Pathways and Measurable Parameters

The Project has the potential to cause changes in water and sediment quality in waterbodies located within the Local Assessment Area (LAA) and Regional Assessment Area (RAA), which are defined in Section 16.1.4. Potential effects on surface water, groundwater, and sediment quality are measurable changes of chemical parameters that extend beyond the variability of existing conditions that may potentially exceed relevant water quality guidelines for the protection of human receptors (e.g., drinking water and recreational water quality guidelines) and ecological receptors (e.g., guidelines for the protection of freshwater aquatic life).

Changes in surface water and sediment quality may result from increased suspended sediment loading into the aquatic environment due to land disturbances, such as the removal of vegetation and/or topsoil for road construction, instream works at water crossings, and dustfall. Measurable water quality parameters used to monitor suspended sediment loading include total and dissolved metals, phosphorus, major ions, water hardness (as calcium carbonate [$CaCO_3$]), total suspended solids (TSS), and nephelometric turbidity units (NTU). Visual observation of sedimentation is also used to monitor suspended sediment loading in waterbodies.

Changes to surface water, groundwater, and sediment quality may occur due to excavation and runoff and seepage from project-specific quarries, borrow sources, stockpiles, and highway components (e.g., road base materials) constructed of crushed rock and granular materials from quarries and rock cuts. Crushed rock may potentially contribute to acid rock drainage (ARD) and metal leaching (ML), and the transport of nitrogen blasting residues to the aquatic environment. Measurable water quality parameters used to monitor water and sediment quality potentially influenced by ARD/ML and blasting residues include total and dissolved metals, major ions, pH, and nitrogen species (e.g., total nitrogen, ammonia, nitrate, and nitrite).

The Project does not propose to use groundwater as a water source and will not discharge solid or liquid effluent to the environment. As a result, the only direct effect the Project may have on groundwater quality is the unintended release of substances (e.g., spills or accidents). Potential effects on water and sediment quality from unintentional releases are addressed in Chapter 25 (accidents and malfunctions). However, the Project may indirectly affect groundwater quality through a change in groundwater flow patterns or rates through excavation, ground disturbance, or permafrost degradation pathways (Section 15.4.4.1). A change in groundwater flow via one of these pathways may result in mixing of previously separate groundwater flow pathways that change the quality of the resulting flowpath.

Table 16.2 summarizes the potential effects of the Project on water and sediment quality, the pathways in which the effects may occur, and the measurable parameters used to monitor and assess the magnitude, geographic extent, and duration of potential effects.

Table 16.2 Potential Effects, Effects Pathways, and Measurable Parameters for Water and Sediment Quality

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Changes to surface water and/or sediment quality	Erosion and sedimentation due to the following land disturbances: • Clearing of vegetation in the project footprint • Instream works at water crossings (e.g., culvert installation) • Alteration of permafrost	• pH (in pH units), conductivity (microsiemens per centimeter [µS/cm]), turbidity (NTU), total suspended solids (TSS), total dissolved solids (TDS), total and dissolved metals, total and dissolved nutrients (milligrams per litre [mg/L] when measured in water; miligrams per kilogram [mg/kg] when measured in sediment), and/or visual observation of sedimentation. • Additional parameters measured in sediment include particle size (% clay, % gravel, % sand, and % silt)
	Fugitive dustfall	TSS, TDS, total and dissolved metals (mg/L)
	ARD/ML due to runoff and leachate from: • Quarries • Rock cuts • Stockpiles • Embankment/Road Base materials	Total and dissolved metals, major ions (mg/L), hardness ($CaCO_3$), and pH
	Nitrogen loading due to runoff and leachate from project components developed from the use of explosives: • Quarries • Rock cuts • Stockpiles • Embankment/Road Base materials	Total nitrogen, ammonia, nitrate, and nitrite; (mg/L in water; mg/kg in sediment)
Changes to groundwater quality	A change in groundwater flow caused by excavations, ground disturbance, or permafrost degradation (direct effects), may cause a change in the quality of the groundwater in these systems (indirect effect).	Changes in groundwater quality as measured by a change in concentration of parameters (generally mg/L) from pre-construction conditions

16.1.4 Boundaries

The spatial and temporal boundaries of the water and sediment quality effects assessment are described in Sections 16.1.4.1 and 16.1.4.2, respectively.

16.1.4.1 Spatial Boundaries

Potential project-related changes to surface water and sediment quality are assessed in terms of potential residual effects within the following study areas:

- **Project Development Area (PDA):** The area of direct Project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 m wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sites with access roads on a 30 m ROW.
- **Local Assessment Area (LAA):** The area within which measurable project-related effects (direct or indirect) are expected to occur (Figure 16.1). The LAA for surface water and sediment is the area within 1 kilometre (km) of the preliminary alignment route centerline, quarry and borrow sources and associated access roads, and extended westward to include the mainstem of Mackenzie River (Deh Cho) and potential water sources for construction of the Mackenzie Valley Winter Road (MVWR).

  The LAA is divided into a northern section (i.e., Tulita to Prohibition Creek) and a southern section (i.e., Wrigley to Tulita). The northern and southern sections of the LAA are separated by a 10 km break in the proposed alignment at Tulita to account for the Great Bear River Bridge (not part of the Project).
- **Regional Assessment Area (RAA):** The area that provides context for determining significance of project effects and potential cumulative effects. The surface water and sediment quality RAA is the area within approximately 15 km of the PDA.

Potential project-related changes to groundwater quality are assessed relative to the following areas:

- **Project Development Area (PDA):** The area of direct project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 m wide highway ROW, laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sites with access roads on a 30 m ROW.
- **Local Assessment Area (LAA):** The area within which measurable project-related effects (direct or indirect) are expected to occur. The groundwater quantity LAA is the area within a 0.5 km buffer of the preliminary alignment route centerline, quarries and borrow sources and associated access roads. The LAA is divided into a northern section (i.e., Tulita to Prohibition Creek) and a southern section (i.e., Wrigley to Tulita). The northern and southern sections of the LAA are separated by a 10 km break in the Project alignment at the Hamlet of Tulita to account for the Great Bear River Bridge (not part of the Project), as shown in Figure 16.1.

- **Regional Assessment Area (RAA):** The area that provides context for determining significance of project effects and potential cumulative effects. The groundwater quantity RAA is the area within approximately 5 km of the PDA or the mainstem of the Mackenzie River (Deh Cho), whichever is closer (Figure 16.1). The Mackenzie River (Deh Cho) is a regional groundwater flow divide (K'alo Stantec, 2022b) that will limit the influence of project activities on one side of the river to groundwater on the other.

16.1.4.2 Temporal Boundaries

The temporal boundaries for the Project consist of the following phases:

- **Construction phase:** The Project will take approximately 10 years to construct over a timeframe of up to 20 years. The conceptual schedule assumes the highway will be constructed in three consecutive segments, beginning in approximately 2026: Wrigley to the Dehcho–Sahtu border (102 km); Tulita south to the Dehcho–Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells sometime between 2041 and 2046.
- **Operations and maintenance phase:** The operations and maintenance phase will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the highway is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, quarries and borrow sources not needed for operations and maintenance will occur during the construction phase.

- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Surface Water Local Assessment Area
- Surface Water Regional Assessment Area
- Groundwater Local Assessment Area
- Groundwater Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Mackenzie River Sub-Basin

0 10 20 Kilometres
(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 8/7/2023
TR by CS on 8/7/2023

Client/Project
144903025-0151 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
16.1

Title
Water and Sediment Quality Assessment Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
Imagery date: 2021

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

16.1.5 Residual Effects Characterization

Potential residual effects of the Project on water and sediment quality are characterized in terms of direction, likelihood, magnitude, geographic extent, timing, duration, frequency, and reversibility (as defined in Table 16.3). Quantitative measures or, where applicable, descriptions of qualitative measures, are provided in Table 16.3.

Table 16.3 Characterization of Residual Effects on Water and Sediment Quality

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse**: A residual effect that moves measurable parameters of water or sediment quality in a negative direction relative to baseline **Neutral:** No measurable long-term trend in water and sediment quality parameters relative to existing conditions
Likelihood	The probability that the residual effect will occur	**Unlikely –** The residual effect is almost certainly not to occur. **Possible –** The residual effect could occur. **Certain –** The residual effect will certainly occur.
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Surface Water and Sediment Quality** **No Measurable Change:** No measurable change from pre-construction conditions and/or upstream reference sites **Low:** A measurable change that is anticipated to be within the variability of pre-construction conditions and/or upstream reference sites **Moderate:** A measurable change that is anticipated to be outside the variability of pre-construction conditions (and/or upstream reference sites) and in exceedance of applicable guidelines, legislated requirements, and/or management, but is unlikely to have an adverse effect on ecological or human receptors in the LAA or RAA **High:** A measurable change that is anticipated to be outside the variability of pre-construction conditions (and/or upstream reference sites) and in exceedance of applicable guidelines, legislated requirements, and/or management, and is likely to have an adverse effect on ecological or human receptors in the LAA or RAA **Groundwater Quality** **No Measurable Change:** Concentrations of groundwater quality parameters are consistent within the range of potential inter-annual variation. **Low:** Concentrations of groundwater quality parameters deviate from the potential range of inter-annual variation but do not exceed guideline concentrations.

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Magnitude (cont'd)		**Moderate:** Concentrations of groundwater quality parameters deviate from the potential range of inter-annual variation and exceed guideline concentrations by up to a factor of two. **High:** Concentrations of groundwater quality parameters deviate from the potential range of inter-annual variation and exceed guideline concentrations by an order of magnitude.
Geographic Extent	The geographic area in which a residual effect occurs	**PDA:** Residual effects are restricted to the PDA. **LAA:** Residual effects extend into the LAA. **RAA:** Residual effects interact with those of other projects in the RAA.
Timing	Considers when the residual effect is expected to occur, where relevant to the VC	**Not Sensitive**: Seasonal aspects are unlikely to affect changes to water or sediment quality. **Sensitive:** Seasonal aspects may affect changes to surface water quality (i.e., from spring thaw to autumn freeze-up, when terrain, soils and permafrost are the most susceptible to ground disturbance).
Duration	The time required until the measurable parameter or the VC returns to its existing condition, or the residual effect can no longer be measured	**Short-term**: The effect is restricted to a portion of the construction phase. **Medium-term**: The effect occurs throughout construction (up to 20 years). **Long-term:** The effect occurs beyond construction or throughout operations (more than 20 years).
Frequency	Identifies how often the residual effect occurs and how often during the project or in a specific phase	**Single event:** The effect occurs only once. **Multiple irregular event:** The effect occurs at no set schedule. **Multiple regular event:** The effect occurs at regular intervals. **Continuous:** The effect occurs continuously.
Reversibility	Pertains to whether a measurable parameter or the VC can return to its existing condition after the project activity ceases	**Reversible:** The residual effect is likely to be reversed after activity completion and reclamation. **Irreversible:** The residual effect is unlikely to be reversed.

16.1.6 Significance Definition

A significant residual effect on water quality and/or sediment quality is one that is likely to result in a persistent measurable change in parameters that adversely affect ecological and/or human receptors. The potential for project-related changes in water and/or sediment quality to cause adverse effects on ecological receptors, human health, traditional land use, and community well-being is assessed separately for other VCs: Chapter 9 (human health and community wellness; non-traditional land and resource use), Chapter 10 (caribou and moose), Chapter 11 (cultural use), Chapter 17 (fish and fish habitat), and Chapter 19 (wildlife and wildlife habitat).

For groundwater quality, the significance of potential project effects will be determined based on the characterization of residual effects as outlined in Table 16.3 using the following criteria:

- If the magnitude of the effect is no measurable change or low, the effect is not significant.
- If the magnitude of the effect is moderate and the geographic extent of the effect is confined to the PDA or LAA, the effect is not significant.
- If the magnitude of the effect is moderate and the geographic extent of the effect extends to the RAA, the effect is significant.
- If the magnitude of the effect is high, the significance evaluation of the effect will be based on the characterization of the effect's geographic extent, duration, and reversibility.

Consideration of these attributes for evaluation of whether residual effects are significant or not significant highly relies on professional judgement.

The preceding definition of significance applies to groundwater quality as a resource. Indirect effects from a change in groundwater quality on other VCs are not evaluated in this chapter.

16.2 Existing Conditions for Water and Sediment Quality

Existing conditions for surface water and sediment quality are presented in the surface water and sediment quality technical data report ([TDR]; Appendix 16A; K'alo-Stantec, 2022a). Existing conditions for groundwater quality are presented in the hydrogeology TDR (Appendix 15B; K'alo-Stantec, 2022b).

16.2.1 Methods

A literature review was completed to understand the extent of available surface water and sediment quality data along the project alignment and within the RAA and LAA. Background information on surface water quality for the Sahtu and Dehcho regions was obtained from the following sources:

- The GNWT Community-Based Monitoring Program (GNWT, 2020, pers. comm.)
- The GNWT Water Quality Monitoring Network Evaluation report (Summit Environmental Ltd., 2014)

- Environment and Climate Change Canada (ECCC), Northern Water Quality Monitoring Network (ECCC, 2022b)
- Mackenzie Gas Project Environmental Impact Statement (EIS), Biophysical Baseline Report for Water Quality (EIS Volume 3, Section 6; IORVL, 2004)
- Data from Water Resources, Indigenous and Northern Affairs Canada (INAC) for the Mackenzie Valley Pipeline (GNWT, 2021, pers. comm.)
- Rempel and Gill (2011): Bioassessment of streams along the Mackenzie River Valley, Canada, using the Reference Condition Approach: biological, habitat, landscape, and climate data
- Golder (2015): Central Mackenzie Surface Water and Groundwater Baseline Assessment. Report 1: Technical State of Knowledge
- Tulita Renewable Resources Council Traditional Land and Resource Use Study for Tulita District Mackenzie Highway Project 2022 (TRRC, 2022)

Prospective road source material was screened for ARD/ML potential in October 2020 (K'alo-Stantec, 2021). In total, 11 granular sources where clast lithology indicated the possibility of ARD/ML potential were sampled (9 of these 11 sites are identified as primary material sources). In addition, quarry sites Dhu1 and Dhu2 were tested for ARD/ML potential (K'alo-Stantec, 2021).

The hydrogeology TDR (Appendix 15B; K'alo-Stantec, 2022b) presents the groundwater system existing conditions and provides a conceptual model of local and regional groundwater flow systems to use in the evaluation of potential project effects. A summary of the conceptual model is provided in Section 16.2.3.

16.2.2 Overview of Surface Water and Sediment Quality Existing Conditions

The Project is in the Mackenzie-Great Bear Sub-Basin of the Mackenzie Valley Basin (MRBB, 2021). This Sub-Basin spans more than a third of the Northwest Territories (NWT) and extends from Fort Simpson (Łíídlıı Kųę), in the south to the Makenzie River delta in the north, and from the Nunavut border in the east to the Yukon border in the west (MRBB, 2021).

Although watercourses within the Mackenzie-Great Bear Sub-Basin are generally of good quality, some localized effects on water quality have been observed nearby anthropogenic influences such as wastewater discharges (MRBB, 2003, 2021). In addition, Indigenous people have reported increasing water temperatures and turbidity compared to past years. However, the scientific data generally do not show widespread anthropogenic effects on water quality or on fish health (MRBB, 2021). The NWRRC study participants raised concerns regarding the quality of water in Fort Good and reported that the water along the shoreline appears to have an oily sheen (NWRRC, 2023). While Fort Good Hope is not located in the LAA or RAA, NWRRC study participants shared concerns about previous development in the LAA and RAA, specifically oil drilling that occurred in Bluefish Creek, which study participants have attributed to be the cause of water quality decline around Bluefish Creek leading down to the area of Fort Good Hope (NWRRC, 2023).

Natural water quality of the Mackenzie-Great Bear Sub-Basin, including water flowing into the RAA, is generally influenced by water flowing through the Precambrian Shield of the Mackenzie Mountains, as well as mountains surrounding the Liard River, which drains into the Mackenzie River (Deh Cho) (Golder, 2015). This flowing water causes streambank erosion, which mobilizes metals and nutrient-rich sediment. Consequently, the Mackenzie River (Deh Cho) is known for naturally elevated suspended sediment and turbidity compared to other rivers in the arctic. Natural concentrations of turbidity in the Mackenzie River (Deh Cho) are highest during the spring snow melt and are often in exceedance of Canadian Water Quality Guidelines for recreation and aesthetics (MRBB, 2003).

Through the project-specific engagement program, a review of publicly available literature, and project-specific TLRU studies, a list of drinking water resources relative to the Project that have been identified that are of interest to Indigenous Governments, Indigenous Organizations, and other affected parties (Dessau, 2012 [PR#13]; Golder, 2015; TRRC, 2022). Several locations overlap the LAA and RAA, as described in Table 16.4.

Table 16.4 Drinking Water Resources Identified by Indigenous Governments, Indigenous Organizations and Other Affected Parties Relative to the Project

Location	Within LAA	Within RAA[1]	Identified By: (if applicable)
Springs which feed the large streams from Norman Wells to the Great Bear River; including Prohibition Creek	✓	✓	Sahtu Dene and Métis
Springs which feed the large streams from Norman Wells to the Great Bear River; including Vermillion Creek	✓	✓	Sahtu Dene and Métis; NWRRC
Springs which feed the large streams from Norman Wells to the Great Bear River; including Nota Creek	✓	✓	Sahtu Dene and Métis; NWRRC
Canyon Creek	-	✓	NWRRC
Bluefish Creek	-	✓	NWRRC
Great Bear River (as it intersects with the LAA and RAA)	✓	✓	TRRC; NWRRC
Big Smith Creek	-	✓	Sahtu Dene and Métis
Bear Rock (Petınızah) (spring)	✓	-	Sahtu Dene and Métis

Note:

[1] Occurs within the RAA outside the LAA and PDA

Sources: Golder, 2015; NWRRC, 2023; TRRC, 2022

Participants of the NWRRC study also reported that the water level at Canyon Creek is too low to use as a drinking water source, however Canyon Creek used to be a good source of drinking water.

The surface water and sediment quality TDR (Appendix 16A; K'alo-Stantec, 2022a) describes the extent to which existing conditions surface water and sediment quality data have been previously collected within the LAA and RAA. Additional site-specific baseline surface water and sediment quality data were not collected for this DAR because management plans and mitigation measures will be implemented to address the potential project-specific effect pathways described in Section 16.1.3. In addition, site-specific water quality data will be collected as part of construction and compliance monitoring to build upon existing regional surface water and sediment quality data and to facilitate adaptive management (Section 16.8). Results of the preliminary ARD/ML assessment indicate that ARD/ML potential of existing material sources is low and is not expected to adversely affect water quality of the receiving watercourses (K'alo-Stantec, 2021).

16.2.3 Conceptual Hydrogeological Model

Groundwater flow systems are generally conceptualized as nested regional, intermediate, and local scale systems (Toth, 1963). Regional groundwater flow systems develop from large-scale topographic, physiographic, and geologic features (such as the Central Mackenzie Valley [CMV], larger than the RAA). Local groundwater flow systems develop from smaller-scale variation of topography and geologic features and local flow (i.e., within the PDA and/or LAA) is often dominated by one component of the regional flow system (Freeze and Cherry, 1979). The predominant features of the conceptual groundwater model of the CMV and the PDA, as it traverses the Mackenzie Plain from Wrigley to Norman Wells, include the following (K'alo-Stantec, 2022b):

- The PDA is largely within the discharge zone of regional groundwater flow-paths that extend from recharge areas beyond the RAA within the Franklin and McConnell Mountain Ranges.
- Surficial geology within the RAA is predominately low permeability glaciolacustrine (43.0%) and till (21.3%) with smaller fractions of moderate to high permeability alluvial (15.3%), colluvium 9.4%), and glaciofluvial (5.9%) sediments and other (5.1%) materials.
- Surficial geology within the LAA includes low permeability till (23.3%) and glaciolacustrine (20.6%) materials, moderate to high permeability organic (15.3%), glaciofluvial (14.1%), colluvium (11.0%), eolian (6.1%), and fluvial (4.9%) materials, and (4.2%) other materials.
- Surficial geology along the PDA includes low permeability glaciolactustrine (25.8%) and till (21.3%) materials, moderate to high permeability glaciofluvial (19.5%), organic (12.7%), eolian (7.6%), fluvial (6.4%), and colluvium (5.8%) materials, and (0.9%) other materials.
- Low permeability glaciolacustrine and till deposits, if present, will act as a barrier to local and regional groundwater discharge and artesian (above ground surface) pressure conditions have the potential to develop in underlying stratigraphy.

- Permafrost, where it exists, is expected to be a barrier to groundwater flow and will separate the groundwater flow system into shallow, seasonal, supra-permafrost flow within the active layer and deeper, perennial sub-permafrost flow components. The degree to which this separation exists is expected to increase north along the PDA as the presence of permafrost increases from sporadic discontinuous (10-35% of land area) near Wrigley, through intermediate discontinuous (35% to 65% of land area), to extensive discontinuous (65% to 90% of land area) permafrost near Norman Wells.
- Where extensive discontinuous permafrost is present, interaction between supra-permafrost and sub-permafrost groundwater flow systems may be limited to taliks, regions of thawed strata that allow fluid flow. Taliks within the CMV may be concentrated along regional fault trace and fracture systems where regional flow gradients prevent permafrost from becoming established, and beneath large lakes and streams. Regional groundwater discharge likely occurs predominately through these perennial conduits.
- Permafrost, where it exists, will limit the volume of local groundwater recharge (i.e., occurring within the RAA, LAA, and/or PDA) that reaches the sub-permafrost groundwater system. The limitation will be greater along northern portions of the PDA than southern portions due to the increased presence of permafrost.
- Permafrost, where it exists, limits groundwater flow within the RAA to the shallow supra-permafrost flow component. The limitation will be greater along northern portions of the PDA than southern portions due to the increased presence of permafrost. Groundwater flow limited to the supra-permafrost component limits overall groundwater storage and results in rapid groundwater discharge to surface following spring melt or precipitation events.
- Borrow source excavations target glaciofluvial and fluvial materials for construction fill that also tend to be high permeability and well drained. These characteristics limit the formation of ground ice and may reduce the compartmentalizing effect of permafrost where present in these materials.

16.3 Project Interactions with Water and Sediment Quality

Table 16.5 identifies project activities that have the potential to interact with surface water, groundwater, and sediment in the construction and operations and maintenance phases of the Project. Interactions that have the potential to result in effects on surface water and sediment quality within the LAA or RAA are indicated by a check mark. These interactions are discussed in detail in Section 16.4, in the context of effects pathways, standard and project-specific mitigation, and residual effects. A justification for activities not expected to interact with surface water, groundwater, and/or sediment quality is provided following the table.

Project schedules and activities for the construction phase and the operations and maintenance phase are described in detail in Sections 5.4 and 5.5, respectively. Project-related accidents and malfunctions are not considered in this chapter and are described in Chapter 25 (accidents and malfunctions).

The identification of project activities and their potential interactions with water and sediment was based on engagement with interested parties, knowledge of road construction projects in the NWT, professional judgment of technical specialists involved in the assessment, and a review of existing conditions. The selection of interactions is also informed by the potential effects and effects pathways for each VC as described in Section 16.1.3.

Table 16.5 Project-Environment Interactions with Water and Sediment Quality

Physical Activities	Timing	Environmental Effects		
		Change to Water Quality	Change to Sediment Quality	Changes to Groundwater Quality
Construction Phase				
Mobilization of equipment, materials, and fuel, resupply, and demobilization	Summer	–	–	-
Establishment and operation of camps	Year-round	✓	✓	-
Site preparation of ROW, access, and workspaces	Winter	✓	✓	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	✓	✓	✓
Material hauling and stockpiling along the ROW	Year-round	✓	✓	-
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓	✓	✓
Culvert installations	Summer or winter	✓	✓	-
Road base placement, compaction, and surfacing	Summer	✓	✓	-
Water withdrawal for construction activities	Year-round	-	-	-
Closure and reclamation of MVWR and temporary borrow sources quarries, camps, and workspaces	Summer	✓	✓	✓
Employment and contracted goods and services[1]	Year-round	–	–	-
Operations and Maintenance Phase				
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	✓	✓	✓
Material hauling and stockpiling	Summer	✓	✓	-
Operation of, and activities at, maintenance yards	Year-round	–	–	-

Physical Activities	Timing	Environmental Effects		
		Change to Water Quality	Change to Sediment Quality	Changes to Groundwater Quality
Water withdrawal for dust control	Summer	–	–	-
Employment and contracted goods and services[1]	Year-round	–	–	-
Presence and use of the highway	Year-round	✓	✓	✓
Highway and access road maintenance, including snow clearing, repair, grading, dust control	Year-round	✓	✓	-
Vegetation control	Summer	–	–	-
Bridge and culvert maintenance	As needed	✓	✓	-

Notes:
✓ = Potential interaction
– = No interaction

[1] Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, "Employment and contracted goods and services" have been introduced as an additional component under each Project phase.

Project activities are linked to a potential change in groundwater quality through an indirect pathway whereby project activities affect groundwater flow and, subsequently, indirectly affect groundwater quality.

16.3.1 Project Interaction Exclusions

The following Project components and activities are not expected to interact with water or sediment quality during the construction or operations and maintenance phases:

- Equipment mobilization/demobilization and resupply, as these activities are not expected to interact with water or sediment quality during either phase of the Project unless there is an accidental event, as existing authorized infrastructure and services will be used. Accidental events (e.g., accidental fuel spills) are assessed separately in Chapter 25 (accidents and malfunctions).
- The establishment and operation of camps is not expected to interact with groundwater quality since the effect pathway, ground disturbance, will have already occurred during site preparation (site preparation of ROW, access, and workspaces), and there will be no discharge of wastes to surface waters.

- Employment and contracted goods and services, as these activities will not directly result in changes to water or sediment quality during either phase.
- Water withdrawal for construction and for dust control, as this activity is not expected to directly result in measurable changes to water or sediment quality. Water withdrawal will be completed from candidate sources identified in Chapter 5 (Project Description), and extraction volumes will be limited to amounts that will not affect the ecological function of the waterbody.
- Operation of, and activities at, maintenance camps, as these activities are not expected to interact with water or sediment quality during either phase of the Project unless there is an accidental event (e.g., accidental fuel spills). Accidental events (e.g., accidental fuel spills) are assessed separately in Chapter 25 (accidents and malfunctions) and in the Spill Contingency Plan (see Volume 5).
- Emissions and waste management, as project-related wastes (including camp domestic waste, sewage, greywater, plastics, and hazardous and inert wastes) will be disposed at approved municipal facilities and are therefore not assessed herein. The management of project-related waste is described in the Waste Management Plan (WMP; see Volume 5). Dust emissions are considered under each project activity and light and noise emissions do not interact with surface water or sediment quality.
- Vegetation control is not anticipated to interact with water or sediment quality. Brushing will generally occur approximately every 3 years and will involve using a mower to cut back saplings and shrubs to maintain sight distances for public safety. Riparian vegetation will be maintained whenever possible, and brush will not be disposed of in or near waterbodies.

16.4 Assessment of Residual Effects on Water and Sediment Quality

Based on project interactions with the environment identified in Table 16.5, the Project may result in changes to water and sediment quality. These potential effects are considered to be primarily associated with the construction phase of the Project, but potential effects related to operations and maintenance are also considered herein. The potential effects, effect pathways, and mitigation measures that will reduce or eliminate the effects on water quality are summarized in Table 16.6, and details are provided in Section 16.4.2.1 Effect Pathways and Section 16.4.2.2 Mitigation. Residual effects are characterized in Section 16.4.2.3 following implementation of mitigation measures.

Table 16.6 Potential Effects and Mitigation Measures for Water and Sediment Quality

Potential Effect	Effect Pathway	Mitigation Measures
Change in surface water and/or sediment quality	Erosion and sedimentation due to the following land disturbances: • Clearing of vegetation in the project footprint (construction) • Instream works at water crossings (e.g., culvert installation during construction and culvert maintenance during operations and maintenance) • Alteration of permafrost (construction)	Mitigation measures to prevent or reduce potential effects associated with erosion and sedimentation per: • ESCP (see Volume 5) • PPP (see Volume 5)
	Dustfall due to: • Construction activity • Vehicle use during operations and maintenance	Mitigation measures to prevent or reduce potential effects associated with dustfall as per: • ESCP (Volume 5)
	ARD/ML due to runoff and leachate during construction and operations and maintenance: • Quarries • Rock cuts • Stockpiles • Embankment/Road Base materials	Mitigation measures to prevent or reduce potential effects associated with ARD/ML are described in Section 16.4.2.2 and are included in the following management plans: • QDPs [1] • ESCP (see Volume 5)
	Nitrogen loading due to runoff and leachate from project components developed from the use of explosives (construction only): • Quarries • Rock cuts • Stockpiles • Embankment/Road Base materials	Mitigation measures to prevent or reduce potential effects associated with blasting-related nitrogen loading are described in Section 16.4.2.2 and will be included in the following management plans: • Explosives Management Plan (ExMP) [1] • QDPs [2] • ESCP (see Volume 5)
Change in Groundwater Quality	A change in groundwater flow, such as the increased connection between supra-permafrost and sub-permafrost groundwater flow systems (indirect effect) caused by permafrost degradation (direct effect) may cause a change in the quality of the groundwater in these systems (indirect effect).	Mitigations to reduce disturbance to soils and permafrost and groundwater flows will mitigate changes to groundwater quality. These include mitigation measures in the: • PPP • ESCP • QDPs[1]

Notes:

[1] An Explosives Management Plan will be developed during project permitting.

[2] Quarry Development Plans will be developed during the quarry permitting application process and will be specific to each quarry/borrow source. A draft QDP framework is included in Volume 5.

16.4.1 Analytical Assessment Techniques

The potential for residual effects was assessed following implementation of mitigation measures. Effects were also assessed based on the following:

- The integration of data from other VCs in this DAR (e.g., Water Quantity; Fish and Fish Habitat; Terrain, Soils, and Permafrost)
- The level of sensitivity of surface water and sediment to potential effects
- A review of surface water effects assessments for similar all-season highway projects in the Northwest Territories (e.g., Tłı̨chǫ Highway [MVRB, 2018], Prairie Creek All Season Road [CZC, 2015], and Inuvik to Tuktoyaktuk Highway [Hamlet of Tuktoyaktuk et al., 2011] DAR and Effects Assessments)

This assessment of residual effects followed a qualitative approach that relies on professional judgement to evaluate potential project-related changes to water and sediment quality. The hydrogeological conceptual model (see Section 15.2.4) was a fundamental tool used to assess the effect of project activities upon groundwater.

16.4.2 Changes to Surface Water and/or Sediment Quality

16.4.2.1 Effects Pathways

Project-related changes to surface water and sediment quality may result from increased suspended sediment loading into the aquatic environment due to land disturbances, such as the removal of vegetation during clearing, stripping of borrow/quarry sources, excavation of road cuts, instream works at water crossings (e.g., culvert installations), alteration of permafrost, and dustfall.

Changes to surface water and sediment quality may also occur if project components (e.g., quarries, granular borrow sources, road cuts, rock material stockpiles, embankment and road base materials) have the potential for ARD/ML. Runoff and leachate from these materials have the potential to enter watercourses and affect surface water and sediment quality.

Elders, land users and community members in the Sahtu Region previously expressed concern about potential project effects on human health through water and air quality, and consequently the health of the region's wildlife, fish, and vegetation (Golder, 2015). Sahtu Region residents have expressed concerns about potential project effects on water quality and quantity in the Sahtu Region including contamination, which could be far reaching due to the speed at which surface and groundwater flows. Residents raised concerns about potential project effects on patterns of surface water flow and potential groundwater changes, as well as increased sediment in surface water from vegetation clearing along waterbodies, including effects of blasting, runoff and thawing permafrost, erosion, flooding and scouring. Additionally, Sahtu residents discussed potential project effects from reduced land subsistence, which can also affect groundwater and surface water (Dessau, 2012 [PR#13]; Golder, 2015).

Tulita Renewable Resources Council study participants raised concerns about potential project effects to open-water sources from vehicle breakdown, specifically near Bear Rock (Petınıʔah), which have potential to cause contamination, or effect the flow of water in Great Bear River (TRRC, 2022).

The Project will likely use ammonium nitrate/fuel oil (ANFO) explosives for the development of quarries and road cuts. The undetonated nitrogen component of the explosives, ammonium nitrate (AN), is highly water-soluble. Runoff and leachate from quarries and quarry materials may result in releases of nitrogen to the aquatic environment, which can be detected as nitrate, nitrite, and ammonia.

16.4.2.2 Mitigation

Mitigation measures to prevent or reduce changes in water and sediment quality are summarized by effect pathway.

16.4.2.2.1 Mitigation of Erosion and Sedimentation

16.4.2.2.1.1 Removal of Vegetation and/or Topsoil

The removal of vegetation and topsoil during ROW clearing and preparation of quarry and borrow sources can increase bank instability, expose soils, increase erosion potential, and mobilize sediments into watercourses via bank failure or runoff from exposed surfaces. The potential for erosion and sedimentation due to the removal of vegetation and topsoil is well understood, and various well established and standard approaches will be used in the design and construction of the Project to limit or eliminate risks associated with this effect pathway.

Mitigation measures to prevent or reduce erosion and sediment loading into the aquatic environment due to the removal of vegetation and topsoil include implementation of standards and BMPs described in the ESCP, guided by (but not limited to) the following resources:

- Northern Land Use Guidelines: Roads and Trails (GNWT, 2015a)
- Northern Land Use Guidelines: Pits and Quarries (GNWT, 2015b)
- The GNWT, Department of Transportation - Erosion and Sediment Control Manual (GNWT, 2013a)
- Measures to Protect Fish and Fish Habitat (DFO, 2022a)

The Project includes the development of an ESCP (Volume 5) and a PPP (Volume 5), which provide reference to BMPs to be used for erosion and sedimentation control. Key mitigation measures to prevent or reduce erosion and sediment loading into the aquatic environment due to the removal of vegetation and topsoil include the following:

- Riparian vegetation will be maintained whenever possible.

- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent practical.
- Undisturbed areas will be avoided until they are scheduled for clearing/stripping to limit unnecessary soil degradation and compaction.
- Clearing will be limited to areas required for construction and safe operations.
- Material stockpiles will be kept a minimum of 30 m from a watercourse or waterbody with the appropriate erosion control mitigation in place to prevent sediment from entering a watercourse or waterbody.
- Clearing of new areas will be completed when the ground is frozen to limit disturbance to soils and permafrost.
- Trees will be felled toward the ROW and access roads wherever possible to reduce damage to vegetation outside of the ROW and access roads.
- Cleared brush and unsalvageable trees will be windrowed, mulched, and spread on the ROW, where possible.
- Clearing will not be conducted during high rainfall or runoff events.
- Clearing will be completed by hand, where required, to prevent damage to the ground, such as rutting, compaction and erosion.
- Organic topsoil will be left in place to retain a protective layer during the construction of the road to limit permafrost degradation and protect the soils from erosive factors of water.
- Tree roots will be grubbed only in areas required for construction or stripping.
- Runoff control will be implemented to avoid entry to waterbodies, including installing drainage per design specifications, diverting water from entering watercourse, and controlling of flow velocity.
- Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns.
- Grading of stream banks at approaches shall be limited, where possible.
- BMPs for erosion control will be implemented according to the ESCP.
- Erosion and sedimentation control measures will be maintained until disturbed areas are revegetated or until such areas have been permanently stabilized by other effective measure.
- Cleared snow will be directed away from watercourses and drainages.
- Runoff control will be implemented to avoid entry to waterbodies, including: installing drainage per design specifications; diverting water from entering watercourse; and controlling of flow velocity.
- Erosion and sedimentation control measures will be implemented per the GNWT Erosion and Sediment Control Manual (GNWT, 2013a) and will be in place prior to construction activities and before the spring melt/freshet.

With the implementation of these mitigation measures and BMPs, and the procedures outlined in the ESCP (Volume 5), potential effects due to erosion and sedimentation related to vegetation and topsoil clearing are anticipated to be negligible and not result in adverse or long-term changes to water and sediment quality. Water and sediment quality monitoring will be conducted as required to confirm effectiveness of the mitigation measures and to facilitate adaptive management (Section 16.8).

16.4.2.2.1.2 Instream Works at Water Crossings

Instream works at water crossings (e.g., culvert installations) can result in the release of fine sediments directly from excavation in and around the stream and indirectly from run-off from exposed soils. The potential for erosion and sedimentation from instream works is well understood, and various effective, well established, and standard approaches will be used in the design and construction of the Project to reduce risks associated with this effect pathway.

The design and implementation of standards, BMPs, and mitigation measures associated with instream works will be guided by (but not limited to) the following resources:

- Northern Land Use Guidelines: Roads and Trails (GNWT, 2015a)
- The GNWT, Department of Transportation - Erosion and Sediment Control Manual (GNWT, 2013a)
- Measures to Protect Fish and Fish Habitat (DFO, 2022a)
- Code of Practice: Culvert Maintenance (DFO, 2022b)

As described, the Project will include the development of an ESCP. Mitigation measures that will prevent or reduce erosion and sediment loading into the aquatic environment due to instream water crossings include the following:

- All temporary crossings will follow Fisheries and Oceans Canada's (DFO's) codes of practice for temporary fords and/or ice bridges and snow fills (DFO, 2022c).
- A project-specific ESCP will be developed and implemented.
- Material stockpiles will be kept a minimum of 30 m from a watercourse or waterbody with the appropriate erosion control mitigation in place to prevent sediment from entering a watercourse or waterbody.
- Effective erosion and sediment control measures (such as silt fencing) will be installed before starting work in and around watercourses to prevent sediment from entering the water body. Culverts will be designed and installed to maintain flows and fish passage (GNWT, 2015a).

With the implementation of these mitigation measures and BMPs, and the procedures outlined in the ESCP, potential effects due to erosion and sedimentation related to instream works at water crossings are anticipated to be negligible and not result in adverse or long-term changes to water and sediment quality. Water and sediment quality monitoring will be conducted as required to confirm effectiveness of the mitigation measures and to facilitate adaptive management (Section 16.8).

16.4.2.2.1.3 Alteration of Permafrost

Based on available regional permafrost mapping, the Project spans extensive discontinuous permafrost (predominantly near Norman Wells), intermediate discontinuous permafrost (e.g., Mackenzie Plain area), and sporadic discontinuous permafrost (area surrounding Wrigley) zones (soils, terrain and permafrost TDR, Appendix 14A; K'alo-Stantec, 2023). To the extent feasible, disturbance of permafrost areas will be avoided because could cause thawing and ground subsidence, potentially leading to soil erosion and sedimentation into watercourses (GWNT, 2015a). Appropriate construction techniques will be required to prevent significant thawing of soils in areas along the project corridor where permafrost is located (GNWT, 2013a).

The potential for erosion and sedimentation from the degradation of permafrost is well understood, and various established approaches will be used in the design and construction of the Project to reduce risks associated with the development of the highway in areas of permafrost.

The design and implementation of mitigation measures and BMPs to prevent or reduce erosion and sedimentation associated with the degradation of permafrost will be guided by (but not limited to) the following resources:

- Northern Land Use Guidelines: Roads and Trails (GNWT, 2015a)
- The GNWT Department of Transportation - Erosion and Sediment Control Manual (GNWT, 2013a)
- Guidelines for Development and Management of Transportation Infrastructure in Permafrost Regions (TAC, 2010)

The Project includes the development of a PPP and ESCP (Volume 5). Mitigation measures and BMPs that will prevent or reduce permafrost degradation and sedimentation include the following:

- A minimum of 10 centimetres (cm) of packed snow or ice will be used on winter access roads.
- Construction equipment will be operated on designated winter roads or constructed embankment only.
- Clearing of new areas will be completed when the ground is frozen to limit disturbance to soils and permafrost.
- Clearing will not be conducted during high rainfall or runoff events.
- Clearing will be completed by hand, where required to prevent damage to the ground.
- Placement of embankment will occur primarily during winter (December 15 to April 1), during frozen conditions. If work is to be completed under non-frozen conditions, equipment will be equipped with mushroom shoes.
- Use of equipment on highly saturated soil will be avoided, where possible.
- The Project will follow mitigation measures in the PPP to reduce ponding, erosion, and damage to permafrost.

- Borrow source floors will be sloped to reduce ponding of water.
- Excavations will be contoured prior to closure to reduce steep slopes.
- Project design will avoid ice-rich areas, where possible.
- Cleared brush and unsalvageable trees will be windrowed, mulched, and spread on the ROW, where possible.
- If surface organic material must be removed for construction, it will be stockpiled and re-applied, where possible.
- Geotextile and embankment placement will be completed in the winter to limit disturbance to soils and permafrost.
- Travel of vehicles will be confined to existing infrastructure roads and trails as much as possible to avoid disturbing vegetated areas.
- If ice-rich permafrost is identified during excavation activities, suitable measures will be taken to protect permafrost and ground ice encountered during material extraction activities.
- Ice-rich soils or materials that are susceptible to physical erosion encountered during excavation will be covered to reduce permafrost degradation.
- Excavations and developed borrow sources will be visually monitored throughout the summer and fall to confirm there is no physical erosion resulting from the degradation of permafrost.
- Construction equipment will travel on designated winter roads or constructed embankment only.
- Undisturbed areas will be avoided until they are scheduled for clearing/stripping to limit unnecessary soil degradation and compaction.
- The embankment will be constructed predominantly using a “fill approach” with minimal disruption to the subgrade rather than a “cut and fill” approach; however, road cuts will be needed where grades at a steep valley approach can be reduced by cutting into the hill slope.
- Steep grades where subsidence may occur as a result of permafrost thaw will be avoided, where possible.
- Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns.
- Erosion and drainage patterns will be observed and documented per the ESCP.
- Runoff control methods will be used to protect permafrost soils, including diverting water entering the site, modifying slope surfaces, reducing slope gradients, controlling flow velocity, providing adequate or increased drainage, and diverting flows away from exposed soil areas for mitigating permafrost degradation.
- Culvert design will include requirements for bedding materials and geotextile to protect surrounding permafrost from thaw. Rip rap will be incorporated into culvert design to avoid erosion around each culvert.

- Modification to the location or number of drainage culverts will be determined in consultation with the Engineer, as based on observed site conditions.
- Grading of stream banks at approaches shall be limited, where possible.
- Accumulated snow may be dispersed (e.g., snow drifts flattened and/or plowed) to reduce potential long-term effects on permafrost. In areas where snow drifting becomes a reoccurring issue, strategies such as snow fencing will be considered to keep snow drifts off the road surface and away from drainage ditches.
- Disturbance of the active layer during construction and maintenance activities will be limited.

With the implementation of these mitigation measures and BMPs, and the procedures outlined in the PPP and ESCP (Volume 5), potential effects due to erosion and sedimentation related to alteration of permafrost are anticipated to be negligible and not result in adverse or long-term changes to water and sediment quality. Water and sediment quality monitoring will be conducted as required to confirm effectiveness of the mitigation measures and to facilitate adaptive management (Section 16.8).

16.4.2.2.2 Mitigation of Dustfall

Dustfall associated with road construction and operation can result in the deposition of fine sediments in watercourses. The potential for dustfall to influence water and sediment quality from transportation infrastructure projects is well understood, and several well established and standard approaches will be used in the construction and operation of the Project to reduce effects associated with dustfall. The design and implementation of mitigation measures and BMPs associated with dustfall will be guided by (but not limited to) Northern Land Use Guidelines: Roads and Trails (GNWT, 2015a).

In addition to erosion and sedimentation controls outlined in Section 16.4.2 and the ESCP (Volume 5) that will help control dustfall related to the clearing of vegetation and topsoil, mitigation measures specific to dustfall control include the following:

- A dust control program using water will be implemented during construction and operations.
- Dust suppression will be conducted as necessary to reduce dust and sediment from entering watercourses or waterbodies. Dust suppression will follow the GNWT Guideline for Dust Suppression.
- Vehicle speeds will be limited to 50 kilometres per hour (km/h) on unfinished project road surfaces.
- Where possible, windrowed material will be mulched and spread over cleared areas within the project footprint to protect the soil and permafrost.

- Efficient project planning will be used to reduce haul distances and the number of trips required to move road construction materials to reduce the amount of dustfall.
- The contractor will be encouraged to use passenger vehicles (e.g., van or bus) to move crews.

With the implementation of these mitigation measures and BMPs, and the procedures outlined in the ESCP (Volume 5), potential effects due to dustfall are anticipated to be negligible and not result in adverse or long-term changes to water and sediment quality. Water and sediment quality monitoring will be conducted as required to confirm effectiveness of the mitigation measures and to facilitate adaptive management.

16.4.2.2.3 Mitigation of Acid Rock Drainage and Metal Leaching (ARD/ML)

Changes to surface water and sediment quality may occur if project components (e.g., quarries, granular borrow sources, stockpiles, road base materials) have the potential for ARD/ML. Runoff and leachate from these components have the potential to enter watercourses and affect surface water and sediment quality.

The design and implementation of mitigation measures and BMPs associated with the development and use of borrow source and quarry materials for the Project will be guided by (but not limited to) the following resources:

- Northern Land Use Guidelines: Roads and Trails (GNWT, 2015a)
- Northern Land Use Guidelines: Pits and Quarries (GNWT, 2015b)
- Mine Environmental Neutral Drainage (MEND) Prediction Manual (Price, 2009)

To prevent or reduce the potential for project-related ARD/ML, only material with low ARD and ML potential will be used for the Project. Generally, rock material sources proposed are anticipated to have low ARD potential due to their location within geological units dominated by carbonate and dolomitic rocks.

Sources to be used for the Project with neutralization potential ratio (NPR) between 1.0 and 3.0 that cannot reasonably be avoided will be further evaluated to identify if potential acid generation can be mitigated through measures such as site-specific planning, designated use of material, and water management. Consequently, only materials with low ARD/ML potential will be used for the development of the Project. Therefore, ARD/ML is not anticipated to be a potential source of project-related changes to water and sediment quality.

As described in the surface water and sediment quality TDR (Appendix 16A; K'alo-Stantec, 2022a), 11 prospective material sources were screened for ARD/ML potential (not a full ARD/ML assessment) and indicate that ARD/ML potential is likely to be low and is not expected to adversely affect water quality of the receiving watercourses (K'alo-Stantec, 2021). Therefore, potential effects on surface water and sediment quality associated with ARD/ML are anticipated to be negligible.

16.4.2.2.4 Mitigation of Nitrogen Loading Due to Use of Explosives

The use of ANFO explosives is anticipated for the development of quarries and highway materials. The undetonated nitrogen component of the explosives, AN, is highly water-soluble. The use of ANFO explosives may result in releases of nitrogen (which can be detected as nitrate, nitrite, and ammonia) from quarries and quarry materials to the aquatic environment.

Blasting-related nitrogen compounds can enter waterbodies through spillage (during the loading of blastholes or during transportation), by the movement of water through the blasthole, by the erosion of explosives from flowing water through the blasthole, and by leaching of undetonated explosive from the blast rubble and quarry materials.

- An ExMP will be developed and will include control measures to prevent or reduce the mobilization of nitrogen compounds to the aquatic environment.
- Storage of explosives will be controlled and runoff from storage areas will be contained.
- To the extent possible, blasting activities will be completed during winter months to avoid freshet runoff.
- Blast holes will be kept free of water, where possible, to avoid the incomplete combustion of ANFO.
- Explosives will be sealed and kept dry to prevent the incomplete combustion of ANFO.
- The handling and transport of explosives will be carried out by the supplier and blasting contractor under a licence to conduct such work and according to the requirements of applicable regulations including the *Explosives Act*, *Transport of Dangerous Goods Act*, and National Fire Code of Canada.

With the implementation of these mitigation measures and BMPs, as well as adherence to a project-specific ExMP, potential effects due to the use of explosives are anticipated to be negligible and not result in adverse or long-term changes to water and sediment quality. Therefore, blasting activities are not anticipated to result in adverse or long-term changes to water and sediment quality.

16.4.2.3 Residual Effects

In consideration of the scope and scale of project-related activities, effect pathways (Section 16.1.3), and mitigation measures (Section 16.4.2.2) relevant to surface water and sediment quality, project-related residual effects are not anticipated to result in adverse effects on aquatic life, wildlife, or drinking water quality for human consumption. The characterization of residual effects on surface water and sediment quality is further summarized.

The Project is anticipated to move measurable parameters in a neutral direction. This is because no measurable long-term trend in surface water and sediment quality parameters is anticipated relative to existing conditions.

With the implementation of well-established mitigation measures and management practices to reduce or eliminate effects associated with erosion and sedimentation, ARD/ML, and blasting, project activities are predicted to result in low-magnitude changes to surface water and sediment quality that generally remain within the variability of existing conditions.

Residual effects are not anticipated to extend beyond the LAA. Water that drains into the mainstem of the Mackenzie River (Deh Cho) from much smaller watercourses that intersect the PDA will undergo substantial mixing before being transported downstream in the Mackenzie River (Deh Cho) and beyond the LAA.

The timing of residual effects is anticipated to be influenced by seasonal changes. This is because erosion and sedimentation that could influence surface water and sediment quality (e.g., from the clearing of vegetation and topsoil, instream works, and dustfall) are anticipated to be negligible in the winter when surficial terrain and waterbodies are frozen and covered in snow.

The duration of residual effects is characterized as medium-term and limited to the construction phase of the Project. This is because the effect pathways relevant to potential changes in surface water and sediment quality are directly associated with the development of the Project (including the development of material sources) and will generally not persist into operations and maintenance. Exceptions during the operations and maintenance phase include culvert and bridge maintenance and the creation of fugitive dust by summer highway users. However, culvert and bridge maintenance (which will include relevant mitigations outlined Section 16.4.2.2) and fugitive dust (which will include the regular use of water for dust control) are not anticipated to result in measurable changes to surface water or sediment quality during the operations and maintenance of the highway.

The frequency of residual effects during the construction phase is anticipated to include multiple irregular events that occur at no set schedule. This is because construction activities that have the potential to influence surface water and sediment quality will occur at different times and places within the PDA as the development of the Project progresses.

Residual effects are anticipated to be reversible because changes in surface water and sediment quality will be influenced by construction activities that are finite. Land disturbances associated with the construction of the Project are well understood and will be managed to eliminate or reduce the potential for long-term effects that extend beyond the construction phase using best practices, mitigation measures, and site-specific reclamation programs (e.g., the facilitation of vegetation regrowth where necessary to prevent erosion).

16.4.3 Changes to Groundwater Quality

16.4.3.1 Effects Pathways

The effect pathways for changes to groundwater quality are associated with excavation, ground disturbance and permafrost degradation.

16.4.3.1.1 Excavation

Excavations, if they advance below the groundwater table in permafrost-free areas, will result in the flow of groundwater into the excavation that must be removed (pumped out). As a result, the excavation will become a local sink for groundwater flow and groundwater levels near the excavation will decline in a cone of depression centered on the excavation. Wetlands, streams, or lakes hydraulically connected to the groundwater system within the cone of depression area may begin to infiltrate to ground. The chemistry of surface water is generally different from the chemistry of groundwater, and infiltration (groundwater recharge) of surface water to the underlying groundwater system may change the chemistry of that system.

Important changes in groundwater chemistry from the introduction of surface water could include organic material and/or bacterial or viral organisms that are generally not present in groundwater. These additions would affect the quality of the groundwater use for potential groundwater users near the excavations.

16.4.3.1.2 Ground Disturbance

Ground disturbance activities such as site preparation of the ROW, access roads, and workspaces (Table 16.5) may alter the characteristics of the ground surface such that the rate that precipitation or melt water infiltrates to the groundwater system (recharge) changes. Meteoric water (i.e., snowmelt and precipitation) is generally lower in total dissolved solids and other chemical constituents than groundwater. As a result, increased recharge may dilute the concentrations of aqueous parameters present in groundwater.

16.4.3.1.3 Permafrost Degradation

Project activities that may affect groundwater through permafrost degradation may occur along the entire PDA, but effects are more likely to occur where permafrost is classified as extensive continuous (65% to 90% of the land area; i.e., primarily in the northern half of the PDA [K'alo-Stantec, 2023b]).

Excavations, ground disturbance, and the presence of the highway are effects pathways where there is the potential to cause degradation of permafrost, a change in groundwater flow, and an associated change in groundwater quality. Permafrost degradation may increase the hydraulic connection between supra- and-sub-permafrost components of the groundwater flow system (see Chapter 15, water quantity). This may cause a change in water quality in the downgradient component and a change in the water quality of downgradient surface water environments.

16.4.3.2 Mitigation

Design-based mitigation to reduce or eliminate adverse effects on groundwater quality are summarized in Table 16.6, organized according to the effect pathway each mitigation targets (i.e., excavation, ground disturbance, and permafrost degradation).

Additional detail on mitigation to limit the removal of vegetation and/or topsoil for road construction (i.e., ground disturbance) is provided in Chapter 18 (vegetation and wetlands).

Additional detail on mitigations to limit the degradation of permafrost are provided in Chapter 14 (terrain, soils, and permafrost).

16.4.3.3 Residual Effect

With the mitigation measures summarized in Table 16.6, the Project is likely to result in a change in groundwater quality (i.e., a residual effect) if groundwater is affected by excavation, ground disturbance, or permafrost degradation.

Potential residual effects on groundwater quality caused by unintended releases during an accident or malfunction are addressed in additional detail in Chapter 25 (accidents and malfunctions). As a result, these residual effects are not addressed further in the groundwater and quality assessment.

16.4.3.3.1 Excavation

Residual effects on groundwater quality caused by excavations are expected to be no measurable change to low in magnitude based on the following rationale:

- A change in groundwater quality from groundwater level drawdown caused by an excavation implies infiltration from a water source with different chemistry (e.g., a stream or lake).
- Infiltration from lakes or streams within a cone of depression will only occur in sufficient amount to change groundwater quality from a subset of these features; those with a strong hydraulic connection to the underlying groundwater system. Some lakes and streams will have only a weak hydraulic connection to the underlying groundwater system.
- There are no identified groundwater users within the PDA, LAA, or RAA that would be affected by the addition of organic matter and/or bacterial or viral organisms (hydrogeology TDR, Appendix 15B; K'alo-Stantec, 2022b).

Residual effects associated with excavations are not expected to be sensitive to timing since borrow source, quarry, and road cut excavations will operate year-round and result in permanent changes in topography. As a result, the likelihood, sensitivity, duration, frequency, and reversibility of associated residual effects are expected to be possible, not sensitive, long-term, continuous, and irreversible, respectively.

16.4.3.3.2 Ground Disturbance

Residual effects on groundwater quality caused by ground disturbance are expected to be no measurable change to low in magnitude and limited to the PDA.

Ground disturbance that can be remediated (e.g., temporary camp locations) are expected to be possible, not sensitive, medium-term (e.g., during the construction phase), continuous, and reversible. Effects related to ground disturbance caused by permanent changes, such as the presence of the highway, are expected to be possible, not sensitive, long-term, continuous, and irreversible.

16.4.3.3.3 Permafrost Degradation

Residual effects on groundwater quality caused by permafrost degradation are subject to the same characterizations as those of the groundwater quantity effect pathway (Section 15.4.4). As a result, the magnitude of the groundwater quality change associated with permafrost degradation for the Project is anticipated to be no measurable change to moderate, and the geographic extent is expected to be limited to the PDA or LAA. The likelihood, sensitivity, duration, frequency, and reversibility are expected to be possible, not sensitive, long-term, continuous, and irreversible.

16.4.4 Summary of Residual Effects

Residual effects resulting from the Project on changes to surface water and sediment quality will occur during the construction of the Project. These changes to surface water and sediment quality are predicted to be neutral in direction (i.e., no measurable long-term trend in surface water and sediment quality parameters relative to existing conditions) and low in magnitude; not extend beyond the LAA; and be medium-term, limited to the construction phase, and not persist into operations.

Effects will be influenced by seasonal changes in ice and snow cover. Effects will include multiple irregular events associated with construction activities and are likely reversible due to the finite duration of the construction phase of the Project (Table 16.7).

Table 16.7 Residual Effects on Water and Sediment Quality

Residual Effect	Residual Effects Characterization*								
	Project Phase	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Changes to Surface Water and Sediment Quality	C/O	N	P	L	LAA	S	MT	IR	R
Changes to Groundwater Quality	C/O	A	P	NMC[1], L[2], M[3]	PDA[1,3] LAA[2]	NS	LT	C	I

KEY

*See Table 16.3 for detailed definitions

Project Phase:
C: Construction
O: Operations and Maintenance

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMC: No Measurable Change
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
S: Sensitive
NS: Not Sensitive

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

Notes:

1 Applies to the ground disturbance effects pathway (Section 16.4.3.1)
2 Applies to the excavation effects pathway (Section 16.4.3.1)
3 Applies to the permafrost degradation effect pathway (Section 16.4.3.1)

Residual effects resulting from the Project on groundwater quality after mitigation is implemented will occur and are predicted to be adverse in direction. The magnitude and geographic extent of residual effects depend on the pathway mechanism that causes the effect (Section 16.4.3) as follows:

- Residual effects on groundwater quality from excavations are expected to have magnitudes that range from no measurable change to low and are geographically limited to the LAA (Table 16.7, Section 16.4.3).
- Residual effects on water and sediment quality from ground disturbance are expected to be no measurable change to low in magnitude, short-term and reversible (where remediation occurs) or long-term and irreversible (where remediation won't occur), and geographically limited to the PDA (Table 16.7, Section 16.4.3).
- Residual effects on water and sediment quality from permafrost degradation are expected to be no measurable change to moderate in magnitude, continuous and irreversible, and geographically limited to the LAA (Table 16.7, Section 16.4.3).

Residual effects on water and sediment quality are summarized in Table 16.7. With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirements related to watershed management and drinking water, and consideration of engagement input and incorporation of Traditional Knowledge.

The design of the Project and mitigation measures for protection of water and sediment quality will respect the values of the Petiniʔah (Bear Rock) CZ, Mio Lake CZ, Norman Range SMZ, K'ąąlǫ Tué (Willow Lake Wetlands) SMZ, and Deh Cho (Mackenzie River) SMZ as areas with important ecological habitats. Mitigation measures to protect water quality take into account the Project's location within Tulita's community drinking water source catchment.

16.5 Assessment of Cumulative Effects on Water and Sediment Quality

16.5.1 Residual Effects Likely to Interact Cumulatively

Existing environmental conditions reflect cumulative effects on the environment from past and present projects and physical activities. Past and present projects and physical activities have influenced the existing conditions for surface water and sediment quality (Section 16.2). The assessment of cumulative effects focuses on the same residual effect as previously assessed (i.e., a change in surface water and sediment quality).

Table 16.8 identifies other past, present, and reasonably foreseeable projects and physical activities within the RAA with effects that have the potential to interact cumulatively with residual effects on water and sediment quality from the Project.

Where adverse residual effects from the Project act cumulatively with those from other past, present, and reasonably foreseeable projects and physical activities, a cumulative effects assessment is undertaken to determine their significance.

As described in Section 16.4.4, residual effects on this VC are not anticipated to extend beyond the LAA. Therefore, other projects within the RAA that are not anticipated to extend potential effects on the LAA are excluded as potential sources of cumulative effects. Excluded projects are as follows:

- Geotechnical activities are excluded from potential cumulative effects on surface water and sediment quality because the only two identified projects of this type within the RAA are relatively small in scale and related to the development of a visitor centre (Parks Canada) and a health centre (GNWT Department of Infrastructure [INF]) in Tulita. According to the Land Use Permits issued by the Sahtu Land and Water Board, land disturbances related to these projects are limited to the development of groundwater monitoring wells and, in the case of the visitor centre, minor compaction of grass. In consideration of the scope, environmental footprint, and mitigation measures associated with these geotechnical investigations, cumulative effects on surface water and sediment in the project LAA are not anticipated.
- Mining and exploration activities are excluded from potential cumulative effects because the only foreseeable mining-related project within the RAA is a proposed diamond drilling and exploration operation (Devonian Metals Ltd.) at the existing Wrigley Zinc property, approximately 12 to 13 km upstream of the southern extent of the LAA. According to a November 2020 Land Use Permit Application with the MVLWB, activities of this project will be limited to geophysical, geotechnical, and geological surveying. These activities are not expected to result in measurable changes to downstream surface water or sediment quality in the project LAA. In consideration of the scope, environmental footprint, and mitigation measures associated with this exploration activity, cumulative effects on surface water and sediment in the project LAA are not anticipated.

Table 16.8 Projects with the Potential to Contribute to Cumulative Effects in the RAA

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effect	
	Changes to Surface Water and Sediment Quality	**Changes to Groundwater Quality**
Past and Present Physical Activities and Resource Use (Base Case)		
Geotechnical	–	–
Oil, Gas & Seismic*		
Access roads, staging areas and seismic lines only (drilling locations are not within the RAA)	✓	–
Infrastructure		
Mackenzie Valley Winter Road, including bridges and bridge-sized culverts	✓	✓

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effect	
	Changes to Surface Water and Sediment Quality	**Changes to Groundwater Quality**
Canyon Creek All Season Access Road	✓	✓
Norman Wells Pipeline	✓	✓
Mackenzie Valley Fibre Link	✓	✓
Mackenzie Highway #1 Operations and Maintenance	✓	–
Prohibition Creek Access Road	✓	✓
Quarries and Borrow Sources		
HRN Quarry	✓	✓
Mining & Exploration	–	–
Municipal Operations, including water, waste, power, and community development		
Wrigley Municipal Activities	✓	✓
Tulita Municipal Activities	✓	✓
Norman Wells Municipal Activities	✓	✓
Project-Related Physical Activities (Project Case)		
Mackenzie Valley Highway Project	✓	✓
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)		
Quarries		
Dhu-1 Quarry	✓	✓
Infrastructure		
Great Bear River Bridge	✓	✓
Oil and Gas		
Enbridge Maintenance Camp	✓	–

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = Includes support activities such as: production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas.

16.5.2 Changes to Surface Water and Sediment Quality

16.5.2.1 Cumulative Effects Pathways

Potential cumulative effects on surface water and sediment quality arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project (Sections 16.4.2 and 16.4.3). These effect pathways include potential erosion and sedimentation resulting from projects and activities involving land disturbances, such as the removal of vegetation and/or topsoil, instream works, alteration of permafrost, and dustfall. Other projects involving the development of quarries with explosives also have the potential to interact cumulatively with the Project.

A detailed list of projects and activities within the RAA that have the potential to interact cumulatively with the Project is provided in Section 4.6.1, Table 4.2.

16.5.2.2 Mitigation for Cumulative Effects

Mitigation measures to reduce or eliminate potential cumulative effects on surface water and sediment quality are the same as those presented in Table 16.6 and Sections 16.4.2 and 16.4.3.

16.5.2.3 Cumulative Effects

Other past, present, or foreseeable projects and activities in the RAA have the potential to result in changes to surface water and sediment quality via the same effects pathways described in Sections 16.4.2 and 16.4.3. These effect pathways may interact cumulatively with project-related changes to surface water and sediment quality.

In consideration of the scope, scale, and proximity of other past, present, or foreseeable projects and activities in the RAA, cumulative effects on surface water and sediment quality are anticipated to move measurable parameters in a direction that is neutral. This is because cumulative effects are anticipated to result in no measurable long-term trend in surface water and quality.

With the implementation of well-established mitigation measures and management practices to reduce or eliminate effects associated with erosion and sedimentation, ARD/ML, and blasting, cumulative effects are predicted to have no measurable change relative to project-related residual effects. Therefore, cumulative effects on surface water and sediment quality are characterized the same as residual effects (i.e., low magnitude).

Cumulative effects, by definition, can only occur at the same time and place as project-related residual effects. Therefore, the geographic extent (LAA), timing (seasonal), duration (medium-term), and frequency (multiple irregular events) of cumulative effects are the same as previously characterized for residual effects (Section 16.4.4).

Cumulative effects are anticipated to be reversible because changes in surface water and sediment quality due to project-related residual effects will be influenced by construction activities that are finite. Project-related effect pathways relevant to surface water and sediment quality are directly associated with the development of the Project and will not persist into operation. Land disturbances associated with the construction of the Project are well understood and will be managed to eliminate or reduce the potential for long-term effects that extend beyond the construction phase using best practices, mitigation measures, and site-specific reclamation programs (e.g., the facilitation of vegetation regrowth where necessary to prevent erosion).

16.5.3 Changes to Groundwater Quality

16.5.3.1 Cumulative Effects Pathways

Potential cumulative effects on groundwater quality arising from past, present, and reasonably foreseeable future projects and physical activities include the same effects pathways as those resulting from the Project (Section 16.4.2.1). These include excavation, ground disturbance, and permafrost degradation. The pathway mechanisms through which cumulative effects on groundwater quality occur are the same mechanisms as described in Table 16.2 and Section 16.1.3.

16.5.3.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects on groundwater quality from excavation, ground disturbance, and permafrost degradation pathways include those presented in Table 16.6.

No additional mitigation measures are recommended to reduce or eliminate cumulative effects on groundwater quality beyond those measures presented in Section 16.4.2.2 and Table 16.6. It is assumed that other projects and activities would apply similar mitigation measures to those presented in Table 16.6.

16.5.3.3 Cumulative Effects

Residual effects from the Project to groundwater quality are not anticipated to interact with the effects of other projects in the RAA and therefore are not expected to contribute to cumulative effects within the RAA.

Municipal operations include effluent discharge to surface water, which is a potential effects pathway to groundwater quality. However, if these projects operate within guidelines under the applicable approvals required for their operation, it is anticipated that the residual effects on a change in groundwater quality will be no measurable change to low magnitude change.

The residual effects of other past or present projects (Table 16.8) on baseline groundwater quality conditions with the Project LAA are difficult to determine. Existing groundwater quality data (groundwater chemistry) were lacking at a level of detail required to characterize baseline conditions beyond general statements on regional and local groundwater chemistry (Section 16.2.3).

Reasonably foreseeable projects and developments include the Dhu-1 Quarry, the Great Bear River Bridge, and the Prohibition Creek Access Road. The projects are not expected to act cumulatively to affect groundwater flow, which is the pathway through which these projects may cumulatively affect groundwater quality (Section 16.1.3). Therefore, these projects are not expected to cumulatively affect groundwater quality.

The magnitude of cumulative effects is expected to range from no measurable change to moderate within the LAA, consistent with the assessment completed for residual effects. Likelihood, sensitivity, timing, duration, frequency, and reversibility are expected to be possible, not sensitive, long-term, continuous, and irreversible, respectively.

16.5.4 Summary of Cumulative Effects

Cumulative effects on surface water and sediment quality are characterized as 'neutral' in direction and low magnitude. The geographic extent (LAA), timing (seasonal), duration (medium-term), and frequency (multiple irregular events) of cumulative effects are the same as previously characterized for residual effects (Sections 16.4.2 and 16.4.3). Cumulative effects are anticipated to be reversible.

Cumulative effects on groundwater quality within the LAA from the Project and past, present, and reasonably foreseeable future projects and activities are predicted to be adverse in direction and range from no measurable change to low in magnitude. Cumulative effects will persist for the long term due to the long operational period and permanent changes to the environment imposed by many of these projects. For many of these project and activities, cumulative effects will likely be irreversible.

Table 16.9 Summary of Cumulative Effects

Residual Cumulative Effect	Residual Cumulative Effects Characterization							
	Direction	**Likelihood**	**Magnitude**	**Geographic Extent**	**Timing**	**Duration**	**Frequency**	**Reversibility**
Changes to Surface Water and Sediment quality	N	U	NMC	LAA	S	MT	IR	R
Contribution from the Project to the residual cumulative effect	The Project is not anticipated to contribute to measurable cumulative effects to surface water and sediment quality in the RAA.							
Changes to Groundwater Quality	A	P	NMC[1], L[2], M[3]	PDA[1,3], LAA[2]	NS	LT	C	I
Contribution from the Project to the residual cumulative effect	The Project is not anticipate to contribute to measurable cumulative effects to changes to groundwater quality in the RAA.							

KEY

*See Table 16.3 for detailed definitions

Project Phase

C: Construction

O: Operations and maintenance

Direction:

A: Adverse

N: Neutral

Likelihood:

U: Unlikely

P: Possible

CE: Certain

Magnitude:

NMC: No Measurable Change

L: Low

M: Moderate

H: High

Geographic Extent:

PDA: Project Development Area

LAA: Local Assessment Area

RAA: Regional Assessment Area

Timing

S: Sensitive

NS: Not Sensitive

Duration:

ST: Short-term

MT: Medium-term

LT: Long-term

Frequency:

S: Single event

IR: Irregular event

R: Regular event

C: Continuous

Reversibility:

R: Reversible

I: Irreversible

Notes:

1 Applies to the ground disturbance effects pathway (Section 16.4.3.1)

2 Applies to the excavation effects pathway (Section 16.4.3.1)

3 Applies to the permafrost degradation effect pathway (Section 16.4.3.1)

16.6 Determination of Significance

16.6.1 Significance of Residual Effects

Residual effects of the Project include low magnitude, reversible changes to surface water and sediment quality that are geographically limited to the LAA (Table 16.7).

Based on these characterizations, as well as the significance definition in Section 16.1.6, the residual effects of the Project on surface water and sediment quality are predicted to be not significant.

Based on the characterizations of residual effects outlined in Table 16.7 and summarized in Section 16.4.4, and the significance definition in Section 16.1.6, residual effects of the Project on groundwater quality are predicted to be not significant.

16.6.2 Significance of Cumulative Effects

Cumulative residual effects of the Project include low magnitude, reversible changes to water and sediment quality and groundwater quality that are geographically limited to the LAA (Table 16.9).

Based on these characterizations, as well as the significance definition in Section 16.1.6, these cumulative residual effects on water and sediment quality are predicted to be not significant.

Cumulative residual effects on groundwater quality range from no measurable change to moderate effects geographically limited to the LAA. Likelihood, sensitivity, timing, duration, frequency, and reversibility of cumulative residual effects on groundwater quality are expected to be possible, not sensitive, long-term, continuous, and irreversible, respectively. Based on these characterizations, as well as the significance definition in Section 16.1.6, cumulative effects on groundwater quality are predicted to be not significant.

16.6.3 Project Contribution to Cumulative Effects

Within the LAA, contribution from the Project to the cumulative residual effect cannot be quantified because quantified magnitudes of change in water and sediment quality due to the Project and other projects are not known. However, such a quantified relative contribution within the LAA will not be relevant if the magnitude of residual effects is low.

Outside the LAA (within the RAA), the Project does not contribute to cumulative residual effects.

The contribution of residual effects of the Project to cumulative effects on groundwater quality within the LAA are expected to range from no measurable change to moderate in magnitude, consistent with the assessment of residual effects (Section 15.4.4). Likelihood, sensitivity, timing, duration, frequency, and reversibility are expected to be possible, not sensitive, long-term, continuous, and irreversible, respectively.

The contribution of residual effects of the Project to cumulative effects within the RAA are predicted to be no measurable change since residual effects of the Project are anticipated to be limited to the LAA.

16.7 Prediction Confidence

For surface water and sediment quality, with the successful implementation of mitigation measures, the prediction confidence is rated 'high.'

Confidence in the prediction of project-related effects relies heavily on the mitigation measures described in Sections 16.4.2 and 16.4.3. These mitigations are established, well understood, and comprise best management standards and practices. However, without the effective implementation of suitable mitigation measures to reduce or eliminate changes to surface water and sediment quality due to erosion and sedimentation, fugitive dust, ARD/ML, and explosives-related nitrogen loading, this assessment would result in higher-magnitude effects and low prediction confidence.

For groundwater quality, confidence in the assessment of potential effects is increased by considering that the Project does not require excavations that extend far below the groundwater table and will not discharge effluent to ground or the surface water environment. As a result, many common pathways to significant residual changes in groundwater quality are not present.

Confidence in the assessment of potential effects on groundwater quality is reduced based on the lack of existing conditions groundwater quality data from which to characterize potential residual effects. Additionally, the long, linear disturbance nature of the project results in the PDA crossing a variety of conceptual groundwater flow systems, the variability of which limits the potential to describe or define these systems in detail.

In summary, the prediction confidence in assessing potential project effects on groundwater quality is low to moderate based on this discussion and on professional judgement.

16.7.1 Assumptions

Results of this effects assessment are dependent on effective implementation of mitigation measures described in Sections 16.4.2 and 16.4.3. The characterizations of residual effects (Section 16.4) and cumulative effects (Section 16.5) were developed under the assumption that mitigation measures and BMPs will adhere to the procedures and objectives described by the following guidance:

- The GNWT Department of Transportation – Erosion and Sediment Control Manual (GNWT, 2013a)
- Measures to Protect Fish and Fish Habitat (DFO, 2022a)
- Guidelines for Development and Management of Transportation Infrastructure in Permafrost Regions (TAC, 2010)

- Guideline for Dust Suppression (GNWT, 2013b)
- Northern Land Use Guidelines: Roads and Trails (GNWT, 2015a)
- Northern Land Use Guidelines: Pits and Quarries (GNWT, 2015b)
- Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters (Wright and Hopky, 1998)

In addition to the assumption that appropriate and effective mitigation measures will be successfully implemented to reduce (or in some cases prevent) potential adverse effects on surface water and sediment quality, it is assumed that future assessments of ARD/ML potential at each candidate material source will be consistent with preliminary screening results that indicate ARD/ML potential is likely to be low (K'alo-Stantec, 2021). For this reason, it is assumed that surface water and sediment quality of the receiving watercourses will not be adversely affected by run-off in contact with locally sourced rock materials from selected locations within the RAA.

16.7.2 Gaps and Uncertainties

Data gaps for existing conditions were identified in the assessment. These data gaps include information requested in the DAR Terms of Reference (ToR; MVEIRB, 2015 [PR#66]) and are as follows:

- A description of sediment load (suspended and bed load) for each major drainage or major watercourse (ToR Section 5.1.3; MVEIRB, 2015). Historical and recently reported concentrations of TSS were summarized for three locations in the Mackenzie River (Deh Cho) (i.e., Wrigley, Tulita, and Norman Wells) in the surface water and sediment quality TDR (Appendix 16A; K'alo-Stantec, 2022a). Suspended sediments and/or sediment bed loads were not identified for each watercourse that may be affected by the Project, but no further bridge construction work is planned at major drainages. Sites within the RAA and LAA for which historical TSS data are available are summarized in the surface water and sediment quality TDR (Appendix 16A; K'alo-Stantec, 2022a). Where applicable, pre-construction baseline conditions for sediment load should be established nearer to the time of construction.
- The identification of existing water quality and variations for each area of water use that may be affected by the highway (ToR Section 5.1.3; MVEIRB, 2015). Except for TSS as described, information on the seasonal and/or annual variability of surface water and sediment quality for watercourses that may be affected by project-related activities (i.e., particularly smaller watercourses that intersect the PDA) was limited and not summarized. However, regional water quality has limited value for predicting changes to water quality from construction. Construction monitoring will be used to monitor effectiveness of mitigation measures applicable to water quality at the time when the activity is taking place.

- Detailed information about traditional water-use locations that may be affected by the Project was not identified across the whole LAA. Protection of water quality in the Mackenzie Valley, and the Tulita drinking water catchment area is of high cultural importance. Some watercourses in the LAA are traditionally used as sources of sustenance, including drinking water and for harvesting of fish. Additional information on specific water uses and locations, if available, will be incorporated in the design of site-specific monitoring programs that reflect the intended use of a watercourse.
- Existing groundwater quality data (i.e., groundwater chemistry) were not available to characterize baseline conditions (gap) such that neither quantitative nor qualitative definitions of residual effects characterizations (Table 16.3) for groundwater quality could be confidently developed (uncertainty).

As explained in Sections 16.4.2 and 16.4.3, mitigation measures will be implemented to reduce effects on surface water and sediment quality from erosion and sedimentation, ARD/ML, and explosives-related nitrogen loading. As a result, collection of additional site-specific water and sediment quality data to characterize existing conditions is not anticipated for the DAR. Additional water quality data, however, will be required for pre-construction and compliance monitoring and to facilitate adaptive management (Section 16.8).

Uncertainties of this assessment include those associated with the assumptions (Section 16.7.1) and data gaps as described. Briefly, these uncertainties include the following:

- Mitigation measures to reduce (or in some cases prevent) measurable changes in surface water and sediment quality are established best practices and generally effective. Although the listed mitigations are anticipated to reduce or eliminate the extent of measurable changes to water and sediment quality, they do not guarantee no measurable changes (i.e., no effects).
- The ARD/ML potential of locally sourced rock materials. Preliminary screening results indicate low ARD/ML potential (K'alo-Stantec, 2021); however, additional samples will be collected and analyzed for ARD/ML potential during the ongoing selection and characterization of potential material sources.
- Existing surface water quality (including seasonal and long-term variability) and sediment quality within watercourses that intersect the PDA and which may be affected by the Project
- Existing water uses and locations in watercourses within the RAA
- The degree to which permafrost degradation will contribute to changes in surface water and sediment quality due to erosion and sedimentation
- The degree to which ongoing operation of the Project will contribute to changes in surface water and sediment quality in the future

16.8 Follow-up and Monitoring

Surface water quality and, if needed, sediment quality data will be collected as part of construction and compliance monitoring programs at water course crossings and in water bodies adjacent to borrow sources and quarries.

As described in Section 23.4, monitoring sites will include nearfield locations downstream of watercourse crossings, and in water bodies adjacent to borrow sources and quarries. Monitoring will include inspection of construction practices, mitigation measures employed and the functionality of those mitigation measures. Monitoring will also include certain water quality parameters during instream works. Due to a lack of baseline water and sediment quality monitoring in some watercourses potentially affected by the Project, suitable upstream reference sites will be sampled to help characterize pre-construction reference conditions, where needed to help identify potential project-related effects.

In-situ physical parameters (e.g., turbidity, pH, dissolved oxygen, and temperature) in surface water will be routinely monitored during construction at upstream and downstream sites. If project-related effects associated with physical parameters are observed at locations identified to be important for drinking water and fish harvesting, additional parameters (e.g., TSS, total and dissolved metals, nutrients) relevant to specific water uses and guidelines will be monitored in water and sediment.

In specific cases where historical water/sediment quality data may be appropriate to investigate potential project-related effects, the available surface water and sediment quality data identified for sites within the RAA and LAA (Appendix 16A; K'alo-Stantec, 2022a) may be used to support future project-specific monitoring programs.

Ongoing engagement with Indigenous Governments, Indigenous Organizations and other affected parties will also help inform the design of future monitoring programs to account for specific water uses and water use locations within the RAA and LAA.

To confirm the preliminary conclusions of the ARD/ML survey (K'alo-Stantec, 2021), additional samples of potential quarry material and other material to be disturbed (such as road cuts) will be collected and analyzed for ARD/ML potential during the selection and characterization of potential material sources and evaluation of road cuts.

Management plans will be developed to assess and mitigate potential residual effects of excavation on groundwater quality for each borrow source and quarry site as required by the GNWT (2015b). These plans will provide an adaptive management framework that outlines required actions should groundwater withdrawal and subsequent discharge begin to affect groundwater quality or other VCs.

Information pertaining to compliance and effects monitoring is provided in Chapter 23 (compliance and effects monitoring). Briefly, the goal of compliance and effects monitoring is to verify compliance with conditions of regulatory authorizations and other legal requirements such as conditions of land use permits, water licences and quarry permits, environmental criteria

(e.g., water quality, air emissions), and codes of practice. In addition, compliance and effects monitoring also confirm the predictions made in the environmental assessment, confirm mitigation measures are working as intended to reduce effects, and inform changes that may be required to mitigations or monitoring as part of an adaptive management approach.

16.9 References

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17.0 ASSESSMENT OF POTENTIAL EFFECTS ON FISH AND FISH HABITAT

Fish and Fish Habitat was selected as a valued component (VC) because of its importance in supporting aquatic life, wildlife, human health, and community well-being. Changes in fish and fish habitat may adversely affect the productivity and sustainability of fisheries, which in turn may affect local community fisheries. Fish and fish habitat in the Sahtu and Dehcho regions is of high cultural importance to Indigenous Governments, Indigenous Organizations and other affected parties. Larger watercourses are traditionally used for harvesting fish, while smaller watercourses may provide prey and nutrients to fisheries.

The Mackenzie Valley Highway Project (the Project) has the potential to affect fish and fish habitat. Waterbodies that may be affected are those that are crossed by the Project and near to the Project. Project-specific components that could interact with fish and fish habitat include construction of new watercourse crossings (culverts), riparian clearing, construction camps, quarries, water withdrawal, and highway operation and maintenance activities. This assessment does not include effects of existing crossing structures, such as bridges, except for potential maintenance of these crossings during highway operation.

The assessment of potential effects on fish and fish habitat concludes that with the application of mitigation measures, residual effects resulting from the Project on fish and fish habitat will be adverse. Residual effects and cumulative effects due to changes in habitat are not expected to negatively affect the productivity and sustainability of fish populations crossed by the Project and near to the Project, and therefore are predicted to be not significant. Applying a precautionary approach to address uncertainty, the assessment has identified the potential for increased fishing pressure to adversely affect large-bodied fish populations leading to a potential significant effect.

17.1 Scope of Assessment

17.1.1 Regulatory and Policy Setting

The assessment of potential effects on fish and fish habitat is guided by the project Terms of Reference (ToR; Mackenzie Valley Environmental Impact Review Board [MVEIRB], 2015 [Public Registry {PR}#66]), federal legislation, and the Sahtu Land Use Plan (SLUP).

17.1.1.1 *Fisheries Act*

The *Fisheries Act* provides for the protection of fish and their habitat (including benthic invertebrates). The *Fisheries Act* prohibits causing harmful alteration, disruption, or destruction (HADD) of fish habitat (section 35), death of fish by means other than fishing (section 34.4[1]), and the introduction of a deleterious substance (section 36). The Act also includes provision for flow and passage (section 34.3) and a framework for regulatory decision-making (section 34.1).

The *Fisheries Act* requires that projects avoid causing HADD of fish and fish habitat, unless authorized by the Minister of Fisheries and Oceans Canada (DFO). Projects with the potential to obstruct fish passage, modify flow, or result in entrapment of fish may also qualify as causing HADD to fish. Where a non-compliance of the *Fisheries Act* cannot be avoided or mitigated, an Authorization under paragraph 35(2)(b) of the *Fisheries Act* is required. The Fisheries Protection Program, maintained by DFO and its collaborative partners, is responsible for the review of projects to determine if a non-compliance of the *Fisheries Act* is likely to occur.

17.1.1.2 *Species at Risk Act*

The federal *Species at Risk Act* (SARA) provides protection for species at risk (SAR) in Canada. The legislation provides a framework to facilitate recovery of species listed as threatened, endangered, or extirpated, and to prevent species listed as special concern from becoming threatened or endangered. Species at risk and their habitats are protected under SARA, which prohibits: (1) the killing, harming, or harassing of endangered or threatened SAR (sections 32 and 36); and (2) the destruction of critical habitat of an endangered or threatened SAR (sections 58, 60, and 61).

17.1.1.3 Sahtu Land Use Plan

Specific to the areas to which the SLUP applies, the Project must meet the 13 general conformity requirements (CR) of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023). The SLUP's conformity requirements include consideration of fish and fish habitat in CR#7:

> *"1) Land use activities must be designed using the most current information for identified species of interest and species at risk as obtained from the Government of the Northwest Territories Department of Environment and Climate Change Canada (GNWT-ECC), Environment and Climate Change Canada's Canadian Wildlife Service, DFO, Parks Canada Agency, the Sahtú Renewable Resources Board (SRRB) and the local Renewable Resources Councils (RRC) .*
>
> *2) Impacts to wildlife, their habitat and migration patterns, and important community harvesting areas must be prevented or mitigated to the extent possible."*
>
> *"b) In addition, DFO has established in-water construction timing windows for the protection of fish and fish habitat. These are updated from time to time and are available at* https://www.dfo-mpo.gc.ca/pnw-ppe/timing-periodes/index-eng.html*. During these periods, no in-water work or shoreline work is allowed except under site- or project-specific review and with the implementation of protective measures."* (SLUPB, 2023)

Conformity requirement #2 requires that *"The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge.".* Additionally, per CR#14, the Project must be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 2023), including the following:

- Petiniɂah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)
- K'ąąlǫ Tué (Willow Lake Wetlands) Special Management Zone (SMZ) (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

17.1.1.4 Other Relevant Guidance

Federal and territorial guidance documents most pertinent to fish and fish habitat are:

- DFO (2013): Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada
- DFO (2010): Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut
- DFO Codes of Practice as applicable at the time activities are undertaken (available at: Codes of practice (dfo-mpo.gc.ca))

17.1.2 Influence of Engagement

The GNWT has engaged with Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapters 2 (Consultation and Engagement), 3 (Traditional Knowledge), and 11 (culture and traditional land use) of this Developer's Assessment Report (DAR). The GNWT has recently initiated Consultation with Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to fish and fish habitat. This feedback has been considered and summarized in Table 17.1 and has been integrated into the assessment of potential effects on fish and fish habitat that follows.

Table 17.1 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils identified fish species of cultural importance near the Project.	Auld and Kershaw, 2005; IMG-Golder Corporation, 2006; Norman Wells Renewable Resource Council (NWRRC), 2023; SRRB, 2021b; SLUPB, 2022	The GNWT has reviewed and considered the species of importance and important habitats identified by Indigenous Governments, Indigenous Organizations, and other affected parties. The GNWT has considered this information in the selection of water sources to be considered for the Project. For example, owing to concerns raised, Trout Lake near Bear Rock (Petınıʔah) has been removed as a water source.	For information about fish species of cultural importance and important fish habitat, see Section 17.2.2 (Table 17.4 and Table 17.6). See also Section 11.3.3.7 for additional information about important harvesting areas and harvested species.
Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils identified important fish habitat, and fishing locations near the Project.	5658 NWT Ltd. and GNWT, 2011 (PR#16); Dessau, 2012 (PR#13); EBA, 2006; Golder, 2015; IMG-Golder Corporation, 2006; NWRRC, 2023; Tulita Renewable Resources Council (TRRC), 2019; TRRC, 2022; SLUPB, 2013		
Community engagement participants reported that all of the creeks being crossed by the current Mackenzie Valley Winter Road are fish-bearing. They shared that the fish in the creeks are small.	August 2021 Engagement; November to December 2022 Engagement; November 2022 to February 2023 Engagement	The GNWT has identified mitigation measures to reduce the effects of the Project on fish and fish habitat. A Fish and Fish Habitat Protection Plan (FFHPP) will be developed and implemented. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning. The GNWT is open to and interested in discussions with community members on how best to integrate community-based monitoring into project mitigation.	For mitigation measures to reduce effects of the Project on fish and fish habitat, see Table 17.8 See also: Section 17.4.2 (Change in Fish Habitat) Section 17.4.3 (Change in Fish Health) Section 17.4.4 (Change in Water Quality) Section 17.5 (Residual Effects) Section 17.6 (Assessment of Cumulative Effects on Fish and Fish Habitat) Volume 5 for management plans.
Elders and land users in the Sahtu Region expressed concern about potential project effects on the Wrigley (Pehdzéh Kı̨ N'deh) area,[1] which may affect the health of the region's fish. Specific concerns included project effects on fish habitat; project effects on spawning and fish abundance due to direct effects from development and industry; and indirect effects as a result of climate change.	SRRB, 2021; Golder, 2015		

Comment	Source	GNWT Response	Where Addressed
Community engagement participants reported that erosion and sedimentation are changing the water, which is affecting fish, including fish migration; participants reported that Arctic grayling are declining because there is a lack of silt fencing. Effects from climate change (temperature change) and seismic activity affecting fish and fish habitat were also identified as concerns.	November to December 2022 Engagement	A project-specific Erosion and Sedimentation Control Plan (ESCP) will be developed and implemented. Seismic activity is not part of the Project and there are no past, present or reasonably foreseeable seismic activities that will interact with the residual effects of the Project. There is noted uncertainty in the assessment of effects on fish and fish habitat as discussed in Section 17.8.2	Section 17.4.4.1 (Change in Water Quality: Increased Sedimentation) Section 17.6 (Assessment of Cumulative Effects on Fish and Fish Habitat Table 17.10) Section 17.8.2 (Gaps and Uncertainties)
Community engagement participants expressed concern that vibration from large truck loads crossing creeks may affect fish migration at culverts. Participants reported that small fish have been injured because of the bolts used in the culverts.	April to July 2022 Engagement; November to December 2022 Engagement	Vibrations from vehicles crossing watercourses may cause a short-term (seconds) startle response due to low anticipated volumes of vehicle traffic during the project operation no residual effect on fish health is anticipated including fish migration. Culverts will be designed and constructed to maintain water flow and fish passage. Culverts will be periodically inspected to determine if they are functioning as per design (e.g., allow fish passage) and for evidence of erosion and sedimentation. If a barrier to fish passage or erosion and sedimentation issues are observed corrective actions would be implemented to correct the problem.	Section 17.4.2 (Change in Fish Habitat) Section 17.4.3 (Change in Fish Health)

Note:

[1] Pehdzéh Kį N'deh area was not identified or disclosed in the report

17.1.3 Potential Effects, Pathways and Measurable Parameters

The Project may cause changes to fish and fish habitat and may also result in changes in the health of fish. Fish habitat, as defined in Section 2(1) of the *Fisheries Act*, means all waters frequented by fish and any other areas upon which fish depend directly or indirectly to carry out their life processes, including spawning grounds and nursery, rearing, food supply, and migration areas. Fish health for the purpose of this assessment means the physical condition of a fish which contributes to its growth and reproduction. Potential effects on fish and fish habitat are measurable changes, such as area of altered or lost habitat, barriers to fish passage, or increases in sediment that exceed guidelines (e.g., Canadian Council of Ministers of the Environment [CCME] Guidelines for the Protection of Aquatic Life).

Changes to fish and fish habitat may occur through the placement of culverts and rip rap in watercourses to be crossed by the Project and changes to riparian areas. Fish habitat can be affected through barriers to fish passage which may prevent fish accessing habitat to perform life history functions such as spawning and rearing, and increased fishing pressure due to increased access during operations and maintenance of the Project. Changes to water quality affecting fish health can occur due to erosion and sedimentation during construction or operation of the Project, or through accidental spills releasing deleterious substances into the water column (see Chapter 25, accidents and malfunctions).

Few studies on the effects of noise on fish from vehicle traffic have been conducted and mainly in areas near urban centers with high volumes of vehicular traffic over sustained periods of time, such as rush hours (Holt and Johnston 2015; Crovo et al. 2015). Vehicle traffic during operation of the Project is anticipated to be low at approximately 50 vehicles per day (see Section 5.2.2). Effects of noise on fish during operation of the Project from vehicular noise are anticipated to be limited to startle responses lasting seconds, after which fish would resume their normal behaviour, and would not impede fish migration. The effect on fish from noise behaviour is not assessed further.

Table 17.2 summarizes the potential effects of the Project on fish and fish habitat, the pathways in which the effects may occur, and measurable parameters used to monitor and assess the magnitude, geographic extent, and duration of effects.

Table 17.2 Potential Effects, Effects Pathways and Measurable Parameters for Fish and Fish Habitat

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in fish habitat	• Direct loss or alteration of habitat from vegetation clearing and trimming of riparian area along the highway right-of-way (ROW). • Direct loss or alteration of fish habitat from the placement of structures (e.g., culverts, rip rap) below the ordinary high water mark (OHWM). • Barriers to fish passage due to poor culvert placement or increased stream velocity may prevent fish from accessing preferred habitat. • Winter water withdrawal from lakes can reduce available overwintering habitat and/or cause reductions in littoral zone. • Winter water withdrawal from watercourses can reduce available overwintering habitat or impede fish passage.	• Area (hectares [ha]) of riparian habitat lost or altered. • Area (ha) of fish habitat below the OHWM altered or lost. • Flow velocity (metres per second [m/s]) in culvert to meet fish passage requirements for fish species present following Di Rocco and Gervais (2023) • Water withdrawn compared to available under-ice lake volume (cubic metres [m^3]). • Winter water withdrawal from watercourses will be based on instantaneous flow (m^3/s) and mean annual discharge (MAD)(m^3/s) compared to DFO's Framework to Support Flow Requirements to Support Fisheries in Canada (DFO, 2013b).
Change in fish health	• Water withdrawal during isolation, road construction, or for camp use can cause entrainment or impingement of fish on pump screen. • Water withdrawal for camp use and dust suppression from streams with low flow or withdrawal above 10% instantaneous flow or when below 30% mean annual discharge (MAD) may affect fish health or lead to stranding. • Winter water withdrawal can result in oxygen depletion affecting fish health. • Increased access to fishing. • Injury or death of fish due to the use of explosives near water. • Increased sediment load in a watercourse. • Use of quarry materials for embankments or rip rap that can lead to acid rock drainage (ARD) or metal leaching (ML) affecting fish health.	• Size of fish screens compared to Interim Code of Practice for End-of-pipe Fish Protection Screens for Small Water Intakes in Freshwater (DFO, 2020). • Instantaneous flow (m^3/s) and MAD (m^3/s) compared to DFO's Framework to Support Flow Requirements to Support Fisheries in Canada (DFO, 2013b). • Water withdrawn compared to available under-ice lake volume (m^3). • Flow velocity (m/s) in culverts to meet fish passage requirements for fish species present. • Visual inspection of culverts to verify they meet design specifications. • Number (count) of fish entrained or impinged. • Number (count) of fishers using road to access fishing locations (voluntary).

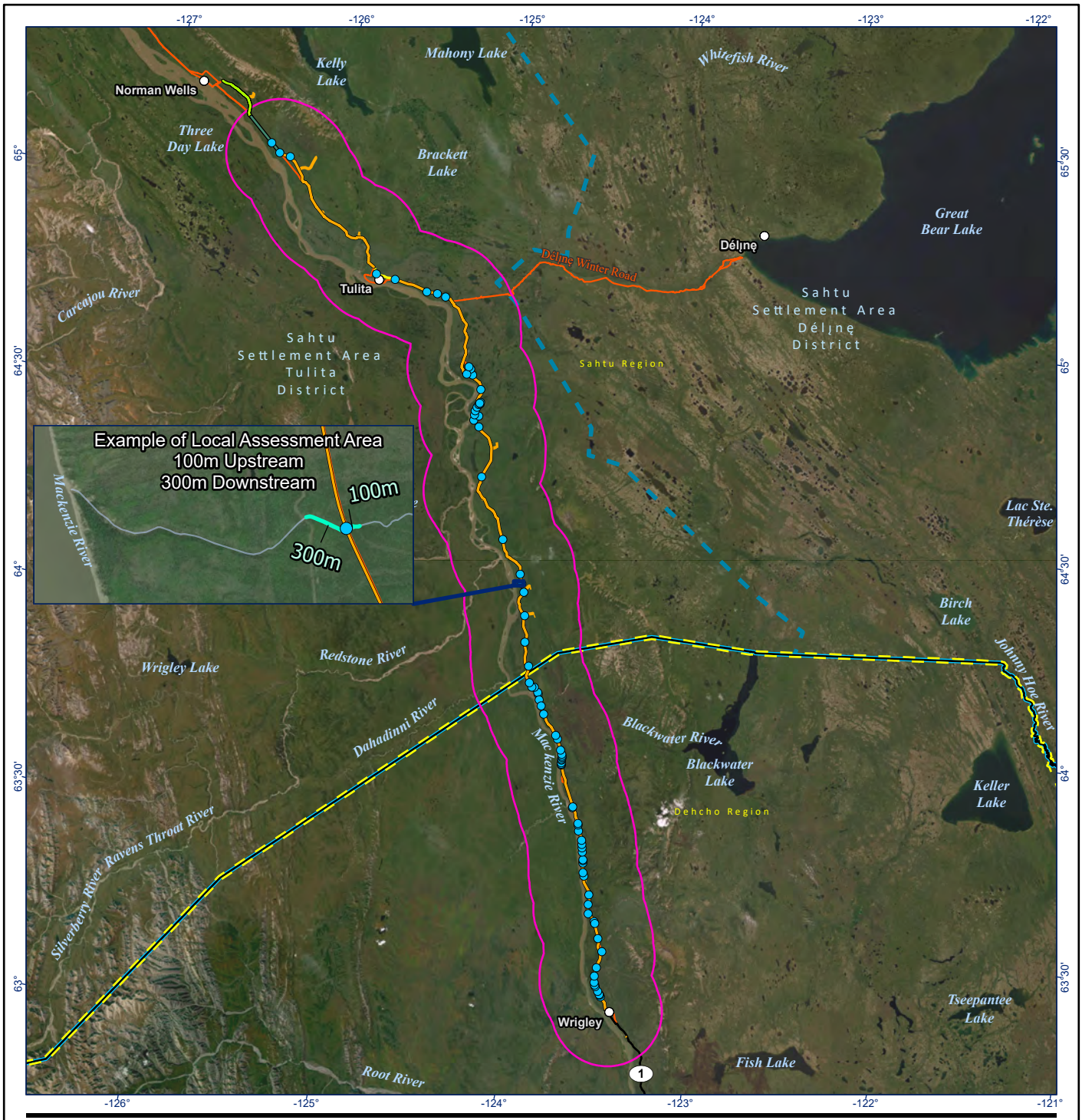
Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in fish health (cont'd)	• Residue on quarry material from the use of ammonium nitrate explosives in quarry operations may affect fish health due to negative changes in water quality. • Increased sediment in the water column due to highway construction, operations, and maintenance (e.g., dust, erosion, instream works).	• Qualitative evaluation of change in fishing pressure. • Instantaneous pressure change (kilopascals [kPa]) and, if spawning or incubation period, then also particle velocity (millimetres per second [mm/s]). • Turbidity using Nephelometric Turbidity Units (NTU) or total suspended solids (TSS) measured levels in accordance with CCME guidelines. • Measurement of water chemistry parameters, if needed, against CCME guidelines.

17.1.4 Boundaries

17.1.4.1 Spatial Boundaries

Three study areas are described as follows:

- **Project Development Area (PDA)**: The area of direct project disturbance within which physical works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 metres (m) wide highway ROW, and quarry/borrow sites with access roads on a 30 m ROW.
- **Local Assessment Area (LAA)**: Defined as the area 300 m downstream and 100 m upstream of each crossing structure proposed to be constructed as part of the Project. The crossing structure reference point is defined as the current highway route, as defined as the centerline of the alignment routing corridor (see Section 5.2.3). The LAA is where measurable project-related effects (direct or indirect) are expected to occur (Figure 17.1).
- **Regional Assessment Area (RAA)**: Defined by the area within approximately 15 kilometres (km) of the PDA. The RAA includes the Mackenzie River (Deh Cho), and associated tributaries and drainages. A 15 km buffer was selected to provide regional context for determining significance of Project-specific effects and potential cumulative effects to be assessed (Figure 17.1).



- Assessed Proposed Watercourse Crossing
- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Local Assessment Area
- Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres
(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by DS on 8/3/2023
TR by CS on 8/3/2023

Client/Project
144903025-0144 REVB

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
17.1

Title
Fish and Fish Habitat Assessment Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Imagery: Maxar
World Hillshade: Esri, USGS. Imagery date: 2021

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

17.1.4.2 Temporal Boundaries

Temporal boundaries used in the assessment reflect the specific project phases and activities:

- **Construction phase:** The Project is estimated to take approximately 10 years to construct, over a timeframe of up to 20 years. The schedule is conceptual and assumes the alignment will be constructed in three consecutive segments, beginning in approximately 2026: Wrigley to the Dehcho/Sahtu border (102 km); Tulita, south to the Dehcho/Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (PCAR) (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells sometime between 2041 and 2046.
- **Operations and maintenance phase:** The operations and maintenance phase will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the highway is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, and borrow sources and quarries used only for construction are included within the construction phase.

17.1.5 Residual Effects Characterization

Potential residual effects of the Project on fish and fish habitat are characterized in terms of direction, magnitude, geographic extent, timing, duration, frequency, and reversibility (as defined in Table 17.3). Quantitative measures or, where applicable, descriptions of qualitative measures, are provided in Table 17.3.

Table 17.3 Characterization of Residual Effects on Fish and Fish Habitat

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse:** A residual effect that moves measurable parameters of fish and fish habitat in a negative direction relative to baseline **Neutral:** No net change in measurable parameters for the fish and fish habitat relative to baseline
Likelihood	The probability that the residual effect will occur	**Unlikely:** The residual effect is almost certainly not to occur **Possible**: The residual effect could occur **Certain**: The residual effect will certainly occur

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Magnitude	The amount of change in measurable parameters or fish and fish habitat relative to existing conditions	**No Measurable Change:** No measurable change in the fish and fish habitat can be noted **Low:** A measurable change to fish habitat but would not affect the productivity or sustainability of fish populations **Moderate:** Measurable change to fish habitat and may have a short-term effect on productivity (< 1 year) but not affect long-term sustainability of fish populations **High:** Measurable change to fish habitat that could affect the long-term productivity and sustainability of fish populations
Geographic Extent	The geographic area in which a residual effect occurs	**PDA:** Residual effects are restricted to the PDA **LAA:** Residual effects extend into the LAA **RAA:** Residual effects interact with those of other projects in the RAA
Timing[1]	Considers when the residual effect is expected to occur, where relevant to fish and fish habitat	**No sensitivity:** Effect does not occur during sensitive life stage (e.g., fish spawning) or timing does not affect the VC **Moderate sensitivity:** Effect may occur during a lower sensitivity period of a critical life stage, such as pre- or post-spawning run **High sensitivity:** Effect occurs during a critical life stage (e.g., fish spawning and incubation)
Duration	The time required until the measurable parameter or fish and fish habitat returns to its existing condition, or the residual effect can no longer be measured	**Short-term:** The residual effect is restricted to the period of construction **Medium-term:** The residual effect extends through to the completion of reclamation activities **Long-term:** The residual effect will continue through operations and maintenance phase
Frequency	Identifies how often the residual effect occurs and how often during the project or in a specific phase	**Single event:** Occurs once, not anticipated to be repeated **Multiple irregular event:** Occurs at no set schedule **Multiple regular event:** Occurs at regular intervals **Continuous:** Occurs continuously
Reversibility	Pertains to whether a measurable parameter or fish and fish habitat can return to its existing condition after the project activity ceases	**Reversible:** The residual effect is likely to be reversed after activity completion and reclamation **Irreversible:** The residual effect is unlikely to be reversed

Note:

[1] In terms of Timing, the critical life stages include episodes (such as spawning, rearing, migration, overwintering, and feeding). Timing is also relevant to Indigenous activities, such as harvesting of fish.

17.1.6 Significance Definition

The potential effects of the Project are deemed significant if the productivity and sustainability of fish populations crossed by the Project and near to the Project are negatively affected. This may result if:

- Habitat alteration or destruction of fish habitat cannot be mitigated, avoided, or offset.
- Death of fish may result in loss of productivity or sustainability of a fish population.
- Blockage of fish passage may result in loss of productivity and sustainability of a fish population (for example, if fish cannot access spawning or overwintering areas).

Determination of whether effects are significant will be based on the determination of the effectiveness of avoidance and mitigation measures applied to project activities. Fish population abundance data is not available, and there were no observations indicating fish captured were in poor health for the watercourses along the project highway alignment. However, productivity of fish populations is directly linked to the health of fish habitat where productivity refers to the ability for a fish to complete its life cycle. The health of fish habitat can therefore be used as surrogate for measuring whether productivity of a fishery may be affected. Significance of effects will be determined based on the understanding of the effectiveness of avoidance and mitigation measures to break pathways of effects on fish and fish habitat. If productivity of a fishery is maintained and recruitment is unaffected, sustainability of the fishery should also be maintained.

17.2 Existing Conditions for Fish and Fish Habitat

17.2.1 Methods

A fish and fish habitat technical data report (K'alo-Stantec, 2022; Appendix 17A) was completed to address data gaps from the ToR (MVEIRB, 2015 [PR#66]). Data was obtained through a literature review of currently available information and previous field assessments along the Project alignment (5658 NWT Ltd. and GNWT 2011; Dessau 2012). The literature review incorporated review of relevant fisheries literature, Traditional Knowledge, and TLRU information. Fish and fish habitat surveys of watercourses proposed to be crossed by the Project were conducted in the fall of 2020 and 2021. Detailed information on field methodology is provided in K'alo-Stantec (2022) in Appendix 17A.

17.2.2 Overview

Fishing is an important cultural and social activity in the Sahtu Region (SLUPB, 2023; Auld and Kershaw, 2005) as well as in the Dehcho Region (Dessau, 2012 [PR#13]). The Mackenzie River (Deh Cho) is an important area for fish harvesting but lakes are also fished (Sahtu Heritage Places and Sites Working Group, 2000; Dehcho Land Use Planning Committee [DLUPC], 2006). Other rivers and watercourses reported as important for fish harvesting include Great Bear River (TRRC, 2022; NWRRC, 2023), Blackwater River (Auld and Kershaw 2005), Birch Creek, Oscar Creek, Bluefish Creek, and Sucker Creek (NWRRC, 2023).

Through the Project-specific engagement program, a review of publicly available literature, and project-specific TLRU studies, participants identified 20 fishing locations and areas of interest to fish and fish habitat relative to the Project within the PDA, LAA, and RAA, as described in Table 17.4.

Table 17.4 Fish Harvesting Locations Identified by Indigenous Governments, Indigenous Organizations and Other Affected Parties Relative to the Project

Location	Within LAA	Within RAA[2]	Identified By:
Pehdzéh Kį N'deh area[1]	✓*	✓	Pehdzéh Kį First Nation; Dehcho First Nations; Sahtu Dene and Métis
Sahtu Region	✓*	✓	Sahtu Dene and Métis
Great Bear River near Tulita (fishing area)	✓	-	TRRC
Great Bear River (as it intersects with the LAA and RAA) (fishing)	✓	✓	Communities in the Sahtu Region (SRRB); Elders in the K'ásho Got'ıné and Tulít'a regions; TRRC; NWRRC
Ochre River (fish spawning site)	✓*	-	Pehdzéh Kį First Nation; Dehcho First Nations
Blackwater River (fish spawning site; fishing)	✓*	-	Pehdzéh Kį First Nation; Dehcho First Nations; Sahtu Dene and Métis
Hodgson Creek (Near Wrigley)	✓*	-	Pehdzéh Kį First Nation
Mackenzie River (Deh Cho) around Norman Wells[3]	✓	✓	Sahtu Dene and Métis
Mackenzie River around Tulita[4] (fishing sites)	✓	✓	Sahtu Dene and Métis
Mackenzie River (Deh Cho)(south of Wrigley) (fishing sites)	-	✓	Pehdzéh Kį First Nation; Dehcho First Nations
Dehdéleıę Tué (Sucker Lake/ Three Day Lake)	-	✓	Sahtu Dene and Métis
Bluefish Creek (fishing and spawning site)	-	✓	NWRRC
Oscar Creek (fishing site)	-	✓	NWRRC
Sucker Creek (fishing site)	-	✓	NWRRC
Birch Creek (fishing site)	-	✓	NWRRC
Windy Island	✓	✓	Sahtu Dene and Métis
Little Bear River	-	✓	Sahtu Dene and Métis
Redstone River	✓	✓	Community engagement
Lakes surrounding the Tulita area (fish spawning)[5]	✓	✓	TRRC

Location	Within LAA	Within RAA[2]	Identified By:
Trout Lake (fishing site)	✓*	✓	NWRRC
Canyon Creek	-	✓	NWRRC
Christmas Creek	-	-	Community engagement
Tate Lake	-	-	Community engagement
Jackfish Lake	-	✓	Community engagement

Notes:

[1] Pehdzéh Kį N'deh area as described in DLUPC, 2006

[2] Occurs within the RAA outside the LAA and PDA

[3] Specific locations were not identified in the report – location identified as Norman Wells

[4] Specific locations were not identified in the report – location identified as Tulita

[5] Specific locations were not identified in the report – location identified as Tulita

* May occur within PDA

Sources: 5658 NWT Ltd. and GNWT, 2011 (PR#16); Auld and Kershaw, 2005; Dessau, 2012 (PR#13); EBA, 2006; Golder, 2015; IMG-Golder Corporation, 2006; NWRRC, 2023; TRRC, 2019; TRRC, 2022; SLUPB, 2013; DLUPC, 2006; project-specific Engagement program (2021-2023)

The harvesting of whitefish species are important in the Sahtu (Auld and Kershaw, 2005) and Dehcho (Dessau, 2012 [PR#13]) regions, although other fish species are also harvested in the RAA such as Arctic grayling (*Thymallus arcticus*), walleye (*Sander vitreus*), Northern pike (*Esox lucius*), trout (*Salvelinus spp.*), suckers (*Catostomus spp.*), and salmon (*Oncorhynchus spp.*) (TRRC, 2022; NWRRC, 2023).

Available TLRU information also indicated that fish are an important resource for harvesting and there are important spawning areas within the LAA (TRRC, 2022; Section 3.2.1 in Appendix 17A). Spawning areas within the RAA identified during community engagements include Ochre River and Blackwater River (DLUPC, 2006), and Canyon Creek and Bluefish Creek (NWRRC, 2023).

A total of 92 crossings have been identified along the project alignment (Figure 17.1 and Appendix 5A) to be crossed using culverts. Crossings include watercourses, intermittent drainages, and wetlands. Fish captures have been reported at 5 watercourses, while 59 watercourses had the potential to at least support fish on a seasonal basis. Another 22 watercourses were determined to be unlikely to provide fish habitat due to no defined channels and lack of presence or only isolated ponding of water. It is unknown whether four of the watercourses provide fish habitat as they were not assessed (K'alo-Stantec, 2022, Appendix 17A).

A total of 33 fish species had been documented within the RAA (K'alo-Stantec, 2022, Appendix 17A). Of these 33 species, only 19 have been reported in watercourses crossed by the Project (Table 17.5). Large-bodied fish (e.g., Arctic grayling, northern pike, burbot, whitefish species) have only been reported (K'alo-Stantec, 2022, Appendix 17A) in four of the watercourses to be crossed by the Project:

- Four Mile Creek
- Twelve Mile Creek
- Prohibition Creek
- Unnamed Watercourse at kilometre marker (KM) 774.1 (Identified as KM 774.04 in K'alo-Stantec, 2022).

Prohibition Creek had the highest diversity of fish species (i.e., 13 species) and was the only watercourse to contain whitefish species. Except for the listed four watercourses, all other watercourses where fish have been reported contain six or less species, with most having only forage species present (K'alo-Stantec, 2022, Appendix 17A).

Table 17.5 Fish Species Reported in Watercourses Crossed by the Project

Common Name	Scientific Name
Arctic grayling (blue fish) [1]	*Thymallus arcticus*
Broad whitefish [1]	*Coregonus nasus*
Mountain whitefish [1]	*Prosopium williamsoni*
Round whitefish [1]	*Prosopium cylindraceum*
Cisco [1]	*Coregonus sp.*
Northern pike [1]	*Esox lucius*
Burbot (loche) [1]	*Lota lota*
Longnose sucker [1]	*Catostomus catostomus*
Brook stickleback	*Cluea inconstans*
Finescale dace	*Chrosomus neogaeus*
Pearl dace	*Margariscus margarita*
Emerald shiner	*Notropis atherinoides*
Spottail shiner	*Notropis hudsonius*
Fathead minnow	*Pimephales promelas*
Trout-perch	*Percopsis omiscomaycus*
Lake chub	*Couesius plumbeus*
Spoonhead sculpin	*Cottus ricei*
Slimy sculpin	*Cottus cognatus*

Notes:
"1" = fish commonly harvested
Data Sources: IORVL, 2004; K'alo-Stantec, 2022

A number of fish species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils have been identified in Table 17.6 following a review of publicly available literature (Appendix 11A) and shared through the project-specific engagement program and project-specific TLRU studies.

Table 17.6 Culturally Important Fish Species Identified by Indigenous Governments, Indigenous Organizations and Other Affected Parties

Common Name	Latin Name	Identified By
Arctic char[1]	*Salvelinus alpinus*	SRRB
Artic grayling (bluefish)	*Thymallus arcticus (Pallas)*	Pehdzéh Kį First Nation; Dehcho First Nations; Sahtu Dene and Métis; SRRB; NWRRC
Broad whitefish	*Coregonus nasus (Pallas)*	Pehdzéh Kį First Nation; Dehcho First Nations; SRRB; NWRRC
Burbot (loche)	*Lota lota*	Pehdzéh Kį First Nation; Dehcho First Nations; Sahtu Dene and Métis; SRRB; NWRRC
Bull trout	*Salvelinus malma*	SRRB
Chum salmon (dog-face salmon)	*Oncorhynchus keta (Walbaum)*	Pehdzéh Kį First Nation; Dehcho First Nations; SRRB; NWRRC
Dolly Varden	*Salvelinus confluentus*	SRRB
Coney (Inconnu)	*Stenodus leuichthys (Güldenstadt)*	Pehdzéh Kį First Nation; Dehcho First Nations; Sahtu Dene and Métis; SRRB; NWRRC
Jackfish/northern pike	*Esox lucius (Linnaeus)*	Pehdzeh First Nations; Dehcho First Nations; SRRB
Lake cisco	*Coregonus artedii (Lesueur)*	Pehdzéh Kį First Nation; Dehcho First Nations; SRRB
Sculpin	*Cottus sp.*	Community engagement
Lake trout	*Salvelinus namaycush*	Pehdzéh Kį First Nation; Dehcho First Nations; Sahtu Dene and Métis; SRRB
Lake whitefish (crooked back)	*Coregonus clupeaformis (Mitchill)*	Pehdzéh Kį First Nation; Dehcho First Nations; Sahtu Dene and Métis; SRRB; NWRRC
Longnose sucker	*Catostomus catostomus (forster)*	Pehdzéh Kį First Nations; Dehcho First Nations; SRRB
Mountain whitefish	*Prosopium williamsoni*	Pehdzéh Kį First Nations; Dehcho First Nations
Pickerel/walleye	*Stizostedion vitreum (Mitchill)*	Pehdzéh Kį First Nations; Dehcho First Nations; Sahtu Dene and Métis; SRRB; NWRRC

Common Name	Latin Name	Identified By
Round whitefish	*Prosopium cylindraceum (Pallas)*	Pehdzéh Kı̨ First Nations; Dehcho First Nations
Trout-perch	*Percopsis omiscomaycus (Walbaum)*	Pehdzéh Kı̨ First Nations; Dehcho First Nations
White sucker	*Catostomus commersoni (Lacépède)*	Pehdzéh Kı̨ First Nations; Dehcho First Nations

Note:

[1] Arctic char are not present in the Mackenzie River (Deh Cho) system

Sources: Auld and Kershaw, 2005; IMG-Golder Corporation, 2006; NWRRC, 2023; SRRB, 2021b; SLUPB, 2022; DLUPC, 2006; project-specific engagement program (2021-2023)

Two fish species within the RAA, bull trout (*Salvelinus confluentus*; Western Arctic population) and Dolly Varden (*Salvelinus malma*), are considered populations of Special Concern under SARA (Government of Canada [GOC], 2022). Both species are listed as "sensitive" in the Northwest Territories (Working Group on General Status of NWT Species, 2021). Sensitive species are not at risk of extinction or extirpation but may require special protection to prevent them from becoming at risk. These species are ranked as medium priority for further consideration (Working Group on General Status of NWT Species, 2021). Arctic grayling (*Thymallus arcticus)*, inconnu (*Stenodus leucichthys*), and Arctic cisco (*Coregonus autumnalis*) have historical presence in the RAA and are listed as "sensitive" (Working Group on General Status of NWT Species, 2021). Species listed as "special concern" or "sensitive" have no additional regulatory requirements associated with them under territorial or federal legislation. These four species of management concern are unlikely to be present or to use fish habitats within the Project's LAA:

- Dolly Varden are unlikely to occur within tributaries of the Mackenzie River (Deh Cho) within the project RAA. The southern range of the northern population of Dolly Varden is the Gayna River, which is located downstream of Norman Wells and beyond the RAA. Dolly Varden have been reported in previous studies conducted within the RAA; however, these fish were likely misidentified bull trout (Reist et al., 2002).
- Bull trout in the eastern tributaries of the Mackenzie River (Deh Cho), such as those along the project alignment, are likely individuals from tributaries on the west side of the Mackenzie River (Deh Cho) migrating to potential feeding or overwintering areas (Mochnacz et al., 2013). Bull trout prefer to spawn in small, steep gradient streams with gravel substrate (Mochnacz et al., 2013). Bull trout have been reported in a tributary to the Redknife River and the Great Bear River (Mochnacz et al., 2013), however the small size of most watercourses (drainage areas of less than 10 km) along the Project alignment and poor overwintering potential suggests bull trout would not occur in most of these watercourses.

- Inconnu and Arctic cisco prefer large river systems and are not known to migrate up small tributaries of the Mackenzie River (Deh Cho), such as those that would be crossed by the Project. Inconnu are found throughout the Mackenzie River (Deh Cho) and Great Slave Lake (Stephenson et al., 2005; Scott and Crossman, 1998) while Arctic cisco have been reported as far south as the Liard River (Sawatzky et al., 2007). Larval Arctic cisco are swept downstream to the Mackenzie River (Deh Cho) delta and along the Beaufort Sea coast to nursery areas before returning to the Mackenzie River (Deh Cho) and its larger tributaries, such as the Great Bear River, to spawn (Evans et al., 2002).
- Arctic grayling is present in some larger watercourses to be crossed by the Project. Spawning occurs over gravel and cobble bottoms in the spring as ice-cover begins to break up, (Scott and Crossman 1998). Young-of-the year remain in their natal streams for up to 15 months (Ford et al. 1995). Adults may move into larger river or lakes to overwinter (Scott and Crossman 1998).

Watercourses crossed by the Project in both the Sahtu and Dehcho regions are mainly small unnamed watercourses with small drainage areas, typically less than 10 square kilometers (Tetra Tech, 2021, 2022). Water depths of watercourses in the Sahtu Region were typically less than 0.5 m while those in the Dehcho Region were typically less than 1 m. In both regions, water depths over 1 m were either associated with wetland areas or beaver impoundments. The shallow depth of these watercourses suggests they would freeze to the bottom during winter and therefore would not provide overwintering habitat.

Based on a desktop review of existing information and field assessments, 37 of the 41 potential watercourse and wetland crossings within the Sahtu Region were either confirmed fish habitat or have fish habitat potential. Most of the watercourses which have fish habitat potential likely only support forage fish species. The exceptions are Twelve Mile Creek, Four Mile Creek, and Prohibition Creek. Twelve Mile Creek and Four Mile Creek are known to provide suitable habitat for Arctic grayling (*Thymallus arcticus*), northern pike (*Esox Lucius*), and burbot (*Lota lota*). Prohibition Creek provides habitat for Arctic grayling, northern pike, and several whitefish species (*Coregonus sp.*) (K'alo-Stantec, 2022; Appendix 17A).

In the Dehcho Region, desktop assessments of 49 watercourses or wetlands were conducted, and supplementary field assessments were conducted in September 2020. Field assessments focused on 25 locations where there was no existing bridge crossing. Of the 49 watercourses and wetlands:

- Seventeen were unlikely to provide fish habitat due to a lack of connectivity or flow.
- Four watercourses could not be assessed at the time due to freeze-up occurring and it is unknown if they provide fish habitat.
- Twenty-six watercourses afford fish habitat or have fish habitat potential. An unnamed watercourse at KM 774 is known to support Arctic grayling; however, most of the watercourses with fish habitat potential likely only support forage fish species.

Site-specific habitat descriptions of watercourses to be crossed by the Project found in the technical data report (K'alo-Stantec, 2022; Appendix 17A).

There are no fish advisories for human consumption within the RAA related to contaminants (GNWT, 2022).

It is not uncommon for wild fish species to have parasites; however, high parasite infestation may affect fish health (Iwanowicz 2011). There are no reports of abnormal levels of parasites in fish within the RAA. Common parasites found in freshwater fish in the Northwest Territories are listed by Stewart and Bernier (1999).

Other than in waters overlying Sahtu Lands where Sahtu Dene and Métis have exclusive rights to fish commercially, there are no exclusive rights to fish granted to land claim beneficiaries within the RAA. Guiding and outfitting opportunities are found within the RAA for large-bodied fish species (e.g., Arctic grayling, northern pike); however, watercourses crossed by the Project are small and unlikely to support large-bodied fish or only juveniles of large-bodied fish, and therefore do not afford good guiding or outfitting opportunities. Recreational fishing likely occurs primarily in the Mackenzie River (Deh Cho) or larger systems along the project alignment, such as the Blackwater River. Most watercourses along the project alignment are too small to provide fishing opportunities.

The RAA is located within Zone 2 for the identification of the Northwest Territories restricted activity timing windows for the protection of fish and fish habitat (DFO, 2013a). Restricted activity timing windows are determined based on species presence and spawning habitat potential within waterbodies. The following restricted activity timing windows apply to watercourses crossed by the Project:

- **April 1 to July 15:** Most watercourses crossed by the Project provide habitat potential for spring- and summer-spawning fish.
- **December 1 to July 15:** Twelve Mile Creek and Four Mile Creek (Sahtu Region) support spring-spawning species and burbot, which spawn in winter.
- **August 15 to July 15:** Prohibition Creek supports spring-, summer-, and fall-spawning fish species.

17.3 Project Interactions with Fish and Fish Habitat

For each potential effect, Table 17.7 identifies the physical activities and components of the Project that can interact with fish and fish habitat. Interactions that can result in effects on fish and fish habitat within the LAA or RAA are indicated by a check mark. These interactions are discussed in detail in Section 17.4 in the context of effects pathways, standard and project-specific mitigation, and residual effects. A justification for activities not expected to interact with fish and fish habitat is provided following the table.

Project schedules and activities for the construction phase and the operations and maintenance phase are described in detail in Sections 5.4 and 5.5, respectively. Project-related accidents and malfunctions are not considered Project interactions and are described in Chapter 25.

Table 17.7 Project-Environment Interactions with Fish and Fish Habitat

Physical Activities	Timing	Environmental Effects	
		Change in Fish Habitat	Change in Fish Health
Construction Phase			
Mobilization of equipment, materials, and fuel, resupply, and demobilization	Summer and winter	-	✓
Establishment and operation of camps	Year-round	-	✓
Site preparation of ROW, access, and workspaces	Winter	✓	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	-	✓
Material haul	Year-round	-	✓
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓	✓
Culvert installations	Summer or winter	✓	✓
Road base placement, compaction, and surfacing	Summer	-	✓
Water withdrawal to support construction activities	Year-round	-	✓
Closure and reclamation of Mackenzie Valley Winter Road (MVWR) and temporary borrow sources/quarries, camps, and workspaces	Summer	-	✓
Employment and contracted goods and services[1]	Year-round	-	✓
Operations and Maintenance Phase			
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	-	✓
Material haul and stockpiling	Summer	-	✓
Operation of and activities at maintenance yards	Year-round	-	✓
Water withdrawal for dust control	Summer	-	✓
Employment and contracted goods and services[1]	Year-round	-	✓
Presence and public use of the highway	Year-round	✓	✓
Highway and access road maintenance including snow clearing, repair, grading, dust control	Year-round	✓	✓
Vegetation control	Summer	✓	✓
Bridge and culvert maintenance	As needed	✓	✓

Notes:

✓ = Potential interaction

– = No interaction

[1] Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, "Employment and contracted goods and services" have been introduced as an additional component under each project phase.

The potential interactions between project activities and the environment were considered for the construction phase and the operations and maintenance phase of the Project. The identification of project activities and their potential interactions was based on engagement with Indigenous Governments, Indigenous Organizations, and other affected parties, the professional judgment of technical specialists involved in the assessment, and a review of existing conditions. The selection of interactions is also informed by the potential effects and effects pathways for fish and fish habitat as described in Section 17.1.3.

17.4 Assessment of Residual Effects on Fish and Fish Habitat

Based on project interactions with the environment identified in Table 17.7, the Project may affect the fish and fish habitat. Potential effects, effect pathways (Table 17.2), and mitigation measures that will reduce or eliminate the effects on fish and fish habitat are identified in Table 17.8. Potential residual effects and associated analytical assessment techniques are described in subsequent subsections.

Table 17.8 Potential Effects and Mitigation Measures for Fish and Fish Habitat

Effect Name	Effect Pathway	Mitigation Measures
Change in Fish Habitat	• Loss or alteration of riparian area	• The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent practical.
		• Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the ROW and approved access roads).
		• A buffer strip of undisturbed vegetation of at least 30 m wide will be maintained between the highway ROW and other areas to be cleared.
		• Riparian vegetation will be maintained whenever possible.
	• Loss or alteration of fish habitat below the ordinary high water mark (OHWM)	• All temporary crossings will follow DFO's Code of Practice for Temporary Fords (DFO, 2022a) and/or Ice Bridges and Snow Fills (DFO, 2022b).
		• Temporary crossings will be constructed perpendicular to the watercourse.
		• Snow fill temporary crossings will be constructed of clean snow fill.
		• Snow fill crossings will be v-notched prior to the spring melt/freshet before April 1 each year.
		• Temporary bridges, if required, will not be placed below the OHWM.
		• Culvert maintenance will follow the DFO Code of Practice for Culvert Maintenance (DFO, 2022c).
		• Instream work will be limited, to the extent possible.
		• Rip rap will be free of silt and other debris.

Effect Name	Effect Pathway	Mitigation Measures
Change in Fish Habitat (cont'd)		• Rip rap repair and culvert construction will be timed to avoid restricted activity periods for fish as applicable to the watercourse. Rip rap will be free of silt and other debris.
		• Grading of stream banks at approaches shall be limited, where possible. Rip rap repair and culvert construction will be timed to avoid restricted activity periods for fish as applicable to the watercourse.
		• The objective of site closure will be to approximate pre-development conditions to the extent possible. Grading of stream banks at approaches shall be limited, where possible.
		• Temporary isolation will occur for the placement of rip rap and culverts and will follow the Interim Code of Practice: Temporary Cofferdams and Diversion Channels (Interim) (DFO, 2020a).
		• Beaver dam removal will be done in accordance with the Code of Practice: Beaver Dam Breaching and Removal (DFO, 2022d) and conditions of the GNWT General Wildlife Permit.
	• Barriers to fish passage	• Culverts will be designed and constructed to maintain water flow and fish passage.
		• Ice in culverts will be thawed by steaming, where needed to maintain flow.
		• Flow velocity (metres per second [m/s]) in culvert will meet fish passage requirements for fish species present based on Di Rocco and Gervais (2023).
		• Water flow and fish passage will be maintained during construction.
Change in Fish Health	• Water withdrawal	• Winter water withdrawal will be within the limits of water licences and in accordance with the DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013a) and other appliable guidance (e.g., DFO 2013b).
		• Water withdrawal will be in accordance with DFO's Interim Code of Practice: End-of-pipe Fish Protection Screens for Small Water Intakes in Freshwater (Interim) (DFO, 2020b).
	• Increased fishing pressure due to improved access	• Pullouts will not be located near watercourses with sport fish.
		• Project personnel will be prohibited from hunting and fishing while housed in work camps for the Project.
	• Use of explosives near waterbodies	• Only material with low ARD/ML potential will be used for the Project.
		• An Explosives Management Plan (ExMP) will be developed and implemented. Blasting will not occur within 100 m of fish-bearing waterbodies such that instantaneous pressure will be less than 50 kPa where fish may be present and particle velocity will be less than 13 mm/s near a spawning bed where eggs or larval fish may be present.

Effect Name	Effect Pathway	Mitigation Measures
Change in Fish Health (cont'd)	• Inadequate culvert design creating high water velocities and turbulence in culvert, resulting in injury to fish	• Flow velocity (metres per second [m/s]) in culvert will meet fish passage requirements based on Di Rocco and Gervais (2023) for fish species present.
Change in Water Quality	• Increased sedimentation	• In-water construction activities will be conducted during no or low flow periods where possible and with erosion control mitigation in place. Sediment and erosion control measures will be regularly inspected to confirm they are performing as intended.
		• Ponded water will be directed away from existing waterbodies.
		• Sediment control measures will be implemented per the GNWT Erosion and Sediment Control Manual (GNWT, 2013) and will be in place prior to construction activities and before the spring melt/freshet.
		• Excavated spoil material will be disposed of at least 30 m from the watercourse. Sediment control measures will be implemented per the GNWT Erosion and Sediment Control Manual (GNWT, 2013) and will be in place prior to construction activities and before the spring melt/freshet.
		• Material stockpiles will be kept a minimum of 30 m from a watercourse or waterbody with the appropriate erosion control mitigation in place to prevent sediment from entering a watercourse or waterbody.
	• Accidental spills	• Fuel handling and refueling will be in accordance with an Operating Procedure to be included in the SCP Standard Operating Procedures. Fuel will be stored in containers with secondary containment capable of containing 110% of the largest container.
		• A Spill Contingency Plan (SCP) will be developed and implemented.
		• Areas and containers used to store project wastes will be constructed, operated, and maintained in a manner to prevent waste from discharging to the surrounding environment. Fuel handling and refueling will be in accordance with an Operating Procedure to be included in the SCP Standard Operating Procedures.
		• Maintenance yards will have a liner of concrete installed under areas of vehicle storage and maintenance. Areas and containers used to store project wastes will be constructed, operated, and maintained in a manner to prevent waste from discharging to the surrounding environment.

Effect Name	Effect Pathway	Mitigation Measures
Change in Water Quality (cont'd)		• Vehicles parked for more than 2 hours will use drip trays. Maintenance yards will have a liner of concrete installed under areas of vehicle storage and maintenance.
		• Machinery will arrive on-site and will be maintained in a clean condition and free of invasive species and noxious weeds. Vehicles parked for more than 2 hours will use drip trays.
		• Washing, refueling, and servicing machinery and storage of fuel and other materials for machinery will be conducted a minimum of 100 m from the high -water mark and in a manner to prevent any deleterious substances from entering the water. Machinery will arrive on-site and will be maintained in a clean condition and free of invasive species and noxious weeds.
		• Machinery will not be left in any waterbody.

17.4.1 Analytical Assessment Techniques

The general approach to assessing potential effects on fish and fish habitat follows the sequence and methods outlined in Chapter 4 (assessment methods). A conservative approach is used to address uncertainty, which increases confidence in the final determination of significance.

Watercourses where no fish were captured during field surveys and no prior fish data was available were identified as fish habitat based on habitat potential.

Watercourses were considered unlikely to provide fish habitat if:

- There was no connectivity to another waterbody, based on satellite imagery
- The drainage conveyed seasonal surface water runoff (i.e., snow melt, rain events) but was otherwise dry

The assessment used a habitat-based approach based on potential fish species presence and their life history requirements (e.g., spawning, rearing, migration, overwintering). Fisheries and Oceans Canada's Pathways of Effects (DFO, 2018) were used to identify effects pathways which may occur as a result of project activities. Mitigation measures were identified which either break the effect or reduce the magnitude of the effect. Detailed habitat assessment methodology is provided in K'alo-Stantec (2022). No SARA-listed fish species are reported for watercourses crossed by the Project. Species listed as SARA species within the RAA are all listed as Special Concern and as such have no regulatory requirements associated with them, therefore these species would be assessed like all other fish species occurring in the PDA. Past professional experience from assessments conducted on other linear projects (e.g., Inuvik to Tuktoyaktuk Highway) was also used to inform the significance of effects.

17.4.2 Change in Fish Habitat

Change in fish habitat may result during the construction and operations and maintenance phases of the Project, as shown in Table 17.8. The proposed works has potential to alter instream habitat, riparian vegetation (i.e., cover), and stability of the watercourse bed and banks. The severity of the potential residual effect is determined by physical factors (e.g., channel width, flow characteristics, substrate type), construction timing, fish habitat potential, and fish species that are potentially present at the watercourse level.

17.4.2.1 Loss or Alteration of Riparian Vegetation

Riparian vegetation will be lost or altered at watercourse crossings. Loss of riparian habitat will occur along the width (9 m) of the roadway plus generally 5.5 m on each side to account for embankment slopes, at each watercourse crossing location (at embankment height of 1.8 m and 3:1 sideslope. Alteration of riparian habitat will be through the trimming of vegetation close to the ground along the 60 m ROW width. Where the project ROW follows the existing MVWR alignment, an approximately 20 m wide ROW has already been altered through regular vegetation control; therefore, an additional 40 m of alteration of riparian habitat will occur for these sections of the Project. Based on the current alignment route, the project route deviates from the existing MVWR alignment at four watercourse crossings; therefore, up to 31 m of riparian vegetation will be lost at these locations (60 m minus the 29 m of riparian habitat to be lost directly at the crossing location). Lost riparian vegetation extends 30 m outward from the watercourse banks. Maintenance of the ROW by trimming vegetation will be conducted periodically during highway operations.

Loss of riparian vegetation can lead to flow alterations, increased sedimentation, and reduced invertebrate abundance (Denbeste and McCart, 1984; Johansen et al., 2005). Overhanging riparian vegetation is important as it moderates water temperature through shading (Johansen et al., 2005; Sokolowski and Pratt, 2007). As riparian area within the ROW, except for the actual roadway, will only be trimmed, trimmed vegetation will still provide riparian functionality and benefits to fish habitat.

Vegetation clearing, which may occur in the riparian area, will only be to maintain that area affected during construction. No additional effects are anticipated from this activity.

The implementation of mitigation (Table 17.8) and best management practices will reduce the magnitude of anticipated residual effects.

17.4.2.2 Loss or Alteration of Fish Habitat Below the OHWM

During construction, the Project will result in loss of fish habitat through the permanent infilling around culvert installations. The loss of fish habitat will be limited to the footprint of the infilling around each of the culvert installations and remaining habitat within each watercourse will remain available to fish populations. The placement of riprap on the banks of the watercourses will result in the loss and alteration of fish habitat. In addition, there will be alteration of fish habitat as a result of the installation of culvert aprons on the upstream and downstream ends of culverts. Rip

rap used for bank stabilization and culvert will be free of or have low ARD/ML material. The placement of riprap will permanently alter fish habitat in the area surrounding each crossing location within the footprint of the bank stabilization and apron, changing the existing substrate and bank material composition. The permanently altered fish habitat will still be accessible to fish.

Culvert and bridge maintenance are not anticipated to further the loss or alteration of habitat (i.e., no increase in loss or alteration footprint from construction). If alteration or loss of habitat is anticipated due to maintenance activities, the works would be subject to territorial and federal approvals and would be submitted for review under a separate cover. The application of mitigation measures (Table 17.8) and best management practices will reduce, but are not anticipated to eliminate, residual effects.

17.4.2.3 Barriers to Fish Passage

Barriers to fish passage can occur through improper installation of culverts. Improper installation of culverts can result in perched culverts or increases in stream velocity, which can prevent fish passage and restrict access to important habitat areas (e.g., spawning habitat). Site-specific culvert design will take into account topography, road geometry, substrate material fish passage, and fish habitat. Best management practices for the installation of culverts have been established to reduce the potential for perched culverts. Culverts will be designed for fish passage based on swimming performance analyses by Di Rocco and Gervais (2023) for the fish species which may be present at any given crossing and season, with the lowest swimming performance ability to meet DFO fish passage requirements. Culvert designs will be reviewed and approved by DFO during the permitting process. Additional information on culvert design can be found in Chapter 5, Section 5.4.7.1.

Accumulation of debris in culverts may affect fish passage through a culvert; however, culvert maintenance can have a net positive effect on fish passage through the removal of debris.

With the implementation of best management practices and mitigation (Table 17.8), no residual effect is anticipated. Barriers to fish passage is not considered further in this assessment.

17.4.3 Change in Fish Health

The interpretation of change in fish health for this assessment refers to health of fish at an individual level and population level and can include injury and death of fish.

17.4.3.1 Water Withdrawal

Water withdrawal may occur through dewatering for isolation during construction (if the watercourses are flowing at the time of culvert installation), camp use, construction of travel lanes, compaction where water is used, and dust control. Potential for injury or death of fish may occur as a result of impingement against pump intakes or entrainment. Water withdrawal from waterbodies can lower water levels, which may limit fish habitat—especially overwintering habitat. Lower water levels can further limit overwintering habitat through reduced dissolved oxygen levels,

which affects fish health (Cott et al., 2008a, 2008b). Fish health may also be affected through water withdrawal activities, which can limit migration of fish and may prevent fish from accessing preferred habitat.

The potential effects from water withdrawal can be effectively mitigated. Pump intakes used for water withdrawal for instream isolations and project water requirements will follow DFO Interim Code of Practice for End-of-pipe Fish Protection Screens for Small Water Intakes in Freshwater (DFO, 2020b). Water withdrawals in waterbodies during winter will follow the DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut (DFO, 2010a) and water withdrawal from streams will meet low risk criteria (DFO, 2013b). A fish salvage of the isolated workspace will be completed prior to instream works. All applicable regulatory permits and authorizations will be obtained before the start of fish salvage and instream activities. Fish salvaged from isolated workspace prior to instream works and moved to an area of equivalent or greater habitat potential by a qualified fisheries biologist.

Residual effects on fish because of fish salvages will be of short duration (hours) and limited to stress. With the implementation of mitigation (Table 17.8), residual effects are anticipated to be negligible for this effect pathway and therefore are not considered further in this assessment.

17.4.3.2 Increased Fishing Pressure

During operation of the Project, there will be increased access to fish-bearing waters during the open water season. Increased access during the open water season may lead to increased fishing pressure, resulting in reduced stock levels. This effect would only occur at larger watercourses that support large-bodied fish; in particular, watercourses crossed by existing bridges. Arctic grayling is the most common large-bodied fish found in watercourses crossed by the Project and the most likely to be affected by an increase in fishing pressure. In the Fort McMurray area of Alberta, increased access and overfishing were considered the main cause of declining populations of Arctic grayling in the area (Valastin and Sullivan, 1997; Schwalb et al., 2015). The example in the Fort McMurray area may be extreme as highway volume is considerably higher in this area than what is projected by the Project (approximately 50 vehicles/day) and therefore has the potential for higher fishing pressure than would be expected as a result of the Project. Most watercourses along the Project only support forage fish, which are not typically targeted by fishing activities and would not be subject to increased fishing pressure. Other fish species of community concern, such as whitefish and trout, are largely absent from watercourses crossed by the Project, although they may be found at the mouth of these watercourses at the Mackenzie River (Deh Cho) and increased fishing pressure for these species is unlikely.

Increased fishing pressure within the Mackenzie River (Deh Cho) and larger lakes in the RAA would be limited. Access to the Mackenzie River (Deh Cho) would primarily be from communities connected to the Project, as there are limited opportunities to access the Mackenzie River (Deh Cho) from watercourses crossed by the Project. Most watercourses crossed by the Project are not navigable and therefore could not be accessed by boat. Access to lakes within the RAA would be limited to all-terrain vehicles or snow machines. As there is no direct access to lakes via the Project in summer and limited areas in which to park a vehicle and trailer, increased fishing pressure on

lakes that might affect fish populations is not anticipated. Access during the winter period has been available in the past from the MVWR, and access to additional lakes may become available during the construction phase, as suitable lakes are expected to be used as water sources. Potential increased fishing pressure on the Mackenzie River (Deh Cho) and lakes within the RAA is not anticipated to affect fish populations in these waterbodies.

17.4.3.3 Use of Explosives Near Waterbodies

Explosives will be used during quarry operations both during the construction and operations and maintenance of the Project. Explosives may also be used at up to 14 rock cut locations along the highway; however, rock cut locations are yet to be determined. All quarries to be used in the construction and operation of the Project are 1 km or greater from a waterbody, thereby reducing the potential for effects on fish and fish habitat. Overpressures of 100 kPa or more, or peak particle velocities of 13 mm/s or more during spawning or fish incubation periods, can lead to injury or death of fish (DFO, 2010b). Overpressure will be limited to no more than 50 kPa, as current guidelines of 100 kPa may not be protective of early life stages of fish (Godard et al., 2008), and peak particle velocity guidelines of less than 13 mm/s will be met. The potential effects on fish health from the use of quarry materials is discussed under changes in water quality (Section 17.4.4.2). Overpressure and peak particle velocity can be managed through the implementation of mitigation measures (Table 17.8) and best management practices; therefore, no residual effect is anticipated for this effect pathway and is not considered further in this assessment.

17.4.3.4 Inadequate Culvert Design

Inadequate culvert design can lead to high water velocities in culverts creating turbulence within the culvert. High levels of water turbulence can result in fish making contact with the culvert, causing injury to the fish. Culvert design for fish passage based on swimming performance analyses by Di Rocco and Gervais (2023) for fish species which may be present at any given crossing with the lowest swimming performance ability should reduce the potential for levels of in-culvert turbulence, which could lead to injury to fish; therefore, no residual effect is anticipated for this effect pathway and is not considered further in this assessment.

17.4.4 Change in Water Quality

Water quality can be affected through erosion and sedimentation during construction (e.g., vegetation removal, grading, excavation, and change in flow where instream works occur) and operations and maintenance of the Project (e.g., vegetation management), or through accidental spills into watercourses. The effects of spills are assessed in Chapter 25 and are not assessed further here.

17.4.4.1 Increased Sedimentation

Increases in sediment in watercourses can damage gills, which affects fish health, or smother fish eggs, which results in death to fish. Reduced visibility in the water column due to increased suspended sediment can also reduce fish feeding success, thereby potentially affecting fish health. Construction at watercourses will be conducted in the dry. Where flowing water is present, temporary instream isolations will be used to allow work to be conducted in the dry. Isolation limits the potential for sediment entering the water column during construction activities, such as excavation of the beds and banks for the placement of culverts and rip rap. Isolation methods may produce short duration sediment pulses when installing and removing isolation structures, resulting in potential changes to surface water quality due to increased concentrations of total suspended sediment; however, this effect is expected to be short-term (1 to 10 hours) with a rapid return to background levels (Reid and Anderson, 2000; Reid et al., 2002) and expected to be limited to the LAA. In addition, these pulses of sediment can typically be mitigated using erosion and sediment controls described in Table 17.8. Rip rap underlain by geotextile material placed at water crossing locations is designed to prevent erosion that could result in sediment entering a watercourse.

Temporary vehicle crossings can also lead to the introduction of sediment to a watercourse. Mitigation measures related to temporary vehicle crossings are described in Table 17.8, the ESCP (Volume 5), and applicable measures in DFO's Code of Practices for Temporary Stream Crossings (DFO, 2022a, 2022b), which will be followed to mitigate sedimentation of watercourses.

Construction of the Project and use of the highway by the public once constructed can cause dust to become airborne and some of this material to become deposited within a watercourse. This dust may result in increased sedimentation within watercourses. Dust control measures will be implemented during construction and operation of the Project.

The management of sedimentation is undertaken through the implementation of mitigation measures (Table 17.8) and best management practices detailed in the ESCP (Volume 5), which are expected to be effective at mitigating changes to water quality as applicable to fish health and fish habitat such that the effect would be neutral and typically only measurable for several minutes; therefore, residual effects are anticipated to be negligible. This potential effect is not assessed further here.

Additional information on water quality can be found in Chapter 16.

17.4.4.2 Use of Quarry Materials

The use of quarry material may have ARD potential or contain ammonia/nitrate residue from the use of explosives, which can reduce water quality and, in turn, affect fish health.

With the application of mitigation measures (Table 17.8) and best management practices, changes in water quality due to the use of quarry materials can be avoided; therefore, no residual effects are anticipated. This effect pathway is not considered further in this assessment.

17.4.4.3 Mitigation

Standard industry best practice and avoidance measures, along with specific mitigation (Table 17.8), will be implemented during construction and operations and maintenance of the Project to reduce effects on fish and fish habitat. Additional mitigation may be required through the issuance of licences and permits through the regulatory process. Key mitigation measures used to avoid or reduce potential effects on fish and fish habitat include:

- Culverts will be designed and constructed to maintain water flow and fish passage.
- Culvert maintenance will follow the DFO Code of Practice: Culvert Maintenance (DFO, 2022c).
- Instream work will be limited to the extent possible.
- Temporary isolation will occur for the placement of rip rap and culverts (if flowing water is encountered) and will follow the interim DFO Code of Practice: Temporary Cofferdams and Diversion Channels (DFO, 2020a).
- Water flow and fish passage will be maintained during construction, including during any instream isolations.
- Beaver dam removal will be done in accordance with the DFO Code of Practice: Beaver Dam Breaching and Removal (DFO, 2022d) and conditions of the GNWT General Wildlife Permit.
- Water withdrawal will be in accordance with DFO Measures to Protect Fish and Fish Habitat (DFO 2022e) and the interim Code of Practice: End-of-pipe Fish Protection Screens for Small Water Intakes in Freshwater (DFO, 2020b).
- Water withdrawal will be within the limits of water licences and in accordance with the DFO Measures to Protect Fish and Fish Habitat (e.g., DFO, 2010, 2013a) and other applicable guidance (e.g., DFO 2013b).
- Sediment control measures will be implemented per the GNWT Erosion and Sediment Control Manual (GNWT, 2013) and will be in place prior to construction activities and before the spring melt/freshet.
- Material stockpiles will be kept a minimum of 30 m from a watercourse or waterbody with the appropriate erosion control mitigation in place to prevent sediment from entering a watercourse or waterbody.
- Riparian vegetation will be maintained whenever possible.
- Washing, refueling, and servicing machinery and storage of fuel and other materials for machinery will be conducted a minimum of 100 m from the high water mark and in a manner to prevent any deleterious substances from entering the water.

17.5 Residual Effects

Residual effects after the application of mitigation will occur through the loss and alteration of both riparian area and fish habitat below the OHWM. A residual effect on fish population health may occur if there is an increase in fishing pressure due to the operation of the Project.

17.5.1 Change in Fish Habitat

As described in Section 17.4.2, residual effects on fish habitat will occur through the loss and alteration of riparian habitat and fish habitat below the OHWM as a result of construction for the placement of culverts at crossings and ROW vegetation trimming.

17.5.1.1 Loss or Alteration of Riparian Area

Riparian habitat will be permanently lost along the 9 m width of the left and right banks to construct the roadbed at each crossing. The riparian areas at crossings that follow the MVWR alignment have previously been trimmed within its 30 m ROW. The Project's ROW will be 60 m and therefore an additional length of 30 m of riparian vegetation on each bank of the crossing will be trimmed. Alignment changes have been made which affect four crossings where riparian habitat was not previously altered. At these locations, the full 60 m ROW will be trimmed minus the 9 m width of the roadbed where riparian habitat will be lost (i.e., 51 m). Altered riparian habitat along the ROW at watercourse crossings due to trimming will retain ground vegetation in these areas and afford some riparian functionality, which benefits fish habitat.

The area of loss and alteration of riparian habitat includes the length of area affected extended to 30 m from the OHWM for each watercourse bank. The loss and alteration of riparian area at each crossing location is as follows:

- Loss of riparian habitat is 540 square metres (m^2)
- Altered riparian habitat for alignment on MVWR alignment is 1,800 m^2
- Altered riparian habitat for alignment that deviates from MVWR alignment is 3,060 m^2

Loss of riparian habitat where the roadbed is constructed will not result in increased sedimentation because the banks will be protected by rip rap to prevent erosion and sedimentation. For watercourses with unstable banks, rip rap will prevent sedimentation at these locations. In the ROW where riparian habitat will be altered, vegetation will be cropped but root masses will remain intact. This can help reduce erosion and sedimentation into adjacent watercourses.

Where riparian vegetation is altered, the banks of the watercourse will not be disturbed. These factors will reduce or negate potential sedimentation due to the alteration of riparian habitat while maintaining a level of riparian functionality. The removal of vegetation has the potential to affect water temperature and water flows; however, this is typically associated with larger clearings that occur through large-scale operations (e.g., past forestry practices) which may affect kilometres of riparian area along a watercourse. The loss of riparian vegetation as a result of the Project will be limited to the width of the highway roadbed at watercourse crossings.

A review of the potential effects of winter pipeline construction, which is similar in scale to a highway crossing, on fish and fish habitat in Hodgson Creek, found no effect on stream discharge, velocity, temperature, dissolved oxygen, or water chemistry (McKinnon and Hnytka, 1988). Changes in invertebrate supply are anticipated to be negligible due to vegetation being cropped and maintained in the ROW areas, and the small scale of riparian loss at the roadway. Following a review of literature, Cott et al. (2015) reported that where riparian vegetation removal can be localized and reduced, the resultant effects from a single linear development are likely negligible to the overall functioning of a stream if best management practices are followed. Installed culverts and rip rap will add some cover for small fish (e.g., forage fish) to negate part of the loss of overhead cover through riparian trimming.

The loss and alteration of riparian habitat will occur in the construction phase and periodic alteration of riparian habitat due to trimming during the operation and maintenance phase of the Project. The likelihood of the effects is certain and the direction is adverse. The effect is continuous, limited to the PDA, of low magnitude, and irreversible.

17.5.1.2 Loss or Alteration of Fish Habitat Below the OHWM

Loss of habitat is expected to occur from the infilling associated with culvert installation at watercourses and through the tie-in of rip rap in the stream bed for erosion and sediment control. The infilling of the sides of culverts is necessary to construct the roadbed of the highway. The effects due to the placement of rip rap can be mitigated through limiting the height of the rip rap protection, where feasible, and sizing of the rip rap used in culvert design (Fischenich, 2003). The area of habitat loss at each watercourse will be small in relation to the overall watercourse and similar habitat is widely available elsewhere in the watercourse. No limiting habitat features (e.g., spawning areas) will be lost that may result in reduced fish populations.

Alteration of habitat will occur at each watercourse crossing through rip rap placement to prevent bank erosion and for the aprons at both ends of the culvert. The alteration of habitat through rip rap can be beneficial for aquatic fauna. Coarse substrate the size of rip rap are limited or absent from watercourses crossed by the Project, and addition of rip rap can add complexity to the aquatic environment in these systems. Spaces between rip rap stones can provide velocity refuge and cover for aquatic invertebrates and small fishes (Fischenich, 2003).

Construction activities and resulting changes to fish habitat are not expected to disrupt sensitive life stages of fish. Limiting habitat features like spawning habitat for large-bodied fish would not be affected and spawning habitat for forage fish is largely available in the watercourses crossed by the Project. When construction occurs during the winter period, watercourses are expected to be frozen to the bottom with no fish presence. Construction activities that may occur during open water periods will be short-term. Similar habitat is available in each watercourse and will remain accessible to fish during the open water construction period.

Watercourses along the project highway alignment are largely undisturbed. The loss and alteration of fish habitat below the OHWM will occur through construction and continue during the operations and maintenance phase of the Project. The likelihood of an effect is certain with the direction of the effect adverse and limited to the PDA, but of low magnitude with the implementation of mitigation. The effect is long-term, continuous, and irreversible.

17.5.2 Change in Fish Health

A residual effect on fish health may occur if fishing pressure increases during construction and operation of the Project due to increased access at large-bodied fish-bearing waters. Most watercourses crossed by the Project do not provide fishing opportunities due to their small size and fish species found in these systems are predominantly forage fish. Increased fishing pressure is expected to occur during the open water seasons of operations and maintenance. The increase in fishing pressure could result in reduced fish stocks through overfishing, although likely limited to only Arctic grayling at major watercourse crossings (e.g., Ochre River, Blackwater River) and possibly those watercourses that are closer to communities. Fishing pressure at watercourses may be reduced by restricting construction workers from fishing during construction, avoiding constructing pullouts near watercourses containing large-bodied fish, and through educating users to the highway on maintaining healthy fish stocks.

Change in fish health populations due to increased fishing pressure may occur during the open water season of operations and maintenance of the Project. The likelihood of an effect is possible with the direction of the effect adverse and occurring within the LAA in systems containing large-bodied fish. The magnitude of the effect can range from moderate to high depending on fishing pressure at individual watercourses. The magnitude of the effect would be higher if fishing pressure increased during important migratory periods, such as spawning migrations. The frequency of the fishing pressure is anticipated to be irregular. The effect is reversible with the implementation of fishery management practices.

17.5.3 Summary of Residual Effects

Residual effects from the Project are anticipated for changes in fish habitat and potential changes to fish health as it pertains to the health of fish populations, which may result from increased fishing pressure at watercourses crossed by the Project. Residual effects characterization is provided in Table 17.9.

Table 17.9 Residual Effects on Fish and Fish Habitat

Residual Effect	Residual Effects Characterization*								
	Project Phase	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in Fish Habitat	C	A	CE	L	PDA	NS	LT	S	I
Change in Fish Habitat	O	A	CE	L	PDA	NS	LT	C	I
Change in Fish Health	C	A	P	L	LAA	NS	ST	IR	R
Change in Fish Health	O	A	P	L-H	LAA	MS	LT	IR	R

KEY

***** See Table 17.3 for detailed definitions

Project Phase:
C: Construction
O: Operations and Maintenance

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMC: No Measurable Change
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirement related to fish and fish habitat for identified species of interest and species at risk, and consideration of engagement input and incorporation of Traditional Knowledge. Where in-water construction timing windows for the protection of fish and fish habitat cannot be met, site-specific measures for protection of fish will be implemented, including those identified in the Draft FFHPP (Volume 5).

The design of the Project and mitigation measures for protection of fish and fish habitat will respect the values of the Petiniʔah (Bear Rock) CZ, Mio Lake CZ (which could be used for winter water withdrawal only), Norman Range SMZ, K'ąąlǫ Tué (Willow Lake Wetlands) SMZ and the Deh Cho (Mackenzie River) SMZ.

17.6 Assessment of Cumulative Effects on Fish and Fish Habitat

This sub-section assesses the potential cumulative effects arising from the Project. A cumulative effect occurs if, following mitigation, fish and fish habitat is affected, for the same effect, by both the Project and other projects and physical activities.

17.6.1 Residual Effects Likely to Interact Cumulatively

The Project has the potential to interact cumulatively with other linear projects which have watercourses draining into the Mackenzie River (Deh Cho). Those projects which have the potential to contribute to cumulative effects are identified in Table 17.10.

Table 17.10 Projects with the Potential to Contribute to Cumulative Effects in the RAA

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects	
	Change in Fish Habitat	Change in Fish Health
Past and Present Physical Activities and Resource Use (Base Case)		
Geotechnical	-	-
Oil, Gas & Seismic*	-	-
Infrastructure		
Mackenzie Valley Winter Road, including bridges and bridge-sized culverts	✓	-
Canyon Creek All Season Access Road	✓	✓
Norman Wells Pipeline	✓	-
Mackenzie Valley Fibre Link	✓	-
Prohibition Creek Access Road	✓	✓
Quarries and Borrow Sources	-	-
Mining & Exploration	-	-
Municipal Operations, including water, waste, power, and community development		
Wrigley Municipal Activities	-	-
Tulita Municipal Activities	-	-
Norman Wells Municipal Activities	-	-
Project-Related Physical Activities (Project Case)		
Mackenzie Valley Highway Project	✓	✓

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects	
	Change in Fish Habitat	Change in Fish Health
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)		
Quarries		
Dhu-1 Quarry	✓	-
Infrastructure		
Great Bear River Bridge	✓	✓
Oil and Gas	-	-

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = Includes support activities such as production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas.

17.6.2 Change in Fish Habitat

Other projects that have the potential to contribute to cumulative effects with the Project are linear projects which have crossings at watercourses draining into the Mackenzie River (Deh Cho). Projects such as the Great Bear River Bridge and Canyon Creek and Prohibition Creek access roads have localized residual effects on fish habitat, such as loss or alteration of fish habitat below the OHWM through culverts and rip rap, and loss and alteration of riparian area in their respective ROW. The MVWR can interact cumulatively at only four watercourse crossings where the Project's alignment has been altered, otherwise the Project overlays the MVWR alignment for the majority of its length. Once the Project is operational, the MVWR will no longer operate.

The Norman Wells Pipeline project has watercourse crossings that are buried; however, alterations of riparian areas are maintained through periodic trimming of the vegetation within its ROW. The Mackenzie Valley Fibre Link is also buried. Its ROW lies within the project ROW except where the project alignment has been altered, affecting crossings at four watercourses. Riparian alteration will be maintained through periodic trimming of the vegetation.

Cumulative changes to fish habitat from projects that include water withdrawal are not considered, since the Projects' contribution is considered negligible (Section 17.5.2).

17.6.2.1 Cumulative Effects Pathways

Effects from the loss or alteration of riparian areas may affect water temperature, nutrient inputs into watercourses, and invertebrate populations. For watercourses that are crossed by the Project, the Norman Wells Pipeline, and the fibre line, these effects could interact cumulatively on a single watercourse. For other projects that may interact cumulatively with the Project, the cumulative effect would be the potential loss of invertebrate prey items and nutrients into the Mackenzie River (Deh Cho). There would be no water temperature effects on the large volume of water flowing in the Mackenzie River (Deh Cho) due to the relatively small-scale riparian loss or alteration at each watercourse crossing, which would result in a localized effect on water temperature.

The infilling on the sides of culverts and installation of piers for the proposed Great Bear River Bridge will result in a loss of fish habitat. The placement of rip rap on the banks of the ROW adjacent to installed culverts and rip rap aprons on the ends of culverts will also result in alteration of fish habitat. The alteration of fish habitat can alter the functionality of that habitat either beneficially or detrimentally. As these works occur on separate individual watercourses, the pathway for cumulative effects will relate to the interchange of species and food supply between the Mackenzie River (Deh Cho) and these other systems.

There is no loss of fish habitat below the OHWM for crossings related to the Norman Wells Pipeline and fibre line projects. Alteration of fish habitat below the OHWM for both these projects has largely recovered to their natural state, except at some crossings where rip rap was used to prevent bank erosion at the crossing site.

17.6.2.2 Mitigation for Cumulative Effects

There are no new mitigation measures for cumulative effects. Projects previously constructed followed standard mitigation and best practices used for watercourse crossings. Projects which may occur in the foreseeable future would also follow standard mitigation and best management practices similar to the Project.

17.6.2.3 Cumulative Effects

The projects identified in Table 17.10 and the Project will result in residual effects through the loss and alteration of fish habitat.

The types of effect from the Project, the Canyon Creek and Prohibition Creek access roads, and the Great Bear River Bridge projects are identical, as watercourse crossings, with a few minor exceptions, are on separate individual watercourses. Therefore, cumulative effects would not occur at individual watercourses crossed by these projects. As these watercourses drain into the Mackenzie River (Deh Cho), the potential for cumulative effects would be on the fisheries of the Mackenzie River (Deh Cho), primarily in potential loss of prey (fish and invertebrates) entering the Mackenzie River (Deh Cho). Due to the higher number of watercourses crossed by the Project compared to the other road projects, the contribution of potential cumulative effects are higher from the Project.

17.6.3 Change in Fish Health

Cumulative effects for change in fish health relates to a change in fish population due to increased fishing pressure leading to overfishing of species such as Arctic grayling. Potential cumulative effects with the Project can be anticipated from the Canyon Creek and Prohibition Creek access roads, and the Great Bear River Bridge (Table 17.10) which create potential for increased fishing pressure leading to overfishing and reduced fish stocks. The potential cumulative effects of these individual road projects during the construction phase are replaced by the effects of the Project during the operations phase, as the highway segments connect.

17.6.3.1 Cumulative Effects Pathways

Transportation corridors provide increased access to areas not previously available to many people. This increased access can lead to increased fishing pressure, which can result in overfishing and reduced fish stocks. Increased fishing pressure would be limited to those watercourses which bear large-bodied fish species, such as Arctic grayling, and is likely to be greater at locations closer to communities. Populations of fish in smaller tributaries to the Mackenzie River (Deh Cho), such as those found along the Prohibition Creek and Canyon Creek access roads and the potential Prohibition Creek access road, may be more susceptible to overfishing due to their likely small population size. The Project will connect and make use of these access roads during construction thereby potentially increasing traffic along these roads, resulting in the potential for increased fishing pressure.

Fish stocks which use tributaries to the Mackenzie River (Deh Cho) crossed by these road transportation corridors may also use Mackenzie River (Deh Cho) for part of their life history functions. For example, Arctic grayling may use a tributary of the Mackenzie River (Deh Cho) for spawning and rearing but migrate back into the Mackenzie River (Deh Cho) or to other larger systems to overwinter. Overfishing in the tributaries crossed by these projects and the Project may reduce fish stocks in other areas, where harvested.

17.6.3.2 Mitigation for Cumulative Effects

The mitigation measure for overfishing is to avoid construction of pullouts or parking availability at these fish-bearing watercourses, which will limit access to large-bodied fish. Fishery management measures may be able to be put in place, such as through the Northwest Territories Sport Fishing Regulations, which could restrict fishing during spawning periods by non-Indigenous persons or the placement of catch limits on species which may be subject to overfishing (e.g., Arctic grayling). These measures would need to be developed and approved by regulators responsible for fisheries management, the SRRB, and other resource managers.

17.6.3.3 Cumulative Effects

Limiting access to parking at large-bodied fish-bearing watercourses may reduce the potential for overfishing; however, it may not completely eliminate full access and the potential for overfishing. As a precautionary approach it is assumed some fish stocks may become stressed due to overfishing.

17.6.4 Summary of Cumulative Effects

The residual effects of change in fish habitat from both the loss and alteration of riparian areas and areas below the OHWM are not expected to affect productivity of these individual systems. The loss and alteration of fish habitat at any one watercourse will be less than one percent of available habitat. As productivity of these systems is not anticipated to be affected, their contribution to the Mackenzie River (Deh Cho) in terms of nutrients and prey organisms should not be affected. If a *Fisheries Act* authorization is required for one of the projects in the foreseeable future (e.g., Great Bear River Bridge, where an authorization is required), offsetting will be required to match or exceed lost or altered fish habitat. The characteristics of the residual cumulative effects for change in fish habitat are provided in Table 17.11. The effect is certain and direction adverse within the RAA. The duration is long-term and continuous. Although the effect is irreversible, the magnitude of the effect is low.

Increased access for fishing opportunities due to the Project and its connection with other transportation corridors in the RAA can be expected to result in increased fishing pressure of some fish populations (e.g., Arctic grayling). This increased fishing pressure, especially on smaller systems, can result in stress on fish populations. The application of mitigation will reduce the cumulative effects but not necessarily negate them. The characteristics of the residual cumulative effects for change in fish health are provided in Table 17.11.

The effect is possible and direction adverse within the RAA. The duration is long-term, but the frequency is irregular (e.g., when people fish). The effect can be reversible with fisheries management initiatives. The magnitude is anticipated to be medium to high depending on the fishing pressure that occurs associated with these projects.

Table 17.11 Summary of Cumulative Effects

Residual Cumulative Effect	Residual Cumulative Effects Characterization							
	Direction	**Likelihood**	**Magnitude**	**Geographic Extent**	**Timing**	**Duration**	**Frequency**	**Reversibility**
Change in Fish Habitat	A	CE	L	RAA	NS	LT	C	IR
Contribution from the Project to the residual cumulative effect	The Project is the largest contributor to this residual cumulative effect due to the number of watercourse crossings associated with it compared to those projects it may interact with cumulatively.							
Residual Cumulative Change in Fish Health	A	P	M-H	RAA	HS	LT	IR	R
Contribution from the Project to the residual cumulative effect	The Project is the largest contributor to this residual effect. The Project will connect the other transportation corridor projects together, increasing the potential for overfishing in the RAA.							

KEY

*See Table 17.3 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMC: No Measurable Change
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

N/A: Not applicable

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

17.7 Determination of Significance

17.7.1 Significance of Residual Effects

The change in fish habitat due to the loss or alteration of fish habitat below the OHWM and in the riparian area will occur at each crossing site along the project highway alignment where there is no existing crossing (e.g., bridge). The loss and alteration of fish habitat below the OHWM is a result of placement of culverts and rip rap at each crossing site and the infilling around the culvert sides for construction of the roadbed. The loss of riparian area will occur with the construction of the roadbed at the crossing. Alteration of riparian habitat is through trimming of vegetation along the ROW at each crossing site. Trimming of the vegetation leaves vegetation intact but lowers the height of the vegetation. These changes occur over relatively small areas, less than 1% of available habitat at each crossing location in largely undisturbed systems. With the application of accepted best management practices and mitigation, the magnitude of effect at each crossing site is low, although the effects are adverse in direction. The changes to fish habitat are not anticipated to result in the loss of productivity of fisheries in these watercourses and therefore the effect is considered not significant.

The change in fish health of fish populations could occur with increased fishing pressure during operation of the highway, which can lead to increased access to watercourses containing large-bodied fish. This increased access can lead to fishing opportunities for users of the highway, which could result in overfishing of some populations of large-bodied fish, in particular Arctic grayling. This increase in fishing pressure would only be anticipated to occur during the open water season of project operation but could coincide with important migratory movements of some large-bodied fish. Concern was raised at community meetings of the potential of overfishing due to increased access to fishable watercourses during project operation. Mitigation against overfishing is limited and may include not constructing pullouts near watercourses which have large-bodied fish to reduce fishing access to these watercourses.

Population numbers of large-bodied fish along the project highway alignment is unknown and therefore the level of increased fishing pressure that a population can withstand and still be sustainable is unknown. The degree of increased fishing pressure which may occur along the Project alignment is also unknown, but as a precautionary approach to acknowledge the uncertainty, increased fishing pressure resulting in overfishing has the potential to adversely affect large-bodied fish populations and therefore has the potential to be a significant effect. The GNWT will work with SRRB and other resource managers to address uncertainty regarding the effects of increased access created by the Project on harvested resources in the assessment areas. This would include monitoring of harvest that can be used to identify the need for management actions to be taken by the appropriate resource management organization.

In conclusion, a significant effect would only be for the change in fish population health if overfishing were to occur during construction and operations and maintenance of the Project.

17.7.2 Significance of Cumulative Effects

The change in fish habitat due to the loss and alteration of riparian habitat and fish habitat below the OHWM is not significant. Mitigation and best management practices employed during the construction of watercourse crossings are known to be effective at breaking or reducing effects on habitat. It is anticipated that there will be no loss of aquatic productivity at the crossings by the Project or other projects it interacts with cumulatively and therefore no loss of productivity within the RAA.

The change in fish health of fish populations has the potential to be significant if increased access to large-bodied fish bearing waters leads to overfishing. Not all crossings of large-bodied fish bearing waters may provide suitable fishing opportunities due to fish habitat limitations or access challenges (e.g., high banks). The implementation of management strategies to prevent overfishing can also reduce the potential for overfishing. There is uncertainty if increased access to large-bodied fish bearing watercourses will lead to overfishing but, as a conservative approach, it is assumed the potential exists.

17.7.3 Project Contribution to Cumulative Effects

The Project is the largest contributor to both change in fish habitat and change of fish health of fish populations of the cumulative projects. The Project has the largest number of crossings compared to those projects which may interact cumulatively. The Project connects other transportation-related projects to each other, increasing its contribution to a change in fish health populations.

17.8 Prediction Confidence

The predicted confidence for residual effects and residual cumulative effects for fish and fish habitat is high for the change in fish habitat effect. This prediction for changes to fish habitat is based on the accuracy of the project design information, fish and fish habitat data, and the known effectiveness for mitigation and best management practices to be used during the Project. Mitigation was identified that would break or reduce the various pathways of effects which will result from the Project. Proposed construction design for watercourse crossings has been successfully used before in the Northwest Territories (e.g., Inuvik to Tuktoyaktuk Highway) and elsewhere in Canada with no significant effects on fish and fish habitat.

The confidence level for change in fish health populations due to increased fishing pressure is low. The low confidence level is a result of the uncertainty of whether watercourses known to contain large-bodied fish provide suitable fishing opportunities along the project highway alignment; the lack of data on stock size of large-bodied fish; and if fishing pressure increased, the extent of that increase and its effects on fish populations. Prediction confidence can be increased through additional engagement with Indigenous Governments, Indigenous Organizations and other affected parties on the potential for fishing opportunities at relevant crossings and through monitoring of recreational fisheries along the project alignment.

17.8.1 Assumptions

This assessment was based on the following assumptions:

- There will be no changes in the highway alignment
- All new crossings will only require culverts
- All identified mitigation will be applied correctly

17.8.2 Gaps and Uncertainties

Data gaps related to fish and fish habitat for the Project include:

- Not all project crossings have been field assessed for fish and fish habitat.
- Population estimates for fish found along the project alignment are unknown.

The following are uncertainties as they relate to the assessment of the Project:

- Potential for changes to the alignment during the design of the Project
- Uncertainty whether watercourses where no fish were captured are fish-bearing
- Whether watercourses with large-bodied fish crossed by the Project would provide favourable fishing opportunities
- Changes in population or SAR status of fish species which occur in the RAA prior to construction of the highway and over the life of the Project due to factors external to the Project (e.g., climate change) may affect the assessment of effects
- Changes or additions of new DFO codes of practice may affect the types of mitigation measures to be applied to the Project.

17.9 Follow-up and Monitoring

The objectives of fish and fish habitat monitoring may include:

- Verify compliance with terms and conditions of authorizations and commitments
- Verify effectiveness of mitigation measures
- Verify effects predictions

A Fish and Fish Habitat Protection Plan is included in Volume 5. Monitoring of fish and fish habitat as identified in this plan integrates the requirements of the water quality and water quantity monitoring programs, as water quality and quantity are key aspects of fish and fish habitat. Visual observations and monitoring undertaken as part of the ESCP will also be used to fulfil the objectives. Monitoring as part of the ESCP will also include turbidity monitoring during instream works (see draft ESCP in Volume 5).

During operations, monitoring will include routine periodic inspection of culverts to determine if they are functioning as per design (e.g., allow fish passage) and for evidence of erosion and sedimentation. If a barrier to fish passage or erosion and sedimentation issues are observed, corrective actions would be implemented to address the problem.

The GNWT will work with SRRB and other resource managers such as DFO to address uncertainty regarding the potential effects of increased access created by the Project on the sustainability of large-bodied fish populations in the assessment areas. This would include monitoring of harvest that can be used to identify the need for management actions to be taken by the appropriate resource management organization. The need for such a program will be evaluated in cooperation with regulators and resource management agencies including the GNWT, DFO and agencies such as the SRRB. Additional monitoring requirements, if identified as part of the Project's approval and permitting, will be incorporated into a project-specific fish and fish habitat monitoring plan.

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18.0 ASSESSMENT OF POTENTIAL EFFECTS ON VEGETATION AND WETLANDS

Vegetation and wetlands were selected as a Valued Component (VC) as they support ecosystem functions such as nutrient and water cycling, habitat, and carbon accumulation, and provide socio-economic and cultural value to Indigenous Governments, Indigenous Organizations, and other affected parties. The Mackenzie Valley Highway Project (the Project) has the potential to affect vegetation and wetlands during the construction and operations and maintenance phases of the Project through pathways such as land clearing, alteration of surface and sub-surface water flow paths, and disturbance of the underlying soils.

Changes to vegetation and wetlands from the Project may also affect fish and fish habitat (see Chapter 17), caribou and moose (see Chapter 10), wildlife and wildlife habitat (see Chapter 19), birds and bird habitat (see Chapter 20), and culture and traditional land use, including harvesting (see Chapter 11). Changes may occur due to loss or alteration of naturally vegetated areas. Vegetation is identified as a Subject of Note in the Terms of Reference (ToR) issued by the Mackenzie Valley Environmental Impact Review Board (MVEIRB, 2015 [Public Registry {PR}#66]). Assessment of vegetation and wetlands as a VC facilitates the assessment of other VCs, including terrain, soils, and permafrost; air quality; water and sediment quality; and water quantity.

The assessment of potential effects on vegetation and wetlands concludes that with the application of mitigation measures, residual effects resulting from the Project on vegetation and wetlands will be adverse. Residual effects and cumulative effects will not threaten the long-term persistence or viability of plant communities or species, including those of cultural or traditional importance, or threaten the long-term viability of local or regional wetland function and therefore will be not significant.

18.1 Scope of Assessment

18.1.1 Regulatory and Policy Setting

The assessment of potential effects on vegetation and wetlands is guided by the ToR (MVEIRB, 2015) and the following federal and territorial legislation and guidance.

18.1.1.1 Federal

18.1.1.1.1 *Species at Risk Act*

The *Species at Risk Act* (SARA) is federal law that aims to prevent endangered or threatened species from becoming extinct or extirpated and manages species of special concern to help prevent them from becoming endangered or threatened. The status of species is assessed and designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), which then recommends a designation for legal protection by being officially listed under SARA. Both plant and animal species can be listed under SARA. There are five vascular plant species and one moss species protected under SARA in the Northwest Territories (NWT); however, none of these species has a range which overlaps with the Project (Government of Canada. 2019).

Under SARA, the individual, the residence, and the habitat of listed species are protected on all federal lands, and on other lands where an order under SARA has been issued for an individual species where it has been determined that the provincial, territorial, or other government is not effectively protecting the species and its habitat through its laws.

18.1.1.1.2 *Fisheries Act*

The *Fisheries Act* provides for the protection of fish and their habitat (including benthic invertebrates). The *Fisheries Act* prohibits causing harmful alteration, disruption, or destruction (HADD) of fish habitat (section 35 of the *Fisheries Act*), death of fish by means other than fishing (section 34.4[1]), and the introduction of a deleterious substance (section 36). The Act also includes provision for flow and passage (section 34.3) and a framework for regulatory decision-making (section 34.1).

The *Fisheries Act* requires that projects avoid causing HADD of fish and fish habitat, unless authorized by the Minister of Fisheries and Oceans Canada (DFO). Projects with the potential to obstruct fish passage, modify flow, or result in entrapment of fish may also qualify as causing HADD to fish. Where a non-compliance of the *Fisheries Act* cannot be avoided or mitigated, an Authorization under paragraph 35(2)(b) of the *Fisheries Act* is required. The Fisheries Protection Program, maintained by DFO and its collaborative partners, is responsible for the review of projects to determine if a non-compliance of the *Fisheries Act* is likely to occur.

18.1.1.1.3 Federal Policy on Wetland Conservation

The Federal Policy on Wetland Conservation (Government of Canada, 1991) commits all federal departments to the goal of no net loss of wetland functions that:

- Are on federal lands and waters; or,
- Are in areas affected by the implementation of federal programs and activities where the continuing loss or degradation of wetlands or their functions have reached critical levels; or,
- May affect wetlands that are ecologically or socio-economically important to a region in NWT (includes wetland areas that are used as hunting, trapping, and fishing resources).

Wetland functions that coincide with areas of federal regulatory jurisdiction, such as habitat for species listed under SARA and migratory birds considered under the *Migratory Bird Convention Act*, are of particular concern to federal regulatory agencies and wetland compensation may be required if an effect on SARA listed species, fish, or migratory birds is predicted.

While the federal policy applies directly to projects occurring on federal land and waters, or those that receive federal funds, it also provides guidance on national priorities for wetland conservation. Although no wetlands of international importance are likely to be affected by the Project (Ramsar Convention Secretariat, 2019), this policy is used as guidance to maintain consistency with national priorities for wetland conservation. The federal wetland policy has not been updated since 1991.

18.1.1.2 Territorial

18.1.1.2.1 Species At Risk in Northwest Territories

The *Species at Risk (NWT) Act* identifies and protects plant and animal species at risk (SAR) in NWT. The Act protects occurrences and habitat of designated SAR and their habitats to avoid further decline and to promote recovery. There is one plant species, hairy braya (*Braya pilosa*), listed as At Risk under the *Species at Risk (NWT) Act*.

Species of conservation concern (SOCC) are those plant species listed by the Working Group on General Status of NWT Species (2016) as May Be at Risk or Sensitive. Species with a rank of May be at Risk are the highest priority for more detailed assessment by the NWT Species at Risk Committee. Species ranked Sensitive are not at high risk of extinction or extirpation but require some special attention or protection to prevent them from becoming more at risk. Species in both of these categories are not protected under the *Species at Risk (NWT) Act*.

18.1.1.2.2 *Wildlife Act*

The *Wildlife Act* of the NWT provides general provisions for regulating the prevention of wildlife and plants declared to be pests, including the import, control, and destruction of these species (under subsection 100[1]).

18.1.1.2.3 *Forest Management Act*

The *Forest Management Act* concerns the management and use of forests in Northwest Territories. It contains provisions on its administration and on the functions and powers of forest officers, forest management agreements, permits and licences, enforcement, offences and penalties, and on the resolution of disputes.

18.1.1.2.4 *Forest Protection Act*

The *Forest Protection Act* was created by the Government of the Northwest Territories (GNWT) to set provisions to secure the protection of forests in Northwest Territories. It covers the extinguishment of fires, clearance, fires to clear land, fires in engines, the administration of the Act by forest officers, enforcement, and offences and penalties.

18.1.1.2.5 *Waters Act*

The *Waters Act* and its Waters Regulations regulate the direct and indirect use of waters and disposal of wastes and physical alterations to inland waterbodies.

18.1.1.3 Sahtu Land Use Plan

Specific to the areas to which the Sahtu Land Use Plan (SLUP) applies, the Project must meet the 13 general conformity requirements (CR) of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023). The SLUP's conformity requirements include consideration of species introduced in CR#8 and sensitive species and features in CR#9, which are reproduced below as they relate to vegetation and wetlands:

> CR#8: *"Land use activities must not result in the intentional introduction of non-native plant and animal species, or of domestic animal species."*
>
> CR#9: *"1) Any land use activity requiring a land use permit or water license must be designed using the most current available information on the location of rare or may-be-at-risk plants, hot and warm springs, mineral licks, karst topography, amphibian sightings, and ice patches and carried out in a manner that minimizes impacts to these features.*
>
> 2) Specifically, land use activities:
>
> *b) that are situated within the boundary of glacial refugia or within 500 m of known hot or warm springs and have the potential to impact rare or maybe-at-risk plants shall require a plant survey. Any rare or maybe-at-risk plants found in the survey shall be monitored for impacts from the activity."* (SLUPB, 2023)

Conformity Requirement #2 requires that *"The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge.".* Additionally, per CR#14, the Project must be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 2023), including the following:

- Petiniɂah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)
- K'ąąlǫ Tué (Willow Lake Wetlands) SMZ (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

18.1.2 Influence of Engagement

The GNWT has engaged with affected Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapter 2 (Consultation and Engagement), Chapter 3 (Traditional Knowledge), and Chapter 11 (culture and traditional land use). The GNWT has recently initiated Consultation with Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to vegetation, wetlands, and plant harvesting. This feedback has been considered and summarized in Table 18.1 and has been integrated into the assessment of potential effects on vegetation and wetlands that follows.

Table 18.1 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
Engaged Indigenous Governments, Indigenous Organizations and other affected parties identified plant harvesting locations near the Project.	Dehcho First Nations, 2011; EBA, 2006; IMG-Golder, 2006; Norman Wells Renewable Resources Council (NWRRC), 2023; SLUPB, 2022; Tulita Renewable Resources Council (TRRC), 2022	The GNWT has identified mitigation measures to reduce or eliminate the effects on vegetation and wetlands. The preliminary highway alignment route deviates from the MVWR in areas of wetlands. Known areas of collection of plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties will be avoided where possible. The GNWT Department of Infrastructure (INF) will develop an invasive alien plant species monitoring program in discussion with GNWT Environment and Climate Change (ECC). The GNWT-INF will undertake regular inspection for invasive alien plant occurrences and apply management through mowing to reduce introduction and spread of invasive alien plant species in the ROW and surrounding natural vegetation.	For information about plant species of interest and important habitat and harvesting locations, see Section 18.2.2.4. For mitigation measures to reduce or eliminate effects on vegetation and wetlands, see Table 18.8 See also: Section 5.2.3 (Design Considerations) Section 18.4.2 (Change in Landscape Diversity) Section 18.4.3 (Change in Community Diversity) Section 18.4.4 (Change in Species Diversity) Section 18.4.5 (Change in Wetland Function) Chapter 9 (Socio-economic Impact Assessment: Human Health and Community Wellness) Chapter 11 (culture and traditional land use, including harvesting) Volume 5 for management, monitoring, and protection plans.
Community engagement participants stated that vegetation is growing faster than it used to. Since the Canyon Creek Road was constructed, participants are seeing more lady slipper, which normally grows along cliffs and muskeg, but is now commonly found along the road out in the open.	November to December 2022 Engagement		
Community engagement participants expressed concern about the introduction of invasive species during construction and requested that all equipment be cleaned and sanitized.	November 2022 to February 2023 Engagement		
Community engagement participants recommended that the GNWT allow the vegetation to grow back naturally following construction.	November 2022 to February 2023 Engagement		
Community engagement participants recommended that the route avoid wetlands and swampy areas.	November 2022 to February 2023 Engagement		

Comment	Source	GNWT Response	Where Addressed
Community engagement participants members expressed concern that development may affect human health through water and air quality, and the health of the region's vegetation.	Golder, 2015	(*cont'd from above)* Abandoned sections of MVWR ROW and access roads will be reclaimed to promote re-establishment of vegetation cover. A Spill Contingency Plan (SCP) will be developed and implemented. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties regarding perceived effects on plant species of interest to Indigenous Governments, Indigenous Organizations and other affected parties.	
Pehdzéh Kį First Nation and Dehcho First Nations expressed concerns about potential effects during construction on the land and forest. Reforestation was identified as important to the participants.	Dessau, 2012 (PR#13)		
Sahtu Dene and Métis expressed concerns about potential effects on resident species, including effects of increasing invasive species which can influence potential for wildfires. Changes in vegetation and wetlands and changes resulting from removal of permafrost may result in decreased plants, and plant harvesting locations available to Indigenous harvesters.	SRRB, 2016		
NWRRC TLRU study participants raised concerns about changing temperatures and the cumulative effects of climate change on vegetation during project construction and operation	NWRRC, 2023		

18.1.3 Potential Effects, Pathways and Measurable Parameters

Potential effects on vegetation and wetlands could occur wherever project activities interact with vegetation or wetland resources. The key focus for the Vegetation and Wetlands VC is the sustainability of plant species and plant communities, and the maintenance of wetland functions. Potential effects could occur through the direct loss of plant species and plant communities that support traditional use activities, provide habitat, and support intrinsic ecological values such as biodiversity. Loss of wetland functions resulting from clearing, ground disturbance, or altering natural drainage patterns could also occur.

The potential effects on vegetation and wetlands considered in this Developer's Assessment Report (DAR) include:

- Change in landscape diversity
- Change in community diversity
- Change in species diversity
- Change in wetland functions

Table 18.2 summarizes the potential effects, effects pathways and measurable parameters.

Table 18.2 Potential Effects, Effects Pathways, and Measurable Parameters for Vegetation and Wetlands

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in landscape diversity	• Fragmentation of native plant communities/landcover types arising from clearing	• Patch area of native landcover types (hectares [ha]) • Perimeter (edge) length (metres [m]) to area (ha) ratio of native landcover type patches • Risk of change in landcover plant composition from competition with alien or invasive alien plant species
Change in community diversity	• Direct loss or alteration of native communities/landcover types from clearing and ground disturbance • Removal of merchantable timber • Indirect alteration of native communities/landcover types, including riparian areas, from the introduction or spread of alien and invasive alien plant species and pests, or dust contaminant deposition	• Area (ha) of native upland and wetland communities and spatial distribution • Area (ha) and qualitative description of spatial distribution of forest stand age classes • Change in amount of merchantable timber (cubic metres [m^3]) • Quantitative (ha) and qualitative estimation of native upland and wetland communities affected by dust contaminant deposition

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in species diversity	• Direct loss of occurrences of plant SOCC or plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties, such as renewable resources councils from clearing and ground disturbance • Indirect loss or alteration of SOCC or plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils from the introduction or spread of invasive alien plants, and dust contaminant deposition	• Qualitative estimation of SOCC lost and spatial distribution • Qualitative estimation of changes in abundance of plants of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils, spatial distribution, and identified collection locations • Qualitative estimation of changes in abundance of plants of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils, spatial distribution, and identified collection locations
Change in wetland function	• Direct loss of wetland area or alteration of wetland function (i.e., hydrology, structure, plant composition, nutrient cycling, and litter accumulation) from clearing or infilling of wetlands • Indirect alteration of wetland area or function (i.e., hydrology, structure, plant composition, nutrient cycling, and litter accumulation) from changes in surface or groundwater flow patterns	• Area (ha) and spatial distribution of wetland types • Qualitative evaluation of altered surface and shallow groundwater flow patterns

18.1.4 Boundaries

18.1.4.1 Spatial Boundaries

The Project Development Area (PDA), Local Assessment Area (LAA), and Regional Assessment Area (RAA) for the assessment of effects on vegetation and wetlands are shown in Figure 18.1. These spatial boundaries are used to assess project effects, including residual and cumulative effects from the Project on vegetation and wetlands.

- **Project Development Area (PDA):** The area of direct project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 m wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sites with access roads on a 30 m ROW.

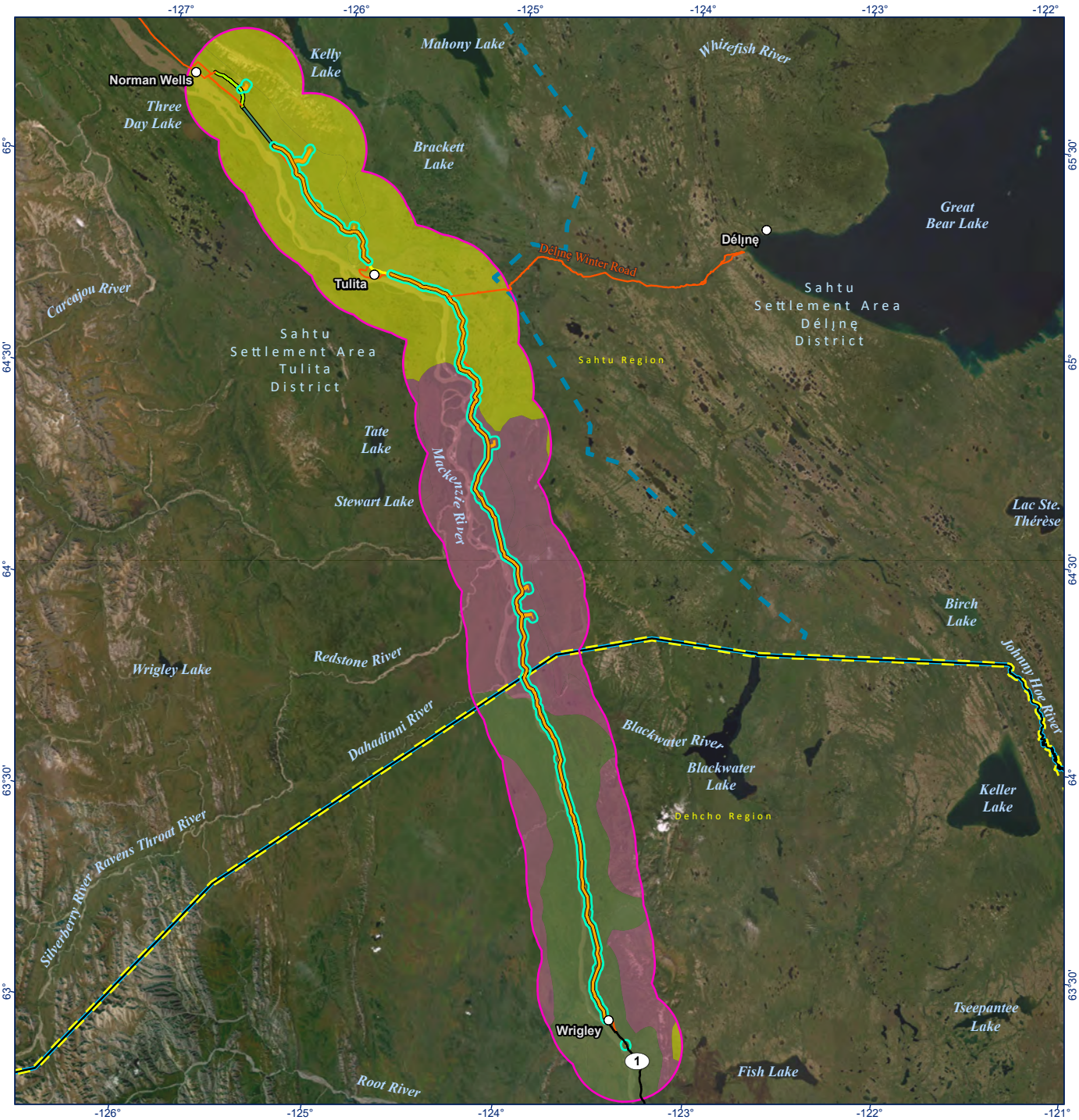
- **Local Assessment Area (LAA)**: The area within which measurable project-related effects (direct or indirect) are expected to occur. The LAA for vegetation and wetlands is a 1 kilometre (km) buffer around the preliminary highway alignment route centerline, quarry and borrow source extents, and associated access roads. The size of the LAA is based on measurable extent of project-related effects (direct or indirect) to vegetation and wetlands, while also considering recommended setback distances for certain wildlife and wildlife habitat features consistent with guidance provided by Environment and Climate Change Canada (ECCC) [Dufour, 2020, pers. comm.].
- **Regional Assessment Area (RAA)**: The area that provides context for determining significance of project effects and potential cumulative effects. The RAA for vegetation and wetlands aligns with that for wildlife and wildlife habitat and is the area within approximately 15 km of the PDA. A 15 km buffer was selected to provide context for determining significance of project-specific effects and potential cumulative effects and is consistent with other highway projects in the NWT (e.g., Inuvik to Tuktoyaktuk Highway [Kiggiak-EBA, 2011]).

18.1.4.2 Temporal Boundaries

The temporal boundaries for the Project consist of the following phases, which are described in more detail in Chapter 5:

- **Construction phase:** The Project will take approximately 10 years to construct over a timeframe of up to 20 years. The conceptual schedule assumes the highway will be constructed in three consecutive segments, beginning in approximately 2026: Wrigley north to the Dehcho–Sahtu border (102 km); Tulita south to the Dehcho–Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells sometime between 2041 and 2046.
- **Operations and maintenance phase:** The operations and maintenance phase will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the highway is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, and borrow sources and quarries used only for construction are included within the construction phase.



Ecoregion
- Boreal Cordillera High Boreal
- Taiga Cordillera Low Subarctic
- Taiga Plains Low Subarctic

- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Local Assessment Area
- Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 8/3/2023
TR by AJ on 8/3/2023

Client/Project
144903025-0102 REVB

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
18.1

Title
Vegetation and Wetlands Assessment Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Open Data, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
Imagery date: 2021

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18.1.5 Residual Effects Characterization

Table 18.3 presents definitions for the characterization of residual effects on vegetation and wetlands. Residual effects are those that remain after mitigation measures have been implemented.

Table 18.3 Characterization of Residual Effects on Vegetation and Wetlands

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse:** A residual effect that moves measurable parameters of vegetation and wetlands in a negative direction relative to baseline **Neutral:** No net change in measurable parameters for vegetation and wetlands relative to baseline
Likelihood	The probability that the residual effect will occur	**Unlikely –** The residual effect is almost certain not to occur **Possible –** The residual effect could occur **Certain –** The residual effect will certainly occur
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible**: No measurable change in vegetation or wetlands **Low**: A measurable change in distribution and abundance of vegetation and wetlands, but no loss within the LAA of any of: • Large intact native vegetation patches • Upland or wetland landcover types • Occurrences of plant SOCC • Plants of importance to Indigenous Governments, Indigenous Organizations, and other affected parties Or, changes in distribution of existing invasive alien plants, but no new invasive alien plants introduced
		Moderate: Loss within the LAA of any of: • Large intact native vegetation patches • Upland or wetland landcover types • Occurrences of plant SOCC which are the only occurrences of that SOCC in the LAA • Plants of importance to Indigenous Governments, Indigenous Organizations, and other affected parties Or, changes in distribution of invasive alien plants in the LAA, and likely introduction of new invasive alien plants

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Magnitude (cont'd)		**High**: Loss within the PDA or LAA of any of: • Large intact native vegetation patches • Upland or wetland landcover types • Occurrences of plant SOCC which are the only occurrences of that SOCC in the RAA • Plants of importance to Indigenous Governments, Indigenous Organizations, and other affected parties Or, changes in distribution of invasive alien plants in the RAA, and likely introduction of new invasive alien plants
Geographic Extent	The geographic area in which a residual effect occurs	**PDA:** Residual effects are restricted to the PDA **LAA:** Residual effects extend into the LAA **RAA:** Residual effects interact with effects of other projects in the RAA
Timing	Considers when the residual effect is expected to occur, where relevant to vegetation and wetlands	**No sensitivity:** Seasonal timing of effect does not affect the vegetation and wetlands. **Moderate sensitivity:** Vegetation and wetlands are moderately sensitive to seasonal timing. **High sensitivity:** Vegetation and wetlands are highly sensitive to seasonal timing.
Duration	The time required until the measurable parameter or the VC returns to its existing condition, or the residual effect can no longer be measured	**Short-term:** The residual effect is restricted to a single construction segment **Medium Term**: The residual effect lasts through the construction phase (up to 20 years) **Long-term:** The residual effect extends beyond construction or throughout operation
Frequency	Identifies how often the residual effect occurs and how often during the project or in a specific phase	**Single event:** The residual effect occurs once **Multiple irregular event:** The residual effect occurs at no set schedule **Multiple regular event:** The residual effect occurs at regular intervals **Continuous**: The residual effect occurs continuously
Reversibility	Pertains to whether a measurable parameter or the VC can return to its existing condition after the project activity ceases	**Reversible:** The residual effect is likely to be reversed after activity completion and reclamation **Irreversible:** The residual effect is unlikely to be reversed

18.1.6 Significance Definition

A significant adverse residual effect on vegetation and wetlands is one that, following the application of avoidance and mitigation measures, threatens the long-term persistence or viability of plant communities or species, including those of cultural or traditional importance, or threatens the long-term viability of local or regional wetland function.

18.2 Existing Conditions for Vegetation and Wetlands

Project activities have the potential to directly or indirectly change the abundance or distribution of vegetation and wetland resources, including: landcover types, native vegetation communities, occurrences of SAR, SOCC, and wetland function. Potential residual effects on vegetation and wetlands (Section 18.4) are assessed relative to the existing conditions of these resources. This section provides an overview of the existing conditions relative to the presence and relative abundance of vegetation and wetlands in the LAA and RAA. More detailed information about existing conditions for vegetation and wetlands within the LAA and RAA is provided in the Vegetation and Wetlands Technical Data Report (TDR; Appendix 18A; K'alo-Stantec, 2022).

18.2.1 Methods

A review of existing data sources and previous studies regarding vegetation and wetland resources was completed within the LAA and RAA to characterize conditions and identify gaps in information. Vegetation communities, wetlands, and occurrences of historical fires were identified from existing provincial and federal spatial data sets. The analysis of baseline conditions and project effects were completed using the spatial data layer of mapped ecosystems overlain with a spatial data layer of existing disturbances and the PDA and LAA. In addition, a review of relevant traditional land and resource use information was completed summarizing data from publicly available sources that provides information on existing conditions and potential project effects as identified by Indigenous Governments, Indigenous Organizations, and other affected parties. For example, recent traditional land and resource use information has highlighted the importance of plants within the LAA (TRRC, 2022; Section 3.1.2.2 in Appendix 18A [K'alo-Stantec, 2022]). In the Northwest Territories, invasive alien plants are those species referred to in GNWT Invasive Alien Species webpage (GNWT, 2023).

Details on the methods used for ecosystem mapping, rare plant, and alien and invasive alien species are described in the Vegetation and Wetlands TDR (Appendix 18A; K'alo-Stantec, 2022).

18.2.2 Overview

The Project is situated in the Mackenzie Valley region of the NWT between the current terminus of the existing all-season highway in Wrigley (Highway #1, kilometre marker [KM] 690) and Prohibition Creek, approximately 28 km south of Norman Wells (Figure 18.1). The Project intersects three, level III ecoregions: the Taiga Plains Low Subarctic, Taiga Cordillera Low Subarctic, and Boreal Cordillera High Boreal. These ecoregions are mainly conifer-dominated though differ in terrain, wetland occurrence, and climate. The Taiga Plains Low Subarctic is the most northerly ecoregion intersected by the Project and is characterized by undulating plains, upland communities of white and black spruce, and permafrost-influenced wetlands (Ecosystem Classification Group, 2007). Further south, within the Taiga Cordillera Low Subarctic ecoregion, fewer waterbodies and peatlands exist and mountainous terrain, foothills, tundra, and spruce woodlands become more common (Ecosystem Classification Group, 2010). The most southerly ecoregion intersected by the Project is the Boreal Cordillera High Boreal. In comparison to the Taiga Cordillera Low Subarctic, the Boreal Cordillera High Boreal has a milder climate, greater precipitation, and taller, more dense stands of spruce woodland (Ecosystem Classification Group, 2010).

Other than local communities, the existing MVWR and the Norman Wells Pipeline, the LAA and RAA are relatively anthropogenically undisturbed. Oil and gas exploration and production infrastructure in the RAA occurs on the west side of, and near, the Mackenzie River (Deh Cho) close to Norman Wells (Auld and Kershaw, 2005). Other existing disturbances include borrow sources and quarries, a fibre optic line, and bridges associated with the MVWR. Landcover in the LAA includes exposed land, which includes areas recently burned in forest fires.

18.2.2.1 Landcover

A total of 64.9% of the LAA (40,759.4 ha), and 61.6% of the RAA (622,993.1 ha), is upland (Table 18.4). The majority of upland area (59.6% of the LAA [37,582.2 ha] and 58.2% of the RAA [602,905.9 ha]) is likely natural vegetation, including broadleaf forest, coniferous forest, mixedwood forest, and bryoid landcover types. Areas of herb and rock rubble, as well as exposed land in the LAA, are mostly a result of human disturbance. However, there are some naturally occurring thinly vegetated areas in the RAA, including barren areas bordering the Mackenzie River (Deh Cho). Of the natural upland vegetation, coniferous forest is the most abundant landcover type occupying 33.9% (21,311.1 ha) of the LAA and 31.7% (320,215.5 ha) of the RAA. Most coniferous forest cover types are located east of the Mackenzie River (Deh Cho) in the Dehcho Region portion of the LAA and west and northeast of the Mackenzie River (Deh Cho) in Sahtu Region portions of the LAA (Figure 18.2 and Figure 18.3).

Wetlands are present in the LAA and RAA in similar abundance, occupying 23.5% (14,760.5 ha) of the LAA and 26.6% (269,092.1 ha) of the RAA (Table 18.4). Wetland-shrub and wetland-treed are the most common wetland type in both the LAA and RAA, occupying 8.7% and 9.4% respectively in the LAA and 9.7% and 11% in the RAA. Wetland-herb wetlands occupy similar percentages of the LAA and RAA at 5.4% in the LAA and 5.7% in the RAA. Wetlands are located throughout the LAA, with highest concentrations of wetlands in the Dehcho Region of the LAA occurring along watercourses adjacent to Mackenzie River (Deh Cho) (Figure 18.2) and the highest concentrations in the Sahtu Region of the LAA occurring near areas of open water (Figure 18.3).

Table 18.4 Landcover Abundance in the LAA and RAA

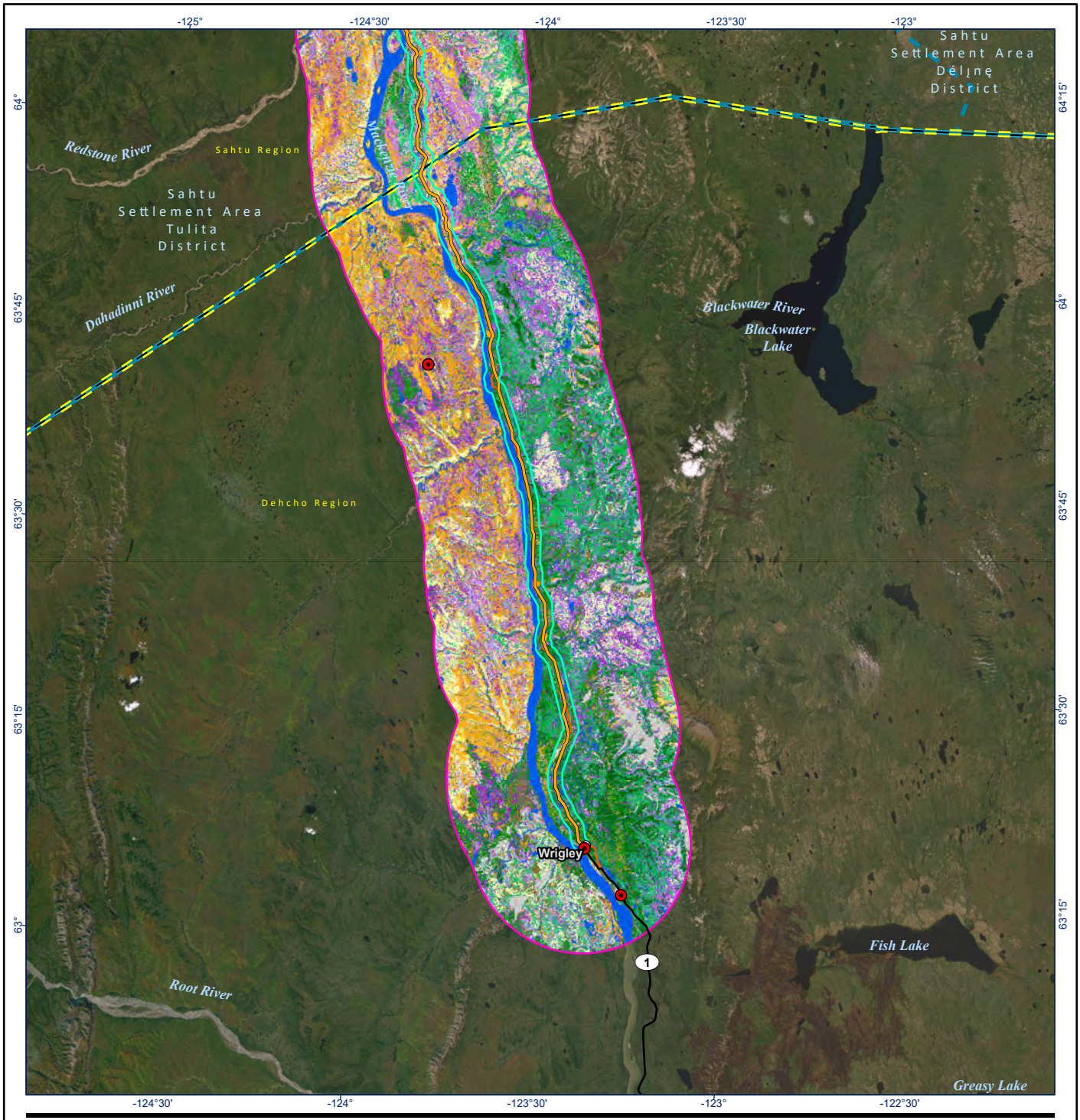
Landcover Type	Cover Type Class	LAA		RAA[2]	
		ha	%	ha	%
Broadleaf Forest	Broadleaf Dense	2,669.3	4.2	78,054.2	7.7
	Broadleaf Open	956.4	1.5	18,757.5	1.9
Broadleaf Forest Subtotal		**3,625.7**	**5.8**	**96,811.6**	**9.6**
Coniferous Forest	Coniferous Dense	3,617.8	5.8	43,662.5	4.3
	Coniferous Open	9,250.3	14.7	153,328.3	15.2
	Coniferous Sparse	8,442.9	13.4	123,224.8	12.2
Coniferous Forest Subtotal		**21,311.1**	**33.9**	**320,215.5**	**31.7**
Mixedwood Forest	Mixedwood Dense	1,144.4	1.8	14,265.0	1.4
	Mixedwood Open	2,098.4	3.3	26,548.9	2.6
	Mixedwood Sparse	5.1	<0.1	11.7	<0.1
Mixedwood Forest Subtotal		**3,247.9**	**5.2**	**40,825.6**	**4.0**
Shrubland	Shrub low	7,282.3	11.6	111,571.8	11.0
	Shrub tall	1,996.1	3.2	18,165.1	1.8
Shrubland Subtotal		**9,278.4**	**14.8**	**129,736.9**	**12.8**
Herbaceous and Unvegetated	Bryoids	12.9	<0.1	157.4	<0.1
	Exposed land[1]	2,943.5	4.7	14,744.8	1.5
	Herb	233.7	0.4	5,342.4	0.5
	Rock / Rubble	106.2	0.2	15,158.9	1.5
Herbaceous and Unvegetated Subtotal		**3,296.3**	**5.2**	**35,403.5**	**3.5**
Wetland	Wetland-herb	3,384.1	5.4	57,480.5	5.7
	Wetland-shrub	5,486.2	8.7	100,003.5	9.9
	Wetland-treed	5,890.3	9.4	111,608.0	11.0
Wetland Subtotal		**14,760.5**	**23.5**	**269,092.1**	**26.6**
Open Water	Water	7,383.1	**11.7**	118,138.8	**11.7**
No Data	No Data	0.0	**0.0**	259.9	**<0.1**
Total		**62,903.1**	**100**	**1,010,483.8**	**100**

Note:

[1] Exposed land includes areas which naturally have less than 5% vegetative cover, such as shorelines of rivers and lakes, exposed rock, recently burned areas, and moraines, and includes cleared areas such as the existing MVWR, Norman Wells Pipeline, and other areas of infrastructure development.

[2] Occurs within the RAA outside the LAA and PDA

Source: Natural Resources Canada and the Government of the Northwest Territories (2017).



Alien and Alien Invasive (weed) Occurrence*

Landcover Type
- Water
- Rock/Rubble
- Exposed Land
- Bryoids
- Shrub - Tall
- Shrub - Low
- Wetland - Treed
- Wetland - Shrub
- Wetland - Herb
- Herb
- Coniferous - Dense
- Coniferous - Open
- Coniferous - Sparse
- Broadleaf - Dense
- Broadleaf - Open
- Mixedwood - Dense
- Mixedwood - Open
- Mixedwood - Sparse
- Proposed Mackenzie Valley Highway Project Route
- Local Assessment Area (LAA)
- Regional Assessment Area (RAA)
- Community
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

* More than one alien or alien invasive plant may occur at each mapped location

0 10 20 Kilometers

(At original document size of 8.5x11)
1:800,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 8/3/2023
TR by AJ on 8/3/2023

Client/Project
144903025-0103-REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
18.2

Title
Landcover Types and Documented Alien and Invasive Alien Species Occurrences within the Mackenzie Valley Highway Project LAA and RAA – Dehcho Region

Notes
1. Coordinate System: NAD 1983 Northwest Territorries Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS. Imagery date: 2021

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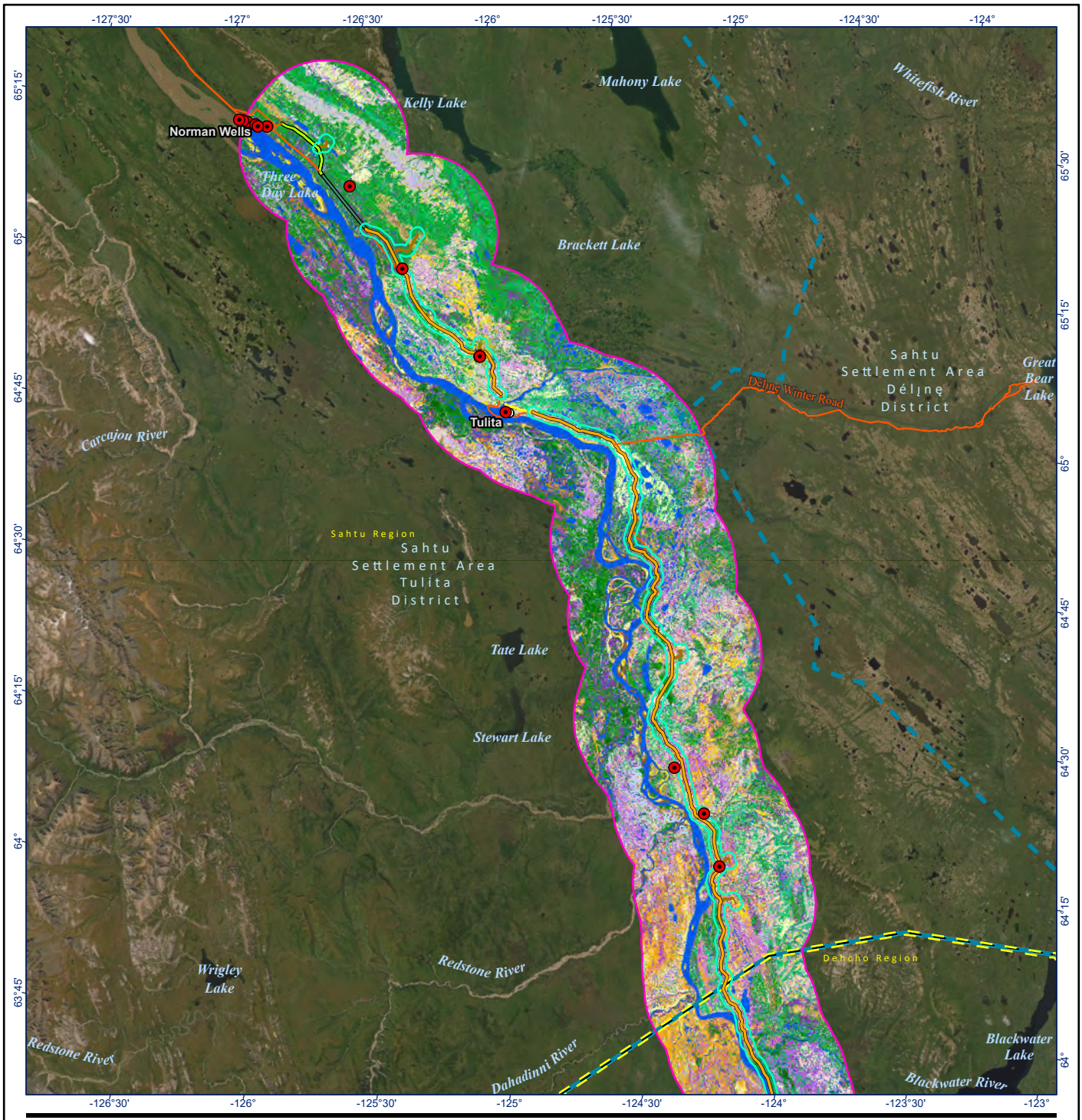

Alien and Alien Invasive (weed) Occurrence*

Landcover Type
- Water
- Rock/Rubble
- Exposed Land
- Bryoids
- Shrub - Tall
- Shrub - Low
- Wetland - Treed
- Wetland - Shrub
- Wetland - Herb
- Herb
- Coniferous - Dense
- Coniferous - Open
- Coniferous - Sparse
- Broadleaf - Dense
- Broadleaf - Open
- Mixedwood - Dense
- Mixedwood - Open
- Mixedwood - Sparse

Proposed Mackenzie Valley Highway Project Route
Canyon Creek All Season Access Road (Constructed)
Prohibition Creek Access Road (In Construction)
Proposed Great Bear River Bridge
Proposed Borrow / Rock Quarry Site and Access
Local Assessment Area
Regional Assessment Area
Community
Northwest Territories Highway
Winter Road
Settlement Area Boundary
Region Boundary

* More than one alien or alien invasive plant may occur at each mapped location

0 10 20 Kilometers
(At original document size of 8.5x11)
1:1,100,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 8/3/2023
TR by AJ on 8/3/2023

Client/Project
144903025-0105-REVA
Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
18.3

Title
Landcover Types and Documented Alien and Invasive Alien Species Occurrences within the Mackenzie Valley Highway Project LAA and RAA – Sahtu Region

Notes
1. Coordinate System: NAD 1983 Northwest Territorries Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
Imagery date: 2021

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

Large portions of the LAA and RAA have burned in the past. However, fires in the LAA are not common, with a maximum of two fires per decade recorded (1990-1999). The percentage of the LAA burned ranged from 0% to 12.8% per decade from 1960 to 2019 (Appendix 18A; K'alo-Stantec, 2022). In comparison to the LAA, the RAA burned more frequently, and had a greater proportion burned. However, this is likely an artifact of the size difference between the LAA and RAA and is not suspected to reflect a greater chance of burning.

Similar to the Dehcho Region, large portions of the LAA and RAA in the Sahtu Region have burned in the past. Fires were generally common in the LAA, with every decade since 1960 experiencing at least one burn. The number of fires ranged from one (1960-1969, 2010-2019) to a maximum of five (1990-1999). Less than 1% to 61.1% of the LAA burned each decade between 1960 and 2019 (Appendix 18A; K'alo-Stantec, 2022).

18.2.2.2 Timber

Merchantable timber includes trees without defects with a diameter at breast height (dbh) of at least 14 centimetres (cm). More detailed information from ground data is needed to provide detailed merchantable timber volume estimates, but merchantable timber volume is expected to be approximately 65% of total timber volume (National Forestry Database, 2022).

Coniferous forests have the greatest total volume of timber in the LAA (448,465 m^3) and mixedwood forests had the highest average stand volume density per hectare in the LAA. On average, trees within mixedwood forest of the LAA were tallest (9.5 m, standard deviation (SD) = 1.6), followed by coniferous forest (9.1 m, SD = 2.2), then broadleaf forest (8.5 m, SD = 2.2). Within the LAA, coniferous forest had the tallest maximum tree height (19 m) (Appendix 18A; K'alo-Stantec, 2022).

Coniferous forest also had the greatest total volume within the RAA, although average stand volume density was lower in the RAA (31.0 cubic metres per hectare [m^3/ha]) than in the LAA (40.2 m^3/ha). In comparison to the LAA, average tree height in coniferous forest within the RAA was also shorter (7.7 m, SD = 2.5). Within the RAA, average tree height was greatest for mixedwood forest (8.9 m, SD = 2.1), followed by coniferous forest (7.7 m, SD = 2.5), then broadleaf forest (6.7 m, SD = 1.9). Tallest maximum tree height occurs in coniferous and mixedwood forest (22 m) (Appendix 18A; K'alo-Stantec, 2022).

Similar to the Dehcho Region, coniferous forests in the Sahtu Region have the greatest total volume in the LAA (288,702 m^3) and mixedwood forests had the highest stand volume density. Tree heights within the LAA range from 5 m to 18 m and were tallest on average within mixedwood forest (8.2 m, SD = 1.9). Tallest maximum tree height within the LAA occurs within broadleaf forest (Appendix 18A; K'alo-Stantec, 2022).

Similar to the LAA, within the RAA of the Sahtu Region total volume was greatest for coniferous forest (5,590,767 m^3) but mixedwood forest had the greatest average stand volume density (30.2 m^3/ha). In comparison to the LAA, maximum tree heights were greater within the RAA for all forest cover types. Tree heights within the RAA range from 4 m to 22 m and on average were greatest within mixedwood forest (7.8 m, SD = 2.0). Tallest maximum tree height also occurs in mixedwood forest within the RAA (Appendix 18A; K'alo-Stantec, 2022).

18.2.2.3 Plant Species of Conservation Concern

A search of the NWT Species Monitoring Infobase (Working Group on General Status of NWT Species, 2016) queried to ecoregions intersecting the RAA, identified 215 plant and lichen SOCC in the Sahtu region. Specifically, 167 rare vascular plant, 42 rare lichen, and 6 rare bryophyte (moss and liverwort) species potentially occur in the intersected ecoregions of the Sahtu Region. No plant, including bryophytes, or lichens occurring in the Boreal Cordillera ecoregion or the Taiga Cordillera ecoregion are listed under SARA or COSEWIC. No rare vegetation assemblages are listed by the NWT Species Monitoring Infobase, SARA, or COSEWIC.

Within the Sahtu Region of the RAA, seven rare vascular plant occurrences have been documented, six of which are considered Sensitive and one is considered May Be At Risk (5658 NWT Ltd. And GNWT, 2011 [PR#16]) (Table 18.5).

Table 18.5 Documented Rare Plant Occurrences within the RAA – Sahtu Region

Scientific Name[1]	Common Name	NWT General Species Rank[1]	SARA Status[2]	COSEWIC Assessment[2]
Elymus canadensis	Canada nodding wild rye	Sensitive	-	-
Potamogeton natans	floating pondweed	Sensitive	-	-
Potamogeton foliosus	leafy pondweed	Sensitive	-	-
Juncus stygius	moor rush	Sensitive	-	-
Danthonia spicata	poverty wild oat grass	Sensitive	-	-
Najas flexilis	slender naiad	Sensitive	-	-
Rhynchospora alba	white beakrush	May Be At Risk	-	-

Notes:

1 Working Group on General Status of NWT Species (2016).

2 Government of Canada (2019).

Source: 5658 NWT Ltd. And GNWT (2011 [PR#16]).

The search of the NWT Species Monitoring Infobase (Working Group on General Status of NWT Species, 2016) queried to ecoregions intersecting the RAA of the Dehcho Region (Boreal Cordillera and Taiga Cordillera ecoregion) identified 107 SOCC including 77 rare vascular plants, 6 rare mosses or liverworts, and 24 rare lichens with potential to occur within the RAA (Vegetation and Wetlands TDR, Appendix 18A; K'alo-Stantec, 2022). All 107 of the SOCC intersecting the Dehcho Region are included in the 215 SOCC identified in the Sahtu Region.

No rare plant occurrences have been documented within the Dehcho Region of the RAA (Dessau, 2012 [PR#13]). Several species reported by Dessau (2012 [PR#13]) were previously considered rare but have since been downgraded and are no longer considered rare. No plant, including mosses, or lichen SOCC potentially occurring in the Dehcho Region of the RAA are listed under SARA or COSEWIC. No vegetation assemblages are listed by the NWT Species Monitoring Infobase, SARA, or COSEWIC.

18.2.2.4 Plant Species of Interest to Indigenous Governments, Indigenous Organizations, and Other Affected Parties

A total of 150 plant, lichen, and fungus species were identified to be plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties in the Dehcho and Sahtu regions from publicly available reports. A total of 144 plants or groups of plants are used for traditional purposes in the Dehcho Region and 28 in the Sahtu Region, with 123 expected in the ecoregions intersected by the LAA and RAA (Appendix 18B). Of the 150 plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties, 11 are trees, 47 are shrubs, 8 are subshrubs, 74 are forbs, 8 are graminoids, 1 is a lichen, and 1 a fungus. No bryophyte species were identified to be of plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties. Vegetation, lichen and fungal species of interest, used for a variety of traditional purposes, have been identified through the project-specific engagement program, a review of publicly available literature, and project-specific TLRU studies.
See Appendix 18B for a consolidated table of this information.

Eleven plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties are also listed as plant SOCC, with seven listed as May Be At Risk (S1S2, meaning species occurrences range from critically imperiled to imperiled; very high to high risk of extirpation) and four listed as Sensitive (S3, meaning vulnerable, at moderate risk of extirpation) (NatureServe, 2012) (Appendix 18A; K'alo-Stantec, 2022). Most of the plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties are ranked as secure (meaning very low or no risk of extirpation) within the NWT and occupy a range of landcover types such as coniferous, broadleaf, mixedwood forest, or shrubland upland sites or treed, shrub, or herbaceous wetland sites. Seven of the plants are alien in the NWT: lily pad root (*Aeonium* sp.), lamb's quarters (*Chenopodium album*), hemp nettle (*Galeopsis tetrahit*), broad-leaved plantain (*Plantago major*), blackcurrant (*Ribes nigrum*), sage (*Salvia officinalis*), and dandelion (*Taraxacum officinale*). Ox-eye daisy (*Leucanthemum vulgare*) is an alien invasive plant.

Many plant species serve different purposes, including medicinal, food, craft, ritual, spiritual, and home fuel. For example, birch bark (*Betula papyrifera, Betula neoalaskana*) is used for baskets, berries (e.g., blueberries [*Vaccinium* spp.]) are collected for food and for dyeing materials, and pasture sage (*Artemisia frigida*) is used for spiritual, ritual, or medicinal purposes (IMG-Golder Corporation, 2006).

Of the 142 plant species identified, 85 occur in uplands, 35 occur in wetlands, and 22 occur in unknown landscape position (Appendix 18B).

Table 18.6 lists specific plant harvesting locations as identified by Indigenous Governments, Indigenous Organizations, and other affected parties through the project-specific engagement program, a review of publicly available literature, and project-specific TLRU studies. Sahtu Dene and Métis and Dehcho First Nations and Pehdzéh Kį First Nation reported 12 locations within the PDA, LAA, and RAA that are of interest relative to plants and plant harvesting, as described in Table 18.6 (EBA, 2006, IMG-Golder-Corporation, 2006; TRRC, 2022; NWRRC, 2023).

Table 18.6 Plant Harvesting Locations identified by Indigenous Governments, Indigenous Organizations and Other Affected Parties Relative to the Project

Location	Within LAA	Within RAA[1]	Identified By:
Dehcho Region	✓*	✓	Dehcho First Nations
Sahtu Region	✓*	✓	Sahtu Dene and Métis; Sahtu Renewable Resources Board (SRRB)
Pehdzéh Kį N'deh area[2]	✓*	✓	Pehdzéh Kį First Nation
Mackenzie Valley Winter Road KM 724 (north or Wrigley)	✓*	-	Pehdzéh Kį First Nation
Mackenzie Valley Winter Road KM 782 (approximately halfway between Tulita and Wrigley)	✓*	-	Pehdzéh Kį First Nation
Wrigley (area)[3]	✓*	-	Pehdzéh Kį First Nation
Along the Mackenzie Valley Winter Road (between Norman Wells and Tulita)[4]	✓*	-	Sahtu Dene and Métis; SRRB; Tulita Renewable Resources Council (TRRC)
Tulita (area)[5]	✓*	-	TRRC
Plane Lake	✓*	-	TRRC
Dehdéleı̨ǫ Tué (Sucker Lake/Three Day Lake)	-	✓	Sahtu Dene and Métis; SRRB
Great Bear River (West) (intersecting with the LAA and RAA)	✓	✓	TRRC
Canyon Creek	-	✓	Norman Wells Renewable Resources Council (NWRRC)

Notes:

1 Occurs within the RAA outside the LAA and PDA

2 Pehdzéh Kį area boundary was not identified or disclosed in the report.

3 Specific locations were not identified in the report.

4 Specific locations were not identified in the report.

5 Specific locations were not identified in the report.

* May occur within the PDA

Sources: EBA, 2006; IMG-Golder Corporation, 2006; NWRRC, 2023; SLUPB, 2022; TRRC, 2022; Dessau, 2012 (PR#13).

18.2.2.5 Alien and Invasive Alien Species

Sixteen alien and four invasive alien plant species have been documented in the RAA (Appendix 18A; K'alo-Stantec, 2022). For these species, there are 42 occurrences of 13 alien and invasive alien plant species documented within the RAA in the Sahtu Region and 14 occurrences of 12 alien and invasive alien plant species documented within the RAA in the Dehcho Region.

18.3 Project Interactions with Vegetation and Wetlands

Table 18.7 identifies the Project's physical activities that might interact with vegetation and wetlands and potentially result in one of the identified potential effects. Interactions that have the potential to result in effects on vegetation and wetlands within the LAA are indicated by a check mark or a dash and are discussed in detail in Section 18.4 in the context of effects pathways, standard and project-specific mitigation measures, and residual effects. A justification for no effect is provided following the table.

Table 18.7 Project-Environmental Interactions with Vegetation and Wetlands

Physical Activities	Timing	Effects			
		Change in Landscape Diversity	Change in Community Diversity	Change in Species Diversity	Change in Wetland Function
Construction Phase					
Mobilization of equipment, materials, and fuel, resupply, and demobilization	Summer and winter	-	-	-	-
Establishment and operation of camps	Year-round	-	-	-	-
Site preparation of ROW, access, and workspaces	Winter	✓	✓	✓	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	✓	✓	✓	✓
Material haul	Year-round	✓	✓	✓	✓
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓	✓	✓	✓
Culvert installations	Summer or winter	-	-	-	✓
Road base placement, compaction and surfacing	Summer	-	-	-	-
Water withdrawal to support construction activities	Year-round	-	-	-	✓

Physical Activities	Timing	Effects			
		Change in Landscape Diversity	Change in Community Diversity	Change in Species Diversity	Change in Wetland Function
Closure and reclamation of MVWR and temporary borrow sources/quarries, camps, and workspaces	Summer	✓	✓	✓	✓
Employment and contracted goods and services[1]	Year-round	-	-	-	-
Operations and Maintenance Phase					
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	✓	✓	✓	✓
Material haul and stockpiling	Summer	✓	✓	✓	✓
Operation of, and activities at, maintenance yards	Year-round	-	-	-	-
Water withdrawal for dust control	Summer	-	-	-	✓
Employment and contracted goods and services[1]	Year-round	-	-	-	-
Presence and use of the highway	Year-round	✓	✓	✓	✓
Highway and access road maintenance including snow clearing, repair, grading, dust control	Year-round	-	-	-	-
Vegetation control	Summer	✓	✓	✓	✓
Bridge and culvert maintenance	As needed	-	-	-	-

Notes:

✓ = Potential interaction

– = No interaction

[1] Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, "Employment and contracted goods and services" have been introduced as an additional component under each project phase.

During construction, interactions between the Project and vegetation and wetlands will occur during site preparation, quarry and borrow source development, material haul, preparation of road embankment, road cuts, culvert installation, access road construction, water withdrawal as well as closure and reclamation of the MVWR, temporary borrow sources/quarries, camps, and workspaces. After construction, interactions between the Project and vegetation and wetlands are expected to continue due to the presence of the highway and at some borrow source and quarry locations.

Mobilization and demobilization of project equipment is not expected to interact with vegetation and wetlands as construction materials and equipment will be transported by barge on the Mackenzie River (Deh Cho), along the existing Mackenzie Highway, or by the MVWR in the winter to designated staging areas. Staging areas identified for equipment and supplies include existing locations on the Mackenzie Highway near Wrigley, existing staging areas within municipal boundaries of nearby towns, locations of permanent borrow/quarry sources, and other previously disturbed areas identified during community engagement. Vegetation and wetlands will likely not be affected by construction camps because camp locations will be located in existing disturbed areas such as existing camp facilities within Norman Wells; dedicated camp locations within municipal boundaries of Norman Wells, Tulita, and/or Wrigley; and one or more borrow sources or quarries to be accessed from the MVWR.

Culvert installations, road base, compaction, and surfacing are not expected to interact with vegetation and wetlands because such work will occur in areas where vegetation has already been removed during the site preparation stage of construction. Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns. However, although culvert installation may affect wetland function, culverts will be installed to maintain flow in wetlands crossed by the Project. Employment and contracted goods and services during construction are not expected to affect vegetation and wetlands in any way.

Interactions between the Project and vegetation and wetlands will continue due to road embankment vegetation control and dust contaminant deposition associated with borrow source and quarry operations, material haul and stockpiling, and traffic on the completed highway. Dust control will require water withdrawal, however no interactions with vegetation or wetlands are expected as a result of summer water withdrawal activities because withdrawal locations are likely to be located on larger watercourses, such as the Mackenzie River (Deh Cho) and those crossed by existing bridges, which will not infringe on wetlands. Water withdrawal will be within the limits of water licences and in accordance with DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013a, 2013b). Snow clearing and grading will be ongoing as part of road maintenance and repair. These activities will occur within the road ROW and are not anticipated to extend into adjacent vegetation or wetlands. The quantity and quality of water leaving the ROW is not expected to change based on snow grading. Bridge and culvert maintenance will also be ongoing but are not expected to affect vegetation and wetlands outside of the road ROW.

18.4 Assessment of Residual Effects on Vegetation and Wetlands

Based on project interactions with the environment identified in Table 18.7, the Project may affect vegetation and wetlands. Potential effects, effect pathways, and mitigation measures that will reduce or eliminate the effects on vegetation and wetlands are identified in Table 18.8. Residual effects and associated analytical assessment techniques are also described.

Table 18.8 Potential Effects and Mitigation Measures for Vegetation and Wetlands

Effect Name	Effect Pathway	Mitigation Measures
Change in Landscape Diversity	• Fragmentation of native plant communities/landcover types arising from clearing • Indirect alteration of native communities/landcover types, including riparian areas, from the introduction or spread of alien and invasive alien plant species and pests, or dust contaminant deposition	• The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical. • Activities will be restricted to workspaces and access roads. Prior to the start of construction, the boundaries of the work area, staging areas, and access roads will be staked and/or flagged. • Removal of vegetation will be limited to the width of the ROW and workspaces. • Equipment originating from outside of the NWT will be cleaned prior to mobilization to avoid introduction of invasive species. • Machinery will be maintained and regularly inspected for fuel, oil, or other fluid leaks. Machinery found to be leaking will be withdrawn from service until repaired. • Erosion and sedimentation control measures will be implemented per the Erosion and Sedimentation Control Plan (ESCP) and will be in place prior to construction activities and before the spring melt/freshet. • Vegetation buffers will be used to protect riparian vegetation, as appropriate. • During spring, summer, and fall, suitable ground equipment will be used to prevent effect on sensitive terrain. • The GNWT will undertake regular inspection for invasive alien plant occurrences during construction and apply management through mowing to reduce introduction and spread in the ROW and surrounding natural vegetation. • Water will only be used for dust suppression, except as provided in the GNWT Guideline for Dust Suppression.

Effect Name	Effect Pathway	Mitigation Measures
Change in Landscape Diversity (cont'd)		• Closure and reclamation will promote re-establishment of vegetation. • Abandoned sections of MVWR ROW and access roads will be closed and reclaimed to promote re-establishment of vegetation ground cover. • The Project will adhere to mitigation measures in the ESCP, Permafrost Protection Plan (PPP), Waste Management Plan (WMP) and Spill Contingency Plan (SCP) to reduce effects on vegetation and wetlands.
Change in Community Diversity	• Direct loss or alteration of native communities/land-cover types from clearing and ground disturbance • Removal of merchantable timber	• Activities will be restricted to workspaces and access roads. Prior to the start of construction, the boundaries of the work area, staging areas, and access roads will be staked and/or flagged. • Travel of vehicles will be confined to existing roads and trails as much as possible to avoid disturbing vegetated areas. • Project vehicles will travel on designated winter roads or constructed embankment only. • The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent possible. • Removal of vegetation will be limited to the width of the ROW and workspaces. • Trees will be felled toward the ROW and access roads wherever possible to reduce damage to vegetation outside of the ROW and access roads. • Merchantable timber will be limbed and decked in a dry area and made available to a receiver with an authorization (timber cutting permit or timber cutting licence) from the GNWT. Merchantable timber includes trees without defects with a dbh of at least 14 cm. • During spring, summer, and fall, suitable ground equipment will be used to prevent effect on sensitive terrain.

Effect Name	Effect Pathway	Mitigation Measures
Change in Community Diversity (cont'd)		• Where vegetation must be cut but is not removed, the cut will be made > 10 cm above the ground to retain the root structure. Clearing will be completed by hand, where required, to prevent damage to the ground such as rutting, compaction and erosion. • Tree roots will be grubbed only in areas required for construction or stripping. Grubbing operations will be conducted to preserve soil surface organic material. • Organic material and topsoil will be set aside for use during reclamation, where possible. • Cleared brush and unsalvageable trees will be windrowed, mulched, and spread on the ROW where possible. • Closure and reclamation will promote re-establishment of vegetation. • Borrow source vegetated surface material, where present, will be replaced after excavation is completed. • Off-road travel will be limited to winter (December 15 to April 1) where possible. • Abandoned sections of MVWR ROW and access roads will be closed and reclaimed to promote re-establishment of vegetation.
Change in Species Diversity	• Direct loss of plant SOCC or plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils from clearing and ground disturbance • Indirect loss or alteration of SOCC or plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils from the introduction or spread of invasive alien plants, invasive plant species or, plant pests and dust contaminant deposition	• The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties regarding perceived effects on plant species of interest to Indigenous Governments, Indigenous Organizations and other affected parties. • Targeted vegetation and wetland surveys of SOCC and specific plant species of interest to Indigenous Governments and Indigenous Organizations, and other affected parties, will be conducted within the PDA in high potential areas, such as fens, bogs, and dry or rocky sites and in a sub-sample of more common landcover types, prior to construction. This will include transplant or seed collection of observed rare or vulnerable plant species. Appropriate mitigation measures (and monitoring if needed) will be developed based on the findings of the surveys. Options are identified in Chapter 18.

Effect Name	Effect Pathway	Mitigation Measures
Change in Species Diversity (cont'd)		• Known areas of collection of plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties will be avoided where possible. • Monitoring programs will be implemented to evaluate if mitigation measures are being implemented and are effective. These include monitoring in accordance with the terms and conditions of permit approvals, as required. • Equipment originating from outside of the NWT will be cleaned prior to mobilization to avoid introduction of invasive alien species. • Machinery will be maintained and regularly inspected for fuel, oil, or other fluid leaks. Machinery found to be leaking will be withdrawn from service until repaired. • Erosion and sedimentation control measures will be implemented per the ESCP, and will be in place prior to construction activities and before the spring melt/freshet. • Quarry dewatering will be conducted in a manner that discharge will not directly enter wetlands or lead to soil erosion. • Water will only be used for dust suppression, except as provided in the GNWT Guideline for Dust Suppression. • Invasive alien plants will be managed through mowing to reduce introduction and spread in the PDA and surrounding natural vegetation. • Abandoned sections of MVWR ROW and access roads will be closed and reclaimed. • Closure and reclamation will promote re-establishment of vegetation.
Change in Wetland Function	• Direct loss of wetland area or alteration of wetland function (i.e., hydrology, structure, plant composition, nutrient cycling and litter accumulation) from clearing or infilling of wetlands	• Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns. • During spring, summer, and fall, suitable ground equipment will be used to prevent effect on sensitive terrain. • Use of equipment on highly saturated soil will be avoided, where possible. Vegetation buffers will be used as visual barriers and to protect riparian vegetation, as appropriate.

Effect Name	Effect Pathway	Mitigation Measures
Change in Wetland Function (cont'd)	• Indirect alteration of wetland area or function (i.e., hydrology, structure, plant composition, nutrient cycling and litter accumulation) from changes in surface or groundwater flow patterns	• Erosion and sedimentation control measures will be implemented per the ESCP. • Silt fencing will be used downgradient of the works where required. • Sediment and erosion control measures will be regularly inspected to confirm they are performing as intended. • Erosion and sedimentation control measures will be maintained until disturbed areas are revegetated or until such areas have been permanently stabilized by other effective measure. • An SCP will be developed and implemented. • All site personnel will receive SCP training and will have awareness of spill prevention. • Fuel will be stored in containers with secondary containment capable of containing 110% of the largest container. • Equipment such as vehicles, generators, and pumps will have secondary containment installed capable of containing fuel drips or leaks during operations and refueling. • Equipment laydown and staging areas will be located at least 100 m from the ordinary high water mark of any waterbody. • Washing, refueling, and servicing machinery and storage of fuel and other materials for machinery will be conducted a minimum of 100 m from the ordinary high-water mark and in a manner to prevent any deleterious substances from entering the water. • Dust suppression will be conducted as necessary to reduce dust and sediment from entering watercourses or waterbodies. • Quarry dewatering will be conducted in a manner such that discharge will not directly enter wetlands or lead to soil erosion.

18.4.1 Analytical Assessment Techniques

Potential effects on vegetation and wetlands were assessed by comparing existing baseline conditions in the LAA and RAA (described in the overview section and the TDR [Appendix 18A; K'alo-Stantec, 2022]) to conditions anticipated to occur with construction of the Project. Specifically, changes in vegetation and wetland resources anticipated to result from construction of the Project were determined by comparing baseline conditions in the LAA with anticipated conditions in the LAA following clearing of the PDA. It is conservatively assumed that clearing, grubbing, stripping, and grading will take place in the entire PDA and that vegetation and wetlands will be directly and completely lost within the full extent of the PDA. The amount of change in patch size, patch edge/area, landcover, plant SOCC, plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties, and wetland function in the LAA was then assessed comparing baseline and anticipated post-construction conditions. Anticipated indirect effects on vegetation and wetlands due to potential changes in light and moisture levels, dust deposition, and invasive alien plant introduction in vegetated areas near but outside the PDA were also assessed.

Changes in wetland function were qualitatively assessed based on professional judgement of wetland responses to changes in hydrology and plant conditions gained from surveying wetlands in the field, including in the NWT, and evaluating changes on other development projects following construction. Effects on landscape diversity and community diversity were quantitatively assessed by examining the change in patch metrics (e.g., patch size and area to perimeter length) and change in area of landcover types. Landcover types were mapped for the PDA, LAA, and RAA using Earth Observation of Sustainable Development NWT data (Natural Resources Canada and the Government of the Northwest Territories, 2017) and forest fire polygon data from the Canadian National Fire Database (CNFDB) (Canadian Forest Service, 2020). Changes to species diversity were evaluated using changes in natural landcover types expected or known to support SOCC plants and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties. Information on landcover types supporting SOCC plants and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties was obtained from available literature and relevant internet sources.

18.4.2 Change in Landscape Diversity

18.4.2.1 Effects Pathways

Project activities could result in changes to the abundance of native vegetation communities at the landscape level, through the direct loss of vegetation due to site clearing and grubbing. Specifically, vegetation will be cleared for preparation of the ROW, development of quarry and borrow sources and associated access roads, and embankment construction, including road cuts in steep grade terrain. Indirect effects resulting from construction activities may occur via changes to hydrology, soil conditions after clean-up and reclamation, dust contaminant deposition, and light and moisture level alteration from creation of new forest edges.

Landscape diversity was evaluated by assessing the natural distribution of patch size and perimeter of vegetation types in the RAA, and how they will change as a result of the Project. Larger patches provide necessary habitat for plants and animals requiring mature habitat, and such species may be vulnerable to fragmentation (Jules, 1998). Fragmentation occurs when larger patches are converted to smaller, spatially separated patches due to clearing activities. Fragmentation also typically results in a loss of mature interior habitat and habitat connectivity (Morrison et al., 1998). Clearing activities also increase the ratio of edge to interior habitat. Increasing isolation of mature habitat patches is a primary cause of declining biodiversity and increasing extinction risk (Wilcox and Murphy, 1985). Populations can become isolated if there is reduced breeding between populations in isolated patches of suitable habitat.

Habitat fragmentation generally results in a change in plant community composition, including vascular and non-vascular plants, and lichens. Fragmentation provides generalist species, edge-adapted species, and invasive species with additional habitat, resulting in increased abundance for such species (Jules, 1998). Species that require mature habitat, however, often experience a loss of suitable living area (Wilcox and Murphy, 1985). Increased light penetration can result in preferential regeneration of suckering tree species, such as aspen (Harper and Macdonald, 2002). Harper et al. (2005) describe examples of shifts in plant community composition and reduction of species diversity due to fragmentation, reduction of patch sizes, and increase in patch perimeter length. Pehdzéh Kį First Nation and Dehcho First Nations expressed concerns about potential effects during construction to the land and forest (Dessau, 2012 [PR#13]). SRRB raised concerns about potential effects on resident species, including effects of increasing invasive species which can influence potential for wildfires (SRRB, 2016).

As the level of landscape fragmentation increases, connectivity between vegetation community habitat types decreases. Reduced connectivity has different effects on wildlife species, with differing abilities for movement through various habitat types and seed dispersal abilities in various plant species (Monkkonen and Reunanen, 1999). As fragmentation continues, connectivity declines at a steady rate until a certain threshold is reached. At that point, an exponential increase will occur in the discontinuity of the landscape (McIntyre and Wiens, 1999; Monkkonen and Reunanen, 1999). The linkage between habitat distribution and connectivity is supported by recent simulation studies (Keymer et al., 2000; Fahrig, 2001). The ability of plants specifically to disperse between patches or remain in patches determines gene flow and the survival of populations and subpopulations.

Vegetation clearing will likely change the light intensity along the edge of the PDA and some distance within remaining adjacent plant communities in the LAA, and this change in light could alter temperature and moisture (Luken et al., 1992). Increased light intensity has been found to support increased white spruce (*Picea glauca*) growth and abundance of grasses, such as bluejoint (*Calamagrostis canadensis*) (Lieffers and Stadt, 1994). Changes in light intensity have also been found to alter species richness and plant diversity, particularly forbs and grasses (Bartemucci et al., 2006), and reduce bryophyte cover and conifer regeneration (Harper et al., 2015). Stand attributes (e.g., tree heights, coniferous versus broadleaf cover), landscape heterogeneity, and time since disturbance can influence the degree of response and the distance of effects from the edge, with effects more pronounced in areas of higher tree canopy cover and tree height, and less pronounced

in landscapes of high heterogeneity, more open stands, and areas dominated by pioneer species (Harper et al., 2005). These effects will tend to decrease with time as vegetation communities mature. The distance of edge effects for boreal forest has been found to be weak and is anticipated to extend to a maximum of 20 m (Harper et al., 2015).

Vehicles using newly constructed roads may also spread alien or invasive alien plant species by bringing in seed of such species in mud and plant material on tires. Forman (1995) cites an Australian study where seeds of 259 plant species were identified in mud washed off vehicle tires at a car wash. Although most alien and invasive alien species establish primarily along newly created edges of cleared areas, some species may colonize interior forest over time (MacFarlane, 2003). Available information on effects from dust contamination indicates dust deposition can cause increased soil pH, decreased plant biomass, and altered species composition (Myers-Smith et al., 2006). Other changes from dust contamination include decreases in tree seedlings/saplings, low shrubs, and forbs and an increase in graminoid species (Brandt and Rhoades, 1972; Gunn, 1998; Myers-Smith et al., 2006; Gill et al., 2014). Covering with or absorption of dust contaminants can also alter plant growth and flowering (Farmer, 1993; Saikkonen et al., 1998). Lichens are susceptible to dust contamination since they receive nutrients from the air rather than the soil (Nash and Gries, 1995), and both mosses and lichens are vulnerable to reductions in light and increases in surface temperature, which can occur from dust contaminant deposition (Adamson and Seppelt, 1990).

Construction of the Project will likely have an effect on fire distribution in the RAA. Fire behaviour across the landscape will likely be affected due to creation of a continuous, wide firebreak. The MVWR is an existing firebreak which will be widened in most places. The highway road surface will be kept unvegetated and vegetation within the ROW will be kept mowed. The presence of the road will result in new sources of fire ignition, including sparks from vehicles and equipment, and potentially increase risk of anthropogenic fires (e.g., unextinguished campfires or arson) due to increased access.

Through the project-specific engagement program, Indigenous Governments, Indigenous Organizations, and other affected parties including the Pehdzéh Kį First Nation, Dehcho First Nations and Sahtu Dene and Métis, expressed concerns about habitat and effect on the land and forest, including plant SOCC. Community members expressed concern that development may affect human health through changes in water and air quality and the health of the region's wildlife, fish, and vegetation (see Chapter 11, Culture and Traditional Land Use, Including Harvesting).

18.4.2.2 Mitigation

Mitigation measures will be implemented during construction and operation of the Project, as identified in the management plans located in Volume 5 and Table 18.8. Key mitigation measures to avoid or reduce the potential effects of the Project on landscape diversity include the following:

- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical.
- Activities will be restricted to workspaces and access roads. Prior to the start of construction, the boundaries of the work area, staging areas, and access roads will be staked and/or flagged.
- Removal of vegetation will be limited to the width of the ROW and workspaces (including active quarry and borrow sources)
- Machinery will be maintained and regularly inspected for fuel, oil, or other fluid leaks. Machinery found to be leaking will be withdrawn from service until repaired.
- Equipment originating from outside of the NWT will be cleaned prior to mobilization to avoid introduction of invasive species.
- Erosion and sedimentation control measures will be implemented per the ESCP (Volume 5).
- Vegetation buffers will be used to protect riparian vegetation, as appropriate.
- During spring, summer, and fall, suitable ground equipment will be used to prevent effect on sensitive terrain.
- The ROW will be regularly inspected for invasive alien plant occurrences and invasive alien plants will be managed through mowing to reduce introduction and spread in the ROW and surrounding natural vegetation.
- Water will only be used for dust suppression, except as provided in the GNWT Guideline for Dust Suppression.
- Closure and reclamation will promote re-establishment of vegetation.
- The ESCP, PPP, WMP and SCP will be followed. These plans include measures to reduce and monitor direct and indirect effects on vegetation and wetlands. Draft management plans are included in Volume 5.
- Abandoned sections of MVWR ROW and access roads will be closed and reclaimed.

18.4.2.3 Residual Effects

Table 18.9 presents average patch size, maximum and minimum patch sizes, and the standard deviation for each landcover type in the LAA for existing conditions and with the Project. For existing conditions, the landcover types with the largest average, maximum, and standard deviation patch size are open water, herbaceous, and coniferous forest. Much of the open water area indicated in Table 18.9 is within the Mackenzie River (Deh Cho). Patches of herbaceous and unvegetated area are mostly represented by the MVWR.

With the exception of herbaceous and unvegetated patches, the average patch sizes in the LAA are unchanged between existing conditions and project construction and operations, except for a 0.1 hectare (ha) reduction in average patch size in coniferous forest and shrubland. The large reduction in average patch size for herbaceous and unvegetated areas is associated with the conversion of the existing MVWR to the PDA. The small amount or no change in the average patch size for all other landcover classes in the LAA indicates only a small amount of change to the average patch size in the LAA resulting from the Project.

There is no reduction in maximum patch size for any of the wetland landcover classes and only a very small reduction in maximum open water patch size because the Project avoids many large wetlands and open water areas. There is a large reduction in maximum patch size for herbaceous and unvegetated areas because, as indicated for average patch size, many patches of this landcover type are associated with the MVWR, much of which will be converted to the PDA. The reduction in maximum patch size for other landcover classes ranges from 3% for shrubland to 35.3% for mixedwood forest. The reduction in maximum patch size for upland landcover types indicates that the Project will fragment some of the larger forested areas along the highway portion of the PDA.

The minimum patch size for all landcover classes is less than 0.1 ha for existing conditions and does not change for construction and operation.

Table 18.10 provides statistics for the perimeter to area ratio of patches of each landcover type in the LAA. For each landcover type, the average, standard deviation, maximum, and minimum perimeter to area ratio are presented for existing conditions and construction and operations. For existing conditions, the average ratio for all landcover types is similar, ranging from 1,300 metres per hectare (m/ha) to 1,700 m/ha. For all landcover types, except herbaceous and unvegetated, the ratio of perimeter to area increases during construction and operations by a small to moderate amount, between 100 m/ha and 1,000 m/ha, indicating that the construction of the Project will make a small to moderate increase in edge length relative to size for patches of all landcover types due to the creation of long edges on both sides the PDA. The large increase in the ratio of herbaceous and unvegetated landcover reflects the creation of the linear edges of the PDA.

Table 18.9 Anticipated Alteration of Landcover Patch Sizes within the LAA

Landcover Type	Existing Conditions				Construction and Operation			
	Average Size (ha)	SD (ha)	Maximum (ha)	Minimum (ha)	Average Size (ha)	SD (ha)	Maximum (ha)	Minimum (ha)
Broadleaf Forest	0.8	3.1	117.7	<0.1	0.8	2.9	107.5	<0.1
Coniferous Forest	2.5	19.7	796.8	<0.1	2.4	16.7	606.2	<0.1
Herbaceous and Unvegetated	3.2	19.6	368.1	<0.1	0.7	3.0	92.4	<0.1
Mixedwood Forest	0.9	3.4	116.0	<0.1	0.9	2.8	75.0	<0.1
Open Water	3.5	44.4	1,808.2	<0.1	3.5	44.2	1,807.5	<0.1
Shrubland	1.0	6.5	326.9	<0.1	0.9	6.2	317.5	<0.1
Wetland-herb	0.5	0.8	17.0	<0.1	0.5	0.8	17.0	<0.1
Wetland-shrub	0.6	1.5	74.4	<0.1	0.6	1.5	74.4	<0.1
Wetland-treed	0.6	1.3	29.9	<0.1	0.6	1.2	29.9	<0.1

Source: Natural Resources Canada and the Government of the Northwest Territories (2017).

Table 18.10 Ratio of Perimeter to Area of Patches in the LAA

Landcover Type	Existing Conditions				Construction and Operation			
	Average Ratio (m/ha)	SD (m/ha)	Maximum (m/ha)	Minimum (m/ha)	Average Ratio (m/ha)	SD (m/ha)	Maximum (m/ha)	Minimum (m/ha)
Broadleaf Forest	1,300	8,100	490,100	200	2,300	38,800	2,191,800	200
Coniferous Forest	1,600	22,900	1,992,100	100	1,900	23,500	1,992,100	100
Herbaceous and Unvegetated	1,500	8,500	240,800	100	4,500	24,600	920,800	100
Mixedwood Forest	1,700	34,800	2,079,000	200	2,100	36,800	2,079,000	200
Open Water	1,300	5,800	158,900	100	1,400	6,100	158,900	100
Shrubland	1,400	9,300	751,300	100	1,600	10,700	751,300	100
Wetland-herb	1,500	19,800	1,633,000	300	1,600	19,900	1,633,000	300
Wetland-shrub	1,300	12,500	1,110,100	200	1,500	13,100	1,110,100	200
Wetland-treed	1,700	36,700	3,562,600	200	1,900	37,600	3,562,600	200

Source: Natural Resources Canada and the Government of the Northwest Territories (2017).

The increase in the perimeter to edge ratio will allow indirect effects in all landcover types along both edges of the PDA, including increased light levels, decreased moisture levels, dust contaminant deposition, and the potential for introduction of alien and invasive alien species. With project mitigation measures listed, indirect effects are anticipated to be reduced to low levels.

As the Project will result in an increase in fragmentation of the landscape, including a decrease in the average and maximum patch size of some landcover types and an increase in the average perimeter to area ratio of all landcover types, the effect on landscape diversity is considered moderate and extends to the LAA. This determination includes uncertainty of accuracy of landcover mapping from published sources.

Project effects are not expected to result in the loss of any landcover types in the LAA, and patches of many sizes and shapes of all landcover types are expected to remain abundant in the LAA and surrounding RAA. Effects are expected to be long-term due to the presence of the highway and the retention of some quarry sites. Dust contaminant deposition and the potential for alien and invasive alien species introduction adjacent to the highway will be ongoing. The VC is not sensitive to seasonal timing because all vegetation will be removed from the PDA (i.e., seasonal aspects are unlikely to affect vegetation and wetlands).

18.4.3 Change in Community Diversity

18.4.3.1 Effects Pathways

Construction activities that include vegetation clearing and ground disturbance for site preparation will result in vegetation loss, including in wetlands. Other activities, such as temporary and permanent quarry and borrow source development, associated access roads, and workspaces might change vegetation community abundance and distribution as well. Changes in microclimate as a result of tree and shrub removal, soil compaction, rutting, and admixing can also alter plant communities, particularly in wetland areas when construction occurs in spring or summer months (Dube et al., 2011).

In particular, the Project may affect vegetation community diversity in the following ways:

- Directly, through vegetation clearing as a result of site preparation
- Indirectly, from changes in water quantity where road development results in changes to drainage patterns

The highway alignment will avoid wetlands to the extent possible; however, complete avoidance of wetlands in the ROW is not feasible. There may be wetlands that are cleared within the 60 m wide ROW, as the Project is expected to follow the existing cleared MVWR ROW as much as possible. Wetland intersects will be reduced where possible, including locating temporary workspaces and access roads beyond wetland boundaries.

18.4.3.2 Mitigation

Mitigation measures will be implemented during construction and operation of the Project, as identified in the management plans located in Volume 5 and Table 18.8. Key mitigation measures to avoid or reduce the potential effects of the Project community diversity include the following:

- Activities will be restricted to workspaces and access roads. Prior to the start of construction, the boundaries of the work area, staging areas, and access roads will be staked and/or flagged.
- Project vehicles will be confined to existing roads and trails to avoid disturbing vegetated areas.
- Removal of vegetation will be limited to the width of the ROW and workspaces (including active borrow sources and quarries).
- Trees will be felled toward the ROW and access roads wherever possible to reduce damage to vegetation outside of the ROW and access roads.
- Merchantable timber will be limbed and decked in a dry area and made available to a receiver with an authorization (timber cutting permit or timber cutting licence) from the GNWT. Merchantable timber includes trees without defects with a dbh of at least 14 cm.
- During spring, summer, and fall, suitable ground equipment will be used to prevent effect on sensitive terrain.
- Where vegetation must be cut but is not removed, the cut will be made > 10 cm above the ground to retain the root structure.
- Tree roots will be grubbed only in areas required for construction or stripping. Grubbing operations will be conducted to preserve soil surface organic material.
- Organic material and topsoil will be set aside for use during reclamation, where possible.
- Cleared brush and unsalvageable trees will be windrowed, mulched, and spread on the ROW where possible.
- Closure and reclamation will promote re-establishment of vegetation.
- The ESCP, PPP, WMP and SCP will be followed. These plans include measures to reduce and monitor direct and indirect effects on vegetation and wetlands Draft management plans are included in Volume 5.
- Borrow source vegetated surface material, where present, will be replaced after excavation is completed.
- Off-road travel will be limited to winter (December 15 to April 1) where possible.
- Abandoned sections of MVWR ROW and access roads will be closed and reclaimed.

18.4.3.3 Residual Effects

Project construction will result in the direct loss or alteration of up to 655.2 ha of upland forest, 204.1 ha of shrubland, 1,185.3 ha of herbaceous and un-vegetated communities, and 300.0 ha of wetlands (Table 18.11). Landcover types with largest change in area will be exposed land (1,210.3 ha), open coniferous forest (246.0 ha) and sparse coniferous forest (158.8 ha), and low shrub (151.0 ha). The percent change in landcover type will be greatest for exposed land (41.1%), herbaceous (8.0%), and rock/rubble (5.6%) landcover. Much of the non-forested landcover affected by the Project is associated with either the existing MVWR or the Norman Wells Pipeline ROW.

Abandoned sections of the MVWR ROW and access roads will be closed and reclaimed to promote re-establishment vegetation such as upland and wetland landcover types. Borrow sources and quarries and associated access roads not required for highway maintenance will be closed and reclaimed. Wetland and open water landcover values in the LAA are 23.5% and 11.7% of the LAA, respectively. Landcover percentages between the Dehcho and Sahtu sections are similar but with somewhat higher percentages of forest and open water and somewhat lower percentages of wetland and shrubland landcover in the Dehcho section compared to the Sahtu section.

The removal of forest and other native vegetation communities will decrease the area available for native vegetation species, particularly species which grow in boreal forest (including many plant SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties, discussed in Section 18.4.4). In addition, the Project will also increase the amount of habitat available for pioneer species and invasive alien plants. Direct effects on vegetation communities will result from clearing activities, and indirect results may occur over time through changes in light and moisture levels and dust contaminant deposition in remaining adjacent vegetation communities in the LAA.

The percentage of native vegetation communities directly lost due to clearing will be a small percentage of the LAA, ranging from 2.0% of wetland communities and 3.2% of broadleaf forest communities in the LAA (Table 18.11). Indirect effects from dust contaminant deposition (to a distance of 40 m from the PDA, based on findings of Gleason et al. [2007]) could affect an additional 2.0% of wetland habitat and 3.8% of forest in the LAA. Indirect effects from all sources, up to a distance of 100 m from the PDA, could affect an additional 5.2% of wetland habitat and 8.3% of forest in the LAA.

Table 18.11 Change in Landcover Types within the LAA

Landcover Type	Cover Type Class	Existing Conditions		Construction and Operation		Change from Existing Conditions[1]	
		ha	% of Total Area	ha	% of Total Area	ha	% Change
Broadleaf Forest	Broadleaf – Dense	2,669.3	4.2	2,582.6	4.1	-86.7	-3.2
	Broadleaf – Open	956.4	1.5	927.2	1.5	-29.1	-3.0
Broadleaf Subtotal		**3,625.7**	**5.8**	**3,509.8**	**5.6**	**-115.9**	**-3.2**
Coniferous Forest	Coniferous – Dense	3,617.8	5.8	3,560.5	5.7	-57.3	-1.6
	Coniferous – Open	9,250.3	14.7	9,004.3	14.3	-246.0	-2.7
	Coniferous – Sparse	8,442.9	13.4	8,284.2	13.2	-158.8	-1.9
Coniferous Subtotal		**21,311.1**	**33.9**	**20,849.0**	**33.1**	**-462.1**	**-2.2**
Mixedwood Forest	Mixedwood – Dense	1,144.4	1.8	1,116.6	1.8	-27.8	-2.4
	Mixedwood – Open	2,098.4	3.3	2,049.5	3.3	-48.9	-2.3
	Mixedwood – Sparse	5.1	<0.1	4.6	<0.1	-0.5	-10.1
Mixedwood Subtotal		**3,247.9**	**5.2**	**3,170.7**	**5.0**	**-77.2**	**-2.4**
Shrubland	Shrub – Tall	1,996.1	3.2	1,943.0	3.1	-53.1	-2.7
	Shrub – Low	7,282.3	11.6	7,131.3	11.3	-151.0	-2.1
Shrubland Subtotal		**9,278.4**	**14.8**	**9,074.3**	**14.4**	**-204.1**	**-2.2**
Herbaceous and Unvegetated	Herb	233.7	0.4	215.0	0.3	-18.7	-8.0
	Bryoids	12.9	<0.1	12.5	<0.1	-0.4	-3.0
	Rock/Rubble	106.2	0.2	100.3	0.2	-5.9	-5.6
	Exposed Land[2]	2,943.5	4.7	4,153.8	6.6	1,210.3	41.1
Herbaceous and Unvegetated Subtotal		**3,296.3**	**5.2**	**4,481.7**	**7.1**	**1,185.3**	**36.0**
Upland Subtotal		**40,759.5**	**64.8**	**41,085.5**	**65.3**	**326.0**	**0.8**

Landcover Type	Cover Type Class	Existing Conditions		Construction and Operation		Change from Existing Conditions[1]	
		ha	% of Total Area	ha	% of Total Area	ha	% Change
Wetland	Wetland – Treed	5,890.3	9.4	5,780.3	9.2	-109.9	-1.9
	Wetland – Shrub	5,486.2	8.7	5,360.8	8.5	-125.4	-2.3
	Wetland – Herb	3,384.1	5.4	3,319.4	5.3	-64.6	-1.9
Wetland Subtotal		**14,760.5**	**23.5**	**14,460.6**	**23.0**	**-300.0**	**-2.0**
Open Water		7,383.1	11.7	7,357.0	11.7	-26.1	-0.4
Total		**62,903.1**	**100.0**	**62,903.1**	**100.0**	**0.0**	**0.0**

Note:

[1] The change in area of each landcover type from Existing Conditions to Construction and Operation is the area of the PDA intersecting that landcover type.

[2] Exposed land includes areas which naturally have less than 5% vegetative cover, such as shorelines of rivers and lakes, exposed rock, recently burned areas, and moraines, and includes cleared areas such as roads, particularly the MVWR, and areas of infrastructure development. Exposed land also includes land cleared for the Project (under Construction and Operation). For this reason, the amount of exposed land increases under Construction and Operation while all other landcover types decrease, and the total area of all landcover remains the same between Existing Conditions and Construction and Operation.

Source: Natural Resources Canada and the Government of the Northwest Territories (2017).

The total volume of coniferous, broadleaf, and mixedwood timber to be cleared during construction is presented in Table 18.12. The amount of merchantable timber (trees with a diameter at breast height of at least 14 cm) is not known, but merchantable timber volume is expected to be approximately 65% of the total timber volume, estimated to be approximately at 12,080 m^3 of merchantable timber (National Forestry Database, 2022). The GNWT will conduct a survey of merchantable timber volume in the PDA to support its applications for timber cutting permit / licence. In locations where sufficient quantities of merchantable timber are present, the trees will be limbed and decked in a dry area and made available to a receiver with an authorization (a timber cutting permit or licence) from the GNWT. If after five years post harvest the trees have not been removed, they will be burned, chipped, or disposed of by another authorized method. Non-merchantable trees will be limbed and stacked for community use, where possible. Other non-merchantable debris will be used for rollback (in areas to be revegetated) or chipped.

Table 18.12 Change in Total Timber Volumes per Landcover Type in the LAA

Cover type	Existing Conditions [1]		Construction and Operation [1]		Change From Existing Conditions	
	m^3	% of Total Volume	m^3	% of Total Volume	m^3	% Change in Volume
Coniferous Forest	737,167.5	83.7	722,300.1	82.0	-14,867.5	-1.7
Broadleaf Forest	70,245.4	8.0	68,138.2	7.7	-2,107.2	-0.2
Mixedwood Forest	73,830.1	8.4	72,219.4	8.2	-1,610.7	-0.2
Timber Volume Cleared	0.0	0.0	18,585.4	2.1	18,585.4	2.1
Total	**881,243.0**	**100.0**	**881,243.0**	**100.0**	**0.0**	**0.0**

Note:

[1] Volume determined by multiplying average stand volume by landcover area (ha) in LAA.

Source: Natural Resources Canada and the Government of the Northwest Territories (2017).

Project effects on different forest stand age classes in the LAA are presented in Table 18.13. Forest stand ages differences are a result of fires that have occurred in the LAA since fire records have been collected (starting in the 1960). Fires have burned irregularly through portions of the LAA and have resulted in a mosaic of forest stand ages. The spatial distribution of fires and associated forest stand establishment have been tracked by decade from 1960 to 2020. Forest older than 62 years is present at the south end of the PDA near Wrigley, while large areas of younger forest are present east of the PDA. In central and northern sections of the PDA, young and old forest stands are interspersed with large wetland areas. Forest stands established before 1960 and between 1990 and 1999 will be most affected by the Project, with 853.5 ha of pre-1960 forest stands and 1,053.4 ha of forest stands established between 1990 and 1999 to be removed. This represents 3.4% of stands of pre-1960 forest stands in the LAA and 3.9% of forest stands established between 1990 and 1999 in the LAA. In total, 36.9% of forest to be removed was established prior to 1960 and 63.1% was established 1960 or later, and 51.4% was established since 1990.

The Project will reduce the area of all landcover types in the LAA. The percentage loss of landcover types ranges from 1.6% of dense coniferous forest in the LAA to 10.1% of sparse mixedwood forest in the LAA (Table 18.11). Abandoned sections of the MVWR ROW and access roads will be allowed to regenerate to natural upland and wetland landcover types. Borrow sources and quarries and associated access roads not required for highway maintenance will be closed and remediated to promote natural revegetation. Therefore, with the large amount of remaining area of all landcover types in the LAA, along with some regenerating landcover area, the effect on community diversity is considered low and extends to the LAA. This determination includes uncertainty of accuracy of landcover mapping from published sources; however, all landcover types are expected to remain abundant in the LAA.

Effects are expected to be long-term due to the presence of the highway and the retention of some borrow sources and quarries for project operations and maintenance. Dust contaminant deposition and the potential for alien and invasive alien plant introduction adjacent to the PDA will be ongoing. Because of complete removal of vegetation from the PDA, the VC is not sensitive to seasonal timing (i.e., seasonal aspects are unlikely to affect vegetation and wetlands).

Table 18.13 Change in Stand Age Composition in the LAA

Decade of Establishment of Forest Stands [1]	Existing Conditions		Construction and Operation		Change From Existing Conditions	
	ha	% of Total Area	ha	% of Total Area	ha	% of Existing
Prior to 1960	25,031.4	39.8	24,177.9	38.4	-853.5	-3.4
1960-1969	257.7	0.4	247.5	0.4	-10.3	-4.0
1970-1979	4,441.4	7.1	4,257.0	6.8	-184.5	-4.2
1980-1989	2,160.2	3.4	2,084.2	3.3	-76.0	-3.5
1990-1999	26,920.4	42.8	25,867.1	41.1	-1,053.4	-3.9
2000-2009	3,320.4	5.3	3,211.4	5.1	-109.0	-3.3
2010-2019	771.5	1.2	742.9	1.2	-28.6	-3.7
Area of Forest Removed by the Project	0.0	0.0	2,315.2	3.7	2,315.2	Undefined
Total	62,903.1	100.0	62,903.1	100.0	0.0	0.0

Source: Canadian Forest Service (2020).

18.4.4 Change in Species Diversity

18.4.4.1 Effects Pathways

A direct loss of plant SOCC and plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties may occur within the PDA because of vegetation clearing during project construction and indirectly due to dust contaminant deposition, introduction and spread of alien and invasive alien species, and edge effects on intersected native vegetation communities during both construction and operations. Indirect effects will extend beyond the PDA.

As indicated, vegetation will be cleared during construction for preparation of the ROW, development of quarry and borrow sources, and associated access roads and embankment construction, including road cuts in steep grade terrain. Plant SOCC present in areas of vegetation clearing will be removed along with plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties. Plants will be permanently removed within the PDA; however, some SOCC and plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties may re-establish in reclaimed temporary disturbances, such as workspaces and quarry/borrow sources not retained for operations.

Removal of vegetation may also indirectly alter light, moisture, and temperature levels through edge effects on remaining vegetation (Luken et al., 1992). These altered conditions can affect plant species composition and abundance (Harper et al., 2015; Dabros et al., 2017; Kohmori et al., 2019), including reduced bryophyte cover (Bartemucci et al., 2006). Changes to ground thermal regime and soil moisture due to vegetation removal can result in permafrost degradation which will likely influence shifts in vegetation community structure and composition. Studies by Cameron and Lantz (2017) found permafrost thaw influenced transformation of woodland sites to graminoid-dominated wetlands. Such changes to site conditions will likely alter species composition and may result in loss of upland plant SOCC or plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties that are unable to tolerate newly created wetland conditions.

Bare areas and areas of low vegetation cover created during construction, along with altered edge effects of nearby vegetation, may also provide opportunities for alien and invasive alien species to establish. Vegetation clearing will remove native plant cover, potentially allowing alien and invasive alien species to establish and spread, particularly within disturbed sites (Davis et al., 2000). In addition, spread of alien and invasive alien species may be transported by project equipment and vehicles. Von der Lippe and Kowarik (2007) found vehicle vectors to be a major contributor for spread of alien and invasive alien species along roadways, with buildup of mud and other substrates on vehicles enabling spread of alien and invasive alien seeds.

Dust contaminant emissions generated during project construction, development and operation of quarry and borrow sources, vehicle use of project access roads, and embankment construction, as well as material haul and stockpiling, could further alter plant composition through changes in plant health and altered competitive ability. Dust contaminant deposition can affect fruit setting, pollen germination, and other attributes (Farmer, 1993).

18.4.4.2 Mitigation

Mitigation measures will be implemented during construction and operation of the Project as identified in the management plans located in Volume 5 and Table 18.8. Key mitigation measures to avoid or reduce the potential effects of the Project to species diversity include the following:

- The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties regarding perceived effects on plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties.
- Targeted vegetation and wetland surveys of SOCC and specific plant species of interest to Indigenous Governments and Indigenous Organizations, and other affected parties, will be conducted within the PDA in high potential areas, such as fens, bogs, and dry or rocky sites and in a sub-sample of more common landcover types, prior to construction. This will include transplant or seed collection of observed rare or vulnerable plant species. Appropriate mitigation measures (and monitoring if needed) will be developed based on the findings of the surveys. Options are identified in Chapter 18.
- Monitoring programs will be implemented to evaluate if mitigation measures are being implemented and are effective. These include monitoring in accordance with the terms and conditions of permit approvals, as required.
- Known areas of collection of plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties will be avoided where possible. Clearing schedules will be communicated in advance of clearing to provide an opportunity to collect plant material from the PDA.
- Equipment originating from outside of the NWT will be cleaned prior to mobilization to avoid introduction of invasive species.
- Machinery will be maintained and regularly inspected for fuel, oil, or other fluid leaks. Machinery found to be leaking will be withdrawn from service until repaired.
- Erosion and sedimentation control measures will be implemented per the GNWT Erosion and Sediment Control Manual (GNWT, 2013) and will be in place prior to construction activities and before the spring melt/freshet.
- Quarry dewatering will be conducted in a manner that discharge will not directly enter wetlands or lead to soil erosion.
- Water will only be used for dust suppression, except as provided in the GNWT Guideline for Dust Suppression.
- Regular inspection for invasive alien plant occurrences will be undertaken during construction and invasive alien plants will be managed through mowing to reduce introduction and spread of invasive alien plants in the PDA and surrounding natural vegetation.
- Closure and reclamation will promote re-establishment of vegetation.
- Abandoned sections of MVWR ROW and access roads will be closed and reclaimed.

Monitoring programs will be implemented to evaluate if mitigation measures are implemented and are effective. These include monitoring in accordance with the terms and conditions of permit approvals, as required.

18.4.4.3 Residual Effects

18.4.4.3.1 Species of Conservation Concern

18.4.4.3.1.1 Direct Effects on Species of Conservation Concern

Although no plant SOCC occurrences have been documented in the PDA or LAA, 215 plant SOCC have potential to occur based on a review of the NWT Species Monitoring Infobase (Working Group on General Status of NWT Species, 2016) and ecoregions intersected by the RAA. A considerable part of the PDA (1,104.9 ha [47.7%]), overlaps areas of the existing MVWR. However, potential direct loss of undocumented SOCC could occur for SOCC forbs, graminoids, subshrubs, and potentially bryophytes and lichens. Direct loss of undocumented SOCC may also occur due to removal of upland forest and shrubland vegetation, which comprises 859.3 ha (37.1%) of the PDA, and removal of wetlands, which comprise 300.0 ha (13.0%) of the PDA (Table 18.11). Shrub, forb, graminoid, lichen, and bryophyte SOCC could be affected in wetlands, upland forest, and shrubland areas as these areas are known to support a diversity of plant species, including many SOCC (Gilliam, 2007).

In the RAA, there are 7 forb and graminoid SOCC species known to occur in wetlands, 4 SOCC which occur in wetlands or uplands, and 11 SOCC which occur only in uplands (Table 18.14). Eight SOCC are shrubs and two SOCC are subshrubs. No tree SOCC are known to occur in the RAA. One shrub SOCC, arctic seashore willow (*Salix ovalifolia*), is known to occur in upland areas and is ranked S2 (defined as imperiled with a high risk of extirpation) in the NWT. The landscape position is unknown for seven other shrub SOCC and the two subshrubs which have been previously found in the RAA.

Of the forb and graminoid SOCC potentially present in the RAA, 141 are perennial plants. These may be at greater risk of loss due to their longer life span and less frequent production of seeds. Annual plants may not be actively growing during construction. Potential effects on perennial forb and graminoid plant SOCC include 73 S2 ranked species, 5 S2S3 ranked species (defined as species either imperiled or vulnerable to extirpation, though uncertainty exists), 58 S3 ranked species (defined as vulnerable with a moderate risk of extirpation), and 5 S3S4 ranked species (defined as species either vulnerable or apparently secure, though uncertainty exists) (GNWT, 2016a; NatureServe, 2012).

Temporary disturbance to SOCC will likely occur in temporary workspaces, such as laydown or staging areas. Trees and shrubs will be cut near ground level in temporary disturbance areas, but the roots and low vegetation will be left in place. As a result, shrub and subshrubs SOCC may be lost or damaged during clearing and use of temporary workspaces. Vegetation is expected to recover from the root layer following use of temporary workspaces. To a lesser extent, low vegetation such as forb, graminoid, lichen, and bryophyte SOCC may also be lost or damaged during clearing and use

of temporary workspaces. As noted, a pre-construction survey of SOCC and rare or may-be-at-risk plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties in the PDA will provide additional information on species presence and determine which species are most likely to be affected by project construction.

Table 18.14 Potential Plant SOCC Habitat, Form and Provincial S-Rank Summary for the RAA

Landscape Position[1]	Form[2]	NWT Provincial Rank[3]	Number of Species
Upland	Shrub	S2	1
	Graminoid	S3	1
	Forb	S2	5
		S3	5
		Upland Total	**12**
Wetland	Forb	S2	1
		S3	1
		S3S4	1
	Graminoid	S2	1
		S3	2
		S3S4	1
		Wetland Total	**7**
Wetland/Upland	Forb	S2	1
		S3	3
		Wetland/Upland Total	**4**
Unknown Landscape Position	Shrub	S2	4
		S3	3
	Subshrub	S2	1
		S3	1
	Forb	S2	52
		S2S3	5
		S3	39
		S3S4	3
	Graminoid	S2	18
		S2S3	1
		S3	15
		S3S4	2

Landscape Position[1]	Form[2]	NWT Provincial Rank[3]	Number of Species
Unknown Landscape Position (cont'd)	Lichen	S1	1
		S1S2	2
		S1S3	4
		S2?	1
		S2S3	17
		S2S4	17
	Bryophytes	Not ranked	6
Unknown Landscape Position Total			**192**
Total			**215**

Notes:

1 United States Department of Agriculture (USDA) Plants Database (2022).

2 USDA Plants Database (2022), GNWT (2016b), Roland et al. (2016), E-Flora BC (2021).

3 GNWT (2016a).

18.4.4.3.1.2 Indirect Effects on Species of Conservation Concern

Indirect effects on plant SOCC from dust contaminants and changes in light levels and moisture availability are expected to extend up to 40 m from road and quarry sites based on findings of Gleason et al. (2007) and Luken et al. (1992), potentially resulting in various levels of dust deposition on up to 2,368 ha. A study by Auerbach et al. (1997) found altered conditions in plant communities adjacent to gravel roadways including higher soil pH, increased nutrient availability, shallower organic horizons, and lower soil moisture. Alteration of soil pH can contribute to colonization and survival of certain species and influence species composition. Species most susceptible to dust contamination include lichens, due to the lack of roots and other absorptive surfaces (Nash and Gries, 1995), and both mosses and lichens due to blockage of light required for photosynthesis and an increase in surface temperature (Adamson and Seppelt, 1990). Potential indirect effects on vascular plant SOCC may also occur, as dust contaminant deposition can negatively affect plants by clogging leaf stomata, altering water balances within leaves, and reducing respiration capacity (Eller, 1977).

The spread of alien and invasive alien species could also result in a loss of plant SOCC. Removal of vegetation can create disturbed, open conditions, which can lead to an increase in abundance of alien and invasive alien species (Charbonneau and Fahrig, 2004). Project roadways may also act as dispersal corridors for spread of alien and invasive alien species. Sixteen alien and four invasive alien species occur within the Dehcho and Sahtu regions and have primarily been observed in areas of anthropogenic disturbance (AKEPIC, 2020). Documented alien invasive species include narrow-leaf hawksbeard (*Crepis tectorum*), reed canary grass (*Phalaris arundinacea*), white sweet-clover (*Melilotus albus*), and alsike clover (*Trifolium hybridum*). These species commonly establish in areas

of disturbance or roadways and disperse via wind, water, stolon expansion, and rapid seed production (USDA, 2022).

No SARA- or COSEWIC-listed plants will be affected by the Project as none occur in the ecoregions intersected by the RAA and are therefore unlikely to occur in the PDA.

As the Project may result in the loss of SOCC plants, if present, effects on species diversity from changes to SOCC are considered moderate to high magnitude. It is possible, though unlikely, that occurrences of a plant SOCC removed from the PDA are the only occurrences of that species in the LAA or RAA. In that case, the effect on that particular SOCC would extend to the LAA or RAA, respectively. This determination includes uncertainty in the occurrence of imperiled plants.

Information on plant SOCC growing requirements, such as light and moisture tolerance, is not available or suitably compiled in public sources to support further assessment and determination of whether the plants are present or absent from the PDA. Targeted vegetation and wetland surveys of SOCC and specific plant species of interest to Indigenous Governments and Indigenous Organizations, and other affected parties, will be conducted within the PDA in high potential areas, such as fens, bogs, and dry or rocky sites and in a sub-sample of more common landcover types, prior to construction. This will include transplant or seed collection of observed rare or vulnerable plant species. Appropriate mitigation measures (and monitoring if needed) will be developed based on the findings of the surveys. Options are identified in Chapter 18.

Monitoring programs will be implemented to evaluate if mitigation measures are implemented and are effective. These include monitoring in accordance with the terms and conditions of permit approvals, as required.

Potential loss of SOCC is expected to be less in areas of the existing MVWR due to past alterations of vegetation layers and potential changes in soil conditions; however, SOCC may still occur. Effects are expected to be long-term due to the presence of the highway and the retention of some quarry sites. Dust contaminant exposure will continue through use of the highway once constructed. Because of removal of vegetation from the PDA, the VC is not sensitive to seasonal timing (i.e., seasonal aspects are unlikely to affect vegetation and wetlands).

18.4.4.3.2 Plant Species of Interest to Indigenous Governments, Indigenous Organizations, and Other Affected Parties

18.4.4.3.2.1 Direct Effects on Plant Species of Interest to Indigenous Governments, Indigenous Organizations, and Other Affected Parties

Removal of vegetation in the PDA will result in loss of occurrences plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties, where present. The abundance of 65 plant species may be reduced due to the removal of upland forested areas (626.9 ha), and 14 plant species due to removal of upland shrubland (204.1 ha), within the PDA (Table 18.14). Loss of forested areas may reduce the abundance of 25 shrub, 24 forb, 9 tree, and 7 sub-shrub species typically occurring in forested areas and potentially present in forested lands in the PDA (Appendix 18B).

Removal of shrubland may affect five forb plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties and one shrub. Two of the plant species potentially occurring in forested landcover types in the PDA, spiney wood fern (*Dryopteris carthusiana*) and rocky mountain pond lily (*Nuphar polysepala*), are ranked May Be At Risk in the NWT and are likely not abundant in the RAA. These species have not been documented in the RAA; however, based on landcover types, they may be present in the RAA, LAA, and PDA. Construction could result in the loss of these species from the LAA or RAA if occurrences are present in the PDA only, although occurrences may remain elsewhere in the LAA or RAA. In addition, two other plant species of interest found in forest landcover types: sand heather (*Hudsonia tomentosa*) and choke cherry (*Prunus virginiana*) (both of which are ranked Sensitive in the NWT) may also be lost if present in the PDA (although occurrences may remain elsewhere in the LAA or RAA).

Other plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties affected by the removal of forested areas of the PDA are ranked secure, have not been ranked territorially, or are alien or invasive alien species. Traditional plant species found in shrubland areas of the RAA are ranked secure, have not been ranked territorially, or are alien or invasive alien species. Although the spatial distribution of these species within forested and shrubland areas in the LAA is unknown, these species are expected to be abundant in the RAA based on the territorial rank and will remain abundant following project construction.

Thirty-four plant and one fungus species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties occur in wetlands and abundance may be altered by the removal of 300.0 ha of wetland by the Project (Table 18.14). None of these plant species occurring in wetlands are ranked as May Be At Risk in the NWT (GNWT, 2016a). Species include 13 forbs, including berry producing plants such as cloudberry (*Rubus chamaemorus*), 15 shrubs, 4 trees, 2 graminoids, (seaside arrow-grass [*Triglochin maritima*] and broad-leaf cattail [*Typha latifolia*]), and 1 fungus.

18.4.4.3.2.2 Indirect Effects on Plant Species of Interest to Indigenous Governments, Indigenous Organizations, and Other Affected Parties

Indirect effects on plants of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties are anticipated to be similar to those predicted for plant SOCC. Dust contaminant emissions will likely reduce species diversity in areas up to 40 m from project construction sites and potentially introduce contaminants to edible plants (Gleason et al., 2007; Shotyk, 2020). Competition by alien and invasive alien species will likely be greatest to herbaceous forb and graminoid plants because alien and invasive alien species within the Dehcho and Sahtu Regions are all herbaceous species. However, competition effects may also extend to trees and shrubs as well, as alien and invasive alien species can inhibit regeneration of saplings (Lazaro-Lobo et al., 2021). Disturbance resulting in degradation of permafrost and conversion of upland to wetland area could potentially reduce the distribution of 85 species of upland plants of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties.

Vegetation recovery in areas of temporary disturbance may differ among plant groups and life-history characteristics of affected species (Jonsson and Esseen, 1998). Large scale disturbances which remove bryoid and humus layers may negatively affect recovery of vascular plants, as many boreal species form extensive seed banks within humus layers (Granstrom, 1982). Traditional plant abundance in areas of temporary disturbance may differ following construction due to a loss of seed bank and altered competition.

As the Project may result in the loss of May Be At Risk plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties, effects are considered moderate to high magnitude. It is possible, though unlikely, that occurrences of one of these plant species of interest are the only occurrences of that species in the LAA or RAA. In that case, the effect on that particular species would extend to the LAA or RAA, respectively. This determination includes uncertainty in the occurrence of May Be At Risk plants and the potential use by Indigenous Governments, Indigenous Organizations, and specific other affected parties. Project effects are not expected to result in the local or regional loss of secure or alien plants, and although abundance will be reduced, species of these plants occurring in the LAA are expected to remain abundant. Effects are expected to be long-term due to the presence of the highway and the retention of some quarry sites. Dust contaminant exposure will continue. Because of complete removal of vegetation from the PDA, the VC is not sensitive to seasonal timing (i.e., seasonal aspects are unlikely to affect vegetation and wetlands).

18.4.5 Change in Wetland Function

18.4.5.1 Effects Pathways

In addition to direct loss of wetlands from project construction, wetland functions may also be indirectly altered. Wetland functions are generally recognized as internal natural processes and features of wetlands that are independent of the benefits provided to humans (Novitzki et al., 1997; Kusler, 2004; Hansen et al., 2008; Burton and Tiner, 2009). Ecosystem services are the benefits humans derive from wetlands and can be evaluated separately from functions, but are sometimes evaluated together, as is done by the Federal Wetland Policy (Government of Canada, 1991).

Project construction has the potential to affect the hydrological, biogeochemical, and habitat functions of wetlands through the removal of wetland vegetation, partial infilling of wetlands, and alteration of surface and sub-surface water flows. These changes may result in altered wetland nutrient levels and downstream export, decomposition and carbon accumulation rates, water infiltration and storage, plant diversity, and wildlife habitat. Changes in wetland function from the Project are expected to occur during construction, starting with vegetation clearing and grading, and continue through operations with the presence of the highway leading to potentially permanent alteration of wetland catchments and water inflows to wetlands and outflows from wetlands.

18.4.5.2 Mitigation

Mitigation measures will be implemented during construction and operation of the Project, as identified in the management plans located in Volume 5 and Table 18.8. Key mitigation measures to avoid or reduce the potential effects of the Project to wetland function include the following:

- Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns.
- During spring, summer, and fall, suitable ground equipment will be used to reduce potential effect on sensitive terrain.
- Use of equipment on highly saturated soil will be avoided, where possible.
- Vegetation buffers will be used as visual barriers and to protect riparian vegetation, as appropriate.
- Erosion and sedimentation control measures will be implemented per ESCP (Volume 5) and will be in place prior to construction activities and before the spring melt/freshet.
- Silt fencing will be used downgradient of the works where required.
- Sediment and erosion control measures will be regularly inspected to confirm they are performing as intended.
- Erosion and sedimentation control measures will be maintained until disturbed areas are revegetated or until such areas have been permanently stabilized by other effective measures.

- An SCP will be developed and implemented (Volume 5).
- All site personnel will receive SCP training and will have awareness of spill prevention.
- Fuel will be stored in containers with secondary containment capable of containing 110% of the largest container.
- Equipment such as vehicles, generators, and pumps will have secondary containment installed capable of containing fuel drips or leaks during operations and refueling.
- Equipment laydown and staging areas will be located at least 100 m from the ordinary high water mark of any waterbody.
- Washing, refueling, and servicing machinery and storage of fuel and other materials for machinery will be conducted a minimum of 100 m from the ordinary high-water mark and in a manner to prevent any deleterious substances from entering the water.
- Dust suppression will be conducted as necessary to reduce dust and sediment from entering watercourses or waterbodies.
- Quarry dewatering will be done such that discharge will not directly enter wetlands or lead to soil erosion.

18.4.5.3 Residual Effects

The hydrology of wetlands partially intersected by the Project may be altered. Wetlands located downstream of the Project in an area of new road alignment or on the downstream side of quarry sites may receive less water following construction and those upstream may have reduced outflow. However, drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns, reducing this effect. Wetlands can receive water from precipitation, groundwater seepage, overland flow, and stream discharge (Mitsch and Gosselink, 1993; Winter et al., 1998). Most wetlands lose water by evapotranspiration, but groundwater recharge and surface outflow from channels can also occur. Changes in hydrology have not been quantified but effects are expected to be greatest where the Project cuts across drainage into or out of wetlands. Changes will also occur to wetlands with a loss of larger portions of contributing drainage basins.

Outflow from wetlands could be reduced where the Project alters drainage from a wetland. In these areas both water and nutrient flow to downstream areas could be reduced. Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns, reducing this effect. Increased or decreased water levels may alter plant composition and the abundance of different structural layers. In areas where wetlands become much wetter than existing conditions, vascular plants, particularly forbs, and grasses will be favoured over non-vascular plants (i.e., mosses, liverworts, and lichens). Larger shifts to drier conditions may reduce vascular plant abundance and favour mosses. In extreme instances some wetlands may convert to upland habitat following loss of contributing catchment area or stream inflow.

The presence of the highway will continue to affect light and moisture conditions in remaining vegetation nearby. The abundance of plants less tolerant of open conditions and higher light exposure will decrease in areas of tree and shrub removal, including many species of mosses and forbs adapted to lower light conditions found under woody cover.

Effects on wetland functions will continue through project operations because drainage alterations will likely remain along with ongoing control (mowing) of woody vegetation and alien and invasive alien species. Dust contamination generated from passing vehicles may also locally alter wetland water chemistry and plant composition in the LAA.

As the Project may result in the reduction of wetland function, effects are adverse. Effects are predicted to be low in magnitude as wetlands and their associated functions will continue in the LAA and RAA. Effects are expected to be predominantly limited to wetlands intersected by the PDA or close to the PDA, although effects may extend into the LAA if contributing drainages are intersected. Effects will be long-term as the road will be permanent, some quarry sites will be retained, the cleared ROW will alter plant conditions throughout operations, and dust contaminant exposure will also continue. Due to seasonal changes in water flow, effects on wetland function have moderate seasonal timing sensitivity.

18.4.6 Summary of Residual Effects

With mitigation (including reclamation of abandoned sections of the MVWR ROW and access roads), residual effects resulting from the Project on landscape diversity, community diversity (including merchantable timber), species diversity (including plant SOCC and plants of interest to Indigenous communities), and wetland function will occur and are predicted to be adverse in direction and low to potentially high in magnitude during construction and operations. The geographic extent of direct effects will be the LAA, and LAA to RAA for change in plant species diversity. Effects will persist due to the presence of the highway (i.e., long term). Effects will be ongoing and are likely irreversible due to the indefinite duration of operation of the Project. A summary of residual effects on vegetation and wetlands is presented in Table 18.15.

With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirements related to species introduced, sensitive species and features, and consideration of engagement input and incorporation of Traditional Knowledge.

The design of the Project and mitigation measures for reducing effects on vegetation and wetlands respects the values of the Petiniʔah (Bear Rock) CZ, Mio Lake CZ, Norman Range SMZ, K'ąąlǫ Tué (Willow Lake Wetlands) SMZ and Deh Cho (Mackenzie River) SMZ, as areas with important wetland habitats and plant harvesting areas. The Project takes into account harvest of merchantable timber.

Table 18.15 Residual Effects on Vegetation and Wetlands

Residual Effect	Residual Effects Characterization*								
	Project Phase	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in Landscape Diversity	C/O	A	CE	M	LAA	NS	LT	C	I
Change in Community Diversity	C/O	A	CE	L	LAA	NS	LT	C	I
Change in Species Diversity	C/O	A	CE	M-H	LAA/RAA	NS	LT	C	I
Change in Wetland Function	C/O	A	CE	L	LAA	MS	LT	C	I

KEY

*See Table 18.3 for detailed definitions

Project Phase
C: Construction
O: Operations and maintenance

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMC: No Measurable Change
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

18.5 Assessment of Cumulative Effects on Vegetation and Wetlands

18.5.1 Residual Effects Likely to Interact Cumulatively

Existing environmental conditions reflect cumulative effects on the environment from past and present projects and physical activities. Past and present projects and physical activities that have been or are being carried out have influenced the existing conditions for vegetation and wetlands (Section 18.4). The assessment of cumulative effects focuses on four adverse residual project effects: change in landscape diversity, change in community diversity, change in species diversity, and change in wetland function.

Table 18.16 presents interactions with other past, present, and reasonably foreseeable future projects and physical activities within the RAA. Chapter 4 presents the names, proponents, use or activity, descriptions, status, and location of these projects and activities.

Where adverse residual effects from the Project act cumulatively with those from other projects and physical activities, a cumulative effects assessment is undertaken to determine their significance. For further information about reasonably foreseeable future projects and physical activities, see Table 4.2.

Table 18.16 Projects and Physical Activities with the Potential to Contribute to Cumulative Effects

Other Projects and Physical Activities with Potential for Cumulative Effects	Effects			
	Change in Landscape Diversity	Change in Community Diversity	Change in Species Diversity	Change in Wetland Function
Past and Present Physical Activities and Resource Use (Base Case)				
Geotechnical	–	–	–	–
Oil, Gas & Seismic*				
Tulita 2D Seismic Program	✓	✓	✓	✓
EL 466 Drilling Program	✓	✓	✓	✓
Windy Island Drilling Program	✓	✓	✓	✓
Summit Creek Drilling Program	✓	✓	✓	✓
Slater River Project	✓	✓	✓	✓
Little Bear Staging Area	✓	✓	✓	✓
Infrastructure				
Mackenzie Valley Winter Road, including bridges and bridge-sized culverts	✓	✓	✓	✓
Canyon Creek All Season Access Road	✓	✓	✓	✓

Other Projects and Physical Activities with Potential for Cumulative Effects	Effects			
	Change in Landscape Diversity	Change in Community Diversity	Change in Species Diversity	Change in Wetland Function
Norman Wells Pipeline	✓	✓	✓	✓
Mackenzie Valley Fibre Link	–	✓	✓	–
Délı̨nę Winter Road	✓	✓	✓	✓
Mackenzie Highway No.1	✓	✓	✓	✓
Prohibition Creek Access Road (PCAR)	✓	✓	✓	✓
Quarries and Borrow Sources				
HRN Quarry	✓	✓	✓	–
Little Bear River Quarry	✓	✓	✓	–
Mining & Exploration				
Wrigley Zinc Property Drilling Program	✓	✓	✓	✓
Municipal Operations, including water, waste, power, and community development				
Wrigley Municipal Activities	–	✓	✓	–
Tulita Municipal Activities	–	✓	✓	–
Norman Wells Municipal Activities	–	✓	✓	–
Project-Related Physical Activities (Project Case)				
Mackenzie Valley Highway Project	✓	✓	✓	✓
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)				
Quarries				
Dhu-1 Quarry	–	✓	✓	–
Infrastructure				
Great Bear River Bridge	–	✓	✓	–
Oil and Gas				
Enbridge Maintenance Camp	✓	✓	✓	✓

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = Includes support activities such as production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas.

Similar to the Project, interactions between other projects and physical activities with vegetation and wetlands are anticipated where there will be physical disturbance of vegetation or wetlands. Checkmarks are given for those other projects and activities. In some cases, the effects of other projects and physical activities are anticipated to affect only vegetation and not wetlands (e.g., the Mackenzie Valley Fibre Link which will likely clear some vegetation but is not anticipated to affect wetland function). For some other projects and physical activities works will occur in vegetated areas but are expected to be sited to avoid wetlands (e.g., municipal activities).

Past and present geotechnical projects to do not interact with vegetation and wetlands as these projects are located within the municipal boundaries of Tulita or existing cleared areas.

18.5.2 Change in Landscape Diversity

18.5.2.1 Cumulative Effects Pathways

Potential cumulative effects on landscape diversity arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project, including direct and indirect effects on landscape diversity due to fragmentation of landcover types, as discussed in Section 18.4.2. NWRRC study participants raised concerns about changing temperatures and the cumulative effects of climate change on vegetation during project construction and operation (NWRRC, 2023). Sahtu Renewable Resources Board expressed concern that changes in vegetation and wetlands and changes resulting from removal of permafrost may result in decreased plants, and plant harvesting locations available to Indigenous harvesters (SRRB, 2016).

18.5.2.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects are the same as those presented in Section 18.4.2. The MVWR will be incorporated into the Project along most of its length. Abandoned sections of the MVWR ROW and access roads will be closed and reclaimed to promote re-establishment of vegetation.

18.5.2.3 Cumulative Effects

Similar to residual Project effects, cumulative effects on landscape diversity arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways: directly through fragmentation of landcover types during clearing and indirectly due to edge effects. Specifically, the MVWR, Canyon Creek All Season Access Road (CCASAR), the Mackenzie Valley Fibre Link, the Norman Wells Pipeline, quarries and borrow sources, and mining and exploration have resulted in cumulative landscape diversity fragmentation. It is expected that the PCAR, Dhu-1 Quarry and Great Bear River Bridge will also contribute cumulatively to landscape diversity landcover fragmentation and edge effects. Specifically, it is estimated that PCAR will remove 77.8 ha, Great Bear River Bridge will remove 46.5 ha, and Dhu-1 Quarry will remove 23.0

ha of native vegetation. The Project will contribute to both direct and indirect cumulative effects on landscape diversity due to landcover fragmentation and edge effects.

Past, present, and reasonably foreseeable projects and physical activities have resulted and will continue to result in an increase in fragmentation of the landscape. The Project will increase fragmentation; however, fragmentation effects will be reduced by aligning the Project with the MVWR along most of its length. Specifically, the Project will result in a reduction in average patch size of 0.1 ha for coniferous forest and shrubland and there will be a small to moderate increase in perimeter length to patch area, between 100 m/ha and 1,000 m/ha, for all natural landcover types.

The effect on landscape diversity from all projects and physical activities is considered moderate based on the known or anticipated extent of effects. Other projects and physical activities are known or anticipated at various locations in the RAA. This determination includes uncertainty of the extent of future projects. Even with all projects and physical activities, patches of many sizes and shapes of all landcover types are expected to remain abundant in the RAA. Effects are expected to be long-term as most projects and activities will be long-term or permanent. Effects will be medium-term for abandoned sections of the MVWR ROW and access roads, which will be closed and reclaimed to promote re-establishment of vegetation, and for borrow sources and quarries and associated access roads not required for highway maintenance, which will be closed and reclaimed. Many projects and physical activities have the potential for indirect effects, particularly fragmentation edge effects.

18.5.3 Change in Community Diversity

18.5.3.1 Cumulative Effects Pathways

Potential cumulative effects on community diversity arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project, including the direct loss or alteration of landcover types and indirectly on landcover types from the spread of dust contamination, alien, and invasive alien plant species, as discussed in Section 18.4.3.

18.5.3.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects for the Project are the same as those presented in Section 18.4.3.

18.5.3.3 Cumulative Effects

Based on the known or anticipated areas of disturbance to vegetation and wetlands, past, present, and reasonably foreseeable projects and physical activities have had and will continue to have direct effects on community diversity, including removal of native landcover type area, change in moisture and light levels in adjacent native vegetation communities, introduction or spread of alien or invasive alien plant species, and generation of dust contamination. Specifically, the MVWR, CCASAR, the Norman Wells Pipeline, Mackenzie Valley Fibre Link, quarries and borrow sources,

mining and exploration, and municipal operations have resulted in cumulative effects on community diversity. It is expected that the Dhu-1 Quarry, Great Bear River Bridge, and PCAR may also contribute cumulatively to effects on community diversity.

The Project will add to these effects, due to direct loss or indirect alteration of landcover types. However, effects will be reduced by aligning the Project with the MVWR along most of its length. In total, the area of native vegetation communities directly lost due to the Project will be a small percentage of the LAA, ranging from 2.0% of wetland communities to 3.2% of broadleaf forest communities in the LAA. Indirect effects from dust contaminant deposition (to a distance of 40 m from the PDA) could affect an additional 2.0% of wetlands and 3.8% of forest in the LAA. These effects on community diversity from all projects and physical activities are considered low and extend to the RAA. This determination includes uncertainty of the extent of future projects. Even with all projects and physical activities, all landcover types will remain abundant in the LAA and RAA. Effects are expected to be long-term as most projects and activities will be long-term or permanent, including the Project, except the effect will be medium-term where the MVWR is not incorporated in the Project. The portion of the MVWR not incorporated into the Project will be closed and reclaimed to promote re-establishment of vegetation. In addition, borrow sources and quarries and associated access roads not required for highway maintenance will also be closed and reclaimed.

18.5.4 Change in Species Diversity

18.5.4.1 Cumulative Effects Pathways

Potential cumulative effects on species diversity arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project, including potential direct loss of occurrences of SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties, and potential indirect effects on occurrences of these species as discussed in Section 18.4.4.

18.5.4.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects are the same as those presented in Section 18.4.4.

18.5.4.3 Cumulative Effects

Based on the known or anticipated areas of disturbance to vegetation and wetlands, past, present, and reasonably foreseeable projects and physical activities have had and will continue to have effects on SOCC, if present, and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties through both direct loss and indirect effects. Specifically, the MVWR, CCASAR, PCAR, the Norman Wells Pipeline, Mackenzie Valley Fibre Link, quarries and borrow sources, mining and exploration, and municipal operations have likely resulted in effects on SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties. It is expected that the Dhu-1 Quarry and Great Bear River Bridge may also

contribute cumulatively to effects on these same species. The Project will add to these effects, although effects will be reduced by aligning the Project with the MVWR along most of its length. The effect on species diversity from all projects and physical activities is considered moderate and extends to the RAA. Even with all projects and physical activities, habitat for SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties is expected to remain in the LAA and RAA because all landcover types will remain common in the LAA and RAA. Effects are expected to be long-term as most projects and activities will be long-term or permanent.

18.5.5 Change in Wetland Function

18.5.5.1 Cumulative Effects Pathways

Potential cumulative effects on wetland function arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project, including the direct loss or alteration of wetlands and indirect effects due to alteration of surface and sub-surface water flows, nutrient levels and downstream export, decomposition and carbon accumulation rates, water infiltration and storage, plant diversity, and wildlife habitat, as discussed in Section 18.4.5.

18.5.5.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects are the same as those presented in Section 18.4.5.

18.5.5.3 Cumulative Effects

Some past, present, and reasonably foreseeable projects and physical activities have affected and will continue to affect wetland function including direct loss or alteration of wetlands and indirect effects due to alteration of surface and sub-surface water flows, nutrient levels and downstream export, decomposition and carbon accumulation rates, water infiltration and storage, plant diversity, and wildlife habitat. Specifically, the MVWR, CCASAR, the Norman Wells Pipeline, and mining have likely resulted in effects on wetland function. It is expected that the PCAR may also contribute cumulatively to effects on wetland function.

However, even considering all projects and physical activities, wetlands of all types and sizes are expected to remain abundant in the RAA with many occurring far from projects or physical activities with little or no adverse effects on wetland function. The Project will add to these effects; however, drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns. Mitigation presented in Section 18.4.5 will be implemented to reduce effects on nearby wetlands and wetland function. The effect on wetland function from all projects and physical activities is considered low and extends to the LAA. Effects are expected to be long-term as most projects and activities will be long-term or permanent. Many projects and physical activities have the potential for both direct and indirect effects.

18.5.6 Summary of Cumulative Effects

Cumulative effects on landscape diversity, community diversity (including merchantable timber), species diversity (including plant SOCC and plants of interest to Indigenous communities), and wetland function from past, present, and reasonably foreseeable projects and activities have occurred and will likely continue to occur and are predicted to be adverse in direction and low to moderate in magnitude. The Project will make a low to moderate contribution to these effects. However, effects will be reduced by aligning the Project with the MVWR along most of its length and promoting re-establishment of vegetation on abandoned sections of the MVWR ROW and access roads. In addition, borrow sources and quarries and associated access roads not required for highway maintenance will be closed and reclaimed. Mitigation measures presented in Section 18.4 will also serve to reduce cumulative effects on vegetation and wetlands. Cumulative effects will extend from the PDA to the RAA. Effects from many projects and activities, including the Project, will persist for the long term due to long operating life of many projects and activities. For many of these project and activities, effects will be ongoing during construction and operation and may be reversible or irreversible. The summary of vegetation and wetland cumulative effects is presented in Table 18.17.

Table 18.17 Summary of Cumulative Effects

Residual Cumulative Effect	Residual Cumulative Effects Characterization*							
	Direction	**Likelihood**	**Magnitude**	**Geographic Extent**	**Timing**	**Duration**	**Frequency**	**Reversibility**
Change in Landscape Diversity	A	CE	M	RAA	N/A	LT	C	R/I
Contribution from the Project to the residual cumulative effect	The Project will increase fragmentation in the RAA; however, average patch size will only be reduced by 0.1 ha for coniferous forest and shrubland and there will be a small to moderate increase in perimeter length to patch area, between 100 m/ha and 1, 000 m/ha, for all natural landcover types, resulting in a moderate magnitude contribution to cumulative effects on landscape diversity at the RAA level.							
Change in Community Diversity	A	CE	L	RAA	N/A	LT	C	R/I
Contribution from the Project to the residual cumulative effect	The Project will reduce abundance of natural upland and wetland landcover categories but all landcover types will remain abundant in the LAA and RAA. Specifically, the area of native vegetation communities directly lost due to the Project ranges from 2.0% of wetland communities to 3.2% of broadleaf forest communities in the LAA. Indirect effects from dust contaminant deposition (to a distance of 40 m from the PDA) could affect an additional 2.0% of wetlands and 3.8% of forest in the LAA; therefore, will make a low magnitude contribution to cumulative effects on community diversity at the RAA level.							

Residual Cumulative Effect	Residual Cumulative Effects Characterization*							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in Species Diversity	A	CE	M	RAA	N/A	LT	C	R/I
Contribution from the Project to the residual cumulative effect	Although no plant SOCC occurrences have been documented in the PDA or LAA, 215 plant SOCC have the potential to occur in the PDA. Many plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties may be present in the PDA, LAA, and RAA. Therefore, effects on plant SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties from the Project could occur. Targeted vegetation and wetland surveys of SOCC and specific plant species of interest to Indigenous Governments and Indigenous Organizations, and other affected parties, will be conducted within the PDA in high potential areas, such as fens, bogs, and dry or rocky sites and in a sub-sample of more common landcover types, prior to construction. This will include transplant or seed collection of observed rare or vulnerable plant species. Appropriate mitigation measures (and monitoring if needed) will be developed based on the findings of the surveys. This includes monitoring in accordance with the terms and conditions of permit approvals, as required. No plant species, including bryophytes, or lichen SOCC potentially occurring in the RAA are listed under SARA or COSEWIC. For these reasons, the Project could make a moderate magnitude contribution to cumulative effects on landscape diversity at the RAA level.							
Change in Wetland Function	A	CE	L	RAA	N/A	LT	C	R/I
Contribution from the Project to the residual cumulative effect	The Project may result in a reduction of wetland function; however, drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns, and mitigation will be implemented to reduce effects on nearby wetlands and wetland function. The Project is therefore predicted to make a low magnitude contribution to cumulative effects on wetland function at the RAA level.							

KEY

* See Table 18.3 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMC: No Measurable Change
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

N/A: Not applicable

18.6 Determination of Significance

18.6.1 Significance of Residual Effects

A significant adverse residual effect on vegetation and wetlands is one that, following the application of avoidance and mitigation measures, threatens the long-term persistence or viability of plant communities or species, including those of cultural or traditional importance, or threatens the long-term viability of local or regional wetland function.

Residual effects will alter the size and characteristics of vegetation landscape diversity; however, the average patch size will only be reduced by 0.1 ha for coniferous forest and shrubland and there will be a small to moderate change in patch area to perimeter length, between 100 m/ha and 1,000 m/ha. Landcover abundance of natural upland and wetland landcover categories will be reduced but will remain abundant with direct losses of native vegetation communities due to the Project ranging from 2.0% of wetland communities to 3.2% of broadleaf forest communities in the LAA. Indirect effects from dust contaminant deposition (to a distance of 40 m from the PDA) could affect an additional 2.0% of wetlands and 3.8% of forest in the LAA. Although no plant SOCC occurrences have been documented in the PDA or LAA, 215 plant SOCC have potential to occur in the PDA. No thresholds for changes to vegetation and wetlands are known to be applicable in the NWT. Although rate of change in connectivity of vegetation community patches has been shown to differ depending on the degree of fragmentation, with the rate changing considerably past a threshold (McIntyre and Wiens, 1999; Monkkonen and Reunanen, 1999), thresholds are not known for plant species occurring in the NWT or comparable areas of other Canadian provinces.

Many plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties may be present in the PDA, LAA, and RAA. Therefore, effects on plant SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties from the Project could occur. A pre-construction survey of higher potential areas of the PDA for plant SOCC and rare or may-be-at-risk plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties, will be conducted. No plant species, including bryophytes, or lichen SOCC potentially occurring in the RAA are listed under SARA or COSEWIC. The Project may result in a reduction of wetland function. However, drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns and mitigation measures will be implemented to reduce effects on nearby wetlands and wetland function. Therefore, with the application of mitigation measures, residual effects on vegetation and wetlands are predicted to be not significant.

18.6.2 Significance of Cumulative Effects

The threshold for a significant adverse cumulative effect on vegetation and wetlands is the same as for residual effects. Many past, present, and reasonably foreseeable projects and activities will have adverse effects on landscape diversity, community diversity, species diversity, and wetland function. However, taking into consideration all projects and physical activities, abundance of natural upland and wetland landcover categories will be reduced but all types will remain abundant in the RAA. With the large amount of area of all landcover types remaining in the RAA, plant SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties are expected to continue to occur, and most would be expected to remain relatively abundant in the RAA. Therefore, cumulative effects on vegetation and wetlands are predicted to be not significant.

18.6.3 Project Contribution to Cumulative Effects

With mitigation, the Project is predicted to make a moderate contribution to cumulative effects on landscape diversity, a low contribution to cumulative effects on community diversity, a moderate contribution to cumulative effects on species diversity, and a low contribution to cumulative effects on wetland function.

18.7 Prediction Confidence

The determination of a not significant effect is made with a moderate level of confidence based on the available data for landcover types, occurrences of plant SOCC and plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties in the LAA. Prediction confidence will increase with data collected during pre-construction surveys of SOCC and rare or may-be-at-risk plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties.

18.7.1 Assumptions

It is assumed that all vegetation and wetlands will be removed from the PDA. This is a conservative assumption because parts of the PDA are already cleared for the MVWR. In addition, abandoned sections of the MVWR ROW and access roads will be closed and reclaimed to promote re-establishment of vegetation. It is expected that in time, potentially several decades, vegetation in upland forest in the LAA outside of the PDA will become upland forest of similar composition to surrounding undisturbed forest, and similarly that lower areas will develop hydric soils and wetland vegetation partially offsetting effects from the Project. This assessment also conservatively assumes that all SOCC species and species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties potentially present in the RAA could be present in the PDA and therefore affected during project construction.

18.7.2 Gaps and Uncertainties

All vegetation and wetland data for the RAA is from existing governmental databases. Data is relatively coarse and does not include detailed vegetation and wetland composition. Limited information is available for the distribution of plant SOCC and plant species important to Indigenous Governments, Indigenous Organizations, and other affected parties. In addition, climate change may have unpredictable effects on the plant species growth, composition and diversity which will develop during re-establishment of vegetation during closure and reclamation. This could also include unpredictable effects on plant SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties.

Prediction confidence will increase with data collected during pre-construction vegetation surveys, including surveys for plant SOCC and rare or may-be-at-risk plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties.

18.8 Follow-up and Monitoring

The objectives of vegetation and wetlands monitoring may include:

- Verifying compliance with terms and conditions of authorizations and commitments
- Verifying effectiveness of mitigations
- Verifying effects predictions

Targeted vegetation and wetland surveys of SOCC and specific plant species of interest to Indigenous Governments and Indigenous Organizations, and other affected parties, will be conducted within the PDA in high potential areas, such as fens, bogs, and dry or rocky sites and in a sub-sample of more common landcover types, prior to construction. This will include transplant or seed collection of observed rare or vulnerable plant species. Appropriate mitigation measures (and monitoring if needed) will be developed based on the findings of the surveys. These are not considered part of the compliance monitoring program.

Monitoring of vegetation will include inspection for invasive alien plant occurrences prior, during and after construction. Inspection will occur during the growing season when plants are actively growing and features supporting identification are present. Inspection will occur in the growing season prior to construction to support pre-construction control efforts. A suggested frequency of monitoring is one inspection per year during construction and one in the year following construction, and five years into Project operations. Identified areas with invasive alien plants will be managed through mowing to reduce introduction and spread of invasive alien plants in the PDA and surrounding natural vegetation. The GNWT-INF will develop an invasive plant species monitoring program in discussion with GNWT-ECC. Additional monitoring requirements, if identified as part of the Project's approval and permitting, will be incorporated into the Project's compliance and effects monitoring activities.

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19.0 ASSESSMENT OF POTENTIAL EFFECTS ON WILDLIFE AND WILDLIFE HABITAT

Wildlife and Wildlife Habitat is a valued component (VC) because it provides ecological, aesthetic, recreational, economic, and cultural value to Indigenous Governments, Indigenous Organizations, and other affected parties. Having access to wildlife and wildlife habitat is important to communities, particularly resource users that continue to practice traditional and recreational hunting and trapping activities throughout the region.

Wildlife and wildlife habitat will potentially be affected by the Mackenzie Valley Highway Project (the "Project"). The assessment of potential effects on wildlife and wildlife habitat considers requirements outlined in the Project Terms of Reference (ToR) for the wildlife and wildlife habitat subject of note (SON) (MVEIRB, 2015 [PR#66]).

Changes to vegetation and wetlands (see Chapter 18) resulting from project-related land clearing will reduce habitat availability. Changes in noise (see Chapter 13) and water quality (see Chapter 16) could affect terrestrial and aquatic habitats, which in turn may affect wildlife health. Residual effects on vegetation and wetlands, noise, and water and sediment quality were also used to support the assessment of potential effects of the Project on wildlife and wildlife habitat.

Changes in wildlife and wildlife habitat may also influence other VCs. For example, changes in wildlife and wildlife habitat can affect biodiversity (see Chapter 21). Traditional land and resource use, including harvesting by Indigenous Governments and Indigenous Organizations may be affected if the Project alters the distribution and abundance of wildlife species of cultural importance (see Chapter 11).

In this assessment, the term "wildlife" considers mammals, amphibians, and insects, including species at risk (SAR) and species of conservation concern (SOCC). Separate VC assessments have been provided for birds and bird habitat (see Chapter 20) and caribou and moose (see Chapter 10), reflecting the ToR SON and key lines of inquiry (KLOI; MVEIRB, 2015). Species at risk are defined as species listed as special concern, threatened, or endangered under the *Species at Risk (NWT) Act* (GNWT, 2020a) or under Schedule 1 of the federal *Species at Risk Act* (SARA; Government of Canada, 2021). Species of conservation concern are defined as species listed as special concern, threatened, or endangered by the NWT Species at Risk Assessment Committee (GNWT, 2020a) or the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; Government of Canada, 2021). This is consistent with the Wildlife and Wildlife Habitat Technical Data Report (TDR; K'alo-Stantec, 2023; Appendix 19A).

Numerous wildlife species inhabit the Mackenzie Valley due to the widespread availability of wetlands, rivers, lakes, forests and rock formations as key habitats. It is not feasible to assess all species having potential to occur in the region; therefore, the assessment of wildlife and wildlife habitat focused on a select group of species and species assemblages that are representative of the wildlife species present and have the greatest potential to be affected by the Project, including SAR, SOCC, and harvested species.

The assessment of potential effects on wildlife and wildlife habitat concludes that with the application of mitigation measures, residual effects resulting from the Project on wildlife and wildlife habitat will be adverse. Residual effects and cumulative effects will not cause or further contribute to the exceedance of a conservation-based threshold or threaten the long-term persistence or viability of SAR/SOCC, or species of cultural or traditional importance and therefore will be not significant.

19.1 Scope of Assessment

19.1.1 Regulatory and Policy Setting

The assessment of potential project-related environmental effects on wildlife and wildlife habitat is guided by the ToR (MVEIRB, 2015 [PR#66]) and notable federal and territorial legislation and guidance, and the Sahtu Land Use Plan (SLUP), as outlined in the following sections.

19.1.1.1 Federal

The SARA provides protection for SAR in Canada. The legislation provides a framework to facilitate recovery of species listed as threatened, endangered, or extirpated and to prevent species listed as special concern from becoming threatened or endangered. Species at risk and their habitats are protected under SARA, which prohibits: (1) the killing, harming, or harassing of endangered or threatened SAR (SARA sections 32 and 36); and (2) the destruction of critical habitat of and endangered or threatened SAR (SARA sections 58, 60, and 61).

19.1.1.2 Territorial

The *Species at Risk (NWT) Act* is used to identify, protect, and recover plant and animal SAR in the Northwest Territories (NWT). The Act provides for the process of assessment and management of species and their habitats to prevent further declines and to promote recovery.

The *Wildlife Act* provides general provisions for regulating the activities relating to the harvest and protection of wild animals in NWT. Section 1(1) defines “wildlife" as “all species of vertebrates and invertebrates found wild in nature in the Northwest Territories” (GNWT, 2018), which includes all wild animals except fish and marine mammals. This means that “wildlife” includes mammals, birds, reptiles, amphibians, insects and other invertebrates. Other animals can be listed as wildlife in the regulations.

19.1.1.3 Sahtu Land Use Plan

Specific to the areas to which the SLUP applies, the Project must meet the 13 general conformity requirements (CR) of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023). The SLUP's conformity requirements include consideration of wildlife in CR#7, species introduced in CR#8 and sensitive species and features in CR#9, which are reproduced below as they relate to the Wildlife and Wildlife Habitat VC (which excludes fish, birds, caribou and moose):

> CR#7: *"1) Land use activities must be designed using the most current information for identified species of interest and species at risk as obtained from the GNWT-ECC* [Environment and Climate Change], *CWS* [Environment and Climate Change Canada - Canadian Wildlife Service], *DFO* [Fisheries and Oceans Canada], Parks Canada Agency, *the Sahtú Renewable Resources Board (SRRB) and the local Renewable Resources Council (RRC)s.*
>
> *2) Impacts to wildlife, their habitat and migration patterns, and important community harvesting areas must be prevented or mitigated to the extent possible."*
>
> *"a) In particular, all reasonable steps should be taken to follow the horizontal setbacks and minimum flight altitudes identified in Table 4 [of the SLUP] when near habitat sites during sensitive periods described in that table, unless human safety is of concern, and measures are developed with the appropriate organizations and the RRC to mitigate impacts to these species and their habitat."*
>
> CR#8: *"Land use activities must not result in the intentional introduction of non-native plant and animal species, or of domestic animal species."*
>
> CR#9: *"1) Any land use activity requiring a land use permit or water license must be designed using the most current available information on the location of rare or may-be-at-risk plants, hot and warm springs, mineral licks, karst topography, amphibian sightings, and ice patches and carried out in a manner that minimizes impacts to these features."*

Conformity Requirement #2 requires that *"The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge."*

Additionally, per CR#14, the Project must be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 2023), including the following:

- Petiniɀah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)
- K'ąąlǫ Tué (Willow Lake Wetlands) Special Management Zone (SMZ) (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

19.1.2 Influence of Engagement

The Government of the Northwest Territories (GNWT) has engaged with Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapter 2 (Consultation and Engagement), Chapter 3 (Traditional Knowledge), and Chapter 11 (culture and traditional land use) of this Developer's Assessment Report (DAR). The GNWT has recently initiated Consultation with Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, and through a review of publicly available TLRU information, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to wildlife and wildlife habitat. This feedback has been considered and summarized in Table 19.1 and has been integrated into the assessment of potential effects on wildlife and wildlife habitat that follows. .

19.1.2.1 Regulatory Engagement

The GNWT Department of Infrastructure (INF) has engaged and collaborated with the GNWT Department of Environment and Climate Change (GNWT-ECC) throughout the development the DAR, and the GNWT-ECC has aided in addressing data gaps relative to the Project ToR (MVEIRB, 2015) and reviewing development of the TDR (K'alo-Stantec, 2023; Appendix 19A), Draft Wildlife Management and Monitoring Plan (WMMP; Volume 5) and DAR within its mandate.

Table 19.1 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
Engaged Indigenous Governments and Indigenous Organizations identified wildlife species of importance.	Auld and Kershaw, 2005; Dehcho First Nations, 2011; IMG-Golder Corporation, 2006; McDonald, 2010; NWRRC, 2023; TRRC, 2022; SRRB, 2021b, 2007; SLUPB, 2023	The GNWT has reviewed and considered the species of importance and important habitats identified by Indigenous Governments and Indigenous Organizations.	For information about wildlife species of importance and important wildlife habitat, see Section 19.2.2.1 (Table 19.5 and Table 19.6). See also Section 11.2.3.1 and Section 11.2.3.4 for additional information about important harvesting areas and harvested species.
Engaged Indigenous Governments and Indigenous Organizations identified important wildlife habitats and areas, and hunting and trapping locations near the Project.	DCLUPC, 2006; Dessau, 2012 (PR#13); NWRRC, 2023; TRRC, 2022; SLUPB, 2022		
Community engagement participants expressed concern about ecosystems and wildlife, and in particular caribou, moose, muskox, bears, bats, beaver, and other furbearers. They expressed concern that effects on wildlife and wildlife habitat may negatively affect culturally significant sites. They attributed these effects to construction activities, increased noise, increased traffic collisions, harvesting pressure, and climate change.	August 2021 Engagement; April to July 2022 Engagement; November to December 2022 Engagement; November 2022 to February 2023 Engagement	The GNWT has identified mitigation measures to reduce the effects of the Project on wildlife and wildlife habitat. A Wildlife Management and Monitoring Plan (WMMP) will be developed and implemented. A project-specific Spill Contingency Plan (SCP) will include procedures to prevent and respond to spills.	For mitigation measures to reduce effects of the Project on wildlife and wildlife habitat, see Table 19.9. See also: Section 19.4.2 (Change in Habitat) Section 19.4.3 (Change in Movement) Section 19.4.4 (Change in Mortality Risk) Chapter 25 (Assessment of Potential Accidents or Malfunctions) Volume 5 for management plans.
Dehcho First Nations reported concern about the consumption of potentially contaminated bear meat from bears that forage in dumps or other contaminated sites.	Dehcho First Nations, 2011		

Comment	Source	GNWT Response	Where Addressed
Norman Wells Renewable Resources Council (NWRRC) study participants raised concerns about the effects of spills on wildlife health.	NWRRC, 2023	*(cont'd from above)* The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning. The GNWT will continue to implement existing wildlife monitoring programs consistent with its role as wildlife resource manager but recognizes that new programs and additional resources may be required to address issues specific to the Project. The GNWT will continue to refine the WMMP for this project throughout the EA process and is open to and interested in discussions with Indigenous Governments, Indigenous Organizations, and other affected parties on how best to incorporate their recommendations. The GNWT will work with SRRB and other resource managers to address uncertainty regarding the effects of increased access created by the Project on harvested resources in the study areas. This would include monitoring of harvest that can be used to identify the need for management actions to be taken by the appropriate resource management organization.	

19.1.3 Potential Effects, Pathways and Measurable Parameters

Table 19.2 summarizes the potential effects of project activities on wildlife and wildlife habitat, the pathways by which they may affect wildlife and wildlife habitat, and the measurable parameters used for evaluating effects. Potential effects and measurable parameters were selected based on professional judgment, recent environmental assessments for road projects in NWT, and regulatory concern for certain species.

Table 19.2 Potential Effects, Effects Pathways, and Measurable Parameters for Wildlife and Wildlife Habitat

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in habitat	Construction and operations and maintenance of the Project could result in a: • direct loss or alteration of wildlife habitat (e.g., vegetation clearing) • indirect loss or alteration of wildlife habitat (e.g., sensory disturbance1, edge effects)	• Quantitative evaluation of the amount (hectares [ha]) of habitat directly lost or altered for: – general wildlife habitat – little brown myotis (*Myotis lucifugus*) – grizzly bear (*Ursus arctos*) • Qualitative evaluation[2] of the amount of habitat directly lost or altered for: – wolverine (*Gulo gulo*) – invertebrate SAR/SOCC • Qualitative evaluation of the amount of indirect habitat loss or altered for wildlife, including the species listed • Area (ha) of other formally defined habitat areas (e.g., Important Wildlife Areas [IWAs]) directly affected • Area (ha) of formally defined SAR critical habitat directly or indirectly affected, if present • Number of formally defined SAR residences (e.g., dens) directly or indirectly affected
Change in movement	Construction and operations and maintenance could result in alteration of wildlife movement patterns[1] or movement corridors	• Qualitative evaluation of project effects on wildlife movement (e.g., barrier permeability)

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in mortality risk	Construction and operations and maintenance of the Project could result in a: • direct increase in mortality risk or number of wildlife fatalities (e.g., vegetation clearing activities, vehicular collisions, human-wildlife conflicts) • indirect increase in mortality risk or number of wildlife fatalities (e.g., altered predator-prey dynamics, harvest pressure)	• Qualitative evaluation of direct mortality risk: – Risk of mortality due to vegetation clearing, site preparation, and maintenance – Risk of collisions with project vehicles (e.g., increase in annual daily traffic volumes) or infrastructure – Risk of human-wildlife conflict • Qualitative evaluation of indirect mortality risk: – Predation risk due to change in predator-prey dynamics (e.g., change in predator mobility) – Hunting/trapping harvest pressure (e.g., year-round access or access to new areas)
Change in wildlife health	Construction and operations and maintenance could expose wildlife to contaminants or other emissions that may affect the health and condition of wildlife	• Qualitative evaluation of the effects of the Project on wildlife health and condition based on information provided in the air quality and surface water and sediment quality assessments.

Notes:

1 Daily and fine-scale effects on wildlife movement patterns (e.g., avoidance behaviour) are assessed as an indirect effect of change in habitat (i.e., reduced ecological effectiveness of habitats adjacent to the Project).

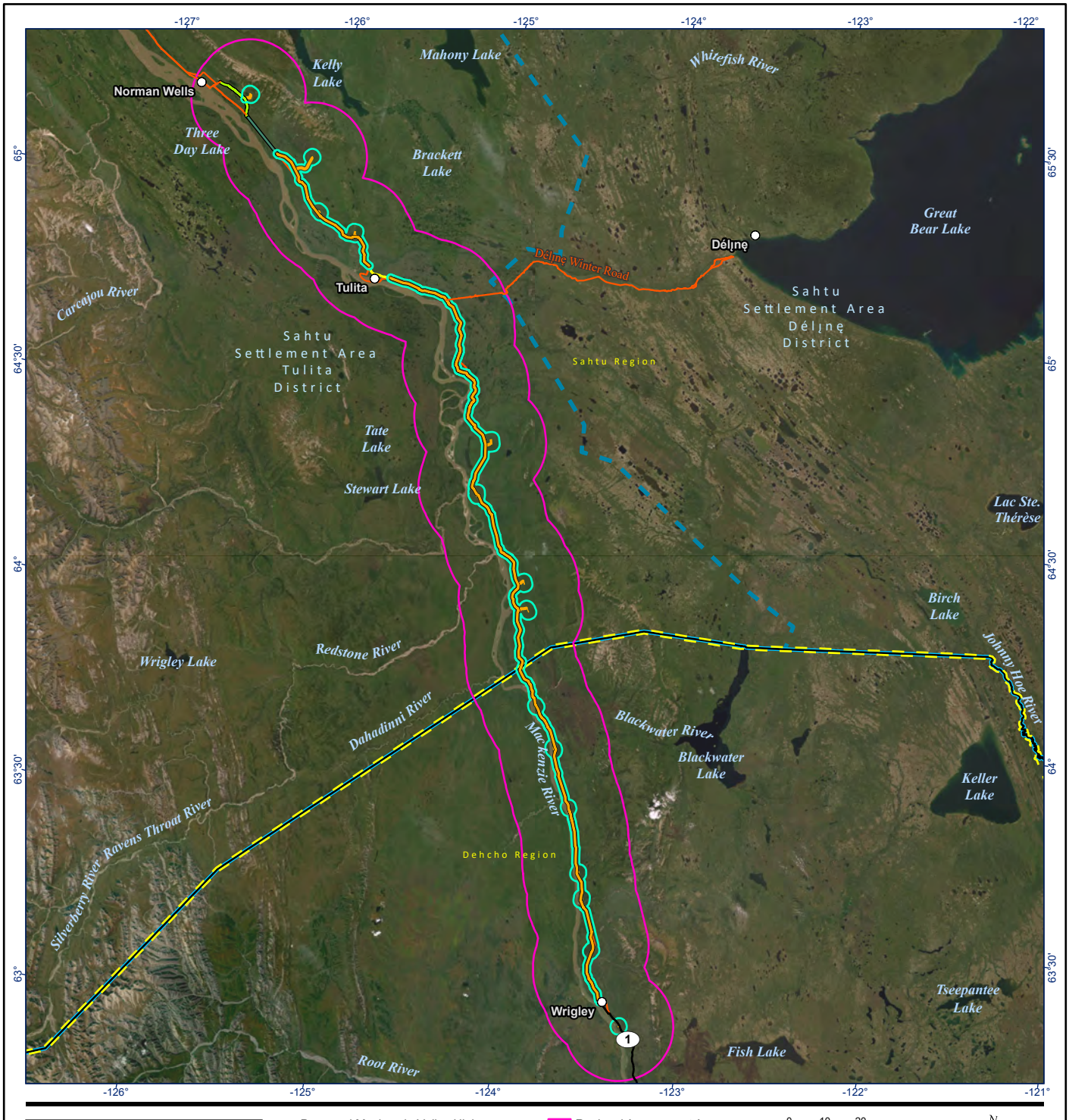
2 Quantitative habitat assessments for wolverine (*Gulo gulo*) and invertebrate species are not included as these species occupy broad habitat types and an assessment based on quantified habitat loss or alteration is uninformative.

19.1.4 Boundaries

19.1.4.1 Spatial Boundaries

The Project Development Area (PDA), Local Assessment Area (LAA), and Regional Assessment Area (RAA) for the assessment of effects on wildlife and wildlife habitat are shown in Figure 19.1. These spatial boundaries are used to assess project effects, including residual and cumulative effects, on wildlife and wildlife habitat.

- **PDA:** The area of direct project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 metres (m) wide highway right-of-way (ROW) mostly following the Mackenzie Valley Winter Road (MVWR), laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sites with access roads on a 30 m ROW.
- **LAA:** The area within which measurable project-related effects (direct or indirect) are expected to occur. This is a 1-kilometre (km) buffer around the preliminary road alignment route centerline, and a 2 km buffer around the extent of borrow sources and quarries. The size of the buffer is based on measurable effects of noise on birds and mammals (e.g., Benitez-Lopez et al., 2010) while also considering recommended setback distances for wildlife and wildlife habitat features (Appendix 19B, Table 19B.1; GNWT, 2015). The size of the LAA is also consistent with guidance provided by Environment and Climate Change Canada (ECCC) (Dufour, 2020, pers. comm.).
- **RAA:** The area that provides context for determining significance of project-specific effects and cumulative effects. The RAA is an area within approximately 15 km of the PDA that is used to capture a wide range of wildlife species and wildlife habitats that could potentially be affected cumulatively by the Project and other past, present, and reasonably foreseeable projects. This RAA is consistent with other highway projects in the NWT (e.g., Inuvik to Tuktoyaktuk Highway [Kiggiak – EBA, 2011]) and follows recommendations from ECCC (Dufour, 2020, pers. comm.).



- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Local Assessment Area
- Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 8/3/2023
TR by AJ on 8/3/2023

Client/Project
144903025-0030 REVB

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
19.1

Title
Wildlife and Wildlife Habitat Assessment Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS. Imagery date: 2021

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

19.1.4.2 Temporal Boundaries

The temporal boundaries are based on the Project phases described in Section 5.4.1.

- **Construction phase**: The Project will take approximately 10 years to construct over a timeframe of up to 20 years. The conceptual schedule assumes the highway will be constructed in three consecutive segments, beginning in approximately 2026: Wrigley north to the Dehcho–Sahtu border (102 km); Tulita south to the Dehcho–Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells sometime between 2041 and 2046.
- **Operations and maintenance phase**: The operations and maintenance phase will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the highway is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, and borrow sources and quarries used only for construction are included within the construction phase.

19.1.5 Residual Effects Characterization

Table 19.3 presents definitions for the characterization of residual effects on wildlife and wildlife habitat. Residual effects are those that remain after mitigation measures have been implemented.

Table 19.3 Characterization of Residual Effects on Wildlife and Wildlife Habitat

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse:** A residual effect that moves measurable parameters of wildlife and wildlife habitat in a negative direction relative to baseline **Neutral:** No net change in measurable parameters for wildlife and wildlife habitat relative to baseline
Likelihood	The probability that the residual effect will occur	**Unlikely –** the residual effect is almost certainly not to occur **Possible –** the residual effect could occur **Certain –** the residual effect will certainly occur
Magnitude	The amount of change in wildlife habitat[1]	***Change in Habitat (Direct)*** **Low:** Project changes less than 10% of general wildlife habitat in the LAA, or less than 5% of habitat for wildlife SAR and SOCC in the LAA **Moderate:** Project changes 10-20% of general wildlife habitat in the LAA, or 5-10% of habitat for wildlife SAR and SOCC in the LAA **High:** Project changes more than 20% of wildlife habitat in LAA, or more than 10% of habitat for wildlife SAR and SOCC in the LAA Effects on formally defined SAR critical habitat (if present), SAR residences, and habitat areas will be characterized based on professional judgement and potential effects on the species or habitat.
	The change in wildlife abundance and/or distribution	***Change in Habitat (Indirect), Movement, Mortality Risk, and Health*** **Negligible:** A measurable change in the abundance of wildlife in the LAA is not anticipated **Low:** A measurable change in the abundance of wildlife in the LAA is not anticipated, although temporary local shifts in distributions in the LAA might occur **Moderate:** A measurable change in the abundance and/or distribution of wildlife in the LAA might occur **High:** A measurable change in the abundance and/or distribution of wildlife may exceed the LAA
Geographic Extent	The geographic area in which a residual effect occurs	**PDA:** Residual effects are restricted to the PDA **LAA:** Residual effects extend into the LAA **RAA:** Residual effects interact with those of other projects in the RAA

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Timing	Considers when the residual effect is expected to occur. Timing considerations are noted in the evaluation of the residual effect, where applicable or relevant	**No sensitivity:** The residual effect does not occur during critical life stage (e.g., bear denning period) or timing does not affect the VC **Moderate sensitivity:** The residual effect may occur during a lower sensitive period of a critical life stage; for many species this is the start or end of the critical period **High sensitivity:** The residual effect occurs during a critical life stage
Duration	The time required until the measurable parameter or the VC returns to its existing condition, or the residual effect can no longer be measured	**Short-term:** The residual effect occurs during one segment of the construction phase, or less than 5 years **Medium-term:** The residual effect lasts through construction (up to 20 years) **Long-term:** The residual effect extends beyond construction, or throughout operations (> 20 years)
Frequency	Identifies how often the residual effect occurs and how often during the project or in a specific phase	**Single event:** The residual effect occurs once **Multiple irregular event:** The residual effect occurs at no set schedule **Multiple regular event:** The residual effect occurs at regular intervals **Continuous:** The residual effect occurs continuously
Reversibility	Pertains to whether a measurable parameter or the VC can return to its existing condition after the project activity ceases	**Reversible:** The residual effect is likely to be reversed after activity completion and reclamation **Irreversible:** The residual effect is unlikely to be reversed

Note:

[1] Based on benchmarks used for other recent environmental assessments (KHLP, 2012; Nalcor, 2012; JRP, 2014; Manitoba Hydro, 2016)

19.1.6 Significance Definition

A significant adverse residual effect on wildlife and wildlife habitat is one that, following the application of avoidance and mitigation measures, causes or further contributes to the exceedance of a conservation-based threshold or threatens the long-term persistence or viability of SAR/SOCC, or species of cultural or traditional importance.

Specific to the assessment of potential effects of the Project on wildlife and wildlife habitat, persistence refers to the likelihood of population survival over the long term (Middleton and Nisbet 1997, EC 2011). The determination of significance considers whether habitats might be altered in such a way as to cause a change or decline in the distribution or abundance of a viable population (locally or regionally) that is dependent upon that habitat, such that the likelihood of long-term population survival is substantially reduced as a result. The determination of significance also considers whether there is a direct (e.g., collision risk) and/or indirect (e.g., increased predation pressure) increase in mortality risk such that the likelihood of persistence is substantially reduced as a result.

19.2 Existing Conditions for Wildlife and Wildlife Habitat

Residual effects (Section 19.4) are assessed relative to the existing condition for wildlife and wildlife habitat. This section provides a brief overview of the existing conditions for wildlife and wildlife habitat, including the occurrence of SAR, SOCC, and harvested species within the LAA and RAA, which are reported in the Wildlife and Wildlife Habitat TDR (K'alo-Stantec, 2023; Appendix 19A).

19.2.1 Methods

The Wildlife and Wildlife Habitat TDR (K'alo-Stantec, 2023; Appendix 19A) was completed to address the ToR (MVEIRB, 2015) using a literature review of currently available information. The literature review incorporated review of relevant wildlife literature, Traditional Knowledge, and traditional land and resource use information (K'alo-Stantec, 2023; Appendix 19A, Section 3). Results are used to characterize the existing conditions for wildlife and wildlife habitat within the LAA and RAA.

19.2.2 Overview

The biophysical characteristics of the LAA are influenced by the Mackenzie River (Deh Cho) valley that defines the landscape and is dominated by coniferous forest habitats interspersed with wetlands and watercourses. The RAA contains potential habitat for 43 species of mammal, 2 species of amphibian, and numerous invertebrate species (GNWT, 2020b). The RAA is also within the range of four mammal SAR, three invertebrate SAR, and one mammal and one invertebrate SOCC (Table 19.4; GNWT, 2020a, 2020c; Government of Canada, 2021).

Table 19.4 Wildlife Species at Risk and Species of Conservation Concern with Potential to Occur in the RAA

Species		Status in NWT[2]		Status in Canada[3]	
Common Name	**Scientific Name**	**SARC Assessment**	***Species at Risk (NWT) Act***	**COSEWIC**	**SARA**
Mammals					
Little brown myotis	*Myotis lucifugus*	Special Concern	Special Concern	Endangered	Endangered
Grizzly bear	*Ursus arctos*	Special Concern	Not Listed	Special Concern	Special Concern
Wolverine	*Gulo gulo*	Not at Risk	Not Listed	Special Concern	Special Concern
Boreal caribou[1]	*Rangifer tarandus caribou*	Threatened	Threatened	Threatened	Threatened
Barren-ground caribou[1]	*Rangifer tarandus groenlandicus*	Threatened	Threatened	Threatened	Not Listed◊
Invertebrates					
Gypsy cuckoo bumble bee	*Bombus bohemicus*	Data deficient	Not Listed	Endangered	Endangered
Suckley's cuckoo bumble bee*	*Bombus suckleyi*	Not Assessed	Not Listed	Threatened	Not Listed◊
Yellow-banded bumble bee	*Bombus terricola*	Not at Risk	Not Listed	Special Concern	Special Concern
Transverse lady beetle	*Coccinella transversoguttata*	Not Assessed	Not Listed	Special Concern	Special Concern

Notes:

1 The assessment of effects on caribou is available in Chapter 10

2 Species at risk in NWT assessed by the Species at Risk Committee (SARC) and listed under the territorial *Species at Risk (NWT) Act* (GNWT, 2022)

3 Species at risk in Canada assessed by COSEWIC and listed under Schedule 1 of the federal *Species at Risk Act* (Government of Canada, 2021)

* Species of conservation concern

◊ Under consideration for Schedule 1 status change

19.2.2.1 Wildlife Species of Interest to Indigenous Governments, Indigenous Organizations, and Other Affected Parties

Through a review of publicly available literature and project-specific TLRU studies with Indigenous Governments, Indigenous Organizations, and other affected parties engaged on the Project, wildlife species of interest have been identified and listed in Table 19.5 (Auld and Kershaw, 2005; Dehcho First Nations, 2011; IMG-Golder Corporation, 2006; McDonald, 2010; NWRC, 2023; TRRC, 2022; SRRB, 2021b, 2007; SLUPB, 2023). As well, important wildlife habitat areas, and specific harvesting and trapping locations have been identified in the LAA and RAA as described in Table 19.6 (Dessau, 2012 [PR#13]; Dehcho First Nations, 2011; NWRRC, 2023; SLUPB, 2023; SLUBP, 2022; TRRC, 2022). The wildlife assessment used a habitat-based approach (see Section 19.4.1) to assess potential project effects on SAR/SOCC including those considered to have cultural importance to Indigenous Governments, Indigenous Organizations, or other affected parties. All species identified by Indigenous Governments, Indigenous Organizations, and other affected parties have been considered through the habitat-based approach, with the exception of Dall sheep and mountain goat, which are typically found further west in the Mackenzie Mountains

Table 19.5 Culturally Important Wildlife Species Identified by Indigenous Governments, Indigenous Organizations, and Other Affected Parties with Potential to Occur in the RAA

Common Name	Scientific Name	Identified By
Arctic fox	*Alopex lagopus*	Sahtu Renewable Resources Board (SRRB); NWRRC
Arctic hare	*Lepus arcticus*	SRRB; Tulita Renewable Resources Council (TRRC)
Arctic ground squirrel	*Spermorphilus parryii*	SRRB
Beaver	*Castor canadensis*	Dehcho First Nations; Pehdzéh Kį First Nation; Wrigley Community; SRRB; TRRC; NWRRC
Black bear	*Ursus americanus*	Dehcho First Nations; Pehdzéh Kį First Nation; SRRB; NWRRC
Black scoter	*Melanitta nigra*	SRRB
Cougar	*Felis concolor*	SRRB
Coyote	*Canis latrans*	SRRB
Dall sheep	*Ovis dalli*	SRRB
Duck	Various	Dehcho First Nations; Pehdzéh Kį First Nation; Wrigley Community; TRRC; NWRRC
Ermine (Weasel)	*Mustela erminea*	Pehdzéh Kį First Nation; SRRB
Fisher	*Martes pennanti*	Pehdzéh Kį First Nation; SRRB

Common Name	Scientific Name	Identified By
Grizzly bear	*Ursus arctos*	Dehcho First Nations; Pehdzéh Kį First Nation; SRRB
Least weasel	*Mustela nivalis*	Pehdzéh Kį First Nation
Lynx	*Lynx canadensis*	Pehdzéh Kį First Nation; SRRB; NWRRC
Marmot	*Marmota spp.*	SRRB
Marten	*Martes americana*	Pehdzéh Kį First Nation; Wrigley Community; SRRB; NWRRC
Mink	*Neovison vison*	Pehdzéh Kį First Nation; SRRB; NWRRC
Mountain goat	*Oreamnos americanus*	SRRB
Muskrat	*Ondatra zibethica*	Dehcho First Nations; Pehdzéh Kį First Nation; SRRB; TRRC; NWRRC
Muskox	*Ovibos mochatus*	SRRB; TRRC; NWRRC
Northern river otter/otter	*Lontra canadensis*	SRRB; Pehdzéh Kį First Nation
Porcupine	*Erethizon dorsatum*	Dehcho First Nations; Pehdzéh Kį First Nation: SRRB
Red fox	*Vulpes vulpes*	Pehdzéh Kį First Nation; SRRB; NWRRC
Red squirrel	*Tamiasciurus hudsonicus*	SRRB
Snowshoe hare	*Lepus americanus*	Pehdzéh Kį First Nation; SRRB; TRRC
Squirrel	Various	Pehdzéh Kį First Nation
White-tailed deer	*Odocoileus virginianus*	SRRB
Wolf	*Canis lupus*	Pehdzéh Kį First Nation; Sahtu Dene and Métis; SRRB; TRRC; NWRRC
Wolverine	*Gulo gulo*	Pehdzéh Kį First Nation; SRRB; NWRRC

Table 19.6 Wildlife Harvesting and Habitat Identified by Indigenous Governments and Indigenous Organizations Relative to the Project

Location	Within LAA	Within RAA[3]	Identified By:
White Sand Creek (trapping)	✓*	-	Pehdzéh Kı̨ First Nation
Dam Creek (trapping)	-	✓	Pehdzéh Kı̨ First Nation
Along the Mackenzie Valley Winter Road (between Tulita and Norman Wells; 'Drive-by' hunting)	✓*	-	NWRRC TLRU study participants
Prohibition Creek (wildlife harvesting/trapping)	-	✓	NWRRC TLRU study participants
Vermilion Creek (wildlife harvesting/trapping)	-	✓	NWRRC TLRU study participants
Canyon Creek (wildlife harvesting/trapping)	-	✓	NWRRC TLRU study participants
Around Bear Rock (Petınızah) (harvesting/wildlife habitat)	✓	-	NWRRC TLRU study participants; TRRC TLRU study participants
Three Day Lake (trapping)	-	✓	NWRRC TLRU study participants
Bluefish Creek (trapping)	-	✓	NWRRC TLRU study participants
Fish Lake[1] (trapping)	-	✓	NWRRC TLRU study participants
Great Bear River in the LAA and RAA (harvesting/wildlife habitat)	✓*	✓	Sahtu Dene and Métis
Pehdzéh Kı̨ N'deh[2] (wildlife habitat)	-	✓	Pehdzéh Kı̨ First Nation; Dehcho First Nations
North of Tulita Airport (wildlife habitat)	-	✓	TRRC TLRU study participants
Four Mile Creek (wildlife habitat)	-	✓	TRRC TLRU study participants
Sucker Creek (wildlife habitat)	-	✓	NWRCC TLRU study participants
Bennett Field (wildlife habitat)	-	✓	NWRCC TLRU study participants

Notes:

1 Fish Lake is a common lake name, and the location is not identified in this report

2 Pehdzéh Kı̨ N'deh area boundary of this area was not identified or disclosed in the report

3 Occurs within the RAA outside the LAA and PDA

* May occur within PDA

Dehcho First Nations have observed increased bear populations throughout the Dehcho Region. (Dehcho First Nations, 2011).

Tulita Renewable Resources Council reported an increase in muskox populations in the Tulita area (TRRC, 2022). Local knowledge from TRRC attributed the increase of muskox to previous road construction and operations in the Tulita area (TRRC, 2022). Participants of a NWRRC study noted they have observed muskox eating all types of vegetation in the TLRU study area, including the grasses, low bush, and the willows and explained that muskox are pushing caribou out of the area (NWRRC, 2023).

Wildlife habitat in the Dehcho Region portion of the LAA is dominated by coniferous forest (43.6%), wetlands (19.8%), and open water (19.3%), while the LAA that overlaps the Sahtu Region is dominated by coniferous forest (28.7%), wetlands (25.2%), and shrubland (20.6%; Table 19.7). Between 1960 and 2019, 18.5% of the LAA within the Deh Cho Region and 75.2% of the LAA within the Sahtu Region has been subject to forest fire (see Appendix 18A; K'alo-Stantec, 2022).

Other than communities, the Norman Wells Pipeline, and other developments such as borrow sources and quarries, a fibre line, and bridges associated with the MVWR, the LAA and RAA are relatively undisturbed by human activities (see Table 19.7). Oil and gas exploration and production infrastructure in the RAA occurs on the west side of and within the Mackenzie River Valley near Norman Wells (Auld and Kershaw, 2005).

Table 19.7 Land Cover Composition[1] in the LAA and RAA for the Dehcho Region and Sahtu Region

Land Cover Category	Land Cover Class[2]	Dehcho Region			Sahtu Region		
		PDA	LAA	RAA	PDA	LAA	RAA
		ha (%)	ha (%)	ha (%)	ha (%)	ha (%)	ha (%)
Upland	Broadleaf Dense	11.6 (1.4%)	1,037.4 (3.9%)	43,781.3 (12.2%)	75.1 (5.0%)	2,523.1 (5.2%)	34,259.4 (5.3%)
	Broadleaf Open	2.1 (0.3%)	114.8 (0.4%)	4,154.7 (1.2%)	27.0 (1.8%)	1,103.9 (2.3%)	14,627.9 (2.2%)
	Coniferous Dense	39.2 (4.9%)	3,374.9 (12.6%)	25,120.5 (7.0%)	18.1 (1.2%)	917.8 (1.9%)	18,580.5 (2.9%)
	Coniferous Open	98.9 (12.2%)	4,600.6 (17.2%)	40,034.2 (11.2%)	147.1 (9.8%)	6,678.1 (13.8%)	113,316.2 (17.4%)
	Coniferous Sparse	42.6 (5.3%)	3,725.0 (13.9%)	51,491.5 (14.3%)	116.2 (7.7%)	6,332.6 (13.0%)	71,845.9 (11.0%)
	Mixedwood Dense	16.6 (2.1%)	1,035.1 (3.9%)	6,786.9 (1.9%)	11.1 (0.7%)	387.3 (0.8%)	7,494.4 (1.1%)
	Mixedwood Open	1.8 (0.2%)	117.1 (0.4%)	2,728.5 (0.8%)	47.1 (3.1%)	2,514.0 (5.2%)	23,834.7 (3.7%)
	Mixedwood Sparse	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.5 (<0.1%)	6.3 (<0.1%)	11.7 (<0.1%)

Land Cover Category	Land Cover Class[2]	Dehcho Region			Sahtu Region		
		PDA	LAA	RAA	PDA	LAA	RAA
		ha (%)	ha (%)	ha (%)	ha (%)	ha (%)	ha (%)
Upland (cont'd)	Shrub Low	4.9 (0.6%)	567.4 (2.1%)	39,005.2 (10.9%)	146.2 (9.7%)	7,903.4 (16.3%)	72,607.6 (11.1%)
	Shrub Tall	3.2 (0.4%)	320.6 (1.2%)	1,616.4 (0.5%)	49.9 (3.3%)	2,091.3 (4.3%)	16,525.8 (2.5%)
	Herbaceous	6.6 (0.8%)	50.6 (0.2%)	1,300.1 (0.3%)	12.1 (0.8%)	210.9 (0.4%)	4,093.2 (0.6%)
	Bryoids	0.0 (0.0%)	7.0 (<0.1%)	20.4 (<0.1%)	0.4 (<0.1%)	6.2 (<0.1%)	137.0 (<0.1%)
	Rock/Rubble	2.1 (0.3%)	45.1 (0.2%)	4,916.4 (1.4%)	3.8 (0.3%)	107.3 (0.2%)	10,285.3 (1.6%)
	Exposed Land[3]	478.6 (59.2%)	1,338.0 (5.0%)	4,862.2 (1.4%)	626.3 (41.5%)	1,713.2 (3.5%)	9,897.9 (1.5%)
	Total	*708.3 (87.7%)*	*16,333.6 (60.9%)*	*225,848.3 (62.9%)*	*1,280.9 (85.0%)*	*32,495.5 (66.9%)*	*397,517.5 (61.0%)*
Wetland	Wetland Herbaceous	12.1 (1.5%)	856.8 (3.2%)	12,668.3 (3.5%)	52.5 (3.5%)	2,976.9 (6.1%)	44,854.8 (6.9%)
	Wetland Shrub	47.1 (5.8%)	2,222.9 (8.3%)	44,730.3 (12.5%)	78.3 (5.2%)	4,503.7 (9.3%)	55,337.6 (8.5%)
	Wetland Treed	34.5 (4.3%)	2,218.9 (8.3%)	46,859.8 (13.1%)	75.5 (5.0%)	4,771.6 (9.8%)	64,769.1 (9.9%)
	Total	*93.6 (11.6%)*	*5,298.5 (19.8%)*	*104,258.6 (29.0%)*	*206.3 (13.7%)*	*12,252.1 (25.2%)*	*164,961.5 (25.3%)*
Water		6.0 (0.7%)	5,187.5 (19.3%)	28,835.2 (8.0%)	20.1 (1.3%)	3,792.3 (7.8%)	89,302.6 (13.7%)
No Data		0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	163.9 (<0.1%)
GRAND TOTAL		***807.9 (100%)***	***26,819.7 (100%)***	***359,038.0 (100%)***	***1,507.3 (100%)***	***48,539.9 (100%)***	***651,945.5 (100%)***

Notes:

1 Measured in hectares (ha)

2 From EOSD NWT (NRCan and GNWT, 2017; K'alo-Stantec, 2022 [Appendix 18A])

3 Exposed land includes areas which naturally have less than 5% vegetative cover, such as shorelines of rivers and lakes, exposed rock, recently burned areas, and moraines, and includes cleared areas such as the existing MVWR, Norman Wells Pipeline, and other areas of infrastructure development

Key results and findings of the TDR (K'alo-Stantec, 2023; Appendix 19A) include:

- Many wildlife species are culturally important to local communities (e.g., bears and furbearers), including for trapping (Auld and Kershaw, 2005; DLUPC, 2006; SLUPB, 2023; SRRB, 2021; TRRC, 2022).
- Harvest composition of large mammals in the Sahtu Region is dominated by barren-ground caribou (*Rangifer tarandus groenlandicus*; 88%), followed by moose (*Alces alces*; 8%), woodland caribou (*Rangifer tarandus caribou*; 3%), and other species (1%; e.g., muskox [*Ovibos moschatus*]; SRRB, 2021).
- The Petiniʔah (Bear Rock) CZ is a large karst formation west of Tulita that is a sacred site and subject to traditional storytelling that also provides habitat for a wide variety of wildlife species (SLUPB, 2023).
- Historical wildlife SAR and SOCC records within the LAA and RAA include observations of little brown myotis, wolverine, and all four invertebrate species.
- Critical habitat for the gypsy cuckoo bumble bee has been identified in the SARA Recovery Strategy for the Gypsy Cuckoo Bumble Bee (*Bombus bohemicus*) in Canada [Proposed] (ECCC, 2022). Critical habitat does not overlap the PDA or LAA, however, a portion of critical habitat intersects the RAA near Norman Wells.
- The LAA is located partly within four IWAs each designated as important habitat for specific wildlife species including beaver (*Castor canadensis*), lynx (*Lynx canadensis*), muskox, and the moose (Sahtu rivers IWA)
- Sensitive wildlife features that wildlife rely on (e.g., mineral licks, overwintering hibernacula, denning sites) are not well-documented within the LAA despite information suggesting that the LAA and RAA have the potential to support these features.

19.3 Project Interactions with Wildlife and Wildlife Habitat

Anticipated interactions between project activities (as described in Section 5.4) and the VC leading to a potential effect (Section 19.1.3) are identified in Table 19.8 with a check mark (✓). These potential interactions are discussed in detail in Section 19.4, in the context of effects pathways, standard and project-specific mitigation/enhancement, and residual effects. Justification for no effect (indicated by a dash [–]) is provided following the table.

Project-related environmental effects can influence wildlife and wildlife habitat directly or indirectly and positively or negatively. A direct effect is characterized by an interaction that occurs and exhibits no intermediate steps (e.g., mortality resulting from vehicle collision), whereas an indirect effect is characterized by an interaction that occurs with intermediary steps (e.g., altered predator-prey dynamics following clearing; Hegmann et al., 1999). Most interactions will affect wildlife and wildlife habitat adversely, but in some cases the effects are positive for certain species or project activities (e.g., creation of edge habitat). Positive effects are described but not characterized further.

Table 19.8 Project Interactions with Wildlife and Wildlife Habitat

Physical Activities	Timing	Environmental Effects			
		Change in Habitat	Change in Movement	Change in Mortality Risk	Change in Wildlife Health
Construction Phase					
Mobilization of equipment, materials, and fuel, resupply, and demobilization	Summer and winter	✓	✓	✓	✓
Establishment and operation of camps	Year-round	✓	✓	✓	–
Site preparation of ROW and workspaces	Winter	✓	✓	✓	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	✓	✓	✓	✓
Material haul	Year-round	✓	✓	✓	✓
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓	✓	✓	✓
Culvert installations	Summer or winter	✓	✓	–	–
Road base placement, compaction, and surfacing	Summer	✓	✓	✓	✓
Water withdrawal to support construction activities	Year-round	–	–	–	–
Closure and reclamation of MVWR and temporary borrow sources quarries, camps, and workspaces	Summer	✓	✓	✓	–
Employment and contracted goods and services[1]	Year-round	–	–	–	–
Operations and Maintenance Phase					
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	✓	✓	✓	✓
Material haul and stockpiling	Summer	✓	✓	✓	✓
Operation of, and activities at, maintenance yards	Year-round	✓	✓	✓	✓
Water withdrawal for dust control	Summer	–	–	–	–
Employment and contracted goods and services[1]	Year-round	–	–	–	–
Presence and use of the highway	Year-round	✓	✓	✓	✓

Physical Activities	Timing	Environmental Effects			
		Change in Habitat	Change in Movement	Change in Mortality Risk	Change in Wildlife Health
Highway and access road maintenance including snow clearing, repair, grading, dust control	Year-round	✓	✓	✓	–
Vegetation control	Summer	✓	✓	✓	–
Bridge and culvert maintenance	As needed	✓	✓	✓	–

Notes:

✓ Potential interaction

– No interaction

[1] Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, "Employment and contracted goods and services" have been introduced as an additional component under each project phase.

Employment and contracted goods and services activities are not expected to result in a change in habitat, mortality risk, movement, or wildlife health for the lifetime of the Project, as there is no pathway for these activities to interact with wildlife and wildlife habitat.

During construction, establishment and operation of camps and closure and reclamation of MVWR and temporary borrow sources/quarries, camps, and workspaces activities are not anticipated to result in a change in wildlife health.

Water withdrawal for construction activities and dust control will only occur at authorized locations and is regulated to protect fish and fish habitat and will not result in a change in habitat, movement, mortality risk or wildlife health (i.e., changes to water levels will be protective of aquatic ecosystems, see Chapter 15 [water quantity]).

During operations and maintenance, water withdrawal for dust control activities is not anticipated to result in a change in wildlife habitat, movement, mortality risk or wildlife health as this will occur intermittently and will not disturb the connectivity of aquatic or terrestrial habitats. Operations and maintenance activities associated with snow removal, repairs, as well as bridge and culvert maintenance are not expected to interact with wildlife health. In addition, vegetation control is not expected to result in a change in wildlife health because the application of pesticides/herbicides is not proposed.

19.4 Assessment of Residual Effects on Wildlife and Wildlife Habitat

This section discusses the interaction pathways for the project activities identified in Table 19.8 (Section 19.3) that can affect habitat, movement, mortality risk, or wildlife health, including analytical assessment techniques, mitigation, and residual effects.

Based on project interactions with the environment identified in Table 19.8, the Project may affect wildlife and wildlife habitat. Potential effects, effect pathways, and mitigation measures that will reduce or eliminate the effects on wildlife and wildlife habitat are identified in Table 19.9. Residual effects and associated analytical assessment techniques are described.

Table 19.9 Potential Effects and Mitigation Measures for Wildlife and Wildlife Habitat

Effect Name	Effect Pathway	Mitigation Measures
Change in Habitat	Direct and/or indirect loss or alteration of wildlife habitat	The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent possible.
		Clearing will be limited to areas required for construction and safe operations.
		Project vehicles will be confined to existing roads and trails to avoid disturbing vegetated areas.
		Removal of vegetation will be limited to the width of the ROW and workspaces.
		Vegetation buffers will be used as visual barriers and to protect riparian vegetation, as appropriate.
		Organic material and topsoil will be set aside for use during reclamation, where possible.
		Erosion and sedimentation control measures will be implemented per the Erosion and Sedimentation Control Plan (ESCP) and will be in place prior to construction activities and before the spring melt/freshet. A draft ESCP is included in Volume 5.
		Beaver dam removal will be done in accordance with the code of practice: Beaver dam breaching and removal (DFO, 2022) and conditions of a GNWT General Wildlife Permit.
		Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns.
		Riparian vegetation will be maintained whenever possible.

Effect Name	Effect Pathway	Mitigation Measures
Change in Habitat (cont'd)		A WMMP will be developed and implemented. The WMMP will contain detailed monitoring and mitigation measures to be implemented for the duration of the construction and operations of the Project. A draft WMMP is included in Volume 5.
		Construction and quarry development activities will adhere to the applicable recommended setbacks and timing restrictions for wildlife outlined in the WMMP, where possible.
		Vegetation clearing will be completed outside the core maternity roosting period for bats of May 1 to August 31. If habitat tree removal or general tree clearing is required during the maternity roosting period, a qualified biologist will review the trees to make a determination on bat occupancy before removal.
		Wildlife monitors will assess for the presence of wildlife on or near the PDA during project activities.
		A pre-construction bear den survey will be completed to identify potential den sites if Project construction activities are planned to occur during the black bear or grizzly bear denning period (October 1 to May 30). If a bear den is confirmed to be active, a site-specific setback buffer will be applied to protect denning bears depending on project activity.
		Personnel will undergo a wildlife awareness program, which will include prevention measures for wildlife mortality (e.g., bear safety) and reporting procedures for wildlife-related incidents and protocols to follow when a nest, den, or wildlife species of management concern is observed. This includes completing wildlife sighting and wildlife incident report forms included in the WMMP.
		Closure and reclamation will promote re-establishment of vegetation.
		Site grading at closure will approximate pre-development conditions.
		Borrow source vegetated surface material, where present, will be replaced after development is completed.
		A dust control program using water will be implemented during construction and operations and maintenance.
		Vehicle speeds will be limited to 50 kilometres per hour (km/h) on unfinished project road surfaces.

Effect Name	Effect Pathway	Mitigation Measures
Change in Movement	Construction and operations and maintenance could result in alteration of wildlife movement patterns or movement corridors	Vegetation buffers will be used as visual barriers and to protect riparian vegetation, as appropriate.
		A buffer strip of undisturbed vegetation of at least 30 m wide will be maintained between the highway ROW and other new areas to be cleared.
		Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns.
		A project-specific ESCP will be developed and implemented
		The height of snowbanks will be limited to the extent possible and to a height of less than 1 m.
		Quarry operations will be located a minimum of 100 m from the ordinary high-water mark of any waterbody.
		Blasting activities will be limited to daytime hours, to the extent practical.
		Vehicles and equipment will be equipped with manufacturer-recommended noise muffling equipment.
		Construction and quarry development activities will adhere to the applicable recommended setbacks and timing restrictions for wildlife outlined in the WMMP, where possible.
		Wildlife monitors will assess for the presence of wildlife on or near the PDA during project activities, in accordance with the WMMP.
		Personnel will undergo a wildlife awareness program, which will include prevention measure for wildlife mortality (e.g., bear safety) and reporting procedures for wildlife-related incidents and protocols to follow when a nest, den, or wildlife species of management concern is observed. This includes completing wildlife sighting and wildlife incident report forms included in the WMMP.
		Closure and reclamation will promote re-establishment of vegetation.
		Site grading at closure will approximate pre-development conditions.
		Borrow source vegetated surface material, where present, will be replaced after development is completed.

Effect Name	Effect Pathway	Mitigation Measures
Change in Mortality Risk	Direct and/or indirect increase in mortality risk or number of wildlife fatalities	Vegetation clearing will be completed outside the core maternity roosting period for bats of May 1 to August 31. If habitat tree removal or general tree clearing is required during the maternity roosting period, a qualified biologist will review the trees to make a determination on bat occupancy before removal.
		Wildlife monitors will assess for the presence of wildlife on or near the PDA during project activities, in accordance with the WMMP.
		A pre-construction bear den survey will be completed to identify potential den sites if Project construction activities are planned to occur during the black bear or grizzly bear denning period (October 1 to May 30). If a bear den is confirmed to be active, a site-specific setback buffer will be applied to protect denning bears depending on Project activity.
		A pre-construction beaver dam and lodge survey will be conducted, as per the WMMP, to identify those potentially to be impacted by construction. Beaver dam removal will be done in accordance with the code of practice: Beaver dam breaching and removal (DFO, 2022) and conditions of a GNWT General Wildlife Permit.
		Personnel will undergo a wildlife awareness program, which will include prevention measure for wildlife mortality (e.g., bear safety) and reporting procedures for wildlife-related incidents and protocols to follow when a nest, den, or wildlife species of management concern is observed. This includes completing wildlife sighting and wildlife incident report forms included in the WMMP.
		An electric fence will be set up around temporary camps if deemed necessary to deter wildlife.
		Personnel will not feed or harass wildlife while working on the Project.
		Project personnel will be prohibited from hunting and fishing while housed in work camps for the Project.
		Construction and quarry development activities will be limited during sensitive periods for wildlife in accordance with the WMMP.
		Food and other wildlife attractants will be stored in bear-proof containers.
		Crews will be trained on wildlife awareness.
		Food waste will be stored and disposed of in a manner to avoid attracting wildlife.

Effect Name	Effect Pathway	Mitigation Measures
Change in Mortality Risk (cont'd)		Equipment, wastes and contaminated soils will be removed once construction is completed.
		The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent practical.
		Clearing will be limited to areas required for construction and safe operations.
		A buffer strip of undisturbed vegetation of at least 30 m wide will be maintained between the highway ROW and other new areas to be cleared.
		Vegetation buffers will be used as visual barriers and to protect riparian vegetation, as appropriate.
		Vehicle speeds will be limited to speed of 50 km/h on unfinished project road surfaces.
		Speed limits will be posted on the public highway
Change in Wildlife Health	Construction and operations and maintenance could expose wildlife to contaminants or other emissions that may affect the health and condition of wildlife	A Spill Contingency Plan (SCP) will be developed and implemented. The SCP will include procedures to prevent and respond to spills. A draft SCP is included in Volume 5.
		Areas and containers used to store project wastes will be constructed, operated, and maintained in a manner to prevent waste from discharging to the surrounding environment.
		Maintenance yards will have a liner or concrete installed under areas of vehicle storage and maintenance.
		Vehicles parked for more than 2 hours will use drip trays.
		A minimum of 10 centimetres (cm) of packed snow or ice will be used on winter access roads.
		Project vehicles will travel on designated winter roads or constructed embankment only.
		Clearing of new areas will be completed when the ground is frozen to limit disturbance to soils and permafrost
		Placement of embankment will occur primarily during winter (December 15 to April 1), during frozen conditions. If work is to be completed under non-frozen conditions, equipment will be equipped with mushroom shoes.
		Borrow source floors will be sloped to reduce ponding of water.
		Travel of vehicles will be confined to existing infrastructure roads and trails as much as possible to avoid disturbing vegetated areas.

Effect Name	Effect Pathway	Mitigation Measures
Change in Wildlife Health (cont'd)		A project-specific ESCP will be developed and implemented.
		Sediment and erosion control measures will be regularly inspected to confirm they are performing as intended.
		Ponded water will be directed away from watercourses.
		Only material with low acid rock drainage and metal leaching potential will be used for the Project.
		Rip rap will be free of silt and other debris.
		Sediment control measures will be in place prior to construction activities and before the spring melt/freshet.
		Riparian vegetation will be maintained whenever possible.
		Excavated material will be placed at least 30 m from a watercourse.
		Snow fill temporary crossings will be constructed of clean snow fill.
		Vegetation buffers will be used as visual barriers and to protect riparian vegetation, as appropriate.
		Machinery on-site will be in a clean condition and free of invasive species and noxious weeds.
		Washing, refueling, and servicing machinery and storage of fuel and other materials for machinery will be conducted a minimum of 100 m from the high-water mark and in a manner to prevent any deleterious substances from entering the water.
		Machinery will not be left in any waterbody.
		Quarry operations will be located a minimum of 100 m from the ordinary high-water mark of any waterbody.
		Blast rock will not enter a waterbody or watercourse.
		Material stockpiles will be kept a minimum of 30 m from a watercourse or waterbody with the appropriate erosion control mitigation in place to prevent sediment from entering a watercourse or waterbody.
		Equipment will be maintained in good working order.
		Blast mats will be used when blasting near receptors sensitive to noise.
		A dust control program using water will be implemented during construction and operations and maintenance.
		Vehicle speeds will be limited to 50 km/h on unfinished project road surfaces.

Effect Name	Effect Pathway	Mitigation Measures
Change in Wildlife Health (cont'd)		Incinerators will be operated in accordance with manufacturer's specifications and emissions will meet Canadian Council of Ministers of the Environment Canada Wide Standards for Dioxins & Furans and Mercury.
		Equipment, wastes, and contaminated soils will be removed once construction is completed.

19.4.1 Analytical Assessment Techniques

The general approach to assessing potential effects on wildlife and wildlife habitat follows the sequence and methods outlined in Chapter 4 – Assessment Methods. Analytical assessment techniques specific to each potential effect are described.

19.4.1.1 Change in Habitat

Change in habitat was assessed by comparing direct and indirect changes in habitat availability from baseline conditions to the residual condition in the LAA, including for key wildlife species (Table 19.2) and for each project phase (i.e., construction, operations and maintenance). The quantitative assessment using land cover types did not include wolverine because they use a broad range of habitat types to meet seasonal foraging and denning requirements (COSEWIC, 2014a). In addition, physical feature data (e.g., deadfall trees, landslide debris) to identify potential denning habitat at site-specific scales (COSWEIC, 2014a) was not possible using broad scale mapping. Similarly, a quantitative assessment using land cover data was not completed for invertebrates because they also use a broad range of habitat types to meet their habitat needs (i.e., a variety of plants are used to obtain nectar and pollen). Therefore, effects on these species are assessed qualitatively.

Direct change in habitat (e.g., vegetation clearing) was calculated as the loss of wildlife habitat that is no longer available to wildlife in the PDA; these effects do not extend into the LAA. In general, once vegetation clearing is completed during the construction component, most of the PDA will provide no suitable wildlife habitat, except for a few species that may take advantage of developed sites. Portions of the PDA will be reclaimed after construction, including 6 of 15 quarries/borrow sources. Land cover classes considered as habitat for each wildlife species or species group; see Table 19.2) are summarized in Table 19.10 and were established using relevant scientific literature, life history information, and professional judgment.

Indirect change in habitat (e.g., sensory disturbance) was assessed qualitatively as the area of reduced habitat effectiveness; these effects are confined to the LAA.

Land cover classes were quantified using Earth Observation of Sustainable Development of Forests Northwest Territories geospatial data (NRCan and GNWT, 2017). This dataset is part of the Multi-source Vegetation Inventory Project (NRCan, 2020) and uses an unsupervised classification and cluster analysis to classify land cover. The dataset includes cover type and density classes and

forest structure height and volume information based on Landsat imagery collected from 2007 to 2013. Mapping was done at a scale of 1:250,000 and was refined through field evaluation by the GNWT (NRCan and GNWT, 2017). Detailed land cover classification methods for this Project are in the Vegetation and Wetlands TDR (K'alo-Stantec, 2022; Appendix 18A).

Table 19.10 Land Cover Classes used to Quantify Habitat Availability for Wildlife

Land Cover Category	Land Cover Class[1]	Wildlife	Grizzly Bear[2]	Little Brown Myotis[3]
Upland	Broadleaf Dense	✓	✓	✓
	Broadleaf Open	✓	✓	✓
	Broadleaf Sparse	✓	✓	–
	Coniferous Dense	✓	✓	–
	Coniferous Open	✓	✓	–
	Coniferous Sparse	✓	✓	–
	Mixedwood Dense	✓	✓	✓
	Mixedwood Open	✓	✓	✓
	Mixedwood Sparse	✓	✓	–
	Shrub Low	✓	✓	–
	Shrub Tall	✓	✓	–
	Herbaceous	✓	✓	–
	Bryoids	✓	✓	–
	Rock/Rubble	✓	✓	–
	Exposed Land	✓	✓	–
Wetland	Wetland Herbaceous	✓	–	–
	Wetland Shrub	✓	–	–
	Wetland Treed	✓	–	–
Water		✓	–	–

Notes:

✓ Land cover class considered habitat for wildlife

– Land cover class not considered habitat for wildlife

1 From EOSD NWT (NRCan and GNWT, 2017; K'alo-Stantec, 2022 [Appendix 18A])

2 Denning habitat: upland land cover classes limited to those with steep slopes ≥ 10 degrees

3 Maternal roosting habitat: upland land cover classes limited to those unburned within the past 40 years or cliff areas (> 30 degrees)

19.4.1.2 Change in Movement, Mortality Risk, and Wildlife Health

Change in movement, mortality risk, and wildlife health were assessed qualitatively through evaluating the relative change in direct and indirect sources of movement (e.g., bisecting migratory corridors), mortality (e.g., vehicle collisions, human-wildlife conflict), and wildlife health (e.g., contamination) compared to the existing condition. The qualitative assessment included a combination of literature review and professional judgment to predict effects on wildlife and wildlife habitat.

19.4.1.3 Assumptions and the Conservative Approach

A conservative approach is used to address uncertainty in the environmental effects assessment, which increases confidence in the final determination of significance. The assessment used a habitat-based approach, which focuses on identifying the quantity and composition of land cover types (i.e., habitats) affected by the Project relative to the availability of those habitats in the LAA and RAA. This approach is considered conservative as it assumes that wildlife species are present if the habitat is available, which is not always the case (e.g., some animals may not be present in a habitat recently affected by fire until the habitat returns to its pre-fire state following the vegetation successional process that require several years). Land cover classes that represent disturbed lands (i.e., exposed land) (47.8% [1,104.91 ha] of the PDA) are also included in the quantification of direct habitat loss, despite providing limited value for most wildlife species. The PDA is conservatively assumed to be lost to wildlife but there are portions that will be reclaimed, and some species will use disturbed sites. The prediction confidence of the assessment for wildlife and wildlife habitat (Section 19.7) incorporates these assumptions.

19.4.2 Change in Habitat

19.4.2.1 Effects Pathways

19.4.2.1.1 Construction

During construction, removal of upland and wetland vegetation has potential to result in direct loss or alteration of habitat within the PDA. The Project also has potential to result in indirect loss or alteration of habitat adjacent to the PDA through emissions and waste management activities (i.e., sensory disturbance and dust deposition) and through the edge effects and fragmentation created by vegetation clearing (from the construction activities in the PDA). Project-related sensory disturbance (i.e., noise and light) from most construction activities (e.g., heavy equipment operation, infrastructure construction, increased traffic volumes) can disturb wildlife and change the use of habitat around the site or road (e.g., habitat avoidance, fine-scale changes in individuals' movement and associated energetic costs).

Vegetation clearing can also result in an indirect alteration of habitats adjacent to the PDA by creating an unnatural transition (i.e., edge effects) between the PDA and adjacent habitat. Edge effects can include changes in microclimate (e.g., Murcia, 1995) and vegetation structure (e.g., Harper et al., 2005), which can result in changes in the wildlife community in those habitats. Dust deposition associated with project construction can affect vegetation composition adjacent to the PDA (e.g., Gill and Lantz, 2014), which may alter habitat use by wildlife. Indirect loss or alteration of habitat creates an area adjacent to the PDA that exhibits some degree of reduced ecological effectiveness, compared to the existing condition; this typically varies by effect pathway and wildlife species.

19.4.2.1.2 Operations and Maintenance

Operations and maintenance of the Project is not anticipated to result in the direct loss or alteration of habitat for wildlife and some disturbed habitats may become habitat for wildlife following reclamation and natural succession. Beaver dam removal may be required during bridge and culvert maintenance activities. An indirect loss or alteration of habitat is likely to occur adjacent to the PDA due to emissions (i.e., sensory distance and dust deposition) and presence of the highway (i.e., continuation of edge effects) (Table 19.8).

Sensory disturbance and dust deposition associated with activities during the operations and maintenance phase of the Project (i.e., borrow source and quarry operations, including blasting, crushing, sorting and stockpiling; material haul and stockpiling; operation of, and activities at, maintenance camps; presence of the highway) can result in reduced ecological effectiveness (i.e., indirect habitat loss) of habitats adjacent to the PDA, as described for the construction phase.

In addition, the presence and use of the highway will lead to increased traffic, which might also result in, sensory disturbance and dust deposition. These indirect effects can result in a change in habitat and have been shown to result in fine-scale changes in wildlife movements near roads (e.g., wolverine [Scrafford et al., 2018]). Presence of the highway will maintain fragmentation and edge effects over the long term that were established during the construction phase.

19.4.2.2 Mitigation

As discussed in Chapter 5, project routing and design have integrated the existing MVWR ROW, to the extent possible, which will reduce change in habitat. In addition to a project-specific WMMP that will be implemented during the construction and operations and maintenance phases, standard industry practices and mitigation measures will also be implemented and are presented in Table 19.9. Key mitigation measures to avoid or reduce change in habitat include:

- The Project will use previously disturbed areas for project activities and infrastructure and workspaces, to the extent possible.

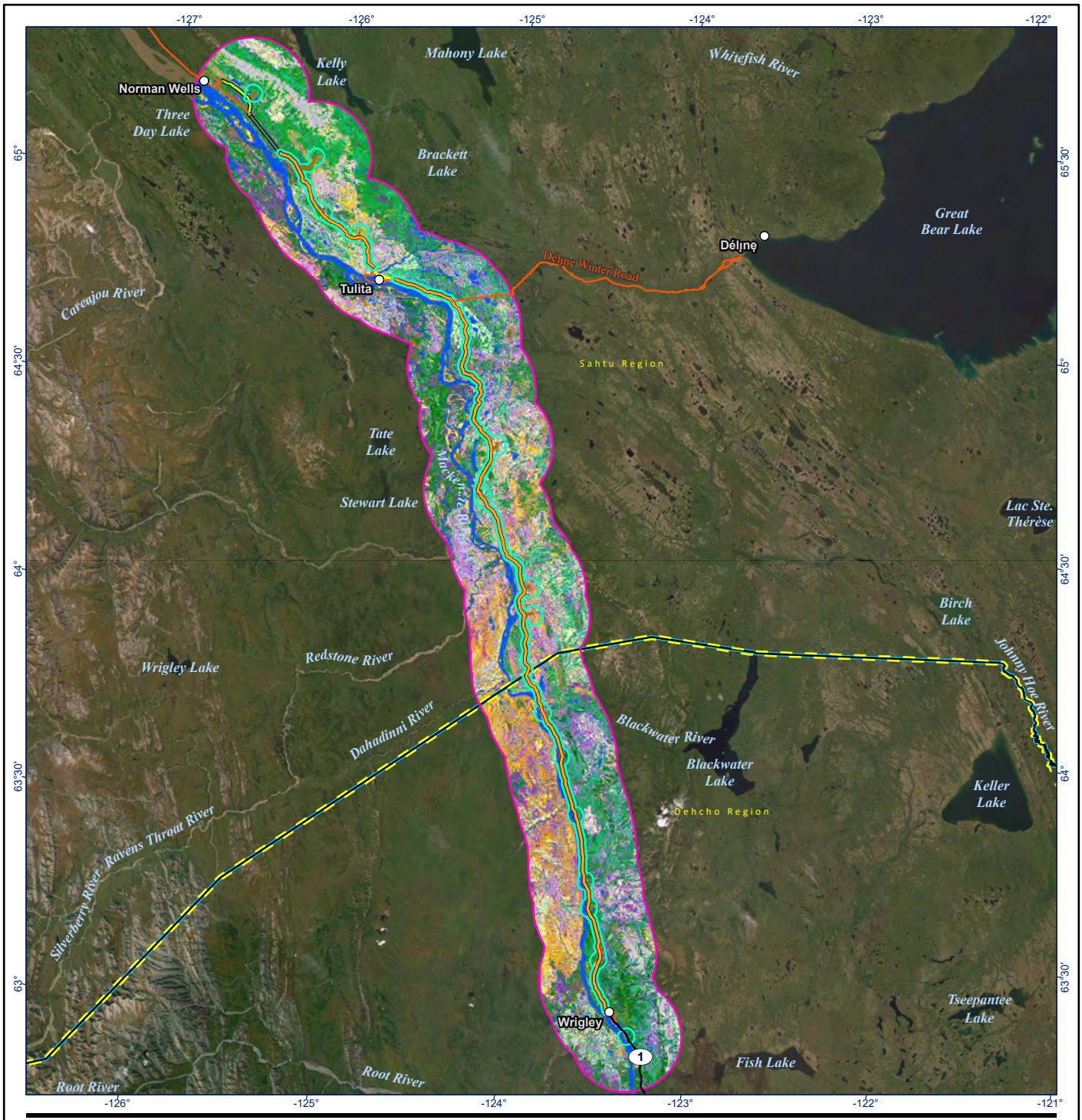
- Vegetation clearing will be completed outside the core maternity roosting period for bats of May 1 to August 31. If habitat tree removal or general tree clearing is required during the maternity roosting period, a qualified biologist will review the trees to make a determination on bat occupancy before removal. Although new bridges are not part of the Project, if bat roosts are encountered during bridge maintenance activities, site-specific mitigation will be developed in accordance with the WMMP.
- Wildlife monitors will assess for the presence of wildlife on or near the PDA during project activities.
- Personnel will undergo a wildlife awareness program, which will include prevention measures for wildlife mortality (e.g., bear safety) and reporting procedures for wildlife-related incidents and protocols to follow when a nest, den, or wildlife species of management concern is observed. This includes completing wildlife sighting and wildlife incident report forms included in the WMMP.
- Closure and reclamation will promote re-establishment of vegetation.
- Borrow source vegetated surface material, where present, will be replaced after development is completed.

19.4.2.3 Residual Effects

19.4.2.3.1 Construction

The project highway alignment routing has reduced the amount of new ROW required by primarily widening of the existing MVWR ROW (from 30 m to 60 m), where feasible. Where needed, new ROW has been designed to avoid sensitive areas and wetlands, reduce slopes and/or sharp curves to accommodate higher traffic speeds, and increase transportation safety. Construction of the Project will result in the direct loss of 2,315.2 ha of wildlife habitat within the LAA (Table 19.11), a 3.1% decrease from existing conditions. However, 47.8% (1,104.91 ha) of this direct loss is exposed land that is subject to existing anthropogenic disturbances (i.e., existing MVWR and quarries), which provide limited suitability for most wildlife species (Figure 19.2). Therefore, construction of the Project will result in the direct loss of 1,210.3 ha of natural land cover within the LAA, a 2.1% decrease from existing conditions.

Development of the PDA, including vegetation clearing, will result in a direct loss or alteration of 1,989.2 ha of upland terrestrial habitats (including 1,104.9 ha of exposed land) and 300.0 ha of wetland habitats (a change of 1.7%) within the LAA (Table 19.7). The Project will remove terrestrial habitat and, to a lesser extent, wetland habitat for wildlife. However, widening the existing MVWR for most of the Project's length will limit direct habitat loss, most of which is already subject to indirect habitat alteration due to the MVWR.



Land Cover
- Water
- Rock/Rubble
- Exposed Land
- Bryoids
- Shrub - Tall
- Shrub - Low
- Wetland - Treed
- Wetland - Shrub
- Wetland - Herb
- Herb
- Coniferous - Dense
- Coniferous - Open
- Coniferous - Sparse
- Broadleaf - Dense
- Broadleaf - Open
- Mixedwood - Dense
- Mixedwood - Open
- Mixedwood - Sparse
- Proposed Mackenzie Valley Highway Project Route
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Proposed Borrow / Rock Quarry Site and Access
- Local Assessment Area
- Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 8/3/2023
TR by SM on 8/3/2023

Client/Project
144903025-0112 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
19.2

Title
Land Cover Classes in the RAA

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer. GNWT, Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS. Imagery date: 2021

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Table 19.11 Residual Change in Habitat within the LAA

Land Cover Category	Land Cover Class[1]	Existing Condition in LAA (ha)			Residual Condition in LAA (ha/% change)		
		Dehcho Region	Sahtu Region	Total	Dehcho Region	Sahtu Region	Total
Upland	Broadleaf Dense	1,037.4	2,523.1	3,560.6	1,025.8 (-1.1%)	2,448.0 (-3.0%)	3,473.9 (-2.4%)
	Broadleaf Open	114.8	1,103.9	1,218.7	112.7 (-1.8%)	1,076.9 (-2.4%)	1,189.6 (-2.4%)
	Coniferous Dense	3,374.9	917.8	4,292.6	3,335.7 (-1.2%)	899.7 (-2.0%)	4,235.3 (-1.3%)
	Coniferous Open	4,600.6	6,678.1	11,278.6	4,501.7 (-2.1%)	6,531 (-2.2%)	11,032.6 (-2.2%)
	Coniferous Sparse	3,725.0	6,332.6	10,057.7	3,682.4 (-1.1%)	6,216.4 (-1.8%)	9,898.9 (-1.6%)
	Mixedwood Dense	1,035.1	387.3	1,422.4	1,018.5 (-1.6%)	376.2 (-2.9%)	1,394.6 (-2.0%)
	Mixedwood Open	117.1	2,514	2,631.1	115.3 (-1.6%)	2,466.9 (-1.9%)	2,582.2 (-1.9%)
	Mixedwood Sparse	0.0	6.3	6.3	0.0 (0.0%)	5.8 (-8.2%)	5.8 (-8.2%)
	Shrub Low	567.4	7,903.4	8,470.9	562.5 (-0.9%)	7,757.2 (-1.8%)	8,319.9 (-1.8%)
	Shrub Tall	320.6	2,091.3	2,411.9	317.4 (-1.0%)	2,041.4 (-2.4%)	2,358.8 (-2.2%)
	Herbaceous	50.6	210.9	261.5	44.0 (-13.1%)	198.8 (-5.7%)	242.8 (-7.2%)
	Bryoids	7.0	6.2	13.2	7.0 (<0.1%)	5.8 (-6.3%)	12.8 (-3%)
	Rock/Rubble	45.1	107.3	152.4	43 (-4.6%)	103.5 (-3.6%)	146.5 (-3.9%)
	Exposed Land[3]	1,338.0	1,713.2	3,051.2	859.4 (-35.8%)	1,086.9 (-36.6%)	1,946.3 (-36.2%)
	Total	*16,333.6*	*32,495.4*	*48,829.1*	*15,625.3 (-4.3%)*	*31,241.5 (-3.9%)*	46,839.9 (-4.1%)

Land Cover Category	Land Cover Class[1]	Existing Condition in LAA (ha)			Residual Condition in LAA (ha/% change)		
		Dehcho Region	Sahtu Region	Total	Dehcho Region	Sahtu Region	Total
Wetland	Wetland Herbaceous	856.8	2,976.9	3,833.6	844.7 (-1.4%)	2,924.4 (-1.8%)	3,769.0 (-1.7%)
	Wetland Shrub	2,222.9	4,503.7	6,726.6	2,175.8 (-2.1%)	4,425.4 (-1.7%)	6,601.2 (-1.9%)
	Wetland Treed	2,218.9	4,771.6	6,990.4	2,184.4 (-1.6%)	4,696.1 (-1.6%)	6,880.5 (-1.6%)
	Total	*5,298.6*	*12,252.2*	*17,550.6*	*5,205.0 (-1.8%)*	*12,045.9 (-1.7%)*	17,250.6 (-1.7%)
Water[2]		5,187.5	3,792.3	8,979.8	5,181.5 (-0.1%)	3,772.2 (-0.5%)	8,953.7 (-0.3%)
PDA		807.9	1,507.3	2,315.2	807.9 (100%)	1,507.3 (100%)	2,315.2 (100%)

Notes:

1 From EOSD NWT (NRCan and GNWT, 2017; K'alo-Stantec, 2022 [Appendix 18A])

2 Development of the PDA is not anticipated to result in the direct loss of open water habitats and the residual condition is an artifact of the resolution of the land cover classification.

3 Exposed land includes areas which naturally have less than 5% vegetative cover, such as shorelines of rivers and lakes, exposed rock, recently burned areas, and moraines, and includes cleared areas such as the existing MVWR, Norman Wells Pipeline, and other areas of infrastructure development

Species most likely to be affected by a direct loss of habitat are those that inhabit forested and shrub habitats, such as furbearers (e.g., American marten [*Martes americana*]) and black bear (*Ursus americanus*), which are also important to current land and resource users for traditional purposes (Auld and Kershaw, 2005; DLUPC, 2006; SLUPB, 2023; SRRB, 2021). Aquatic and semi-aquatic species, such as beaver, may be displaced to other areas of suitable habitat or existing alternate lodges (Labrecque-Foy et al., 2020) if existing beaver dam or lodge removal is required, however it is anticipated that wetland habitat connectivity will remain during construction. A pre-construction beaver dam and lodge survey will be completed to determine site-specific mitigation.

Closure and reclamation of the MVWR and temporary borrow sources/quarries, camps, and workspaces are expected to recover over time due to natural revegetation or reclamation activities designed to promote vegetation communities (see Chapter 18 Vegetation and Wetlands). The recovery of vegetation communities will provide potential habitat for a variety wildlife species depending on site conditions, successional stage and species-specific habitat associations (van Rensen et al., 2015, Wilson and Bayne, 2019).

There is no formally defined SAR critical habitat that will be directly or indirectly affected by construction of the Project. There are no formally defined SAR residences that will be directly or indirectly affected by construction of the Project.

Construction of the Project will result in the direct loss of wildlife habitat within four IWAs, ranging from a decrease of 3.0% to 3.7 % (Table 19.12; Appendix 19A, Figure 3.6 [K'alo-Stantec, 2023]). Mineral lick IWAs and the Willow Lakes IWA are outside the LAA and are not anticipated to interact with the Project. Mineral licks have been reported near Bear Rock (Petınıʔah) (K'alo-Stantec, 2023; TRRC, 2022) and may interact with the Project depending on proximity to the Project .

Table 19.12 Residual Change in Important Wildlife Areas within the LAA

Important Wildlife Area	Existing Condition (ha)	Residual Condition (ha / % change)
Dehcho beaver concentration areas	27,504.5	26,662.3 (-3.1%)
Dehcho lynx concentration areas	21,355.2	20,555.8 (-3.7%)
Sahtu muskox areas	2,435.6	2,360.1 (-3.1%)
Sahtu rivers	1,999.4	1,939.4 (-3.0%)

An indirect loss or alteration of wildlife habitat is expected through sensory disturbance (i.e., noise and artificial light), dust deposition, edge effects, and fragmentation that can result in habitat avoidance and reduced habitat effectiveness for wildlife, including SAR, in areas adjacent to the PDA.

Sensory disturbance from noise and light during construction will not occur along the entire length of the Project, and instead will occur in smaller segments staggered over a period of several years. The conceptual schedule (see Sections 19.1.4.2 and 5.4.1) assumes the alignment will be constructed in three segments: Wrigley north to the Dehcho/Sahtu border (102 km); Tulita south to the Dehcho/Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (45 km). Noise-related effects on wildlife have been reported to occur when noise levels exceed 40 dBA, resulting in avoidance by some bird species (e.g., red-eyed vireo) and amphibians (Shannon et al., 2016). However, physiological consequences (e.g., stress) to terrestrial mammals has not been identified below 52 dBA. Foraging efficiency of bats has not been adversely affected below 80 dBA (Shannon et al., 2016). Baseline noise in the region without any development or winter traffic has been estimated at 35 and 32 dBA during the day and night, respectively (IOL, 2004; see Section 13.2.2). The distance at which the noise associated with construction activities is expected to attenuate to 40 dBA is 2.0 km for road construction activities and 2.5 km for quarry and borrow source activities (see Section 13.4.2). However, measurable effects on wildlife outside of the LAA resulting from sensory disturbance are unlikely and the LAA will continue to support wildlife. Sensory disturbances associated with construction will also cease following the conclusion of construction activities in a particular segment.

Dust deposition resulting from construction of the Project can alter wildlife habitat adjacent to the PDA. Effects of dust deposition on vegetation are likely to be limited to within 40 m of the PDA (see Section 18.4; Meininger and Spatt, 1988; Gleason et al., 2007).

Edge effects and fragmentation will result from vegetation clearing activities, particularly where the PDA intersects forested habitats of the LAA. However, the existing MWVR and other exposed lands (e.g., quarries) have already created edge effects and the Project will contribute a minor additive increase because a large proportion of the preliminary alignment routing overlaps these previously disturbed lands. Project routing that predominantly follows the MVWR has also reduced the potential for adverse effects on wildlife and wildlife habitat resulting from habitat fragmentation, and core areas of large habitat patches will continue to be available in the LAA.

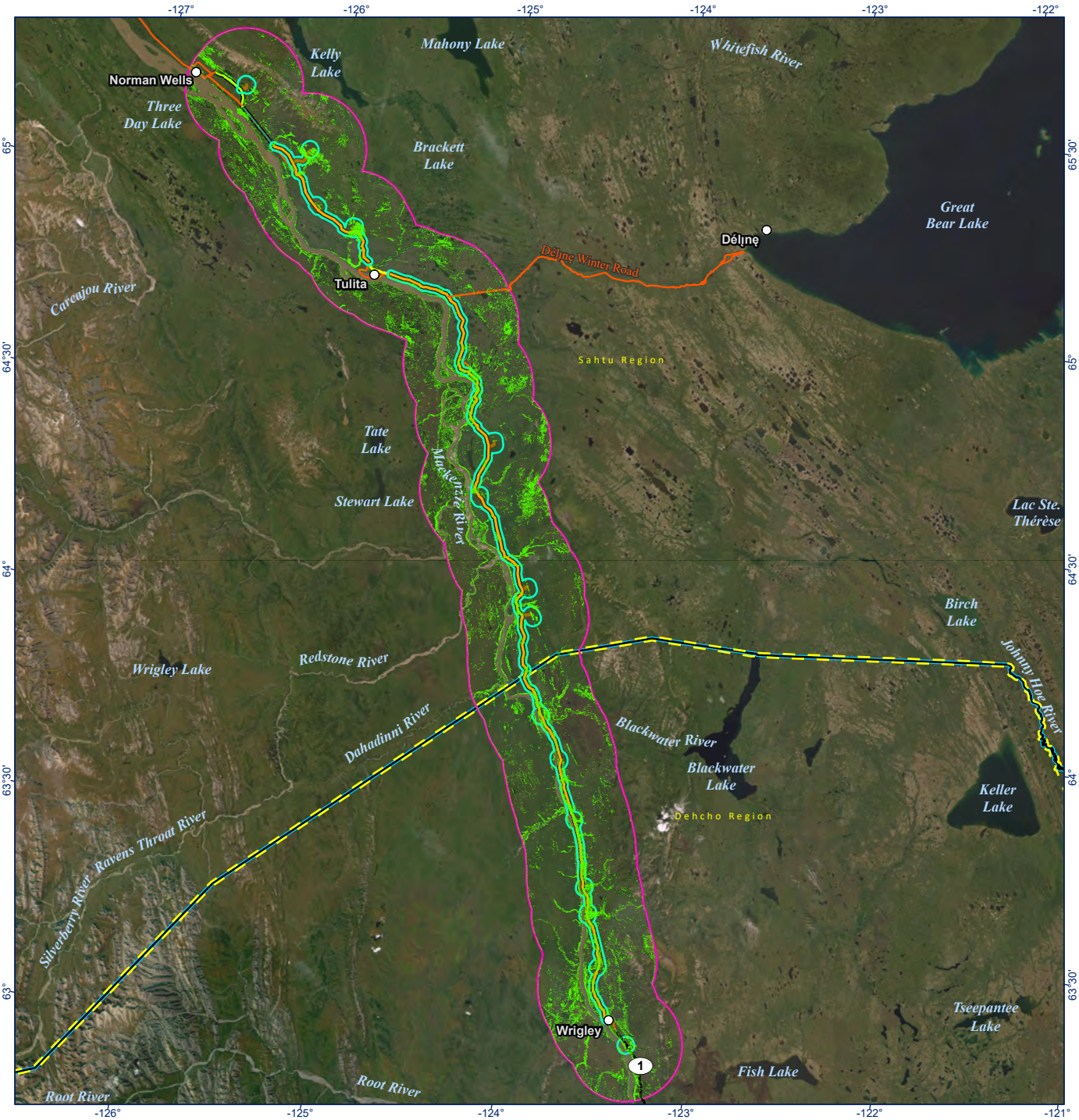
Indirect effects associated with sensory disturbance, dust deposition, edge effects, and fragmentation will be partially mitigated through routing that largely follows the existing MVWR already subject to these disturbances, resulting in reduced ecological effectiveness and avoidance by wildlife. Construction of the Project is anticipated to exacerbate habitat alteration within the LAA, however, by increasing the amount and duration (i.e., year-round at times) of these indirect effects. Species most likely to be affected are those that are sensitive to linear developments and/or anthropogenic disturbances, such as grizzly bear and wolverine.

An assessment of project effects relating to change in habitat on wildlife SAR (Table 19.2) is presented in the following subsections.

19.4.2.3.1.1 Little Brown Myotis

Little brown myotis forage over a wide variety of upland and wetland habitats but require different specialized habitats for maternal roosting sites and overwintering hibernacula (COSEWIC, 2013, Wilson et al., 2014). Although there are no overwintering hibernacula identified as critical habitat in the RAA (ECCC, 2018), karst topography containing caves (i.e., typical features used as overwintering hibernacula) exists within the LAA at the Bear Rock (Petınıʔah) formation north of Tulita (Appendix 19A, Section 3.2.2.5; K'alo-Stantec, 2023). Maternal roosting sites include natural features, such as tree cavities that are generally readily available, in the environment and individuals may travel hundreds of kilometres from overwintering hibernacula to maternal roosting sites for the breeding season (COSEWIC, 2013).

Construction of the Project will result in the direct loss or alteration of 102.8 ha of maternal roosting habitat (i.e., upland land cover classes unburned within the past 40 years or cliff areas > 30 degrees) within the LAA for little brown myotis, a decrease of 2.0% from baseline conditions within the LAA (i.e., 5,176.0 ha; Figure 19.3). Vegetation clearing may also result in indirect habitat loss or alteration by increasing fragmentation and creating edge effects in forest habitats adjacent to the PDA that may support breeding bats (i.e., by altering microclimate).



- Roosting Habitat
- Proposed Mackenzie Valley Highway Project Route
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Proposed Borrow / Rock Quarry Site and Access
- Local Assessment Area
- Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 8/3/2023
TR by SM on 8/3/2023

Client/Project
144903025-0116 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
19.3

Little Brown Myotis Roosting Habitat in the RAA

Notes
1. Coordinate System: NAD 1983 Northwest Territorries Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS. Imagery date: 2021

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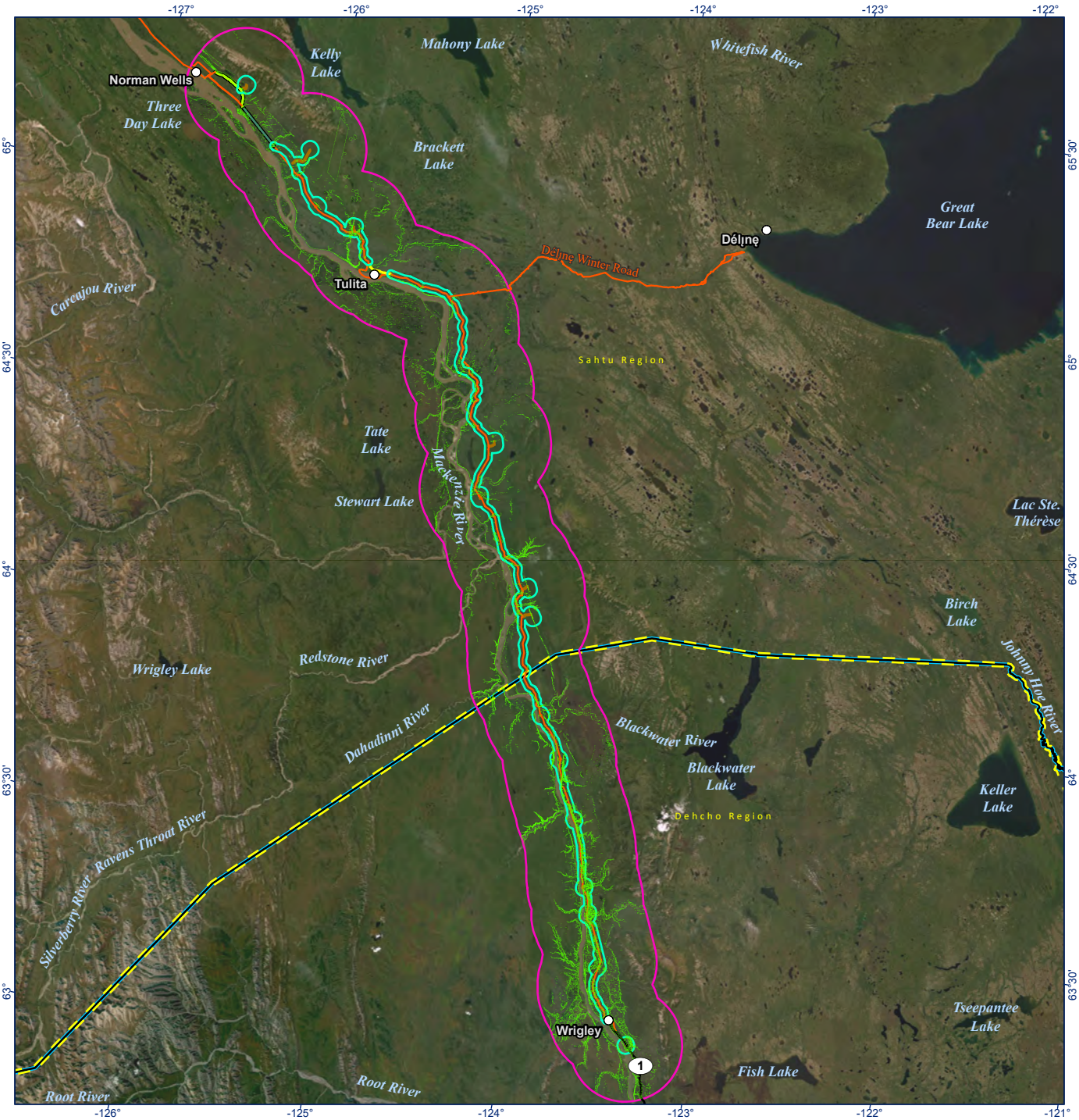
Little brown myotis are relatively tolerant of anthropogenic disturbance and have been shown to use anthropogenic structures for both maternal roosting sites and overwintering hibernacula (COSEWIC, 2013). Currently, little brown myotis breeding within the LAA are subject to limited amounts of anthropogenic disturbance during the breeding season when the MVWR is not in operation. Sensory disturbance associated with construction activities can alter bat activity adjacent to chronic industrial noise (Bunkley et al., 2015) and highway construction (The California Department of Transportation, 2016). However, bats use natural and anthropogenic linear features for commuting and foraging and have been shown to tolerate noise roadways (Abbott et al., 2012); yet in some cases bats have been shown to avoid foraging near busy roadways (Finch et al., 2020).

19.4.2.3.1.2 Grizzly Bear

Grizzly bears are habitat generalists, using a wide variety of tundra, alpine, subalpine, and semi-forested boreal habitats. Denning site and food availability are key habitat requirements (COSEWIC, 2012; SARC, 2017). Denning sites are sensitive to disturbance and are generally found on well-drained, steep slopes where bears may remain in hibernation for over six months (McLoughlin et al., 2002, COSEWIC, 2012; SARC, 2017). Although grizzly bear den sites are frequently found on south facing slopes (McLoughlin et al., 2002, SARC, 2017), grizzly bears also select den sites with cooler aspects (e.g., east, north) (McLoughlin et al., 2002, Smereka et al., 2017). Construction of the Project will result in the direct loss or alteration of 140.9 ha of denning habitat (i.e., upland land cover classes with slopes ≥ 10 degrees) within the LAA for grizzly bear, a decrease of 2.9% from baseline conditions within the LAA (i.e., 4,794.9 ha; Figure 19.4). A direct loss of 2.9% of habitat in the LAA is considered a low magnitude residual effect (i.e., less than 5% change; see Table 19.3).

Grizzly bear may be attracted to cleared sites where there is increased forage availability (which may have survival consequences); but in general, the species is sensitive to, and is likely to avoid, anthropogenic disturbance (COSEWIC, 2012; SARC, 2017). Direct habitat loss will result in a relatively small amount of habitat loss for grizzly bear; most affected habitats are previously disturbed due to the MVWR and existing quarries. Indirect habitat loss due to sensory disturbance during construction can also affect grizzly bear, particularly denning females (SARC 2017). Overall, indirect habitat loss due to sensory disturbance is not expected to result in a measurable change in the abundance of grizzly bear in the LAA; however, temporary local shifts in distributions in the LAA might occur (see Table 19.3).

Sensory disturbance is expected to decrease in the LAA when the noise levels and human activity associated with construction activities are completed within each segment of the PDA. In the NWT, effects of habitat fragmentation on grizzly bear are expected to be low (SARC, 2017) and there is a low density of linear features within the LAA to promote fragmentation.



- Denning Habitat
- Proposed Mackenzie Valley Highway Project Route
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
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- Local Assessment Area
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0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 8/3/2023
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Client/Project
144903025-0115 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
19.4

Title
Grizzly Bear Denning Habitat in the RAA

Notes
1. Coordinate System: NAD 1983 Northwest Territorries Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
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19.4.2.3.1.3 Wolverine

Wolverines are habitat generalists that use a wide variety of boreal and tundra habitats and are typically distributed relative to the availability of a diverse prey base, which includes small mammals and large ungulates (e.g., caribou), rather than specific habitat types (COSEWIC, 2014a; SARC, 2014). Wolverines tend to avoid anthropogenic disturbance (COSEWIC, 2014a), particularly high densities of linear features (e.g., Krebs et al., 2007; Bowman et al., 2010) or those that result in increased recreational activity and human presence; however, they have also been shown to be tolerant of some human activity disturbance when a concentrated food source is available (e.g., Heinemeyer et al., 2017). The winter denning period (February-March) is a critical period for wolverine, and they are particularly sensitive to disturbance during this time (SARC, 2014).

Direct habitat loss will result in a relatively small amount of habitat loss for wolverine; most affected habitats are already subject to disturbance from the MVWR and existing quarries (although dens would be occupied prior to the seasonal opening of the MVWR). Sensory disturbance associated with construction activity also can affect wolverine, particularly denning females, which are known to abandon dens if human activity is nearby (Pulliainen, 1968). However, a measurable change in the abundance of wolverine in the LAA is not anticipated, although temporary local shifts in distributions in the LAA might occur.

Sensory disturbance will cease following the conclusion of construction activities in a particular portion of the LAA (i.e., up to five years). In the NWT, effects of habitat fragmentation on wolverine are expected to be low (SARC, 2014) and there is a low density of linear features within the LAA promoting fragmentation. Wolverine has been assessed as not at risk in the NWT and the species' population has been stable-to-increasing, with reported northward range expansion (SARC, 2014).

19.4.2.3.1.4 Invertebrates

Invertebrate SAR/SOCC (Table 19.4) have broad distributions in Canada and in western NWT and are habitat generalists, occupying a variety of habitats such as meadows, riparian areas, and coniferous forests (COSEWIC, 2014b, 2015, 2016, 2020). Open habitats along the edges of the MVWR ROW (i.e., ditches) that support preferred vegetation communities and flowering plants are likely to provide habitat for invertebrates. Construction of the Project is expected to temporarily remove much of the existing habitat along the MVWR (i.e., through widening of the MVWR). But once construction has been completed, habitat for invertebrates is expected to return to its existing condition following a period of regrowth.

19.4.2.3.1.5 Characterization of Residual Effects for Change in Habitat During Construction

Following the implementation of mitigation measures, residual effects for general wildlife habitat, little brown myotis, grizzly bear, and invertebrate SAR/SOCC are summarized in Table 19.13. The overall residual effects for change in habitat during construction are characterized by the following:

- **Direction is adverse:** There will be a direct and indirect loss or alteration of wildlife habitat
- **Likelihood is certain**: The residual effect will certainly occur
- **Magnitude is low**: Direct loss will result in a < 10% change in wildlife habitat and a < 5% change SAR and SOCC habitat; indirect loss or alteration is not anticipated to result in a measurable change in the abundance of any wildlife species in the LAA, although temporary local shifts in distributions in the LAA might occur
- **Geographic extent is the LAA:** Direct and indirect loss or alteration of habitat associated with sensory disturbance is unlikely to exceed the LAA
- **Timing is high sensitivity:** Although vegetation clearing will occur in the winter, construction will likely occur through the year, including during sensitive periods for wildlife
- **Duration is medium- to long-term:** Sensory disturbance will cease following the construction phase (i.e., up to 20 years) but edge effects and fragmentation will persist into the operations and maintenance phase (i.e., > 20 years)
- **Frequency is continuous:** Effects will occur throughout the construction phase
- **Change is irreversible:** Sensory disturbance will cease following the construction phase, but most effects associated with direct and indirect habitat loss or alteration will persist throughout the life of the Project

19.4.2.3.2 Operations and Maintenance

A direct loss of wildlife habitat is not expected to occur during the operations and maintenance phase of the Project, but beaver dam removal may occasionally be required to maintain proper bridge and culvert operations and avoid flooding. Presence of the highway will maintain fragmentation and edge effects over the long term that were established during the construction phase. Vegetation control within the ROW will occur approximately every three years and will involve mowing dense shrub growth, which could remove habitat for some wildlife species, but the conservative approach taken in this assessment assumes the ROW provides no habitat for wildlife.

Sensory disturbances associated with the presence of the highway, highway and access road maintenance, vegetation control, and bridge and culvert maintenance may also occur. Noise-related effects on wildlife have been reported to occur when noise levels exceed 40 dBA, resulting in avoidance by some bird species (e.g., red-eyed vireo) and amphibians (Shannon et al., 2016). However, physiological consequences (e.g., stress) to terrestrial mammals has not been identified

below 52 dBA, and foraging efficiency of bats has not been adversely affected below 80 dBA (Shannon et al., 2016). The distribution of wildlife relative to linear disturbances can also vary over time and space. For example, while American marten have been shown to avoid open areas (Hargis et al., 1999; Slough, 1988; Lofroth and Steventon, 1990) and roads (Robitaille and Robitaille, 2000), they have also been shown to disperse across expanses of open habitat (Buskirk, 2002) and use linear features as travel corridors (Tigner et al., 2015).

Baseline noise in the region that was assessed in remote areas without any development or winter traffic has been estimated at 35 and 32 dBA during the day and night, respectively (IOL, 2004; see Section 13.2.2). Expected traffic volume is 50 vehicles per day for an indeterminate time, whereas the MVWR experiences the same daily volume but only for the winter. The distance at which noise associated with operations and maintenance activities are expected to attenuate to 40 dBA is 100 m for highway traffic and 2.5 km for quarry and borrow source activities (see Section 13.4.2), which are only expected to occur irregularly. Also, it is anticipated that quarries and borrow sources will not be operated at night; in general, noise emissions at night during the operations and maintenance phase are expected to be minor. Overall, most studies show the effects of roads on mammals to not extend beyond 500 m (Benitez-Lopez et al., 2010).

Highway and access road maintenance, vegetation control, and bridge and culvert maintenance are anticipated to occur infrequently and will contribute a negligible incremental increase in sensory disturbance.

Dust deposition during the operations and maintenance phase will continue to affect vegetation adjacent to the PDA, as described during the construction phase (i.e., within approximately 40 m of the PDA), which includes the potential for altering vegetations communities over time (e.g., increased herbaceous and deciduous tree and shrub habitats, reduction in mosses and lichens; see Section 18.4.2.1).

Presence of the highway during the operations and maintenance phase of the Project, including sensory disturbance, dust deposition, fragmentation, and edge effects, can collectively reduce the ecological effectiveness of wildlife habitat adjacent to the PDA. However, this is expected to be a relatively small incremental increase compared to the existing conditions. While some species may avoid the LAA, particularly habitats close to the PDA, the LAA will continue to support wildlife without disrupting natural population cycles. Edge habitats are likely to provide increased forage opportunities for some wildlife species (e.g., black bear, muskox).

19.4.2.3.2.1 Little Brown Myotis

Sensory disturbance and dust deposition resulting from vehicular traffic during the operations and maintenance phase of the Project, along with maintenance of habitat fragmentation and edge effects, can reduce habitat effectiveness for breeding bats adjacent to the PDA. Currently, little brown myotis breeding within the LAA are subject to limited amounts of anthropogenic disturbance during the breeding season when the MVWR is not in operation. However, sensory disturbance associated with operations and maintenance of roads can alter bat activity (The California Department of Transportation, 2016). Bats use natural and anthropogenic linear features

for commuting and foraging and have been shown to tolerate noise roadways (Abbott et al., 2012); however, in some cases bats have been shown to avoid foraging near busy roadways (Finch et al., 2020). In addition, bats might use existing bridges as potential roosting sites (GNWT 2022), which could result in disturbance during bridge maintenance activities if scheduled to occur during the active bat season. If bridge maintenance activities are scheduled to occur during the active bat season, mitigation measures (e.g., timing, deterrents) will be implemented to reduce potential disturbance. Overall, operations and maintenance activities are unlikely to produce similar amounts and volumes of noise emitted by the examples previously cited.

19.4.2.3.2.2 Grizzly Bear

Sensory disturbance and dust deposition resulting from vehicular traffic during the operations and maintenance phase of the Project, along with maintenance of habitat fragmentation and edge effects, can reduce habitat effectiveness for grizzly bear adjacent to the PDA (similar to the effects described for the construction phase). Grizzly bear may be attracted to roadway ditches where there is increased forage availability and adverse effects associated with dust deposition altering vegetation communities. However, in general, the species is sensitive to, and is likely to avoid, anthropogenic disturbance (COSEWIC, 2012; SARC, 2017).

The distance at which noise associated with operations and maintenance activities are expected to attenuate to 40 dBA is 100 m for highway traffic and 2.5 km for quarry and borrow source activities (see Section 13.4.2). Denning females may be particularly sensitive to disturbance; however, females currently select den sites each year prior to opening of the MVWR and are then subject to sensory disturbance over the winter. During the operations and maintenance phase of the Project, traffic will occur year-round and there will be no disturbance to denning initiated part way through the critical denning period. Although noise associated with quarry and borrow source activities would result in relatively higher levels of potential sensory disturbance to female bears denning nearby, operations and maintenance activities at these sites are expected to occur infrequently.

19.4.2.3.2.3 Wolverine

Sensory disturbance and dust deposition resulting from vehicular traffic during the operations and maintenance phase of the Project, along with maintenance of habitat fragmentation and edge effects, can reduce habitat effectiveness for wolverine adjacent to the PDA (similar to the effects described for the construction phase). The distance at which noise associated with operations and maintenance activities is expected to attenuate to 40 dBA is 100 m for highway traffic and 2.5 km for quarry and borrow source activities (see Section 13.4.2). Denning females may be particularly sensitive to disturbance; however, females currently select den sites each year prior to opening of the MVWR and are then subject to sensory disturbance over the winter.

During the operations and maintenance phase of the Project, traffic will occur year-round and there will be no disturbance to denning initiated part way through the critical denning period. Risks to denning females are higher near the quarries and borrow sources, which will be used infrequently but which will be a greater source of sensory disturbance. Dust deposition may alter vegetation communities adjacent to the PDA, but wolverine is typically not distributed relative to cover type.

19.4.2.3.2.4 Invertebrates

Sensory disturbance and dust deposition resulting from vehicular traffic during the operations and maintenance phase of the Project, along with maintenance of habitat fragmentation and edge effects, are unlikely to reduce habitat effectiveness for invertebrate SAR/SOCC adjacent to the PDA. As habitats within (i.e., ditches) and adjacent to the PDA mature, it is expected that more open habitat types that support preferred food plants will become established, comparable to existing conditions along the MVWR.

19.4.2.3.2.5 Characterization of Residual Effects for Change in Habitat During Operations and Maintenance

Following the implementation of mitigation measures, residual effects during operations and maintenance for general wildlife habitat, little brown myotis, grizzly bear, wolverine and invertebrate SAR/SOCC are summarized in Table 19.13 and overall residual effects for change in habitat during operations and maintenance are characterized by the following:

- **Direction is adverse:** There will be an indirect loss or alteration of wildlife habitat.
- **Likelihood is possible**: The residual effect could occur.
- **Magnitude is low**: Indirect loss or alteration is not anticipated to result in a measurable change in the abundance of any wildlife species in the LAA, although temporary local shifts in distributions in the LAA might occur.
- **Geographic extent is the LAA:** Indirect loss or alteration of habitat associated with sensory disturbance is unlikely to extend beyond the LAA.
- **Timing is high sensitivity:** Operations and maintenance of the Project will occur year-round.
- **Duration is long-term:** The residual effect on wildlife habitat will persist into the operations and maintenance phase (i.e., > 20 years).
- **Frequency is continuous:** Effects will occur throughout the operations and maintenance phase.
- **Change is irreversible:** Effects are irreversible due to the indefinite duration of operations and maintenance of the Project.

Table 19.13 Summary of Residual Effects on Change in Habitat

Wildlife Species	Residual Effects Characterization*								
	Project Phase	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
General Wildlife Habitat	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Little Brown Myotis	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Grizzly Bear	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Wolverine	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Invertebrate	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	U	L	LAA	HS	LT	C	I

KEY

*See Table 19.3 for detailed definitions

Project Phase
C: Construction
O: Operations and maintenance

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
No: Negligible
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

19.4.3 Change in Movement

19.4.3.1 Effect Pathways

Effects on fine-scale wildlife movements (e.g., avoidance) are considered under change in habitat (Section 19.4.2; i.e., reduced habitat effectiveness). The following section considers potential effects on wildlife movement patterns (e.g., seasonal migrations) and movement corridors that may result from the combined effects of a physical (i.e., the all-season road) and sensory barrier to wildlife.

19.4.3.1.1 Construction

All project activities during the construction phase, except for employment and contracted goods and services, can contribute to a change in movement (Table 19.8). Sensory disturbance associated with the emissions and waste management activity (i.e., noise and light) is a pathway for a change in movement, as is the general construction activity and the creation of a wider linear feature. These project activities can create physical or sensory barriers that may temporarily affect wildlife movement in the LAA.

The ability to move between resource patches is important for species' persistence; barriers can reduce access to key resources, lead to range shifts, and alter seasonal movement patterns and dispersal events (Ament et al., 2014; Nathan et al., 2008; Johnson et al., 1992). Increased noise levels can also result in decreased opportunity costs (i.e., time), increased exposure (Beyer et al., 2014), and increased energy expenditure, especially during winter when energy costs are relatively higher (Bradshaw et al., 1998, Saher and Schmiegelow, 2005). The extent to which construction activities alter wildlife movement in the LAA will vary by the duration, frequency, and intensity (e.g., noise level) of disturbance, as well as by wildlife species. The Project is most likely to alter movement for small mammal species that have limited dispersal capabilities.

In addition to upgrading the existing MVWR to a wider ROW (from 30 m to 60 m) for most of the length of the Project, there will be some creation of new highway ROW, in addition to quarries, borrow sources, and access roads, which contribute to increased habitat fragmentation. During construction, the physical presence of these features may present a barrier to wildlife; however, many of the sources of sensory disturbance will only occur seasonally.

19.4.3.1.2 Operations and Maintenance

As with the construction phase, all project activities during the operations and maintenance phase, except for employment and contracted goods and services, can contribute to a change in movement (Table 19.8). The presence of the highway may create a physical barrier to wildlife movement, and the associated highway traffic and other operations and maintenance activities can reduce barrier permeability due to contributions of sensory disturbance. Sensory disturbances associated with the operations and maintenance of the highway, including the associated public vehicle traffic, will become year-round pathways of effects that can result in a change in wildlife movement. Snow clearing may also present a physical barrier to some wildlife species that have difficulty crossing snow ridges adjacent to the highway.

19.4.3.2 Mitigation

As discussed in Chapter 5, project routing and design have integrated the existing MVWR, to the extent practicable, which will reduce potential project interactions with change in movement. In addition to the project-specific WMMP that will be implemented during the construction and operations and maintenance phases, standard industry practices and mitigation measures will also be implemented and are presented in Table 19.9. Key mitigation measures to avoid or reduce change in movement include:

- A buffer strip of undisturbed vegetation of at least 30 m wide will be maintained between the highway ROW and other new areas to be cleared.
- Vegetation buffers will be used as visual barriers and to protect riparian vegetation, as appropriate.
- Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns.
- The height of snowbanks will be limited to the extent possible and to a height of less than 1 m.
- Construction and quarry development activities will adhere to the applicable recommended setbacks and timing restrictions for wildlife outlined in the WMMP, where possible.
- Closure and reclamation will promote re-establishment of vegetation.

19.4.3.3 Residual Effects

19.4.3.3.1 Construction

Project routing has been used to reduce the amount of new ROW required, primarily involving widening of the existing MVWR ROW (from 30 m to 60 m) and the creation of new ROW that is limited to specific areas to reduce slopes and/or sharp curves to accommodate higher traffic speeds and increase safety on the highway. The Project also includes new access roads (30 m wide ROW) that will be developed for the borrow sources and quarries.

Construction of the Project can result in the alteration of wildlife movement, including traditional or seasonal movement corridors, over space and time for some wildlife species through the modification or development of the PDA (i.e., a physical barrier) and through sensory disturbance from vehicles, equipment, and personnel. A reduction in barrier permeability (i.e., the PDA may become more difficult to cross) is possible for less mobile species (e.g., small mammals, amphibians). However, because the Project predominately involves widening an existing linear feature that is used for part of the year, this is expected to be a relatively minor change to wildlife movement for some wildlife species. Aquatic habitats will remain connected through the construction of culverts and maintenance of existing bridges, which will facilitate movement for aquatic and semi-aquatic species (e.g., beaver).

Construction will be completed in sections and effects associated with sensory disturbance are expected to be localized and short-term in any given location. Two existing quarries proposed for use on the Project overlap two muskox IWAs (i.e., areas that consistently contain a relatively high number of individuals) near Norman Wells (Appendix 19A, Figure 3.6; K'alo-Stantec, 2023). As such, there is potential for the Project to temporarily affect local movement of muskox during construction; however, proposed mitigation (timing and setback distances) are expected to reduce potential effects associated with sensory disturbance. Overall, construction will be completed in sections and effects associated with sensory disturbance are expected to be localized and short-term in any given location.

Following the implementation of the mitigation measures, residual effects for change in wildlife movement during construction are characterized as follows:

- **Direction is adverse:** Construction activities may alter wildlife movements.
- **Likelihood is possible**: The residual effect could occur.
- **Magnitude is low**: A measurable change in the abundance of wildlife in the LAA is unlikely, although temporary local shifts in distributions in the LAA might occur.
- **Geographic extent is the LAA:** Residual effects will not extend into the RAA.
- **Timing is high sensitivity:** Although vegetation clearing will occur in the winter, construction will likely occur through the year, including during sensitive periods for wildlife.
- **Duration is medium- to long-term:** Sensory barriers will cease following the construction phase (i.e., up to 20 years) but physical barriers may persist throughout the life of the Project (i.e., >20 years).
- **Frequency is continuous:** Effects will occur throughout the construction phase.
- **Change is irreversible:** Effects are irreversible due to the indefinite duration of the operations and maintenance phase.

Operations and maintenance of the Project might result in the alteration of wildlife movement for certain species (e.g., wolverine [see Scrafford et al., 2018]), as the presence of the highway and associated traffic will present year-round disturbance (i.e., estimated 50 vehicles/day). Wildlife currently interact with the existing MVWR, which might act as a permeable, semi-permeable or impermeable barrier depending on species-specific road avoidance behaviours. Although the Project will result in a small incremental increase in the width of the road, an increase in traffic volume even at relatively low levels can affect wildlife movement depending on species (Mace et al. 1996, Beyer et al 2014, Scrafford et al. 2018). Additionally, snow clearing is already part of existing MVWR operations and maintenance activities, and snow berm heights will remain below 1 m for the larger all-season road. The potential effects of the Project on wildlife movement will be monitored as part of the WMMP.

Following the implementation of the mitigation measures, residual effects for change in wildlife movement during operations and maintenance are characterized as follows:

- **Direction is adverse:** Operations and maintenance activities may alter wildlife movements.
- **Likelihood is possible**: The residual effect could occur.
- **Magnitude is low**: A measurable change in the abundance of wildlife in the LAA is unlikely, although temporary local shifts in distributions in the LAA might occur.
- **Geographic extent is the LAA:** Residual effects will not extend into the RAA.
- **Timing is high sensitivity:** The Project will operate indeterminately, including during sensitive periods for wildlife.
- **Duration is long-term:** Effects on movement will persist during the operations and maintenance phase (i.e., > 20 years).
- **Frequency is continuous:** Effects will occur throughout the operations and maintenance phase.
- **Change is irreversible:** The Project will operate indeterminately.

19.4.4 Change in Mortality Risk

19.4.4.1 Effect Pathways

19.4.4.1.1 Construction

All project activities during the construction phase, except for employment and contracted goods and services, can contribute to a direct change in mortality risk as they involve the removal of upland and wetland habitats (i.e., vegetation clearing, ground disturbance) and/or the movement of machinery and traffic within the PDA (Table 19.8). Vegetation clearing and ground disturbance is most likely to increase mortality risk for less mobile wildlife species (e.g., rodents, amphibians), those that burrow/hibernate beneath the surface (e.g., black bear), or those that inhabit trees (e.g., bats). Project-related transportation and heavy equipment also can crush or collide with less mobile wildlife (e.g., amphibians). Accidental human-caused mortality is more likely in areas where amphibians are concentrated such as breeding ponds/waterbodies or overwintering sites (CMA 2017). Human-wildlife encounters or conflicts (e.g., food waste, garbage) may occur, primarily at camps, which can lead to wildlife mortality through trapping of rodents or destroying larger problem wildlife species such as black bear or red fox.

19.4.4.1.2 Operations and Maintenance

All project activities during the operations and maintenance phase, except for employment and contracted goods and services, have the potential to contribute to a direct and/or indirect change in mortality risk (Table 19.8). During operation, project-related transportation within the LAA and public traffic resulting from the presence of the highway are the primary pathways with potential to increase wildlife mortality risk by increasing the potential for vehicle-wildlife collisions and

mortality, primarily along the highway portion of the PDA (i.e., risk is lower along access roads). Wildlife may also encounter traffic and heavy machinery associated with maintenance activities. Wildlife species most at risk include small (e.g., rodents, snowshoe hare) and large (e.g., muskox, black bear) mammals that may cross the highway or be attracted to the PDA, where an altered vegetation community provides an abundance of forage or where the road provides a mineral source for wildlife.

The presence of the highway and other linear features (e.g., borrow source and quarry access roads) can result in an indirect change in mortality risk for some species. Increased access for predators and hunters/trappers is the primary pathway for an indirect change in mortality risk. The Project will enhance access along a continuous linear feature that may increase predator efficiency and hunter/trapper ease of travel while providing all-season access to portions of the LAA that were previously more isolated. Species most like to be affected include prey species and harvested species such as furbearers (e.g., American marten) and muskox, or those attracted to an abundance of forage along the PDA (e.g., black bear, grizzly bear).

19.4.4.2 Mitigation

As discussed in Chapter 5, project routing and design have integrated the existing MVWR, to the extent practicable, which will reduce potential project interactions with wildlife, resulting in change in mortality risk. In addition to a Project-specific WMMP that will be implemented during the construction and operations and maintenance phases, standard industry practices and mitigation measures will also be implemented and are presented in Table 19.9. Key mitigation measures to avoid or reduce change in mortality risk include:

- Vegetation clearing will be completed outside the core maternity roosting period for bats of May 1 to August 31. If habitat tree removal or general tree clearing is required during the maternity roosting period, a qualified biologist will review the trees to make a determination on bat occupancy before removal.
- Wildlife monitors will assess for the presence of wildlife on or near the PDA during project activities, in accordance with the WMMP.
- Personnel will undergo a wildlife awareness program, which will include prevention measures for wildlife mortality (e.g., bear safety) and reporting procedures for wildlife-related incidents and protocols to follow when a nest, den, or wildlife species of management concern is observed. This includes completing wildlife sighting and wildlife incident report forms included in the WMMP.
- Personnel will not feed or harass wildlife while working on the Project.
- Project personnel will be prohibited from hunting and fishing while housed in work camps for the Project.
- Construction and quarry development activities will be limited during sensitive periods for wildlife in accordance with the WMMP.
- Food and other wildlife attractants will be stored in bear-proof containers.

- Equipment, wastes, and contaminated soils will be removed once construction is completed.
- Speed limits will be posted on the public highway.

19.4.4.3 Residual Effects

19.4.4.3.1 Construction

Construction activities, including vegetation clearing and earthworks, will follow mitigation measures that consider timing restrictions for wildlife species, including sensitive periods for overwintering mammals. Vegetation clearing will be timed to reduce potential effects on little brown myotis bats as they will have dispersed from maternity roosts prior to the start of clearing activities.

During construction, there is potential for increased mortality risk to small mammals due to their limited mobility (e.g., crushed by construction equipment). Overwintering mammals are also at greater risk as they may encounter heavy machinery during ground disturbance activities. A pre-construction bear den survey will be completed, and appropriate timing restrictions and setback buffers will be applied to reduce mortality risk to denning black and grizzly bears.

Vehicle-related wildlife mortality has the potential to affect a wider range of species, including SAR and SOCC. While traffic volumes will increase during construction, speeds will remain slow and will limit the risk of vehicle-wildlife collisions. Vehicles will abide by posted speed limits and multi-passenger vehicles will be used, where practical, to reduce the potential for vehicle-wildlife collisions. Species most likely to be involved in vehicle-wildlife collisions are small mammals (e.g., rodents) and large mammals attracted to the PDA that provide increased foraging opportunities (e.g., black bear, muskox). Proper management of wastes, including at temporary camps, will reduce the potential for wildlife to be attracted to the construction site (e.g., black bear), thus reducing the potential for mortality risk related to human-wildlife conflict.

Following the implementation of the mitigation measures, residual effects for change in mortality risk during construction are characterized as follows:

- **Direction is adverse:** Construction activities will increase wildlife mortality risk.
- **Likelihood is possible**: The residual effect could occur.
- **Magnitude is low**: A measurable change in the abundance of wildlife in the LAA is unlikely, although temporary local shifts in distributions in the LAA might occur.
- **Geographic extent is the LAA/RAA**: Direct mortality risk limited to LAA; however, indirect mortality risk could extend to the RAA.
- **Timing is high sensitivity:** Although vegetation clearing will occur in the winter, construction will occur through the year, including during sensitive periods for wildlife.
- **Duration is medium- to long-term:** Direct effects will cease following the construction phase (i.e., up to 20 years) but indirect effects will persist into the operations and maintenance phase (i.e., > 20 years).

- **Frequency is multiple irregular event:** construction activities may result in direct and/or indirect wildlife morality, but potential mortalities are expected to occur infrequently at no set schedule following the implementation of mitigation measures.
- **Change is irreversible:** Effects are irreversible due to the indefinite duration of operation of the Project.

19.4.4.3.2 Operations and Maintenance

A direct change in mortality risk is most likely to occur through the presence of the highway and the associated traffic (i.e., through wildlife-vehicle collisions), which is generally an effect driven by both traffic volume and speed. The MVWR has an approximate average traffic load of 50 vehicles per day, driving 50 km/h or less, and is open from December 23 to March 28 between Wrigley and Tulita and from December 25 to April 1 between Tulita and Norman Wells (20-year average; see Section 5.3.1).

Species most likely to be affected are those that that are attracted to mineral deposits or the altered vegetation communities along the PDA that provide an abundance of forage (e.g., muskox, black bear). The highway will allow for increased traffic speeds, which may increase wildlife mortality risk, but the widening of the ROW and maintenance and removal of dense brush along the highway ditches will improve visibility of wildlife, which will reduce collision and mortality risk. Mortality risk associated with other maintenance activities will result from increased traffic volumes or the use of heavy machinery will generally occur infrequently and is anticipated to result in a negligible change in mortality risk.

An indirect change in mortality risk is likely to occur as the Project will provide all-season access to the LAA for hunters and trappers, and by altering predator-prey dynamics. Linear features provide an efficient mechanism to move across the landscape that also provides relatively clear, elevated sightlines that are desirable to resource users and predators. There may be areas along the MVWR that were previously more difficult to access outside of the winter season, which may experience increased hunting and trapping pressure once the Project is operational. Similarly, linear features have the potential to increase predator efficiency. Mineral deposits and altered vegetation communities along the ROW may increase the presence of species such as moose, that in turn results in an increased presence of gray wolf, which can increase predation pressure on other wildlife species in the LAA.

While there is potential for increased harvest pressure due to increased access to areas proximal to the Project, the relative increase in the number of harvesters, the species to be harvested and the spatial distribution of increased harvest cannot be predicted. This uncertainty and the need for additional monitoring is discussed in Sections 19.7.2 and 19.8.

Following the implementation of the mitigation measures, residual effects for change in mortality risk during operations and maintenance are characterized as follows:

- **Direction is adverse:** Operations and maintenance activities will increase mortality risk.
- **Likelihood is possible**: The residual effect could occur.
- **Magnitude is low**: A measurable change in the abundance of wildlife in the LAA is unlikely, although temporary local shifts in distributions in the LAA might occur.
- **Geographic extent is the LAA**: Residual effects will not extend into the RAA.
- **Timing is high sensitivity:** The Project will operate indeterminately, including during sensitive periods for wildlife.
- **Duration is long-term:** The residual effect will persist during the operations and maintenance phase (i.e., > 20 years).
- **Frequency is multiple irregular event:** operations and maintenance activities may result in direct and/or indirect wildlife morality, but potential mortalities are expected to occur infrequently at no set schedule following the implementation of mitigation measures.
- **Change is irreversible:** The Project will operate indeterminately.

19.4.5 Change in Wildlife Health

19.4.5.1 Effect Pathways

An exposure pathway must be present for there to be an increased risk to wildlife health, and includes the ingestion of soil, sediment, food, or water and/or direct contact with soil, sediments, or water that may contain contaminants. The effect pathways that may result in a change in wildlife health include:

- Deposition of rock and dust may release contaminants into the surrounding terrestrial and aquatic environment during extraction (e.g., blasting, stockpiling), crushing, transport, and road construction and operations and maintenance.
- Sedimentation and runoff from project activities may release contaminants into surface water, affecting aquatic flora and fauna.

Increasing abundance of bear populations is associated with growing concerns raised by harvesters, including the consumption of potentially contaminated bear meat from bears that forage in dumps or other contaminated sites (Dehcho First Nations, 2011). Dehcho First Nations also expressed concerns regarding wildlife contaminated through exposure to oil and other contaminants to the environment (Dehcho First Nations, 2011).

Sensory disturbance during the construction and operations and maintenance phases of the Project may adversely affect the physical condition of wildlife through increased stress and energy expenditure resulting in a change in wildlife health (Gaynor et al., 2019).

19.4.5.1.1 Construction

During construction, potential effects on wildlife health may occur within the LAA due to one or more of the exposure pathways including site preparation of ROW, access and workspaces, culvert installations, as well as emissions and waste management (Table 19.8). Construction associated with site preparation of ROW, access, and workspaces and embankment and quarry access road construction, including road cuts and culvert installations activities, will occur adjacent to aquatic habitats and have potential to reduce surface water quality in aquatic environments through sedimentation and runoff.

19.4.5.1.2 Operations and Maintenance

As described for the construction phase, there are many activities in the operations and maintenance phase that are likely to result in pathways that are considered under the emissions and waste management activity. During operation, the sedimentation and runoff exposure pathway is not anticipated to result in a change in wildlife health, but deposition of dust will persist and the presence of the highway and associated public traffic is the primary pathways for dust to enter the terrestrial and aquatic environments. Potential effects associated with air emissions from vehicular traffic (i.e., 50 vehicles/day) is not anticipated to result in a change in wildlife health.

19.4.5.2 Mitigation

As discussed in Chapter 5, project routing and design have integrated the existing MVWR, to the extent practicable, which will reduce potential project interactions with change in wildlife health. In addition to a project-specific WMMP that will be implemented during the construction and operations and maintenance phases, standard industry practices and mitigation measures will also be implemented and are presented in Table 19.9. Key mitigation measures to avoid or reduce change in wildlife health include:

- The SCP will include procedures to prevent and respond to spills.
- Maintenance yards will have a liner or concrete installed under areas of vehicle storage and maintenance.
- Vehicles parked for more than 2 hours will use drip trays.
- Placement of embankment will occur primarily during winter (December 15 to April 1), during frozen conditions. If work is to be completed under non-frozen conditions, equipment will be equipped with mushroom shoes.
- A project-specific ESCP will be developed and implemented.
- Washing, refueling, and servicing machinery and storage of fuel and other materials for machinery will be conducted a minimum of 100 m from the high-water mark and in a manner to prevent any deleterious substances from entering the water.
- Blast rock will not enter a waterbody or watercourse.

- A dust control program using water will be implemented during construction and operations and maintenance.
- Equipment, wastes, and contaminated soils will be removed once construction is completed.

19.4.5.3 Residual Effects

19.4.5.3.1 Construction

During construction, there is potential for increased risk to wildlife health through the mobilization of sediment into aquatic habitats and dust deposition.

The Project will follow applicable regulatory requirements and the application of mitigation measures for aquatic resource protection, which will reduce risks to wildlife and wildlife habitat and potential effects are anticipated to be negligible.

Dust deposition is expected to result in minor and localized changes to vegetation and wildlife habitat adjacent to the PDA (i.e., within 40 m; Section 19.4.2.3). Dust deposition resulting from construction activities is not anticipated to contain chemicals of potential concern that could harm wildlife or wildlife habitat.

Harvested wildlife species in NWT, such as beaver, snowshoe hare (*Lepus americanus*), and muskox, have been shown to have limited environmental contamination (Appendix 19A, Section 3.2.2.1; K'alo-Stantec, 2023) and construction of the Project is not expected to result in a change in wildlife health within the LAA.

Following the implementation of the mitigation measures, residual effects for change in wildlife health during construction are characterized as follows:

- **Direction is adverse:** Construction activities will increase risks to wildlife health.
- **Likelihood is unlikely:** The residual effect is almost certainly not to occur.
- **Magnitude is negligible:** A measurable change in the abundance of wildlife in the LAA is not anticipated.
- **Geographic extent is the LAA:** Residual effects will not extend into the RAA.
- **Timing is high sensitivity:** Construction will likely occur through the year, including during sensitive periods for wildlife.
- **Duration is medium-term:** Effects will cease following the construction phase (i.e., up to 20 years).
- **Frequency is continuous:** Effects will occur throughout the construction phase.
- **Change is irreversible:** Potential effects of change in health through exposure to contaminants and sensory disturbance may be reduced following the construction phase, but the all-season highway and associated traffic are expected to persist throughout the life of the Project.

19.4.5.3.2 Operations and Maintenance

Dust deposition is expected to result in minor and localized changes to vegetation and wildlife habitat adjacent to the PDA (i.e., within 40 m; Section 19.4.2.3). However, given the lack of chemicals of potential concern contained within dust emissions and the amount of dust expected from 50 vehicles/day, it is unlikely to result in a measurable change in the abundance of wildlife in the LAA. This is consistent with determinations in other similar projects in the NWT (i.e., Tłı̨chǫ Highway [Golder, 2017]).

Harvested wildlife species in NWT have been shown to have limited environmental contamination (Appendix 19A, Section 3.2.2.1; K'alo-Stantec, 2023) and operations and maintenance of the Project is not expected to result in a change in wildlife health within the LAA.

Following the implementation of the mitigation measures, residual effects for change in wildlife health during operations and maintenance are characterized as follows:

- **Direction is adverse:** Operations and maintenance activities will increase risk to wildlife health.
- **Likelihood is unlikely:** The residual effect is almost certainly not to occur.
- **Magnitude is negligible:** A measurable change in the abundance of wildlife in the LAA is not anticipated.
- **Geographic extent is the LAA:** Residual effects will not extend into the RAA.
- **Timing is high sensitivity:** The Project will operate indeterminately, including during sensitive periods for wildlife.
- **Duration is long-term:** The residual effect will persist during the operations and maintenance phase (i.e., > 20 years).
- **Frequency is continuous:** Effects will occur throughout the operations and maintenance phase.
- **Change is irreversible:** The Project will operate indefinitely.

19.4.6 Summary of Residual Effects

Table 19.14 summarizes the residual effects on wildlife and wildlife during the construction and operations and maintenance phases of the Project.

With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirement related to fish and wildlife and consideration of engagement input and incorporation of Traditional Knowledge.

The design of the Project and mitigation measures for protection of wildlife and wildlife habitat will protect the karst formation of Petiniɂah (Bear Rock) and respect the values of the Petiniɂah (Bear Rock) CZ, Norman Range SMZ, K'ą̨ląǫ Tué (Willow Lake Wetlands) SMZ and Deh Cho (Mackenzie River) SMZ, as areas with important furbearer and bear habitat.

Table 19.14 Residual Effects on Wildlife and Wildlife Habitat

Residual Effect	Residual Effects Characterization*								
	Project Phase	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in Habitat	C	A	CE	L	LAA	HS	MT-LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Change in Movement	C	A	P	L	LAA	HS	MT-LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Change in Mortality Risk	C	A	P	L	LAA	HS	MT-LT	IR	I
	O	A	P	L	LAA	HS	LT	IR	I
Change in Wildlife Health	C	A	U	NMC	LAA	HS	MT	C	I
	O	A	U	NMC	LAA	HS	LT	C	I

KEY

*See Table 19.3 for detailed definitions

Project Phase
C: Construction
O: Operations and maintenance

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMC: No Measurable Change
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

19.5 Assessment of Cumulative Effects on Wildlife and Wildlife Habitat

Project residual effects described in Section 19.4 are likely to interact cumulatively with residual environmental effects from other physical activities including past, present, and reasonably foreseeable projects. The effects of past and current projects contribute to baseline conditions upon which Project effects are assessed. Cumulative effects are described as those resulting from residual Project effects combined with the effects of past, present, and reasonably foreseeable projects and activities.

Future projects that are reasonably foreseeable are those that (a) have obtained the necessary authorizations to proceed or are in the process of obtaining the required authorization, or (b) have been publicly announced with the intention to seek the necessary authorizations to proceed.

Two conditions must be met to initiate an assessment of cumulative effects on a VC:

- The Project is assessed as having measurable adverse residual environmental effects on a VC.
- The adverse residual effects from the Project overlap spatially and temporally with measurable residual effects of other physical activities on a VC.

If either condition is not met, the assessment of cumulative effects is not warranted because the Project is not considered to interact cumulatively with other projects or activities. Except for change in wildlife health, both conditions apply for change in habitat, movement and mortality risk and a cumulative effects assessment is presented below.

The Project is predicted to result in no measurable residual effects on wildlife health (Table 19.14). As such, the Project is not expected to interact cumulatively with residual effects from other physical activities (past, present and reasonably foreseeable). Although, changes in air and water quality can result in changes in the quality of food sources (e.g., plants, fish, small mammals) consumed by wildlife, the conclusions in the cumulative effects assessments for air quality (Volume 4, Chapter 12, see Section 12.5 of the DAR) and surface water and sediment quality (Volume 4, Chapter 16, see Section 16.5) indicate that there is no potential for cumulative effects on air or surface water quality; and therefore, there is no potential for cumulative effects on wildlife health due to changes in air or water quality. In the absence of cumulative effects pathways, wildlife health will not be further assessed.

19.5.1 Residual Effects Likely to Interact Cumulatively

The project and activity inclusion list (Table 19.15) identifies known past, present, and reasonably foreseeable projects and physical activities that could interact cumulatively with the residual effects. Chapter 4 of the DAR presents the names, proponents, use or activity, descriptions, status, and location of these projects and activities.

Table 19.15 Projects with the Potential to Contribute to Cumulative Effects in the RAA

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects			
	Change in Habitat	Change in Movement	Change in Mortality Risk	Change in Wildlife Health
Past and Present Physical Activities and Resource Use (Base Case)				
Geotechnical	–	–	–	–
Oil, Gas & Seismic*				
Tulita 2D Seismic Program	✓	✓	✓	–
EL 466 Drilling Program	✓	✓	✓	–
Windy Island Drilling Program	✓	✓	✓	–
Summit Creek Drilling Program	✓	✓	✓	–
Slater River Project	✓	✓	✓	–
Little Bear Staging Area	✓	✓	✓	–
Infrastructure				
Mackenzie Valley Winter Road, including bridges and bridge-sized culverts	✓	✓	✓	–
Canyon Creek All Season Access Road	✓	✓	✓	–
Norman Wells Pipeline	✓	✓	✓	–
Mackenzie Valley Fibre Link	✓	✓	✓	–
Délı̨nę Winter Road	✓	✓	✓	–
Mackenzie Highway No.1	✓	✓	✓	–
Prohibition Creek Access Road (PCAR)	✓	✓	✓	–
Quarries and Borrow Sources				
HRN Quarry	✓	✓	✓	–
Little Bear River Quarry	✓	✓	✓	–

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects			
	Change in Habitat	Change in Movement	Change in Mortality Risk	Change in Wildlife Health
Mining & Exploration				
Wrigley Zinc Property Drilling Program	✓	✓	–	–
Municipal Operations, including water, waste, power, and community development				
Wrigley Municipal Activities	✓	✓	✓	–
Tulita Municipal Activities	✓	✓	✓	–
Norman Wells Municipal Activities	✓	✓	✓	–
Project-Related Physical Activities (Project Case)				
Mackenzie Valley Highway Project	✓	✓	✓	–
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)				
Quarries				
Dhu-1 Quarry	✓	✓	✓	–
Infrastructure				
Great Bear River Bridge	✓	✓	✓	–
Oil and Gas				
Enbridge Maintenance Camp	✓	✓	✓	–

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with Project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = Includes support activities such as production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas where they occur within the RAA.

19.5.2 Change in Habitat

19.5.2.1 Cumulative Effects Pathways

Potential cumulative effects on wildlife habitat due to reasonably foreseeable activities have similar effects pathways as those identified for the Project (see Section 19.4.2.1) including direct loss or alteration of habitat from vegetation clearing and indirect effects due to sensory disturbance (e.g., noise, artificial lights), dust deposition, edge effects, and fragmentation generated during project construction and operations and maintenance of the Project.

19.5.2.2 Mitigation for Cumulative Effects

Mitigation measures and regional initiatives applicable to limiting cumulative effects on wildlife habitat, including for SAR, within the RAA (including other reasonably foreseeable projects) include adhering to the project-specific WMMP and other management and monitoring plans used to protect and monitor the environment during project construction and operations and maintenance, including the:

- ESCP
- Permafrost Protection Plan (PPP)
- SCP
- Waste Management Plan (WMP)
- Quarry Development Plans (QDP)

19.5.2.3 Cumulative Effects

Past and present activities including oil and gas development (e.g., Norman Wells Pipeline), the MVWR and other winter roads, quarries and borrow sources, mining and exploration activities as well as municipal and community development have resulted in the loss of wildlife habitat in the RAA. These past and current projects and activities reflect the existing (baseline) conditions in the RAA. Although these projects and activities have altered the regional landscape and contributed to existing cumulative effects on wildlife habitat, the amount of existing anthropogenic disturbance (i.e., exposed land) in the Dehcho RAA (1.4%) and Sahtu RAA (1.5%) is relatively low (see Table 19.7). At baseline, the Dehcho Region RAA contains an abundance of wildlife habitat dominated by coniferous forest (43.6%), wetlands (19.8%), and open water (19.3%) whereas the Sahtu Region RAA contains primarily coniferous forest (28.7%), wetlands (25.2%), and shrubland (20.6%) (Table 19.7).

Ongoing and reasonably foreseeable activities and projects will result in additional direct habitat loss and alteration as well as potential sensory disturbance (e.g., noise), which will contribute to cumulative effects on wildlife habitat including SAR/SOCC in the RAA. Specifically, the Dhu-1 Quarry (including camp and winter access road) will result in a direct loss of 23 ha, Great Bear River Bridge, 46.5 ha and PCAR, 77.8 ha. The estimated project development area for the Enbridge Maintenance Camp is not available. Overall, the ongoing and future projects are relatively small in spatial scale and some projects such as the PCAR overlap the existing MVWR, which will reduce cumulative effects on wildlife habitat.

The Project will contribute to existing cumulative effects on habitat, however, the change in habitat (2,315.2 ha) represents a 0.2% decrease from the existing condition in the RAA (1,010,983.5 ha), which includes 1,104.9 ha of exposed land and existing anthropogenic disturbances (i.e., existing MVWR and quarries) (see Table 19.11). The Project is anticipated to contribute 1,404.9 ha of new exposed land cover in the RAA, a 7.5% increase from the existing condition (15,970.4 ha).

The Project will also result in a direct loss or alteration of 102.8 ha of little brown myotis maternity roosting habitat (i.e., a 0.2% decrease from the existing condition in the RAA), and 140.9 ha of grizzly bear denning habitat (i.e., a 0.5% decrease from the existing condition in the RAA). Similarly, for wolverine and invertebrate SAR, which were assessed qualitatively, the Project is expected to result in a low magnitude of change in habitat availability within the RAA relative to the existing condition.

With mitigation, the residual cumulative effects on wildlife habitat from past, present, and reasonably foreseeable projects and physical activities, including the Project are predicted to be low in magnitude and occur over the long-term.

19.5.3 Change in Movement

19.5.3.1 Cumulative Effects Pathways

Potential cumulative effects on wildlife movement arising from past, present, and reasonably foreseeable activities have similar pathways as those resulting from the Project (Section 19.4.3.1), which includes potential physical and sensory barriers generated during Project construction and operations and maintenance of the Project.

19.5.3.2 Mitigation for Cumulative Effects

Mitigation measures and regional initiatives applicable to limiting cumulative effects on wildlife movement, including for SAR, within the RAA (including other reasonably foreseeable projects) include the following:

- A WMMP will be developed and implemented.
- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent possible.

19.5.3.3 Cumulative Effects

Past and present activities likely have contributed to cumulative changes in wildlife movement in the RAA due to potential physical and sensory barriers associated with the construction and operation of the Norman Wells Pipeline, the MVWR and other winter roads, quarries and borrow sources. Ongoing and reasonably foreseeable activities and projects including the Dhu-1 Quarry, Great Bear River Bridge, PCAR and Enbridge Maintenance Camp have potential to contribute to existing cumulatively effects on wildlife movement in the RAA. Overall, the reasonably foreseeable projects are expected to contribute to cumulative effects on wildlife movement including SAR/SOCC; however, the project footprints are relatively small and some projects such as the PCAR overlap the existing MVWR; and therefore, the potential for these projects to contribute to potential changes in regional wildlife movement is limited.

The Project will contribute to residual cumulative effects on wildlife movement due to potential physical barriers and sensory disturbance expected to occur during construction as well as operations and maintenance. With mitigation, the residual cumulative effect on wildlife movement from past, present, and reasonably foreseeable projects and physical activities, including the Project, are predicted to be low in magnitude and expected to occur over the long-term.

19.5.4 Change in Mortality Risk

19.5.4.1 Cumulative Effects Pathways

Potential cumulative effects on wildlife mortality risk arising from past, present, and reasonably foreseeable activities have similar pathways as those resulting from the Project (Section 19.4.2.1), which includes site preparation activities (e.g., vegetation clearing, earthworks), traffic-related mortality, and increased access opportunities for hunters and predators.

19.5.4.2 Mitigation for Cumulative Effects

Mitigation measures and regional initiatives applicable to limiting cumulative effects on mortality risk within the RAA include the following:

- A WMMP will be developed and implemented.
- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent possible.
- Speed limits will be posted on the public highway.

19.5.4.3 Cumulative Effects

Existing linear features including the Norman Wells Pipeline, the MVWR and other winter roads, quarries and borrow sources have contributed to past and existing cumulative effects on wildlife mortality risk in the RAA. Ongoing and reasonably foreseeable activities and projects including the Dhu-1 Quarry, the Great Bear River Bridge, PCAR, and the Enbridge Maintenance Camp have potential to contribute to existing cumulative effects on wildlife mortality risk in the RAA. However, implementation of standard industry practices (e.g., timing restrictions, setbacks) are expected to reduce potential residual cumulative effects on mortality risk. Overall, the reasonably foreseeable projects will result in additional cumulative effects on wildlife mortality risk; however, these projects are comparatively small, involving limited amounts of clearing and vehicle traffic, which will limit the incremental increase in mortality risk.

The Project has potential to contribute to residual cumulative effects on direct and indirect mortality risk (e.g., harvesting) during construction as well as operations and maintenance. However, implementation of mitigation measures and monitoring are expected to reduce wildlife mortality risk during construction and operations and maintenance phases.

With mitigation, the residual cumulative effects on wildlife mortality risk from past, present, and reasonably foreseeable projects and physical activities, including the Project, are predicted to be low in magnitude. Residual cumulative effects will occur as multiple irregular events as reasonably foreseeable projects and physical activities go forward and will occur over the long term during operations.

19.5.5 Summary of Cumulative Effects

Past and present activities as well as reasonably foreseeable projects have and will continue to result in cumulative effects on wildlife habitat, movement and mortality risk. The Project's contributions to direct change in habitat will be low in magnitude following mitigation. Indirect effects on habitat resulting from project noise and activity are expected to be localized, low in magnitude and occur over the long term.

When current and future activities and project effects on wildlife and wildlife habitat are considered, the Project's contribution to direct change in movement and mortality risk will be low in magnitude following mitigation.

Table 19.16 summarizes cumulative effects on wildlife and wildlife habitat.

Table 19.16 Summary of Cumulative Effects

Residual Cumulative Effect	Residual Cumulative Effects Characterization							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in Habitat	A	CE	L	RAA	HS	LT	IR	I
Contribution from the Project to the residual cumulative effect	The Project will result in the direct loss or alteration of 0.2% of wildlife habitat in the RAA compared to existing conditions. Direct loss or alteration of little brown myotis maternity roosting habitat and grizzly bear denning habitat is expected to be low, with a change of 0.2% and 0.5% from existing conditions in the RAA, respectively. Similarly, the Project is expected to result in a low magnitude of change in habitat availability within the RAA for wolverine and invertebrate SAR compared to the existing condition. With mitigation, the contribution from the Project to residual cumulative effects on habitat is expected to be low.							
Change in Movement	A	P	L	RAA	HS	LT	IR	I
Contribution from the Project to the residual cumulative effect	The Project has potential to result in changes to local, daily or seasonal wildlife movement due to physical and sensory barriers. The height of snowbanks will be limited to the extent possible and to a height of less than 1 m to facilitate wildlife movement. With mitigation, the contribution from the Project to residual cumulative effects on wildlife movement is expected to be low.							
Change in Mortality Risk	A	P	L	RAA	HS	LT	IR	I
Contribution from the Project to the residual cumulative effect	The Project will result in increased wildlife mortality risk due to vegetation removal and increased traffic volumes. However, pre-construction surveys and other mitigation measures (e.g., reduced speed limits) will reduce mortality risk along roads. With mitigation, the contribution from the Project to residual cumulative effects on wildlife mortality risk is expected to be low.							

KEY

*See Table 19.3 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
No: Negligible
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

19.6 Determination of Significance

19.6.1 Significance of Residual Effects

The Project will result in the direct loss or alteration of 2,315.2 ha (< 3.1%) of wildlife habitat within the LAA, including 1,104.9 ha of exposed lands that are subject to existing anthropogenic disturbances (i.e., existing MVWR and quarries) and provide limited suitability for most wildlife species. The Project will result in the direct loss or alteration of < 5.0% of habitat within the LAA for little brown myotis and grizzly bear. Similarly, for wolverine and invertebrate SAR assessed qualitatively, the Project is expected to result in a low magnitude of change in habitat availability within the LAA compared to the existing condition.

Vegetation clearing will occur outside of spatial and temporal sensitivities for wildlife and the low traffic volume during operations and maintenance of the Project is unlikely to result in a notable increase in wildlife mortality risk, including for SAR/SOCC. Increased access opportunities for hunters may result in increased harvest rates of harvested species.

The Project is anticipated to have a negligible effect on wildlife health.

Following the application of avoidance and mitigation measures, residual effects on wildlife and wildlife habitat are not expected to threaten the long-term persistence or viability of SAR/SOCC or species of cultural or traditional importance, and there are no established conservation-based thresholds for species considered in this VC. In conclusion, the project effects on wildlife and wildlife habitat are not significant.

19.6.2 Significance of Cumulative Effects

The Project will result in the direct loss or alteration of 2,315.2 ha (< 0.2%) of wildlife habitat within the RAA, including 1,104.9 ha of exposed lands that are subject to existing anthropogenic disturbances (i.e., existing MVWR and quarries) and provide limited suitability for most wildlife species. Development of the Project will result in a direct loss or alteration of 102.8 ha of little brown myotis maternity roosting habitat (i.e., a 0.2% decrease from the existing condition in the RAA), and a 140.9 ha of grizzly bear denning habitat (i.e., a 0.5% decrease from the existing condition in the RAA). Similarly, for wolverine and invertebrate SAR, which were assessed qualitatively, the Project is expected to result in a low magnitude of change in habitat availability within the RAA compared to the existing condition.

Indirect effects of habitat loss or alteration are not expected to extend into the RAA. While the Project may interact cumulatively with several other, relatively small reasonably foreseeable projects within the RAA, the Project will contribute a small incremental change in habitat for wildlife. Habitat for wildlife throughout the year will remain abundant in the RAA, including for SAR/SOCC.

The Project will interact cumulatively with past, present, and reasonably foreseeable projects and activities but vegetation clearing will include avoidance of sensitive wildlife features and the low traffic volume during operations and maintenance of the Project is unlikely to result in a notable increase in wildlife mortality risk, including for SAR/SOCC. Increased access opportunities for hunters may result in increased harvest rates of wildlife.

Following the application of mitigation and environmental protection measures, residual cumulative effects on wildlife and wildlife habitat are not expected to threaten the long-term persistence or viability of SAR/SOCC or species of cultural or traditional importance, and there are no established conservation-based thresholds for species considered in this VC. In conclusion, the effects on wildlife and wildlife habitat are not significant.

19.6.3 Project Contribution to Cumulative Effects

The Project will contribute a small incremental increase in both a change in habitat through vegetation clearing, sensory disturbance, dust deposition, edge effects, and fragmentation, and a change in mortality risk (vegetation clearing, wildlife-vehicle collisions, hunter and predator access).

19.7 Prediction Confidence

The prediction confidence in the final determination of significance is considered moderate. This level of confidence is based on the factors listed, which includes assumptions as well as gaps and uncertainties discussed in Sections 19.7.1 and 19.7.2.

- The quantity and quality of data available
- The conservative approach taken to assessment (Section 19.4.1.3)
- Professional judgement and experience with similar projects
- Effectiveness of mitigation measures, which reflect best industry practices and those used on similar highways Projects in the NWT (e.g., Tłı̨chǫ Highway).

Prediction confidence is expected to increase following the completion of pre-construction surveys and proposed monitoring programs.

19.7.1 Assumptions

A conservative approach is used to address uncertainty in the environmental effects assessment, which increases confidence in the final determination of significance. The assessment used a habitat-based approach, which focuses on identifying the quantity and composition of land cover types (i.e., habitats) affected by the Project relative to the availability of those habitats in the LAA and RAA. This approach is considered conservative as it assumes that wildlife species are present if the habitat is available, which is not always the case (e.g., some wildlife species may not be present in a habitat recently affected by fire until the habitat returns to its pre-fire state following the vegetation successional process that require several years). Additionally, land cover classes that

represent disturbed lands (i.e., exposed land) are included in the quantification of direct habitat loss, despite providing limited value for most wildlife species, and comprises 47.8% (1,104.91 ha) of the PDA. The PDA is conservatively assumed to be lost to wildlife but there are portions that will be reclaimed, and some species will use disturbed sites.

19.7.2 Gaps and Uncertainties

A systematic survey of bear dens within the LAA in the Dehcho Region has yet to be completed and the number and location of dens with potential to interact with the Project is unknown. A pre-construction bear den survey (Section 19.8) in this area will help to inform mitigation measures to protect denning bears. Additionally, the number and location of mineral licks within the LAA is unknown. As such, there is some uncertainty related to potential project effects on these sensitive features. Completing bear den and mineral lick surveys prior to construction will contribute to an increase in prediction confidence.

While there is potential for increased harvest pressure due to increased access to areas proximal to the Project, the relative increase in the number of harvesters, the species to be harvested and the spatial distribution of increased harvest cannot be predicted.

There is uncertainty related to the potential direct and indirect effects of climate change on wildlife distribution and abundance due to potential changes in forage quality and quantity, movement and dispersal, interspecific competition, and predator-prey dynamics (Malpeli et al., 2020, Davidson et al., 2020).

19.8 Follow-up and Monitoring

Pre-construction wildlife surveys will be completed prior to vegetation clearing where the Project can interact with sensitive features such as bear dens and mineral licks. A pre-construction beaver dam and lodge survey will be conducted to identify those with potential to be impacted by construction. Wildlife monitors will assess for the presence of wildlife on or near the PDA during Project activities. Details of proposed monitoring programs are provided in the Draft WMMP (Volume 5).

The database for wildlife-vehicle collisions, implemented und maintained by GNWT-ECC, will be extended to include the MVWR ROW and completed sections of the highway during and after construction.

The GNWT will work with SRRB and other resource managers to address uncertainty regarding the effects of increased access created by the Project on harvested resources in the study areas. This would include monitoring of harvest that can be used to identify the need for management actions to be taken by the appropriate resource management organization.

Monitoring programs will be implemented to evaluate if mitigation measures are implemented and operate as planned. This includes monitoring in accordance with the terms and conditions of permit approvals and development and implementation of a WMMP. The GNWT-INF will establish two positions dedicated to assisting with the implementation of the WMMP.

The GNWT-ECC will continue to implement existing wildlife monitoring programs consistent with its role as wildlife resource manager but recognizes that new programs and additional resources may be required to address issues specific to the Project. The GNWT will continue to refine the WMMP for this project throughout the EA process and is open to and interested in discussions with Indigenous Governments, Indigenous Organizations, and other affected parties on how best to incorporate their recommendations.

19.9 References

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20.0 ASSESSMENT OF POTENTIAL EFFECTS ON BIRDS AND BIRD HABITAT

Birds and Bird Habitat is a Valued Component (VC) because it provides ecological, aesthetic, recreational, economic, and cultural value to Indigenous Governments, Indigenous Organizations, other affected parties. Having access to birds and bird habitat is important to communities, particularly resource users that continue to practice traditional and recreational hunting activities throughout the Dehcho and Sahtu regions.

Birds and bird habitat may be affected by the Mackenzie Valley Highway Project (the Project). The Terms of Reference (ToR) identify birds and bird habitat as a subject of note (SON; MVEIRB, 2015). Potential effects on birds and bird habitat are related to other VCs. For example, changes to vegetation and wetlands (see Chapter 18) resulting from project-related land clearing will reduce habitat availability. Changes in noise (see Chapter 13) and water quality (see Chapter 16) could affect terrestrial and aquatic habitats, which in turn may affect bird health. As such, the residual effects of the Project on vegetation and wetlands, noise, surface water and sediment quality were used to assess potential project effects on birds and bird habitat.

Changes in birds and bird habitat may cause changes to other VCs. For example, changes in birds and bird habitat have the potential to affect biodiversity (see Chapter 21), and land and resource use associated with hunting and areas used by Indigenous Governments, Indigenous Organizations, and other affected parties by altering the distribution and abundance of bird species of cultural importance (see Chapter 11).

In this assessment, the term “bird” considers all bird species that occur within the Mackenzie Valley, including species at risk (SAR) and species of conservation concern (SOCC), while separate assessments have been provided for potential effects of the Project on wildlife and wildlife habitat (see Chapter 19) and caribou and moose (see Chapter 10), reflecting the ToR’s SON and key lines of inquiry (MVEIRB, 2015). Here, SAR are species listed as special concern, threatened, or endangered under the *Species at Risk (NWT) Act* (GNWT, 2020a) or under Schedule 1 of the federal *Species at Risk Act* (SARA; Government of Canada, 2021). SOCC are species assessed as special concern, threatened, or endangered by the NWT Species at Risk Assessment Committee (GNWT, 2020a) or the Committee on the Status of Endangered Wildlife in Canada (Government of Canada, 2021). This is consistent with the Birds and Bird Habitat Technical Data Report (TDR; K’alo-Stantec, 2023; Appendix 20A), which describes existing conditions for the VC.

Numerous bird species inhabit the Mackenzie Valley due to the widespread availability of wetlands, rivers, lakes, forests, and rock formations. As it is not feasible to assess the effects of the Project on all species having potential to occur in the assessment areas (Section 20.2.2), the assessment focuses on a select group of species and species assemblages that are representative of the bird species that have the greatest potential to be affected by the Project (Table 20.2), including SAR, SOCC, and harvested species (e.g. grouse, ptarmigan, ducks, geese). Although there was a focus on SAR, SOCC and harvested species, other forest songbirds were assessed as part of the landbirds

category using a habitat-based approach (e.g., warblers; see Table 20.10 in Section 20.4.1). A full list of bird species with potential to occur in the LAA is presented in Table A.2 of Appendix 20A.

The assessment of potential effects on birds and bird habitat concludes that with the application of mitigation measures, residual effects of the Project on birds and bird habitat will be adverse. Residual effects and cumulative effects will not cause or further contribute to the exceedance of a conservation-based threshold or threaten the long-term persistence or viability of SAR/SOCC, or species of cultural or traditional importance and therefore will be not significant.

20.1 Scope of Assessment

20.1.1 Regulatory and Policy Setting

The assessment of potential project-related environmental effects on birds and bird habitat is guided by the project ToR (MVEIRB, 2015 [PR#66]), the following notable federal and territorial legislation and guidance, and the Sahtu Land Use Plan (SLUP).

20.1.1.1 Federal

The *Migratory Birds Convention Act* (MBCA), and specifically s.5(1) and s.6(a) of the Migratory Birds Regulations, prohibits the destruction or take of a migratory bird, or the disturbance, destruction, or take of a nest or egg of a migratory bird. The protection of birds under the Act is afforded to all native bird species expected to occur in the assessment areas, except upland gamebirds, raptors, belted kingfisher, owls, corvids, and icterid blackbirds, which are protected under territorial legislation (Section 20.1.1.2).

The SARA provides protection for SAR in Canada. The legislation provides a framework to facilitate recovery of species listed as threatened, endangered, or extirpated and to prevent species listed as special concern from becoming threatened or endangered. Bird SAR and their habitats are protected under SARA, which prohibits: (1) the killing, harming, or harassing of endangered or threatened SAR (SARA sections 32 and 36); and (2) the destruction of critical habitat of an endangered or threatened SAR (SARA sections 58, 60, and 61).

20.1.1.2 Territorial

The *Species at Risk (NWT) Act* is used to identify, protect, and recover plant and animal SAR in the Northwest Territories (NWT). This Act facilitates the process of assessment and management of species and their habitats to prevent further declines and to promote recovery.

The *Wildlife Act* provides general provisions for regulating the activities relating to the harvest and protection of wild animals in NWT. Section 1(1) defines “wildlife" as “all species of vertebrates and invertebrates found wild in nature in the Northwest Territories,” and Section 51(1) includes protections for birds and bird nests.

20.1.1.3 Sahtu Land Use Plan

Specific to the areas to which the SLUP applies, the Project must meet the 13 general conformity requirements (CR) of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023). The SLUP's conformity requirements include consideration of wildlife in CR#7, which are reproduced below as they relate to the Birds and Bird Habitat VC:

> CR#7: *"1) Land use activities must be designed using the most current information for identified species of interest and species at risk as obtained from the GNWT--ECC* [Environment and Climate Change], *CWS* [Environment and Climate Change Canada - Canadian Wildlife Service], *DFO* [Fisheries and Oceans Canada], Parks Canada Agency, *the Sahtú Renewable Resources Board (SRRB) and the local Renewable Resources Council (RRC)s*
>
> *2) Impacts to wildlife, their habitat and migration patterns, and important community harvesting areas must be prevented or mitigated to the extent possible."*
>
> *"a) In particular, all reasonable steps should be taken to follow the horizontal setbacks and minimum flight altitudes identified in Table 4 [of the SLUP] when near habitat sites during sensitive periods described in that table, unless human safety is of concern, and measures are developed with the appropriate organizations and the RRC to mitigate impacts to these species and their habitat."*

Conformity Requirement #2 requires that *"The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge."*.

Additionally, per CR#14, the Project must be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 2023), including the following:

- Petiniʔah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)
- K'ąąlǫ Tué (Willow Lake Wetlands) Special Management Zone (SMZ) (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

20.1.2 Influence of Engagement

The Government of the Northwest Territories (GNWT) has engaged with Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapters 2 (Consultation and Engagement), 3 (Traditional Knowledge), and 11 (Culture and Traditional Land Use) of this Developer's Assessment Report (DAR). The GNWT has recently initiated Consultation with Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, and through a review of publicly available TLRU information, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to birds and bird habitat. This feedback has been considered and summarized in Table 20.1 and has been integrated into the assessment of potential effects on birds and bird habitat that follows.

20.1.2.1 Regulatory Engagement

The GNWT-INF has engaged territorial (the Government of the Northwest Territories - Environment and Climate Change [GNWT-ECC]) and federal (Environment and Climate Change Canada [ECCC]) regulatory wildlife agencies throughout the development the DAR, including:

- The GNWT-ECC has been continually involved in the Project, including aiding in addressing data gaps relative to the project ToR (MVEIRB, 2015 [PR#66]) and reviewing development of the TDR and DAR within its mandate.
- Environment and Climate Change Canada has and will continue to be engaged to better understand their concerns relating to migratory birds and SAR.

Table 20.1 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
Important bird habitat and harvesting locations have been identified near the Project by Sahtu Dene and Métis, Pehdzéh Kį First Nation, Dehcho First Nations, and Norman Wells Renewable Resources Council (NWRRC) and Tulita Renewable Resources Council (TRRC) study participants through project-specific TLRU studies.	5658 NWT Ltd. and GNWT, 2011 (PR#16); Dehcho First Nations, 2011; Dessau, 2012 (PR#13); IMG-Golder, 2006; NWRRC, 2023; SLUPB, 2022; SLUPB, 2023; TRRC, 2022	The GNWT has reviewed and considered the bird species of importance and important habitats and harvesting areas identified by Indigenous Governments and Indigenous Organizations.	For information about bird species of interest and important wildlife habitat, see Section 20.2.2.1 (Table 20.5 and Table 20.6). See also Section 11.2.3.5 for additional information about important harvesting areas and harvested species.
Engaged Indigenous Governments, Indigenous Organizations and specific other affected parties identified bird species of importance.	Auld and Kershaw, 2005; Dehcho First Nations, 2011; IMG-Golder Corporation, 2006; McDonald, 2010; NWRC, 2023; TRRC, 2022; SRRB, 2021b, 2007; SLUPB, 2023		
Local knowledge from TRRC and NWRRC study participants identified the proposed Great Bear River Bridge area and Bluefish Creek to Sucker Creek (chain of lakes) as important migration routes and habitat for migratory birds.	NWRRC, 2023; TRRC, 2022	The GNWT has identified mitigation measures to reduce effects on birds and bird habitat. A Wildlife Management and Monitoring Plan (WMMP) will be developed and implemented. The WMMP will contain detailed monitoring and mitigation measures to be implemented for the duration of the construction and operations of the Project. The WMMP will outline how risks to migratory birds will be managed.	For information about bird species of importance and important habitat and harvesting locations, see Section 20.2.2.1. For mitigation measures to reduce effects on birds and bird habitat, see Table 20.9 Potential Effects and Mitigation Measures for Bird and Bird Habitat See also: Section 20.4.2 (Change in Habitat) Section 20.4.3 (Change in Mortality Risk) Chapter 11 (culture and traditional land use, including harvesting)
Sahtu Dene and Métis reported that Petiniɂah (Bear Rock) CZ (Zone #32) provides habitat for a variety of bird species, including nesting areas for raptors. Dehcho First Nations and Pehdzéh Kį First Nation identified the Pehdzéh Kį N'deh area[1] as important wetland habitat for waterfowl around the Wrigley area and north of Blackwater River. Dehcho First Nations and Pehdzéh Kį First Nation also identified all drainages intersecting the Project as potential waterfowl habitat.	SLUPB, 2023; Dessau, 2012 (PR#13)		

Comment	Source	GNWT Response	Where Addressed
NWRRC study participants reported that changes have been observed in bird migration and expressed concern that birds are moving in a different direction and are not observed as often in the TLRU study area as previously before.	NWRRC, 2023	*(cont'd from above)* Vegetation clearing will be done outside of the migratory bird nesting season. Wildlife monitors will assess for the presence of nesting birds on or near workspaces during project activities. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning. The GNWT will work with SRRB and other resource managers to address uncertainty regarding the effects of increased access created by the Project on harvested resources in the NWRRC and TRRC TLRU study areas. This would include monitoring of harvest that can be used to identify the need for management actions to be taken by the appropriate resource management organization.	*(cont'd from above)* Volume 5 for management plans.
NWRRC study participants communicated that birds stop along the Mackenzie Valley Winter Road (MVWR) to eat.	NWRRC, 2023		
Community engagement participants reported that protection of songbirds and their respective habitat is a priority.	November 2022 to February 2023 Engagement		

Comment	Source	GNWT Response	Where Addressed
TRRC study participants raised concerns about potential effects on waterfowl during construction and operations and maintenance along Great Bear River and explained that migration patterns have already shifted because of changing weather in the Sahtu Region.	TRRC, 2022	The proposed construction of the Great Bear River Bridge is not in the scope of the Project; however, the project WMMP will outline how risks to migratory birds will be managed during highway operations.	Chapter 5 (Project Description) Volume 5 for WMMP

Note:

[1] Pehdzéh Kį N'deh area boundary was not identified or disclosed in the report.

20.1.3 Potential Effects, Pathways and Measurable Parameters

Table 20.2 summarizes the potential effects of project activities on birds and bird habitat, the pathways by which they may affect birds and bird habitat, and the measurable parameters used for evaluating effects. Potential effects and measurable parameters were selected based on professional judgment, recent environmental assessments for road projects in NWT, and regulatory concern for certain species.

Table 20.2 Potential Effects, Effects Pathways and Measurable Parameters for Birds and Bird Habitat

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in habitat	Construction, and operations and maintenance of the Project could result in a: • Direct loss or alteration of bird habitat (e.g., vegetation clearing) • Indirect loss or alteration of bird habitat (e.g., sensory disturbance, edge effects)	• Quantitative evaluation of the amount (hectares [ha]) of habitat directly lost or altered for: – general bird habitat – species groups, including those important to Indigenous Governments, Indigenous Organizations, and other affected parties: ▪ waterbirds (e.g., waterfowl, shorebirds) ▪ upland gamebirds (e.g., grouse, ptarmigan) ▪ birds of prey (e.g., raptors, owls) ▪ landbirds (e.g., passerines) – SAR and SOCC, including: ▪ peregrine falcon (*Falco peregrinus anatum/tundrius*) ▪ yellow rail (*Coturnicops noveboracensis*) ▪ lesser yellowlegs (*Tringa flavipes*) ▪ red-necked phalarope (*Phalaropus lobatus*) ▪ short-eared owl (*Asio flammeus*) ▪ olive-sided flycatcher (*Contopus cooperi*) ▪ rusty blackbird (*Euphagus carolinus*) ▪ horned grebe (*Podiceps auritus*) • Qualitative evaluation[1] of the amount of habitat directly lost or altered for: – SAR and SOCC, including: ▪ bank swallow (*Riparia riparia*) ▪ barn swallow (*Hirundo rustica*) ▪ Harris's sparrow (*Zonotrichia querula*) • Qualitative evaluation of the amount of indirect habitat loss or altered for the bird groups and species listed

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in habitat (cont'd)		• Area (ha) of other formally defined habitat areas (e.g., Important Bird Areas [IBAs]) directly affected • Area (ha) of formally defined SAR critical habitat directly or indirectly affected, if present • Number of formally defined SAR residences (e.g., bank swallow nests) directly or indirectly affected
Change in mortality risk	Construction, and operations and maintenance of the Project could result in a: • Direct increase in mortality risk or number of bird fatalities (including nests/eggs; e.g., vegetation clearing activities, vehicular collisions, human-bird conflicts) • Indirect increase in mortality risk or number of bird fatalities (e.g., altered predator-prey dynamics, harvest pressure)	• Qualitative evaluation of direct mortality risk: – Risk of mortality due to vegetation clearing, site preparation, and maintenance – Risk of collisions with project vehicles (e.g., equipment or support vehicles) or infrastructure • Qualitative evaluation of indirect mortality risk: – Predation risk due to change in predator-prey dynamics (e.g., change in predator mobility) – Hunting pressure (e.g., year-round access or access to new areas)
Change in bird health	Construction, and operations and maintenance of the Project could expose birds to contaminants or other emissions that may affect the health and condition of birds	• Qualitative evaluation of the of effects of the Project on bird health and condition based on information provided in the air quality and surface water and sediment quality assessments

Note:

[1] Bank swallow and barn swallow inhabit specific habitat features (i.e., riverbanks and anthropogenic structures, respectively) that are not amenable to formal quantification and Harris's sparrow does not typically breed near the Project and quantification of habitat would be overstated.

20.1.4 Boundaries

20.1.4.1 Spatial Boundaries

The Project Development Area (PDA), Local Assessment Area (LAA), and Regional Assessment Area (RAA) for the assessment of effects on birds and bird habitat are shown in Figure 20.1. These spatial boundaries are used to assess project effects, including residual and cumulative effects, on birds and bird habitat.

- **Project Development Area (PDA):** the area of direct project disturbance within which physical works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 metres (m) wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sources with access roads on a 30 m ROW.
- **Local Assessment Area (LAA):** The area within which measurable project-related effects (direct or indirect) are expected to occur, which is a 1 kilometre (km) buffer around the preliminary road alignment route centerline and access roads, and a 2 km buffer around borrow source and quarry extents. The size of the buffer is based on measurable effects of noise on birds (e.g., Benitez-Lopez et al., 2010; Shannon et al., 2016) while also considering recommended setback distances for birds and bird habitat features (Appendix 20B, Table 20B.1; GNWT, 2015). The size of the LAA is also consistent with guidance provided by ECCC (Dufour, 2020, pers. comm.).
- **Regional Assessment Area (RAA):** The area that provides context for determining the significance of project-specific effects and potential cumulative effects. The RAA is the area within approximately 15 km of the PDA that is used to capture a wide range of bird species and bird habitats that could potentially be affected cumulatively by the Project and other past, present, and reasonably foreseeable projects. This RAA is consistent with other highway projects in the NWT (e.g., Inuvik to Tuktoyaktuk Highway [Kiggiak-EBA, 2011]) and follows recommendations from ECCC (Dufour, 2020, pers. comm.).

- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Local Assessment Area
- Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by DS on 8/3/2023
TR by AJ on 8/3/2023

Client/Project
144903025-0030 REVB

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
20.1

Title
Birds and Bird Habitat Assessment Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS. Imagery date: 2021

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20.1.4.2 Temporal Boundaries

The temporal boundaries for the Project consist of the following phases, which are described in more detail in Section 5.4.1:

- **Construction phase**: The Project will take approximately 10 years to construct over a timeframe of up to 20 years. The conceptual schedule assumes the highway will be constructed in three consecutive segments, beginning in approximately 2026: Wrigley north to the Dehcho–Sahtu border (102 km); Tulita south to the Dehcho–Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells sometime between 2041 and 2046.
- **Operations and maintenance phase**: The operations and maintenance phase will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the highway is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, and borrow sources and quarries used only for construction are included within the construction phase.

20.1.5 Residual Effects Characterization

Table 20.3 presents definitions for the characterization of residual effects on birds and bird habitat. Residual effects are those that remain after mitigation measures have been implemented.

Table 20.3 Characterization of Residual Effects on Birds and Bird Habitat

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse:** A residual effect that moves measurable parameters of birds and bird habitat in a negative direction relative to baseline **Neutral:** No net change in measurable parameters for birds and bird habitat relative to baseline
Likelihood	The probability that the residual effect will occur	**Unlikely:** The residual effect is almost certainly not to occur. **Possible**: The residual effect could occur. **Certain**: The residual effect will certainly occur.

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Magnitude	The amount of change in bird habitat[1]	***Change in Habitat (Direct)*** **Low:** Project changes less than 10% of general bird habitat in the LAA, or less than 5% of habitat for bird SAR and SOCC in the LAA **Moderate:** Project changes 10-20% of general bird habitat in the LAA, or 5-10% of habitat for bird SAR and SOCC in the LAA **High:** Project changes more than 20% of bird habitat in LAA, or more than 10% of habitat for bird SAR and SOCC in the LAA Effects on formally defined SAR critical habitat (if present), SAR residences, and habitat areas will be characterized based on professional judgement and potential effects on the species or habitat.
	The change in bird abundance and/or distribution	***Change in Habitat (Indirect), Mortality Risk, and Bird Health*** **Negligible:** A measurable change in the abundance of birds in the LAA is not anticipated. **Low:** A measurable change in the abundance of birds in the LAA is not anticipated, although temporary local shifts in distributions in the LAA might occur. **Moderate:** A measurable change in the abundance and/or distribution of birds in the LAA might occur. **High:** A measurable change in the abundance and/or distribution of birds may extend beyond the LAA.
Geographic Extent	The geographic area in which a residual effect occurs	**PDA:** Residual effects are restricted to the PDA. **LAA:** Residual effects extend into the LAA. **RAA:** Residual effects interact with those of other projects in the RAA.
Timing	Considers when the residual effect is expected to occur. Timing considerations are noted in the evaluation of the residual effect, where applicable or relevant	**No sensitivity:** The residual effect does not occur during critical life stage (e.g., nesting period) or timing does not affect birds and bird habitat. **Moderate sensitivity:** The residual effect may occur during a lower sensitive period of a critical life stage; for many species this is the start or end of the critical period. **High sensitivity:** The residual effect occurs during a critical life stage.
Duration	The time required until the measurable parameter or the VC returns to its existing condition, or the residual effect can no longer be measured	**Short-term:** The residual effect occurs during one segment of the construction phase, or less than 5 years. **Medium-term:** The residual effect lasts through construction (up to 20 years). **Long-term:** The residual effect extends beyond construction, or throughout operations (>20 years).

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Frequency	Identifies how often the residual effect occurs and how often during the Project or in a specific phase	**Single event:** The residual effect occurs once. **Multiple irregular event:** The residual effect occurs at no set schedule. **Multiple regular event:** The residual effect occurs at regular intervals. **Continuous:** The residual effect occurs continuously.
Reversibility	Pertains to whether a measurable parameter or the VC can return to its existing condition after the project activity ceases	**Reversible:** The residual effect is likely to be reversed after activity completion and reclamation. **Irreversible:** The residual effect is unlikely to be reversed.

Note:

[1] Based on benchmarks used for other recent environmental assessments (KHLP, 2012; Nalcor, 2012; JRP, 2014; Manitoba Hydro, 2016). The change in habitat categories for SAR and SOCC represent a cautionary approach based on species conservation status and sensitivity to incremental habitat loss.

20.1.6 Significance Definition

A significant adverse residual effect on birds and bird habitat is one that, following the application of avoidance and mitigation measures, causes or further contributes to the exceedance of a conservation-based threshold or threatens the long-term persistence or viability of SAR/SOCC, or species of cultural or traditional importance.

Specific to the assessment of potential effects of the Project on birds and bird habitat, persistence refers to the likelihood of population survival over the long term (Middleton and Nisbet 1997, EC 2011). The determination of significance considers whether habitats might be altered in such a way as to cause a change or decline in the distribution or abundance of a viable population (locally or regionally) that is dependent upon that habitat, such that the likelihood of long-term population survival is substantially reduced as a result. The determination of significance also considers whether there is a direct (e.g., collision risk) and/or indirect (e.g., increased predation pressure) increase in mortality risk such that the likelihood of persistence is substantially reduced as a result.

20.2 Existing Conditions for Birds and Bird Habitat

Residual effects (Section 20.4) are assessed relative to the existing condition for birds and bird habitat. This section provides a brief overview of the existing conditions for birds and bird habitat, including the occurrence of SAR, SOCC, and harvested species within the LAA and RAA, which are reported in the Birds and Bird Habitat TDR (K'alo-Stantec, 2023; Appendix 20A).

20.2.1 Methods

The Birds and Bird Habitat TDR (K'alo-Stantec, 2023; Appendix 20A) has been completed to address the ToR (MVEIRB, 2015) using a literature review of currently available information. The literature review incorporates relevant bird literature, Traditional Knowledge and traditional land and resource use information (K'alo-Stantec, 2023; Appendix 20A, Section 3). The TDR and supplementary 2022 Avian Survey report (K'alo-Stantec, 2022a; Appendix 20C) also contains field survey results for breeding songbirds and SAR within the LAA. The results of the literature review and field surveys are used to characterize the existing conditions for birds and bird habitat within the LAA and RAA.

20.2.2 Overview

The biophysical characteristics of the LAA are influenced by the Mackenzie River (Deh Cho), hereafter referred to as Mackenzie River Valley that defines the landscape and is dominated by coniferous forest habitats interspersed with wetlands and watercourses. The RAA has the potential to provide habitat for 213 species of bird, including 85 waterbird species, 5 upland gamebird species, 19 bird of prey species, and 104 landbird species (Smith et al. 2019, GNWT, 2020b, ECCC 2020, eBird 2021). The RAA also has the potential to provide habitat for 11 SAR/SOCC (Table 20.4; GNWT, 2020a, 2020c; Government of Canada, 2021).

Table 20.4 Bird Species at Risk and Species of Conservation Concern (*) with Potential to Occur in the Regional Assessment Area

Species		Status in NT[1]		Status in Canada[2]	
Common Name	**Scientific Name**	**SARC Assessment**	***Species at Risk (NWT) Act***	**COSEWIC**	**SARA**
Yellow rail	*Coturnicops noveboracensis*	Not Applicable	Not Applicable	Special Concern	Special Concern
Lesser yellowlegs*	*Tringa flavipes*	Not Applicable	Not Applicable	Threatened	Not Listed◊
Red-necked phalarope	*Phalaropus lobatus*	Not Applicable	Not Applicable	Special Concern	Special Concern
Short-eared owl	*Asio flammeus*	Not Assessed	No Status	Threatened	Special Concern◊
Common nighthawk	*Chordeiles minor*	Not Applicable	Not Applicable	Special Concern	Threatened◊
Olive-sided flycatcher	*Contopus cooperi*	Not Applicable	Not Applicable	Special Concern	Threatened◊
Bank swallow	*Riparia riparia*	Not Applicable	Not Applicable	Threatened	Threatened
Barn swallow	*Hirundo rustica*	Not Applicable	Not Applicable	Special Concern	Threatened◊
Harris's sparrow*	*Zonotrichia querula*	Not Applicable	Not Applicable	Special Concern	Special Concern ◊
Rusty blackbird	*Euphagus carolinus*	Not Assessed	No Status	Special Concern	Special Concern
Horned grebe	*Podiceps auritus*	Not Applicable	Not Applicable	Special Concern	Special Concern

Notes:

1 Species at risk in NWT assessed by the Species at Risk Committee (SARC) and listed under the territorial *Species at Risk (NWT) Act* (GNWT, 2022). Not applicable: *Species at Risk* (NWT) *Act* does not apply to this species (GNWT, 2022)

2 Species at risk in Canada assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and listed under Schedule 1 the federal *Species at Risk Act* (Government of Canada, 2021)

* Species of conservation concern

◊ Under consideration for Schedule 1 status change

20.2.2.1 Bird Species of Interest to Indigenous Governments, Indigenous Organizations, and Other Affected Parties

Birds of interest identified by Indigenous Governments, Indigenous Organizations, and specific other affected parties engaged on the Project, through a review of publicly available literature, and project-specific TLRU studies, are listed in Table 20.5 (Auld and Kershaw, 2005; Dehcho First Nations, 2011; IMG-Golder Corporation, 2006; McDonald, 2010; NWRC, 2023; TRRC, 2022; SRRB, 2021b, 2007; SLUPB, 2023).

Availability of birds and bird habitat is important to harvesters throughout the Dehcho and Sahtu regions. Several bird harvesting sites (Table 20.6) have been identified through the project-specific engagement program, a review of publicly available literature, and project-specific TLRU studies. Sahtu Dene and Métis and Dehcho First Nations reported 20 locations within the PDA, LAA, and RAA that are of interest relative to birds and bird habitat, as described in Table 20.6 (see Figure 11.3) (SLUPB, 2023; Dessau, 2012 [PR#13]; 5658 NWT Ltd. and GNWT, 2011 [PR#16]; Dehcho First Nations, 2011; IMG-Golder Corporation, 2006).The wildlife assessment used a habitat-based approach (see Section 20.4.1) to assess potential effects of the Project on bird SAR/SOCC including those considered to have cultural importance to Indigenous Governments and Indigenous Organizations.

Table 20.5 Culturally Important Bird Species Identified by Indigenous Governments, Indigenous Organizations, and Specific Other Affected Parties with Potential to Occur in the RAA

Common Name	Latin Name	Identified By
American widgeon	*Mareca americana*	SRRB
Arctic loon	*Gavia arctica*	SRRB
Barrows goldeneye	*Bucephala islandica*	SRRB
Black scoter	*Melanitta nigra*	SRRB
Blue-winged teal	*Anas discors*	SRRB
Brant goose	*Branta bernicla*	SRRB
Bufflehead	*Bucephala albeola*	SRRB
Canada goose	*Branta canadensis*	SRRB; NWRRC
Canvasback	*Aythya valisineria*	SRRB
Common goldeneye	*Bucephala clangula*	SRRB
Common loon	*Gavia immer*	SRRB
Common merganser	*Mergus merganser*	SRRB
Duck	Various	Dehcho First Nations; Pehdzéh Kį First Nation; Wrigley Community; TRRC; NWRRC
Goose	Various	Dehcho First Nations; Pehdzéh Kį First Nation; Wrigley Community; NWRRC

Common Name	Latin Name	Identified By
Greater scaup	*Aythya marila*	SRRB
Greater white-fronted goose	*Anser albifrans*	SRRB
Green-winged teal	*Anas crecca*	SRRB
Grouse/ptarmigan (e.g., willow ptarmigan/chicken)	Various (e.g., *Lagopus lagopus*)	Pehdzéh Kį First Nation; Wrigley Community; TRRC; NWRRC
Harlequin	*Histrionicus histronicus*	SRRB
Kingfisher	*Megaceryle alcyon*	NWRRC
Lesser scaup	*Aythya affinis*	SRRB
Northern pintail	*Anas acuta*	SRRB
Northern shoveler	*Anas clypeata*	SRRB
Oldsquaw	*Clangula hyemalis*	SRRB
Pacific loon	*Gavia pacifica*	SRRB
Red breasted merganser	*Mergus serrator*	SRRB
Red-throated loon	*Gavia stella*	SRRB
Ring-necked duck	*Aythya collaris*	SRRB
Rock ptarmigan	*Lagopus mutus*	SRRB
Ruffed grouse	*Bonasa umbellus*	SRRB
Sandhill crane	*Grus canadensis*	SRRB
Sharp-tailed grouse	*Tympanuchus phasianellus*	SRRB; NWRRC
Snow goose	*Chen caerulescens*	SRRB
Snowy owl	*Nyctea scandiacus*	SRRB
Song birds	*Oscines*	NWRRC
Spruce grouse	*Canachites canadensis*	SRRB; NWRRC
Surf scoter	*Melanitta perspicllata*	SRRB
Trumpeter swan	*Cygnus buccinator*	Pehdzéh Kį First Nation; SRRB; NWRRC
Tundra swan	*Cygnus columbianus*	Pehdzéh Kį First Nation; SRRB; NWRRC
White-winged scoter	*Melanitta fusca*	SRRB
Whiskey jack (Canada jay)	*Perisoreus canadensis*	NWRRC
Yellow-billed loon	*Gavia adamsii*	SRRB

Table 20.6 Bird Habitat and Harvesting Locations Identified by Indigenous Governments, Indigenous Organizations and Other Affected Parties Relative to the Project

Location	Within LAA	Within RAA[2]	Identified By:
Petiniɂah (Bear Rock) CZ (Zone #32) (harvesting/habitat)	✓	-	Sahtu Dene and Métis; NWRRC
Between KM 840 and KM 850 (Between Norman Wells and Tulita) (harvesting)	✓*	-	Sahtu Dene and Métis
Sahtu Region (harvesting/habitat)	✓*	✓	Sahtu Dene and Métis
Blackwater River (as it intersects with the LAA and PDA) (habitat/harvesting)	✓*	-	Dehcho First Nations; Pehdzéh Kį First Nation
Ochre River (as it intersects with the LAA and PDA) (habitat)	✓*	-	Dehcho First Nations; Pehdzéh Kį First Nation
Vermillion Creek South (harvesting)	-	✓	Dehcho First Nations; Pehdzéh Kį First Nation; NWRRC
Prohibition Creek (harvesting)	-	✓	NWRRC
Canyon Creek (harvesting)	-	✓	NWRRC
Bluefish Creek (harvesting/habitat)	-	✓	NWRRC
Sucker Creek (harvesting/habitat)	-	✓	NWRRC
Four Mile Island (harvesting)	✓	✓	Sahtu Dene and Métis
Ten Mile Island (harvesting)	-	✓	NWRRC
Four Mile Creek (harvesting)	-	✓	TRRC
Little Bear River (habitat)	-	✓	Sahtu Dene and Métis
Pehdzéh Kį N'deh area[1] (habitat/harvesting)	✓	✓	Dehcho First Nations; Pehdzéh Kį First Nation
Great Bear River (habitat/harvesting)	-	✓	Dehcho First Nations; Pehdzéh Kį First Nation; TRRC
Proposed Great Bear River Bridge (area overhead) (habitat)	✓	-	TRRC
Wrigley (area) (habitat)	✓*	-	Dehcho First Nations; Pehdzéh Kį First Nation
Tulita (area) (harvesting)	✓*	-	TRRC
Mackenzie River (habitat)	✓	✓	Dehcho First Nations; Pehdzéh Kį First Nation

Notes:

1 Pehdzéh Kį N'deh area boundary of this area was not identified or disclosed in the report

2 Occurs within the RAA outside the LAA and PDA

* May occur within PDA.

Norman Wells Renewable Resource Council TLRU study participants stated that changes have been observed in bird migration and expressed concern that birds are moving in a different direction and are not observed as much in the LAA and RAA as previously before (NWRRC, 2023). Bird habitat in the Dehcho Region portion of the LAA is dominated by coniferous forest (43.6%), wetlands (19.8%), and open water (19.3%), while the LAA that overlaps the Sahtu Region is dominated by coniferous forest (28.7%), wetlands (25.2%), and shrubland (20.6%; Table 20.7). Between 1960 and 2019, 18.5% of the LAA within the Dehcho Region and 75.2% of the LAA within the Sahtu Region has been subject to forest fire (K'alo-Stantec, 2022b; see Appendix 18A).

Other than communities, the Norman Wells Pipeline, and other developments such as borrow sources and quarries, a fibre line, and bridges associated with the MVWR, the LAA and RAA are relatively undisturbed by human activities (see Table 20.7). Oil and gas exploration and production infrastructure in the RAA occurs on the west side of, and within, the Mackenzie River Valley near Norman Wells.

Table 20.7 Land Cover Composition[1] in the LAA and RAA for the Dehcho Region and Sahtu Region

Land Cover Category	Land Cover Class[2]	Dehcho Region			Sahtu Region		
		PDA	LAA	RAA	PDA	LAA	RAA
		ha (%)	ha (%)	ha (%)	ha (%)	ha (%)	ha (%)
Upland	Broadleaf Dense	11.6 (1.4%)	1,037.4 (3.9%)	43,781.3 (12.2%)	75.1 (5.0%)	2,253.1 (5.2%)	34,259.4 (5.3%)
	Broadleaf Open	2.1 (0.3%)	114.8 (0.4%)	4,154.7 (1.2%)	27.0 (1.8%)	1,103.9 (2.3%)	14,627.9 (2.2%)
	Coniferous Dense	39.2 (4.9%)	3,374.9 (12.6%)	25,120.5 (7.0%)	18.1 (1.2%)	917.8 (1.9%)	18,580.5 (2.9%)
	Coniferous Open	98.9 (12.2%)	4,600.6 (17.2%)	40,034.2 (11.2%)	147.1 (9.8%)	6,678.1 (13.8%)	113,316.2 (17.4%)
	Coniferous Sparse	42.6 (5.3%)	3,725.0 (13.9%)	51,491.5 (14.3%)	116.2 (7.7%)	6,332.6 (13.0%)	71,845.9 (11.0%)
	Mixedwood Dense	16.6 (2.1%)	1,035.1 (3.9%)	6,786.9 (1.9%)	11.1 (0.7%)	387.3 (0.8%)	7,494.4 (1.1%)
	Mixedwood Open	1.8 (0.2%)	117.1 (0.4%)	2,728.5 (0.8%)	47.1 (3.1%)	2,514.0 (5.2%)	23,834.7 (3.7%)
	Mixedwood Sparse	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.5 (<0.1%)	6.3 (<0.1%)	11.7 (<0.1%)
	Shrub Low	4.9 (0.6%)	567.4 (2.1%)	39,005.2 (10.9%)	146.2 (9.7%)	7,903.4 (16.3%)	72,607.6 (11.1%)
	Shrub Tall	3.2 (0.4%)	320.6 (1.2%)	1,616.4 (0.5%)	49.9 (3.3%)	2,091.3 (4.3%)	16,525.8 (2.5%)
	Herbaceous	6.6 (0.8%)	50.6 (0.2%)	1,300.1 (0.3%)	12.1 (0.8%)	210.9 (0.4%)	4,093.2 (0.6%)

Land Cover Category	Land Cover Class[2]	Dehcho Region			Sahtu Region		
		PDA	LAA	RAA	PDA	LAA	RAA
		ha (%)	ha (%)	ha (%)	ha (%)	ha (%)	ha (%)
Upland (cont'd)	Bryoids	0.0 (0.0%)	7.0 (<0.1%)	20.4 (<0.1%)	0.4 (<0.1%)	6.2 (<0.1%)	137.0 (<0.1%)
	Rock/Rubble	2.1 (0.3%)	45.1 (0.2%)	4,916.4 (1.4%)	3.8 (0.3%)	107.3 (0.2%)	10,285.3 (1.6%)
	Exposed Land[3]	478.6 (59.2%)	1,338.0 (5.0%)	4,862.2 (1.4%)	626.3 (41.5%)	1,713.2 (3.5%)	9,897.9 (1.5%)
	Total	*708.3 (87.7%)*	*16,333.6 (60.9%)*	*225,848.3 (62.9%)*	*1,280.9 (85.0%)*	*32,495.5 (66.9%)*	*397,517.5 (61.0%)*
Wetland	Wetland Herbaceous	12.1 (1.5%)	856.8 (3.2%)	12,668.3 (3.5%)	52.5 (3.5%)	2,976.9 (6.1%)	44,*854*.8 (6.9%)
	Wetland Shrub	47.1 (5.8%)	2,222.9 (8.3%)	44,730.3 (12.5%)	78.3 (5.2%)	4,503.7 (9.3%)	55,*337*.6 (8.5%)
	Wetland Treed	34.5 (4.3%)	2,218.9 (8.3%)	46,859.8 (13.1%)	75.5 (5.0%)	4,771.6 (9.8%)	64,*769*.1 (9.9%)
	Total	*93.6 (11.6%)*	*5,298.5 (19.8%)*	*104,258.6 (29.0%)*	*206.3 (13.7%)*	*12,252.1 (25.2%)*	*164,961.5 (25.3%)*
Water		6.0 (0.7%)	5,187.5 (19.3%)	28,835.2 (8.0%)	20.1 (1.3%)	3,792.3 (7.8%)	89,302.6 (13.7%)
No Data		0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	163.9 (<0.1%)
TOTALS		***807.9 (100%)***	***26,819.7 (100%)***	***359,038.0 (100%)***	***1,507.3 (100%)***	***48,539.9 (100%)***	***651,945.5 (100%)***

Notes:

1 Measured in hectares (ha)

2 From Earth Observation of Sustainable Development of Forests Northwest Territories (EOSD NWT) (NRCan and GNWT, 2017; K'alo-Stantec, 2022b [Appendix 18A])

3 Exposed land includes areas which naturally have less than 5% vegetative cover, such as shorelines of rivers and lakes, exposed rock, recently burned areas, and moraines, and includes cleared areas such as the existing MVWR, Norman Wells Pipeline, and other areas of infrastructure development.

Key results and findings of the TDR (K'alo-Stantec, 2023; Appendix 20A) include:

- Many bird species are culturally important to local communities (e.g., birds of prey) and for subsistence hunting (e.g., waterbirds, upland gamebirds; e.g., Auld and Kershaw, 2005; SLUPB, 2023; SRRB, 2021; TRRC, 2022).
- The Petiniʔah (Bear Rock) CZ is a large karst formation west of Tulita that is a sacred site and subject to traditional storytelling that also provides habitat for a wide variety of wildlife species, including nesting raptors (SLUPB, 2023). The Petiniʔah (Bear Rock) has also been identified as an Important Wildlife Area (IWA) for peregrine falcon (Wilson and Haas, 2012; K'alo-Stantec, 2023; see Appendix 20A, Figure 3.6).
- The RAA is within the breeding range of 10 bird SAR and 2 bird SOCC (see Table 20.4).
- Historical records exist within the LAA and RAA for 11 of 12 SAR/SOCC (all but yellow rail) with the potential to occur in the RAA (Government of Canada, 2021; GNWT, 2020a, 2020b, 2020c; eBird, 2021; ECCC, 2020).
- The LAA is not expected to provide a notable source of habitat for bird SAR and SOCC when compared to other areas in the RAA and NWT, as these species are generally widely distributed and/or at the northern edge of their range. However, data availability is limited for some SAR.
- The LAA is partially within the Middle Mackenzie River IBA that provides a notable source of staging and migration habitat for migratory birds, especially waterfowl and other waterbird species (IBA Canada, 2020a).
- Brackett Lake IBA also provides a notable source of breeding and migration habitat for waterbird species; it is located in the RAA and outside of the LAA (IBA Canada, 2020b).
- Other sensitive features for birds such as nests, primarily for raptors, are located throughout the LAA and RAA (GNWT, 2020c).
- Notable concentrations of raptor nests exist in the Petiniʔah (Bear Rock) CZ (Zone #32), within the RAA, which is also a culturally sacred site (SLUPB, 2023; GNWT, 2020c).

20.3 Project Interactions with Birds and Bird Habitat

Anticipated interactions between project activities and birds and bird habitat leading to potential effects (Section 20.1.3) are identified in Table 20.8 with a check mark (✓). These potential interactions are discussed in detail in Section 20.5, in the context of effects pathways, standard and project-specific mitigation/enhancement, and residual effects. Justification for no effect (indicated by a dash [–]) is provided following the table.

Table 20.8 Project Interactions with Bird and Bird Habitat

Physical Activities	Timing	Environmental Effects		
		Change in Habitat	Change in Mortality Risk	Change in Bird Health
Construction Phase				
Mobilization of equipment, materials, and fuel, resupply, and demobilization	Summer and winter	✓	✓	✓
Establishment and operation of camps	Year-round	✓	✓	–
Site preparation of ROW, access, and workspaces	Winter	✓	✓	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	✓	✓	✓
Material haul	Year-round	✓	✓	✓
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓	✓	✓
Culvert installations	Summer or winter	✓	✓	✓
Road base placement, compaction, and surfacing	Summer	✓	✓	✓
Water withdrawal to support construction activities	Year-round	–	–	–
Closure and reclamation of MVWR and temporary borrow sources/quarries, camps, and workspaces	Summer	✓	✓	✓
Employment and contracted goods and services[1]	Year-round	–	–	–
Operations and Maintenance Phase				
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	✓	✓	✓
Material haul and stockpiling	Summer	✓	✓	✓
Operation of, and activities at, maintenance yards	Year-round	✓	✓	–
Water withdrawal for dust control	Summer	–	✓	–
Employment and contracted goods and services[1]	Year-round	–	–	–
Presence and public use of the highway	Year-round	✓	✓	–
Highway and access road maintenance including snow clearing, repair, grading, dust control	Year-round	✓	✓	–
Vegetation control	Summer	✓	✓	–
Bridge and culvert maintenance	As needed	✓	✓	–

Notes:

✓ Potential interaction

– No interaction

[1] Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, "Employment and contracted goods and services" have been introduced as an additional component under each project phase.

Project-related environmental effects can influence birds and bird habitat directly or indirectly and positively or negatively. A direct effect is characterized by an interaction that occurs at the same time and place and exhibits no intermediate effects (e.g., mortality resulting from vehicle collisions), whereas an indirect effect is characterized by an interaction that occurs at a later time and space because it has intermediary steps leading to the effect (e.g., project-related clearing leads to altered predator-prey dynamics; Hegmann et al., 1999). Most interactions will affect birds and bird habitat adversely, but in some cases the effects are positive for certain species or project activities (e.g., creation of edge habitats). Positive effects are described but not characterized further.

Employment and contracted goods and services activities are not expected to result in a change in habitat, mortality risk, or bird health for the lifetime of the Project as there is no pathway for these activities to interact with birds and bird habitat.

During construction, water withdrawal will only occur at authorized location, regulated to protect fish and fish habitat, and will not result in a change in habitat (i.e., changes to water levels will be protective of aquatic ecosystems; see Chapter 15 [water quantity]).

Establishment and operation of camps, water withdrawal, presence of the highway, highway and access road maintenance, vegetation control, and bridge and culvert maintenance are not anticipated to result in a change in bird health, as there are no pathways for harmful substances to enter the environment.

20.4 Assessment of Residual Effects on Birds and Bird Habitat

This section discusses the interaction pathways for the project activities identified in Table 20.8 (Section 20.3) that have the potential to affect habitat, mortality risk, or bird health, and includes analytical assessment techniques, mitigation, and residual effects.

Based on project interactions with the environment identified in Table 20.8, the Project may affect birds and bird habitat. Potential effects, effect pathways, and mitigation measures that will reduce or eliminate the effects on birds and bird habitat are identified in Table 20.9. These residual effects and associated analytical assessment techniques are described.

Table 20.9 Potential Effects and Mitigation Measures for Bird and Bird Habitat

Effect Name	Effect Pathway	Mitigation Measures
Change in Habitat	Direct and/or indirect loss or alteration of bird habitat	The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent practical.
		Clearing will be limited to areas required for construction and safe operations.
		Project vehicles will be confined to existing roads and trails to avoid disturbing vegetated areas.
		Removal of vegetation will be limited to the width of the ROW and workspaces.
		Vegetation buffers will be used as visual barriers and to protect riparian vegetation, as appropriate.
		Organic material and topsoil will be set aside for use during reclamation, where possible.
		Erosion and sedimentation control measures will be implemented per the Erosion and Sedimentation Control Plan (ESCP) and will be in place prior to construction activities and before the spring melt/freshet. Draft management plans are included in Volume 5.
		Riparian vegetation will be maintained whenever possible.
		A WMMP will be developed and implemented. The WMMP will contain detailed monitoring and mitigation measures to be implemented for the duration of the construction and operations of the Project (see Volume 5).
		Construction and quarry development activities will adhere to the applicable recommended setbacks and timing restrictions for wildlife outlined in the WMMP, where possible.
		Wildlife monitors will assess for the presence of nesting birds on or near workspaces during project activities.
		The WMMP will outline how risks to migratory birds will be managed in accordance with ECCC's Guidelines to Reduce Risk to Migratory Birds (ECCC, 2021) if activities that could result in risk of harm cannot be avoided (e.g., pre-clearing nest surveys).
		The WMMP will be complied with in relation to species of birds not under GNWT's authority in addition to species under GNWT's authority.

Effect Name	Effect Pathway	Mitigation Measures
Change in Habitat (cont'd)		Vegetation clearing will be completed outside the migratory bird nesting period, which extends from May 1 to August 31. This considers Nesting Zone B8 (May 4 to August 22 for Zone B8; ECCC, 2018) and potential species at risk. Vegetation clearing will also consider the Critical Breeding Periods for Raptor Species of the Northwest Territories (Shank and Poole, 2016) to avoid disturbing species that breed prior to the migratory bird nesting period.
		If an active bird nest is found, beneficial management practices (GNWT, 2020d) will be followed, including applying an appropriate setback and timing restriction and the GNWT-ECC and/or ECCC will be consulted, as appropriate.
		Project staff will take the GNWT's Migratory Bird Awareness Training Webinar and obtain a certificate to demonstrate proof of training.
		Personnel will undergo a wildlife awareness program, which will include prevention measures for wildlife mortality (e.g., bear safety) and reporting procedures for wildlife-related incidents and protocols to follow when a nest, den, or wildlife species of management concern is observed. This includes completing wildlife sighting and wildlife incident report forms included in the WMMP.
		Closure and reclamation will promote re-establishment of vegetation.
		Site grading at closure will approximate pre-development conditions.
		Borrow source vegetated surface material, where present, will be replaced after development is completed.
		A dust control program using water will be implemented during construction and operations and maintenance.
		Vehicle speeds will be limited to 50 km/h on unfinished project road surfaces.
		The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent practical.
		Vegetation clearing will be completed outside the migratory bird nesting period, which extends from May 1 to August 31. This considers Nesting Zone B8 (May 4 to August 22 for Zone B8; ECCC, 2018) and potential species at risk. Vegetation clearing will also consider the Critical Breeding Periods for Raptor Species of the Northwest Territories (Shank and Poole, 2016) to avoid disturbing species that breed prior to the migratory bird nesting period.

Effect Name	Effect Pathway	Mitigation Measures
Change in Mortality Risk		The WMMP will outline how risks to migratory birds will be managed in accordance with ECCC's Guidelines to Reduce Risk to Migratory Birds (ECCC, 2021) if activities that could result in risk of harm cannot be avoided (e.g., pre-clearing nest surveys).
		The WMMP will be complied with in relation to species of birds not under GNWT's authority in addition to species under GNWT's authority.
		If an active bird nest is found, beneficial management practices (GNWT, 2020d) will be followed, including applying an appropriate setback and timing restriction and the GNWT-ECC and/or ECCC will be consulted, as appropriate.
		Wildlife monitors will assess for the presence of nesting birds on or near workspaces during project activities.
		Project staff will take the GNWT's Migratory Bird Awareness Training Webinar and obtain a certificate to demonstrate proof of training.
		Personnel will undergo a wildlife awareness program which will include prevention measures for wildlife mortality (e.g., bear safety) and reporting procedures for wildlife-related incidents and protocols to follow when a nest, den, or wildlife species of management concern is observed. This includes completing wildlife sighting and wildlife incident report forms included in the WMMP.
		Personnel will not feed or harass wildlife while working on the Project.
		Project personnel will be prohibited from hunting and fishing while housed in work camps for the Project.
		Construction and quarry development activities will be limited during sensitive periods for wildlife in accordance with the WMMP.
		Food and other wildlife attractants will be stored in bear-proof containers.
		Crews will be trained on wildlife awareness.
		Food waste will be stored and disposed of in a manner to avoid attracting wildlife.
		Equipment, wastes, and contaminated soils will be removed once construction is completed.
		The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent practical.
		Clearing will be limited to areas required for construction and safe operations.

Effect Name	Effect Pathway	Mitigation Measures
Change in Mortality Risk (cont'd)		A buffer strip of undisturbed vegetation of at least 30 m wide will be maintained between the highway ROW and other new areas to be cleared.
		Vegetation buffers will be used as visual barriers and to protect riparian vegetation, as appropriate.
		Speed limits will be posted on the public highway.
		The Spill Contingency Plan (SCP) will include procedures to prevent and respond to spills.
		Areas and containers used to store project wastes will be constructed, operated, and maintained in a manner to prevent waste from discharging to the surrounding environment.
Change in Bird Health	Construction, operations and maintenance could expose wildlife to contaminants or other emissions that may affect the health and condition of birds	Maintenance yards will have a liner or concrete installed under areas of vehicle storage and maintenance.
		Vehicles parked for more than 2 hours will use drip trays.
		A minimum of 10 centimetres (cm) of packed snow or ice will be used on winter access roads.
		Construction equipment will travel on designated winter roads or constructed embankment only.
		Clearing of new areas will be completed when the ground is frozen to reduce disturbance to soils and permafrost
		Placement of embankment will occur primarily during winter (December 15 to April 1), during frozen conditions. If work is to be completed under non-frozen conditions, equipment will be equipped with mushroom shoes.
		Borrow source floors will be sloped to reduce ponding of water.
		Travel of vehicles will be confined to existing infrastructure roads and trails as much as possible to avoid disturbing vegetated areas.
		A project-specific ESCP will be developed and implemented.
		Sediment and erosion control measures will be regularly inspected to confirm they are performing as intended.
		Ponded water will be directed away from watercourses.
		Only material with low acid rock drainage and metal leaching potential will be used for the Project.
		Rip rap will be free of silt and other debris.
		Sediment control measures will be in place prior to construction activities and before the spring melt/freshet.
		Riparian vegetation will be maintained whenever possible.
		Excavated spoil material will be placed at least 30 m from the watercourse.

Effect Name	Effect Pathway	Mitigation Measures
Change in Bird Health (cont'd)		Snow fill temporary crossings will be constructed of clean snow fill.
		Vegetation buffers will be used as visual barriers and to protect riparian vegetation, as appropriate.
		Machinery onsite will be in a clean condition and free of invasive alien plant species.
		Washing, refueling, and servicing machinery and storage of fuel and other materials for machinery will be conducted a minimum of 100 m from the high-water mark and in a manner to prevent any deleterious substances from entering the water.
		Machinery will not be left in any waterbody.
		Quarry operations will be located a minimum of 100 m from the ordinary high-water mark of any waterbody.
		Blast rock will not enter a waterbody or watercourse.
		Material stockpiles will be kept a minimum of 30 m from a watercourse or waterbody with the appropriate erosion control mitigation in place to prevent sediment from entering a watercourse or waterbody.
		Equipment will be maintained in good working order.
		Blast mats will be used when blasting near receptors sensitive to noise.
		A dust control program using water will be implemented during construction, operations and maintenance.
		Vehicle speeds will be limited to 50 km/h on unfinished project road surfaces.
		Incinerators will be operated in accordance with manufacturer's specifications and emissions will meet Canadian Council of Ministers of the Environment Canada Wide Standards for Dioxins & Furans and Mercury.
		Equipment, wastes, and contaminated soils will be removed once construction is completed.

20.4.1 Analytical Assessment Techniques

The general approach to assessing potential effects on birds and bird habitat follows the sequence and methods outlined in Chapter 4 - Assessment Methods. Analytical assessment techniques specific to each potential effect are described.

20.4.1.1 Change in Habitat

Change in habitat was assessed by comparing direct and indirect changes in habitat availability from baseline conditions to the residual condition in the LAA, including for key bird species (Table 20.2) and for each project phase (i.e., construction, and operations and maintenance).

Direct change in habitat (e.g., vegetation clearing) was calculated as the loss of habitat that is no longer available to birds resulting from the PDA; effects do not extend into the LAA. In general, once vegetation clearing is completed during the construction component, the PDA will provide no suitable bird habitat, except for a few species that may take advantage of developed sites (e.g., barn swallow). Portions of the PDA will be reclaimed after construction and 9 of 15 quarries/borrow sources will continue to be used during operations and maintenance but may provide altered habitats for some wildlife species. Land cover classes considered as habitat for each bird species or species group are summarized in Table 20.10 and were established using relevant scientific literature, life history information, and professional judgment.

Indirect change in habitat (e.g., sensory disturbance) was assessed qualitatively as the area of reduced habitat effectiveness; effects are confined to the LAA.

Land cover classes were quantified using EOSD NWT geospatial data (NRCan and GNWT, 2017). This dataset is part of the Multi-source Vegetation Inventory Project (NRCan, 2020) and uses an unsupervised classification and cluster analysis to classify land cover. The dataset includes cover type and density classes and forest structure height and volume information based on Landsat imagery collected from 2007 to 2013. Mapping was done at a scale of 1:250,000 and was refined through field evaluation by the GNWT (NRCan and GNWT, 2017). Detailed land cover classification methods for this Project are in the Vegetation and Wetlands TDR (K'alo-Stantec, 2022b; Appendix 18A).

Table 20.10 Land Cover Classes used to Quantify Breeding Habitat by Species/Species Groups

Land Cover Category	Land Cover Class[1]	All Bird Habitats	Waterbirds[2]	Birds of Prey[3]	Landbirds[4]	Peregrine Falcon[5]	Yellow Rail[6]	Lesser Yellowlegs[7]	Red-necked Phalarope[8]	Short-eared Owl[9]	Common Nighthawk[10]	Olive-sided Flycatcher[11]	Rusty Blackbird[12]	Horned Grebe[13]
Upland	Broadleaf Dense	✓	–	✓	✓	✓	–	–	–	–	✓	✓	–	–
	Broadleaf Open	✓	–	✓	✓	✓	–	–	–	–	✓	✓	–	–
	Broadleaf Sparse	✓	–	–	✓	✓	–	–	–	–	✓	✓	–	–
	Coniferous Dense	✓	–	✓	✓	✓	–	–	–	–	✓	✓	✓	–
	Coniferous Open	✓	–	✓	✓	✓	–	–	–	–	✓	✓	✓	–
	Coniferous Sparse	✓	–	–	✓	✓	–	–	–	–	✓	✓	✓	–
	Mixedwood Dense	✓	–	✓	✓	✓	–	–	–	–	✓	✓	✓	–
	Mixedwood Open	✓	–	✓	✓	✓	–	–	–	–	✓	✓	✓	–
	Mixedwood Sparse	✓	–	–	✓	✓	–	–	–	–	✓	✓	✓	–
	Shrub Low	✓	–	–	✓	✓	–	–	–	–	✓	–	–	–
	Shrub Tall	✓	–	–	✓	✓	–	–	–	–	✓	–	–	–
	Herbaceous	✓	–	–	✓	✓	–	–	–	✓	–	–	–	–
	Bryoids	✓	–	–	✓	✓	–	–	–	✓	✓	–	–	–
	Rock/ Rubble	✓	–	–	✓	✓	–	–	–	–	✓	✓	–	–
	Exposed Land	✓	–	–	✓	✓	–	–	–	–	✓	✓	–	–

Land Cover Category	Land Cover Class[1]	All Bird Habitats	Waterbirds[2]	Birds of Prey[3]	Landbirds[4]	Peregrine Falcon[5]	Yellow Rail[6]	Lesser Yellowlegs[7]	Red-necked Phalarope[8]	Short-eared Owl[9]	Common Nighthawk[10]	Olive-sided Flycatcher[11]	Rusty Blackbird[12]	Horned Grebe[13]
Wetland	Wetland Herbaceous	✓	✓	–	✓	–	✓	✓	✓	–	–	–	–	–
	Wetland Shrub	✓	✓	–	✓	–	–	✓	✓	–	–	–	✓	–
	Wetland Treed	✓	✓	–	✓	–	–	✓	✓	–	–	✓	✓	–
Water		✓	✓	–	–	–	–	✓	✓	–	–	–	–	✓

Notes:

✓ Land cover class considered habitat for each species/species group

– Land cover class not considered habitat for each species/species group

1 From EOSD NWT (NRCan and GNWT, 2017; K'alo-Stantec, 2022b [Appendix 18A])

2 Wetland land cover classes limited to within 50 m of open water

3 Upland land cover classes limited to within 100 m of rivers or lakes (open water ≥ 10 ha) and cliff areas (> 30 degrees)

4 Landbirds includes upland gamebird species

5 Upland land cover classes limited to cliff areas (> 30 degrees)

6 Wetland land cover classes limited to those ≥ 10 ha

7 Includes all wetland shrub, wetland treed, and water (excluding rivers) land cover classes and wetland herbaceous within 50 m of other wetland/water classes

8 Wetland land cover classes limited to within 50 m of open water (excluding rivers)

9 Upland land cover classes limited to patches ≥50 ha

10 Includes all sparse forest classes and all other forest land cover classes burned within the past 20 years

11 Includes all open and sparse coniferous and mixedwood forest land cover classes and remaining forest classes burned within the past 20 years or within 20 m of rock/rubble, exposed land, and water

12 Upland land cover classes limited to those within 50 m of water

13 Waterbodies ≤ 10 ha in size (excluding rivers)

20.4.1.2 Change in Mortality Risk and Bird Health

The remaining effects were assessed qualitatively through evaluating the relative change in direct and indirect sources of mortality (e.g., vehicle collisions, increased hunting pressure) and bird health (e.g., contamination) compared to the existing condition. The qualitative assessment included a combination of literature review and professional judgment to predict effects on birds and bird habitat.

20.4.1.3 Assumptions and the Conservative Approach

A conservative approach is used to address uncertainty in the effects assessment, which increases confidence in the final determination of significance. The assessment used a habitat-based approach, which focuses on identifying the quantity and composition of land cover types (i.e., habitats) affected by the Project relative to the availability of those habitats in the LAA and RAA. This approach is considered conservative as it assumes that bird species are present if the habitat is available, which is not always the case (e.g., some birds may not be present in a habitat recently affected by fire until the habitat returns to its pre-fire state following the vegetation successional process that requires several years).

Additionally, land cover classes that represent disturbed lands (i.e., exposed land) are included in the quantification of direct habitat loss, despite providing limited value for most bird species, and comprises 47.8% (1,104.91 ha) of the PDA. The PDA is conservatively assumed to be lost to wildlife, however, there are portions that are already disturbed (i.e., MVWR) and portions that will be reclaimed, which will provide habitat for some species that use disturbed sites. The prediction confidence of the assessment for birds and bird habitat (Section 20.7) incorporates these assumptions.

20.4.2 Change in Habitat

20.4.2.1 Effects Pathways

20.4.2.1.1 Construction

During construction, removal of upland and wetland vegetation has potential to result in direct loss or alteration of upland and wetland habitat in the PDA due to establishment and operation of camps; clearing of the ROW, access, and workspaces; borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling; embankment and borrow source/quarry access road construction, including road cuts; and culvert installations (Table 20.9). An indirect loss or alteration of habitat adjacent to the PDA is also possible through sensory disturbance (e.g., noise, light) and potential edge effects and fragmentation created by vegetation clearing (from the construction activities in the PDA listed). Vegetation clearing will result in an indirect alteration of habitats adjacent to the PDA by creating an unnatural transition (i.e., edge effects) between the PDA and adjacent habitat. Edge effects can include changes in microclimate

(e.g., Murcia, 1995) and vegetation structure (e.g., Harper et al., 2005) which can in turn result in changes in the bird community in those habitats.

Project-related sensory disturbance (i.e., noise and light) from most construction activities (e.g., heavy equipment operation, infrastructure construction, increased traffic volumes) has the potential to disturb birds and change the use of habitat around the site or road (e.g., habitat avoidance, fine-scale changes in individuals' movement and associated energetic costs). Dust deposition associated with project construction can affect vegetation composition adjacent to the PDA (e.g., Gill and Lantz, 2014) which may alter habitat use by birds. Indirect loss or alteration of habitat creates an area adjacent to the PDA that exhibits some degree of reduced ecological effectiveness, compared to the existing condition, that typically varies by effect pathway and bird species.

During construction, the PDA will provide limited bird habitat but there may be species that opportunistically exploit altered habitats (e.g., barn swallow).

20.4.2.1.2 Operations and Maintenance

Operations and maintenance of the Project will not result in the direct loss or alteration of habitat for birds and some disturbed habitats may become habitat for birds following reclamation and natural succession. However, an indirect loss or alteration of habitat is likely to occur adjacent to the PDA due to, sensory distance and dust deposition and presence of the highway (i.e., continuation of edge effects) (Table 20.9). Vegetation control within the ROW (i.e., ditches) will occur approximately every three years and will involve mowing dense shrub growth, which could remove habitat for some bird species; but may still provide potential nesting and/or foraging habitat for bird species known to use roadside habitats (e.g., killdeer [*Charadrius vociferus*]) (Abrahams et al. 2010).

Sensory disturbance and dust deposition associated with activities during the operations and maintenance phase of the Project (i.e., borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling; material haul and stockpiling; operation of, and activities at, maintenance camps; presence of the highway; highway and access road maintenance; vegetation control; and bridge and culvert maintenance) have the potential to result in reduced ecological effectiveness of habitats adjacent to the PDA, as described for the construction phase. The presence of the highway will lead to traffic and associated effect pathways (i.e., sensory disturbance and dust deposition). These indirect effects are assessed and have the potential to result in a change in habitat and alter bird movements (i.e., avoidance). Additionally, presence of the highway will maintain fragmentation and edge effects over the long term that were established during the construction phase and while over time these effects may be ameliorated as shrubs soften the edges, these habitats may experience reduced ecological effectiveness or be avoided by some species.

20.4.2.2 Mitigation

As discussed in Chapter 5, project routing and design have integrated the existing MVWR ROW to the extent practicable, which will reduce change in habitat. In addition to a project-specific WMMP that will be implemented during the construction and operations and maintenance phases, standard industry practices and mitigation measures will also be implemented and are presented in Table 20.9. Key mitigation measures to avoid or reduce changes in habitat include:

- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent practical.
- Vegetation clearing will be completed outside the migratory bird nesting period, which extends from May 1 to August 31. This considers Nesting Zone B8 (May 4 to August 22 for Zone B8; ECCC, 2018) and potential species at risk. Vegetation clearing will also consider the Critical Breeding Periods for Raptor Species of the Northwest Territories (Shank and Poole, 2016) to avoid disturbing species that breed prior to the migratory bird nesting period.
- The WMMP will be complied with in relation to species of birds not under GNWT's authority in addition to species under GNWT's authority.
- If an active bird nest is found, beneficial management practices (GNWT, 2020d) will be followed, including applying an appropriate setback and timing restriction and the GNWT-ECC and/or ECCC will be consulted, as appropriate.
- Project staff will take the GNWT's Migratory Bird Awareness Training Webinar and obtain a certificate to demonstrate proof of training.
- Wildlife monitors will assess for the presence of nesting birds on or near the PDA during project activities.
- Personnel will undergo a wildlife awareness program, which will include prevention measures for wildlife mortality (e.g., bear safety) and reporting procedures for wildlife-related incidents and protocols to follow when a nest, den, or wildlife species of management concern is observed. This includes completing wildlife sighting and wildlife incident report forms included in the WMMP.
- Closure and reclamation will promote re-establishment of vegetation.
- Borrow source vegetated surface material, where present, will be replaced after development is completed.

20.4.2.3 Residual Effects

20.4.2.3.1 Construction

The project highway alignment routing has considered reducing the amount of new ROW required by primarily widening the existing MVWR ROW (from 30 m to 60 m) where feasible, and the creation of new ROW that is limited to specific areas to avoid sensitive areas and wetlands, reduce slopes and/or sharp curves to accommodate higher traffic speeds, and increase safety on the highway. Construction of the Project will result in the direct loss of 2,315.2 ha of potential bird habitat within the LAA (Table 20.11), a 3.1% decrease in habitat from existing conditions. However, 47.8% (1,104.9 ha) of this direct loss is exposed land that is subject to existing anthropogenic disturbances (i.e., existing MVWR and quarries), which provide limited suitability for most bird species. In other words, construction of the Project will result in the direct loss of 1,210.3 ha of natural land cover within the LAA, a 2.1% decrease from existing conditions.

Development of the PDA, including vegetation clearing, will result in a direct loss or alteration of 1,989.2 ha of upland terrestrial habitats (including 1,104.9 ha of exposed land) and 300.0 ha of wetland habitats within the LAA (see Table 18.4). The Project will remove terrestrial, and to a lesser extent wetland, habitats for birds. However, widening the existing MVWR for most of the Project's length will limit direct habitat loss, most of which is already subject to indirect habitat alteration due to the MVWR. Species most likely to be affected by a direct loss of habitat are those that inhabit forested and shrub habitats, such as upland gamebirds (e.g., spruce grouse [*Canachites canadensis*]), which are also important to current land and resources users for traditional purposes (Auld and Kershaw, 2005; SLUPB, 2023; SRRB, 2021). Species that nest on disturbed sites (e.g., common nighthawk [*Chordeiles minor*]) or on anthropogenic sites (e.g., barn swallow) are also most likely to be affected by a direct loss of habitat. Effects on species groups (i.e., waterbirds, upland gamebirds, birds of prey, landbirds) and SAR/SOCC are described in greater detail in their respective subsections.

Closure and reclamation of MVWR and temporary borrow sources/quarries, camps, and workspaces are expected to recover over time due to natural revegetation or reclamation activities designed to promote vegetation communities (see Chapter 18 Vegetation and Wetlands). The recovery of vegetation communities will provide potential habitat for a variety bird species depending on site conditions, successional stage, and species-specific habitat associations (van Rensen et al. 2015, Wilson and Bayne 2019).

Construction of the Project will result in the direct loss of 884.3 ha of the Middle Mackenzie River Islands IBA within the LAA, a 3.1% decrease from existing conditions (see Waterbirds subsection for additional detail; Appendix 20A, Figure 3.6; K'alo-Stantec, 2023). The Bracket Lake IBA is outside of the LAA and not anticipated to interact with the Project.

Construction of the Project will result in the direct loss of 136.4 ha of the Petiniʔah (Bear Rock) CZ (Zone #32) within the LAA, a 4.3% decrease from existing conditions (see Birds of Prey subsection for additional detail; Appendix 20A, Figure 3.6; K'alo-Stantec, 2023).

There is no formally defined SAR critical habitat that will be directly or indirectly affected by construction of the Project. There are no formally defined SAR residences that will be directly or indirectly affected by construction of the Project.

Table 20.11 Residual Change in Habitat in the LAA

Land Cover Category	Land Cover Class[1]	Existing Condition (ha)			Residual Condition (ha / % change)		
		Dehcho Region	Sahtu Region	Total	Dehcho Region	Sahtu Region	Total
Upland	Broadleaf Dense	1,037.4	2,523.1	3,560.6	1,025.8 (-1.1%)	2,448.0 (-3.0%)	3,473.9 (-2.4%)
	Broadleaf Open	114.8	1,103.9	1,218.7	112.7 (-1.8%)	1,076.9 (-2.4%)	1,189.6 (-2.4%)
	Coniferous Dense	3,374.9	917.8	4,292.6	3,335.7 (-1.2%)	899.7 (-2.0%)	4,235.3 (-1.3%)
	Coniferous Open	4,600.6	6,678.1	11,278.6	4,501.7 (-2.1%)	6,531 (-2.2%)	11,032.6 (-2.2%)
	Coniferous Sparse	3,725.0	6,332.6	10,057.7	3,682.4 (-1.1%)	6,216.4 (-1.8%)	9,898.9 (-1.6%)
	Mixedwood Dense	1,035.1	387.3	1,422.4	1,018.5 (-1.6%)	376.2 (-2.9%)	1,394.6 (-2.0%)
	Mixedwood Open	117.1	2,514	2,631.1	115.3 (-1.6%)	2,466.9 (-1.9%)	2,582.2 (-1.9%)
	Mixedwood Sparse	0.0	6.3	6.3	0.0 (0.0%)	5.8 (-8.2%)	5.8 (-8.2%)
	Shrub Low	567.4	7,903.4	8,470.9	562.5 (-0.9%)	7,757.2 (-1.8%)	8,319.9 (-1.8%)
	Shrub Tall	320.6	2,091.3	2,411.9	317.4 (-1.0%)	2,041.4 (-2.4%)	2,358.8 (-2.2%)
	Herbaceous	50.6	210.9	261.5	44.0 (-13.1%)	198.8 (-5.7%)	242.8 (-7.2%)
	Bryoids	7.0	6.2	13.2	7.0 (<0.1%)	5.8 (-6.3%)	12.8 (-3%)
	Rock/Rubble	45.1	107.3	152.4	43 (-4.6%)	103.5 (-3.6%)	146.5 (-3.9%)
	Exposed Land[3]	1,338.0	1,713.2	3,051.2	859.4 (-35.8%)	1,086.9 (-36.6%)	1,946.3 (-36.2%)
	Total	*16,333.6*	*32,495.4*	*48,829.1*	*15,625.3 (-4.3%)*	*31,241.5 (-3.9%)*	*46,839.9 (-4.1%)*

Land Cover Category	Land Cover Class[1]	Existing Condition (ha)			Residual Condition (ha / % change)		
		Dehcho Region	Sahtu Region	Total	Dehcho Region	Sahtu Region	Total
Wetland	Wetland Herbaceous	856.8	2,976.9	3,833.6	844.7 (-1.4%)	2,924.4 (-1.8%)	3,769.0 (-1.7%)
	Wetland Shrub	2,222.9	4,503.7	6,726.6	2,175.8 (-2.1%)	4,425.4 (-1.7%)	6,601.2 (-1.9%)
	Wetland Treed	2,218.9	4,771.6	6,990.4	2,184.4 (-1.6%)	4,696.1 (-1.6%)	6,880.5 (-1.6%)
	Total	*5,298.6*	*12,252.2*	*17,550.6*	5,205.0 (-1.8%)	12,045.9 (-1.7%)	17,250.6 (-1.7%)
Water[2]		5,187.5	3,792.3	8,979.8	5,181.5 (-0.1%)	3,772.2 (-0.5%)	8,953.7 (-0.3%)
PDA		807.9	1,507.3	2,315.2	807.9 (100%)	1,507.3 (100%)	2,315.2 (100%)

Notes:

1 From EOSD NWT (NRCan and GNWT, 2017; K'alo-Stantec, 2022b [Appendix 18A])

2 Development of the PDA is not anticipated to result in the direct loss of open water habitats and the residual condition is an artifact of the resolution of the land cover classification.

3 Exposed land includes areas which naturally have less than 5% vegetative cover, such as shorelines of rivers and lakes, exposed rock, recently burned areas, and moraines, and includes cleared areas such as the existing MVWR, Norman Wells Pipeline, and other areas of infrastructure development.

An indirect loss or alteration of bird habitat is expected through sensory disturbance (i.e., noise and artificial light), dust deposition, edge effects, and fragmentation that can result in habitat avoidance and reduced habitat effectiveness for birds, including SAR, in areas adjacent to the PDA.

Sensory disturbance emitted during construction will not occur along the entire length of the Project, and instead will occur in smaller segments staggered over a period of several years and the conceptual schedule (see Sections 20.1.4.2 and 5.4.1) assumes the alignment will be constructed in three segments: Wrigley to the Dehcho/Sahtu border (102 km); Tulita south to the Dehcho/Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (45 km).

Noise-related effects on some bird species have been reported to occur when noise levels exceed 40 A-weighted decibels (dBA), which may result in avoidance and other behavioural changes (e.g., altered song characteristics of songbirds), and population or physiological consequences (e.g., altered species abundance and/or richness, stress) to birds have been identified ≥ 45 dBA (Shannon et al., 2016). Baseline noise in the region that was assessed in remote areas without any development or winter traffic has been estimated at 35 and 32 dBA during the day and night, respectively (IOL, 2004; Chapter 13, Section 13.2.2). The distance at which the noise associated with construction activities is expected to attenuate to 40 dBA is 2.0 km for road construction

activities and 2.5 km for quarry and borrow source activities (see Section 13.4.2). However, measurable effects on birds outside of the LAA are unlikely and the LAA will continue to support birds throughout all seasons. Sensory disturbances emitted during construction will also cease following the conclusion of construction activities in a particular segment.

Dust deposition resulting from construction of the Project has the potential to alter wildlife habitat adjacent to the PDA. Effects of dust deposition on vegetation are likely to be limited to within 40 m of the PDA (see Section 18.4 of the Developer's Assessment Report; Meininger and Spatt, 1988; Gleason et al., 2007).

Edge effects and fragmentation will result from vegetation clearing activities, particularly where the PDA intersects forested habitats of the LAA. However, the existing MWVR and other exposed lands (e.g., quarries) have already created edge effects and the Project will contribute a minor additive increase because a large proportion of the PDA, as based on the current preliminary alignment routing, incorporates these previously disturbed lands. Project routing that predominantly follows the MVWR has also reduced the potential for adverse effects on birds and bird habitat resulting from habitat fragmentation, and core areas of large habitat patches will continue to be available in the LAA.

Indirect effects associated with edge effects and fragmentation have primarily been mitigated as based on the current preliminary alignment routing that largely follows the existing MVWR, where the LAA is already subject to these disturbances that have resulted in reduced ecological effectiveness and avoidance by most bird species. Construction of the Project is anticipated to exacerbate habitat alteration within the LAA by increasing the amount and duration (i.e., year-round at times) of these indirect effects.

20.4.2.3.1.1 Waterbirds

Project routing avoids wetland habitats where possible, mitigating direct and indirect habitat loss and alteration for waterbirds. Construction of the Project will result in the direct loss of 37.4 ha of waterbird habitat within the LAA, a 0.3% decrease from existing conditions (Table 20.12). Waterbird habitat includes open water and wetland land cover classes within 50 m of open water (Table 20.10) that support birds throughout the year, including during the breeding and migration seasons.

Direct and indirect habitat loss or alteration is most likely to affect breeding waterbird species commonly found within the LAA, such as common loon (*Gavia immer*), lesser scaup (*Aythya affinis*), and Canada goose (*Branta canadensis*; Appendix 20A, Section 3.2.2.2; K'alo-Stantec, 2023). Construction of the Project will result in the direct loss of 884.3 ha of the Middle Mackenzie River Islands IBA, a 3.1% decrease from existing conditions. While the PDA will remove upland habitats within the Middle Mackenzie River Islands IBA, it has been primarily established to support migrating waterbirds (IBA Canada, 2020a) and the breeding habitats within it will remain physically undisturbed by the Project (i.e., the Mackenzie River). However, construction will result in an increase in sensory disturbance. The PDA generally remains > 800 m from the Mackenzie River shoreline and breeding waterbirds most likely to be affected are those in smaller wetlands

adjacent to the PDA. The Brackett Lake IBA is outside of the LAA and while the Project will not interact with the IBA, it does provide a notable breeding area for waterbirds within the RAA (IBA Canada, 2021b).

Important migratory stopover sites within the LAA are limited to the Middle Mackenzie River Islands IBA, which supports large numbers of waterfowl species each year, including greater white-fronted goose (*Anser albifrons*), Canada goose, tundra swan (*Cygnus columbianus*), and snow goose (*Anser caerulescens*; Appendix 20A, Section 3.2.2.2; K'alo-Stantec, 2023) that are important to current land and resources users for traditional purposes (Auld and Kershaw, 2005; SLUPB, 2023; SRRB, 2021).

Construction of the Project will not result in the direct loss or alteration of aquatic habitats that support migrating waterbirds within the IBA (i.e., the Mackenzie River); however, construction will result in an increase in sensory disturbance in localized areas that are associated with construction activities. For example, while most of the PDA is contained within the IBA (i.e., within 5 km), most of the PDA follows the existing MVWR and/or remains > 800 m from the Mackenzie River shoreline. Migrating waterbirds are unlikely to use the smaller wetlands adjacent to the PDA as stopover sites in the same capacity as the IBA, and construction of the Project is unlikely to result in a notable indirect loss or alteration of waterbird migration habitat in the LAA.

In general, research has shown that effects of anthropogenic disturbance on the breeding success of waterfowl ranges from a positive (Roy, 2018; Skaggs et al., 2020) to neutral or weak adverse relationship (e.g., Kemkin et al., 2019; Singer et al., 2020). This is consistent with a broader examination of literature that have found similar relationships between roads and birds (e.g., Fahrig and Rytwinski, 2009; Morelli et al., 2014). While the relationship is not consistently adverse, the addition of noise is a change from the existing condition and considered an adverse effect.

Other effect pathways, including dust deposition, edge effects, and fragmentation, have the potential to reduce habitat availability for waterbirds, as described, but effects will be greatest where the PDA is constructed immediately adjacent to wetland and water land cover classes. Ultimately, the indirect loss or alteration of breeding waterbird habitat during construction is anticipated to result in an area of reduced ecological effectiveness adjacent to the PDA, although for breeding waterfowl it may not extend far into the LAA.

Overall, the direct and indirect habitat loss or alteration of waterbird habitat due to the Project is relatively small and are unlikely to result in a measurable change in the abundance of breeding and migrating waterbirds in the LAA (Table 20.13).

20.4.2.3.1.2 Upland Gamebirds

Construction of the Project will result in the direct loss of 2,289.2 ha of the upland gamebird habitat, a 3.5% decrease from existing conditions (Table 20.12). Upland gamebird habitat includes all upland and wetland (i.e., used for foraging) cover classes that support birds throughout the year (Table 20.10). Upland gamebird species are important to current land and resources users for traditional purposes (Auld and Kershaw, 2005; SLUPB, 2023; SRRB, 2021).

Direct and indirect habitat loss or alteration is most likely to affect breeding ruffed grouse (*Bonasa umbellus*) and spruce grouse (*Canachites canadensis*) that are common and abundant within the LAA, and to a lesser extent sharp-tailed grouse (*Tympanuchus phasianellus*), which are uncommon (Appendix 20A, Section 3.2.2.3; K'alo-Stantec, 2023). There are no documented sharp-tailed grouse leks (traditional mating grounds) within the RAA. Willow ptarmigan (*Lagopus lagopus*) and rock ptarmigan (*Lagopus muta*) breed in more northern latitudes and move into the RAA during the non-breeding season, and construction of the Project is unlikely to affect breeding habitat for these species.

Indirect loss or alteration of habitat outside of the breeding season will affect all upland gamebird species; however, this is a less sensitive period of the year for birds and habitat in the LAA remains abundant. Other effect pathways, including dust deposition, edge effects, and fragmentation, have the potential to reduce habitat availability for upland game birds as described, but effects will be greatest where the PDA is constructed immediately adjacent to wetland and water land cover classes.

20.4.2.3.1.3 Birds of Prey

Construction of the Project will result in the direct loss of 50.7 ha of the habitat for birds of prey, a 1.2% decrease from existing conditions (Table 20.12). Habitat for birds of prey includes all upland cover classes within 100 m of rivers or lakes (open water ≥ 10 ha) and cliff areas (> 30 degrees) that support breeding raptors (Table 20.10). The LAA has the potential to support 19 bird of prey species (Appendix 20A, Section 3.2.2.4; K'alo-Stantec, 2023), including many owl and raptors species that do not have specialized nesting habitat requirements. Several raptor species have unique nesting requirements adjacent to waterbodies (i.e., bald eagle [*Haliaeetus leucocephalus*], osprey [*Pandion haliaetus*]) or on cliff areas (i.e., peregrine falcon, golden eagle [*Aquila chrysaetos*]) that are limited in the LAA. These species are most likely to be affected by a direct or indirect change in habitat resulting from project construction, as their nest sites are sensitive to anthropogenic disturbance.

Construction activities have the potential to affect important nesting sites within the LAA. Two active peregrine falcon nests were observed during the 2021 aerial raptor nest survey for the Project that are in, or immediately adjacent to, proposed quarry sources (Appendix 20A, Figure 3.7; K'alo-Stantec, 2023). There are also historical records of raptor nests within the PDA and LAA that represent important raptor nesting habitats that have the potential to interact with the Project (Appendix 20A, Figure 3.7; K'alo-Stantec, 2023). For example, the PDA traverses the Petiniʔah (Bear Rock) CZ (Zone #32) that is an important raptor nesting area for bald eagle, golden eagle, and

peregrine falcon (Appendix 20A, Figure 3.7; K'alo-Stantec, 2023) and is a culturally sacred site (SLUPB, 2023; Appendix 20A, Section 3.1.2.2; K'alo-Stantec, 2023). While the PDA will primarily follow the existing MWVR while traversing the Petiniʔah (Bear Rock) CZ (Zone #32), straightening of the PDA is required (i.e., alternate routing) to safely allow traffic to cross the karst formation that rises 400 m above the Mackenzie River (Appendix 20A, Figure 3.6; K'alo-Stantec, 2023). Additionally, a permanent quarry is proposed within the Petiniʔah (Bear Rock) CZ (Zone #32) that is immediately adjacent to a historical nesting site for golden eagle. Construction of the Project will result in the direct loss of 136.4 ha of the Petiniʔah (Bear Rock) CZ (Zone #32), a 4.3% decrease from existing conditions.

Other effect pathways, including dust deposition, edge effects, and fragmentation, have the potential to reduce habitat availability for birds of prey as described, but effects will be greatest where the PDA is constructed immediately adjacent to rivers, lakes, or cliff areas. Outside of the critical breeding period, adverse effects relating to the direct and indirect loss or alteration of habitat on birds of prey will be negligible, including during the migration season.

20.4.2.3.1.4 Landbirds

Construction of the Project will result in the direct loss of 2,289.2 ha of the landbird habitat, a 3.5% decrease from existing conditions (Table 20.12). Landbird habitat includes all upland cover classes and wetland cover classes (Table 20.10) that support landbirds during the breeding season.

There are no upland land cover classes that will be disproportionately affected by construction of the PDA as there will be proportional losses of broadleaf forest (-3.9% residual change in the LAA), mixedwood forest (-3.6%), coniferous forest (-3.5%), and shrubland (-3.7%) land cover classes (Table 20.12). Following construction of the Project, habitat for landbirds within the LAA will remain abundant relative to the existing condition due to the LAA currently being subject to limited levels of anthropogenic disturbance, as is evident by a residual change of exposed lands by a 55.6% decrease from existing conditions. Direct and indirect habitat loss or alteration is most likely to affect breeding landbird species commonly detected within the LAA, such as Swainson's thrush (*Catharus ustulatus*), hermit thrush (*Catharus guttatus*), chipping sparrow (*Spizella passerina*), Tennessee warbler (*Leiothlypis peregrina*), and white-throated sparrow (*Zonotrichia albicollis*; Appendix 20A, Section 3.2.2.5; K'alo-Stantec, 2023). Landbird species detected most often within each land cover class are presented in Appendix 20A, Section 3.2.2.5 (K'alo-Stantec, 2023).

An indirect loss or alteration of landbird habitat is expected through sensory disturbance, dust deposition, edge effects, and fragmentation that can collectively result in habitat avoidance and reduced habitat effectiveness for landbirds in areas adjacent to the PDA.

In general, it is well-documented that the effects of anthropogenic noise on the breeding success of landbirds is typically adverse, with effects ranging from behavioural changes such as altered song characteristics, to population or physiological consequences such as altered species abundance and/or richness and increased stress (Benitez-Lopez et al., 2010; Shannon et al., 2016). However, bird response to noise is species-specific and in some cases road construction noise has been shown to not affect the distribution and nesting success of breeding passerines (Long et al., 2017).

Other effect pathways, including dust deposition, edge effects, and fragmentation, have the potential to contribute to an area of reduced ecological effectiveness adjacent to the PDA, but the Project will follow much of the existing MVWR and as described, these effects are already present within the LAA, except for dust deposition. These effects are also expected to vary by species and local bird movement. For example, forest-interior species are disproportionately affected compared to edge-tolerant species that are unaffected by roads (Laurance et al., 2004). Additionally, although birds are highly mobile, there is some evidence to suggest that natural and anthropogenic (e.g., roads or utility corridors) forest gaps may impede landscape-level movements of some bird species (Bélisle and St. Clair, 2001).

Breeding landbirds currently experience limited interaction with anthropogenic noise sources within the LAA as the MVWR does not operate during the breeding season. However, presence of the existing MVWR and other linear features (e.g., Norman Wells Pipeline ROW) has likely altered the breeding bird community composition and abundance or distribution within the LAA, as has been documented on other similar and recent highway projects in the NWT (i.e., Tłı̨chǫ Highway; Golder, 2021). Studies for the Tłı̨chǫ Highway concluded that routing the highway along an existing road and applying industry standard mitigation measures limited residual effects on birds to the extent possible, including for SAR (Golder, 2021). Thus, routing the Project along the MVWR as much as possible and applying the mitigation measures will similarly limit residual effects on birds to the extent practicable.

20.4.2.3.1.5 Species at Risk and Species of Conservation Concern

A direct loss of habitat for SAR/SOCC is expected through vegetation clearing and an indirect loss or alteration of habitat is expected through sensory disturbance, dust deposition, edge effects, and fragmentation that can collectively result in habitat avoidance and reduced habitat effectiveness for landbirds in areas adjacent to the PDA. Effect pathways as described are applicable to SAR as is described for the respective bird groups (i.e., effects on olive-sided flycatcher [*Contopus cooperi*] will be consistent with those described for landbirds). However, the direct and indirect loss of breeding habitat has the potential to result in greater consequences for SAR and as a result more conservative residual effects criteria for magnitude are used to assess direct loss of habitat for these species (Table 20.3).

Construction of the Project will result in a direct loss of < 5.0 % for bird habitat, species groups, and SAR/SOCC, except for common nighthawk (Table 20.12).

Common nighthawk breeding habitat includes disturbed sites, such as quarries or the existing MVWR ROW, and a residual change of 5.9% in habitat for the species is expected to be overestimated. For example, of the 1,477.7 ha of common nighthawk habitat within the PDA, 1,104.9 ha (74.8%) is along the existing MVWR. Additionally, the Project will likely provide habitat opportunities for the species following construction (e.g., reclaimed areas, quarries) as the species is relatively common and widespread throughout the LAA and tolerant of anthropogenic disturbance (Appendix 20A, Section 3.2.2.6; K'alo-Stantec, 2023).

Table 20.12 Change in Habitat for Bird Species/ Species Group in the LAA and RAA

Bird Species/Species Group[1]	LAA		RAA	
	Existing Condition (ha)	Residual Condition (ha / % change)	Existing Condition (ha)	Residual Condition (ha / % change)
General habitat	75,359.6	73,044.4 (-3.1%)	1,010,447.4	1,008,132.2 (-0.2%)
Waterbirds	11,110.6	11,073.3 (-0.3%)	151,438.2	151,400.9 (<0.1%)
Upland gamebirds	66,247.1	63,958.0 (-3.5%)	890,881.9	888,592.8 (-0.3%)
Birds of prey	4,254.40	4,203.7 (-1.2%)	65,163.4	65,112.7 (-0.1%)
Landbirds	66,247.1	63,958.0 (-3.5%)	890,881.9	888,592.8 (-0.3%)
Peregrine falcon	462.5	443.9 (-4.0%)	2,713.2	2,694.5 (-0.7%)
Yellow rail	173.6	171.6 (-1.1%)	6,537.4	6,535.5 (<0.1%)
Lesser yellowlegs	19,224.7	18,959.2 (-1.4%)	284,696.6	284,431.0 (-0.1%)
Red-necked phalarope	4,949.9	4,936.5 (-0.3%)	61,792.1	61,778.7 (<0.1%)
Short-eared owl	0.0	0.0 (0.0%)	0.0	0.0 (0.0%)
Common nighthawk	24,852.3	23,374.6 (-5.9%)	304,016.8	302,539.1 (-0.5%)
Olive-sided flycatcher	24,871.9	24,392.0 (-1.9%)	319,871.3	319,391.4 (-0.2%)
Rusty blackbird	16,824.6	16,565.3 (-1.5%)	255,028.8	254,769.5 (-0.1%)
Horned grebe	619.7	613.6 (-1.0%)	8,124.1	8,118.0 (-0.1%)

Note:

[1] See Table 20.10 for habitat descriptions

Direct loss of habitat for bank swallow is anticipated to be negligible, as natural habitats that support these species (i.e., vertical banks) are not abundant in the LAA and culvert installation locations do not occur at steep vertical banks. Quarries or borrow sources will be subject to species-specific mitigation (Section 20.4.4.2). Species-specific surveys in 2022 did not identify any bank swallow nesting activity within the LAA (K'alo-Stantec, 2022a; Appendix 20C).

Direct loss of habitat for barn swallow is possible where structures that support breeding barn swallow exist (e.g., bridges) and must be temporarily used and/or rehabilitated during construction. Species-specific surveys in 2022 identified potential barn swallow nesting activity at three bridge crossings within the LAA (K'alo-Stantec, 2022a; Appendix 20C).

Direct loss of habitat for Harris's sparrow is anticipated to be negligible, as the species typically breeds in more northern latitudes and while its range overlaps the RAA, it is not expected to regularly breed within the LAA.

20.4.2.3.1.6 Characterization of Residual Effects for Change in Habitat During Construction

Following the implementation of mitigation measures described, residual effects on bird habitat, bird species groups as well as species at risk are summarized in Table 20.13. The overall residual effects for change in habitat during construction are characterized by the following:

- **Direction is adverse:** There will be a direct and indirect loss or alteration of bird habitat.
- **Likelihood is certain**: The residual effect will certainly occur.
- **Magnitude is low to moderate:** Direct loss will result in a < 10% change in bird habitat and a < 5% change for SAR and SOCC habitat, except for common nighthawk, but indirect loss or alteration may result in a measurable change in the abundance of birds of prey in the LAA.
- **Geographic extent is the LAA:** Direct and indirect loss or alteration of habitat associated with sensory disturbance is unlikely to exceed the LAA, although temporary local shifts in distributions in the LAA might occur.
- **Timing is high sensitivity:** Although vegetation clearing will occur in the winter, construction will likely occur through the year, including during sensitive periods for birds.
- **Duration is medium- to long-term:** Sensory disturbance will cease following the construction phase (i.e., up to 20 years) but edge effects and fragmentation will persist into the operations and maintenance phase (i.e., > 20 years).
- **Frequency is continuous:** Effects will occur throughout the construction phase.
- **Change is irreversible:** Sensory disturbance will cease following the construction phase, but most effects associated with direct and indirect habitat loss or alteration will persist throughout the life of the Project.

Table 20.13 Summary of Residual Effects on Change in Bird Habitat

Bird Species Group	Residual Effects Characterization*								
	Project Phase	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
General Bird Habitat	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Waterbirds	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Upland Gamebirds	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Birds of Prey	C	A	CE	M	LAA	HS	MT/LT		I
	O	A	P	L	LAA	HS	LT	C	I
Landbirds	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Peregrine falcon	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Yellow rail	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Lesser yellowlegs	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Red-necked phalarope	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Short-eared owl	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Common nighthawk	C	A	CE	M	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Olive-sided flycatcher	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Rusty blackbird	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I

Bird Species Group	Residual Effects Characterization*								
	Project Phase	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Horned grebe	C	A	CE	L	LAA	HS	MT/LT	C	I
	O	A	P	L	LAA	HS	LT	C	I

KEY

***** See Table 20.3 for detailed definitions

Project Phase
C: Construction
O: Operations and maintenance

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
No: Negligible
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

20.4.2.3.2 Operations and Maintenance

A direct loss of bird habitat is not expected to occur during the operations and maintenance phase of the Project. Presence of the highway will maintain fragmentation and edge effects over the long term that were established during the construction phase and while over time these effects may be ameliorated as shrubs soften the edges, these habitats may experience reduced ecological effectiveness or be avoided by some species. This may be exacerbated by sensory disturbances associated with the presence of the highway.

An indirect loss or alteration of bird habitat is possible through sensory disturbance (i.e., noise and artificial light), dust deposition, edge effects, and fragmentation that can result in habitat avoidance and reduced habitat effectiveness for birds, including SAR, in areas adjacent to the PDA.

Noise-related effects on some wildlife species have been reported to occur when noise levels exceed 40 dBA, which may result in avoidance. Other behavioural changes (e.g., altered song characteristics of songbirds) and population or physiological consequences (e.g., altered species abundance and/or richness, stress) to birds have been identified ≥ 45 dBA (Shannon et al., 2016). Baseline noise in the region that was assessed in remote areas without any development or winter traffic has been estimated at 35 and 32 dBA during the day and night, respectively (IOL, 2004; see Section 13.2.2). Expected traffic volume is 50 vehicles per day for an indeterminate time but the

distance at which noise associated with operations and maintenance activities is expected to attenuate to 40 dBA is 100 m for highway traffic and 2.5 km for quarry and borrow source activities (see Section 13.4.2), which are only expected to occur irregularly.

Dust deposition during the operations and maintenance phase will continue to affect vegetation adjacent to the PDA, as described during the construction phase (i.e., within approximately 40 m of the PDA), which includes the potential for altering vegetation communities over time (e.g., increased herbaceous and broadleaf tree and shrub habitats, reduction in mosses and lichens).

Sensory disturbance, dust deposition, fragmentation, and edge effects associated with the use of the highway, once constructed, have the potential to collectively reduce the ecological effectiveness of bird habitat adjacent to the PDA. However, this is expected to be a small incremental increase compared to the existing conditions. Additionally, while some species may avoid the LAA, particularly habitats close to the PDA, the LAA will continue to support birds without disrupting natural population cycles, and edge habitats are likely to provide increased forage opportunities for some bird species (e.g., upland gamebirds).

20.4.2.3.2.1 Waterbirds

Sensory disturbance and dust deposition resulting from vehicular traffic during the operations and maintenance phase of the Project, along with maintenance of habitat fragmentation and edge effects, have the potential to reduce habitat effectiveness for breeding waterbirds adjacent to the PDA.

In general, research has shown that effects of roads (and associated sensory disturbance) on the breeding success of waterfowl ranges from a positive (Roy, 2018) to neutral or weak adverse relationship (e.g., Kemink et al., 2019; Singer et al., 2020). This is consistent with a broader examination of literature that have found similar relationships between roads and birds (e.g., Fahrig and Rytwinski, 2009; Morelli et al., 2014). While the relationship is not consistently adverse, the addition of noise is a change from the existing condition and considered an adverse effect. However, operations and maintenance activities are unlikely to produce similar noise levels emitted by these examples.

The PDA is generally routed away from the Middle Mackenzie River Islands IBA, as described during the construction phase, and waterbirds are highly mobile and will adjust their daily distributions relative to sensory disturbance. However, most waterbirds are likely to become acclimatized to the low traffic levels associated with the use of the highway during operations and maintenance. Additionally, migrating birds are unlikely to rely heavily on wetlands adjacent to the PDA where sensory disturbance will be greatest.

Dust deposition that alters aquatic vegetation communities adjacent to the PDA may reduce habitat suitability for breeding waterbirds; however, dust deposition resulting from the expected traffic volume of 50 vehicles/day is likely to only result in a small incremental increase in dust deposition adjacent to the PDA.

20.4.2.3.2.2 Upland Gamebirds

Sensory disturbance and dust deposition resulting from vehicular traffic associated with the presence of the highway during the operations and maintenance phase of the Project, along with maintenance of habitat fragmentation and edge effects, have the potential to reduce habitat effectiveness for upland gamebirds adjacent to the PDA.

While sensory disturbance may result in avoidance of habitats adjacent to the PDA, dust deposition will continue to affect vegetation adjacent to the PDA, as described during the construction phase (i.e., within approximately 40 m of the PDA), which includes the potential for altering vegetation communities over time (e.g., increased herbaceous and broadleaf tree and shrub habitats). These altered habitats provide more open habitats and increased foraging opportunities that attract grouse and ptarmigan throughout the year. However, grouse are already subject to the effects due to the presence and operation of the MVWR and the Project is anticipated to contribute a small incremental change.

20.4.2.3.2.3 Birds of Prey

Sensory disturbance and dust deposition resulting from vehicular traffic during the operations and maintenance phase of the Project, along with maintenance of habitat fragmentation and edge effects, have the potential to reduce habitat effectiveness for birds of prey within the LAA.

Noise associated with the operations and maintenance of the Project, particularly quarry and borrow source operation, has the potential to disturb breeding birds of prey, particularly nesting raptors. Raptors may avoid the LAA near quarries and borrow sources, but some raptor species have been shown to have higher abundances in proximity to roads that is typically attributed to increased hunting and scavenging opportunities (Benitez-Lopez et al., 2010). Effects associated with edges and fragmentation are likely to function in a similar manner and dust deposition may affect birds of prey if the prey community is altered as a result.

The Project includes a large proportion of previously altered habitats that provide more open habitat and increased foraging opportunities that attract birds of prey throughout the year. These species are already subject to the effects due to the presence and operation of the MVWR and the Project is anticipated to contribute a small incremental increase in change.

20.4.2.3.2.4 Landbirds

Sensory disturbance and dust deposition resulting from vehicular traffic during the operations and maintenance phase of the Project, along with maintenance of habitat fragmentation and edge effects, have the potential to reduce habitat effectiveness for breeding landbirds within the LAA.

In general, it is well-documented that the effects of road disturbance on the breeding success of landbirds is typically adverse and effects range from behavioural changes, such as altered song characteristics, to population or physiological consequences, such as altered species abundance and/or richness and increased stress (Benitez-Lopez et al., 2010; Shannon et al., 2016). Other effect

pathways, including dust deposition, edge effects, and fragmentation, have the potential to contribute to an area of reduced ecological effectiveness adjacent to the PDA. However, the Project will follow much of the existing MVWR and as described, these effects are already present within the LAA. Breeding landbirds currently experience limited interaction with anthropogenic noise sources within the LAA as the MVWR does not operate during the breeding season.

However, presence of the existing MVWR (i.e., presence of a linear feature) has likely altered the breeding bird community composition and abundance or distribution within the LAA, as has been documented on other similar and recent highway projects in the NWT (i.e., Tłı̨chǫ Highway; Golder, 2021). Additionally, studies for the Tłı̨chǫ Highway concluded that routing the highway along an existing road and applying industry standard mitigation measures limited residual effects on birds to the extent possible, including for SAR (Golder, 2021). Thus, routing the Project along the MVWR as much as possible and applying the mitigation measures will similarly limit residual effects on birds to the extent practicable.

Meta-analyses suggest that the effects of roads on breeding birds are species-specific and do not extend beyond 1 km (Benitez-Lopez et al., 2010). Given that the Project will have low daily traffic volumes and it is primarily upgrading an existing road, effects on breeding landbirds are not expected to extend far into the LAA. Additionally, most studies examining the effects of roads on breeding birds have traffic volumes of several thousand vehicles per days and some studies excluded analyzing roads where traffic volumes were ≤ 50 vehicles/hour (Parris and Schneider, 2008). The anticipated traffic level for the Project is comparatively negligible (i.e., 50 vehicles/day).

20.4.2.3.2.5 Species at Risk and Species of Conservation Concern

Sensory disturbance and dust deposition resulting from vehicular traffic during the operations and maintenance phase of the Project, along with maintenance of habitat fragmentation and edge effects, have the potential to reduce habitat effectiveness for breeding SAR/SOCC within the LAA.

Effect pathways are anticipated to interact with SAR/SOCC as described for the respective bird groups (i.e., effects on olive-sided flycatcher will be consistent with those described for landbirds). Additionally, as described for the construction phase, the Project will have limited interaction with many SAR/SOCC, which also includes indirect habitat loss or alteration during the operations and maintenance phase. In general, the Project includes a large proportion of previously altered habitats and SAR/SOCC are already subject to direct and indirect effects of change in habitat due to the presence and operation of the MVWR. As a result, the Project is anticipated to contribute a small incremental increase in change that will further reduce ecological effectiveness in the LAA. However, the Project may provide habitat and/or nesting opportunities for species that prefer edge habitats, disturbed habitats, and/or reclaimed habitats (e.g., borrow sources), or anthropogenic structures (e.g., bridges) for species such as common nighthawk, olive-sided flycatcher, bank swallow, and barn swallow.

20.4.2.3.2.6 Characterization of Residual Effects for Change in Habitat During Operations and Maintenance

Following the implementation of mitigation measures, residual effects for each measurable parameter are summarized in Table 20.13 and overall residual effects for change in habitat during operations and maintenance are characterized by the following:

- **Direction is adverse:** There will be an indirect loss or alteration of bird habitat.
- **Likelihood is possible**: The residual effect could occur.
- **Magnitude is low:** Indirect loss or alteration is not anticipated to result in a measurable change in the abundance of any bird species in the LAA, although temporary local shifts in distributions in the LAA might occur.
- **Geographic extent is the LAA:** Indirect loss or alteration of habitat associated with sensory disturbance is unlikely to extend beyond the LAA.
- **Timing is high sensitivity:** Operations and maintenance of the Project will occur year-round.
- **Duration is long-term:** There will be indeterminate effects on bird habitat adjacent to the PDA.
- **Frequency is continuous:** Effects will occur throughout the operations and maintenance phase.
- **Change is irreversible:** Effects will occur throughout the operations and maintenance phase.

20.4.3 Change in Mortality Risk

20.4.3.1 Effect Pathways

20.4.3.1.1 Construction

All project activities during the construction phase, except for employment and contracted goods and services, have the potential to contribute to a direct change in mortality risk as they involve the removal of upland and wetland habitats (i.e., vegetation clearing, ground disturbance) and/or the movement of machinery and traffic within the PDA (Table 20.9). Vegetation clearing and ground disturbance is most likely to increase mortality risk for less mobile individuals (e.g., fledglings) or nests. Project-related transportation and heavy equipment also have the potential to crush or collide with birds.

20.4.3.1.2 Operations and Maintenance

All project activities during the operations and maintenance phase, except for employment and contracted goods and services, have the potential to contribute to a direct and/or indirect change in mortality risk (Table 20.9). During operation, project-related transportation within the LAA, and public traffic resulting from the presence of the highway, are the primary pathways with potential to increase bird mortality risk by increasing the potential for vehicle-bird collisions and mortality, primarily along the highway portion of the PDA (i.e., risk is low along access roads). Wildlife may also encounter traffic and heavy machinery associated with maintenance activities. Species most at risk include less mobile species (e.g., upland gamebirds) or those that may cross the highway, particularly near wetlands (e.g., waterfowl), or those that are attracted to the PDA (e.g., upland gamebirds, birds of prey).

The presence of the highway and other linear features (e.g., borrow source and quarry access roads) have the potential to result in an indirect change in mortality risk for some species. Increased access for predators and hunters is the primary pathway for an indirect change in mortality risk. The Project will enhance access along a continuous linear feature that may increase predator efficiency and hunter ease of travel while providing all-season access to portions of the LAA that were previously more isolated. Species most like to be affected include prey species (e.g., passerines), harvested species (e.g., waterfowl), and those attracted to the PDA (e.g., upland gamebirds).

20.4.3.2 Mitigation

As discussed in Chapter 5, project routing and design have integrated the existing MVWR to the extent practicable, which will reduce potential project interactions with birds, resulting in change in mortality risk. In addition to a project-specific WMMP that will be implemented during the construction and operations and maintenance phases, standard industry practices and mitigation measures will also be implemented and are presented in Table 20.9. Key mitigation measures to avoid or reduce changes in mortality risk include:

- Wildlife monitors will assess for the presence of wildlife on or near the PDA during project construction activities.
- Vegetation clearing will be completed outside the migratory bird nesting period of May 4 to August 22 (Zone B8; ECCC, 2018) and will consider the Critical Breeding Periods for Raptor Species of the Northwest Territories (Shank and Poole, 2016) to avoid disturbing species that breed prior to the migratory bird nesting periods.
- The WMMP will outline how risks to migratory birds will be managed in accordance with ECCC's Guidelines to Reduce Risk to Migratory Birds (ECCC, 2021) if activities that could result in risk of harm cannot be avoided (e.g., pre-clearing nest surveys).
- The WMMP will be complied with in relation to species of birds not under GNWT's authority in addition to species under GNWT's authority.

- Quarries will be maintained in accordance with beneficial management practices (GNWT 2020d) to reduce the potential for nesting by bank swallow.
- If an active bird nest is found, beneficial management practices (GNWT, 2020d) will be followed, including applying an appropriate setback and timing restriction and the GNWT-ECC and/or ECCC will be consulted, as appropriate.
- Personnel will undergo a wildlife awareness program, which will include prevention measures for wildlife mortality (e.g., bear safety) and reporting procedures for wildlife-related incidents and protocols to follow when a nest, den, or wildlife species of management concern is observed. This includes completing wildlife sighting and wildlife incident report forms included in the WMMP.
- Personnel will not feed, harass, or hunt wildlife while working on the Project.
- Construction and quarry development activities will be limited during sensitive periods for wildlife in accordance with the WMMP.
- Food and other wildlife attractants will be stored in bear-proof containers.
- Equipment, wastes, and contaminated soils will be removed once construction is completed.
- Speed limits will be posted on the public highway.

20.4.3.3 Residual Effects

20.4.3.3.1 Construction

Construction activities, including vegetation clearing and earthworks, will follow mitigation measures that consider timing restrictions for bird species, including sensitive periods for nesting and migrating birds. Vegetation clearing will be timed to reduce potential effects on breeding birds.

During construction, there is potential for increased mortality risk to young birds due to their limited mobility (e.g., crushed by construction equipment). Vehicle-related bird mortality has the potential to affect a wider range of species, including SAR and SOCC. While traffic volumes will increase during construction, speeds will remain slow and will limit the risk of vehicle-bird collisions. Vehicles will abide by posted speed limits and multi-passenger vehicles will be used, where practical, to reduce the potential for vehicle-bird collisions. Species most at risk include less mobile species (e.g., upland gamebirds) or those that may cross the highway, particularly near wetlands (e.g., waterfowl), or those that are attracted to the PDA (e.g., upland gamebirds, birds of prey).

Proper management of wastes, including at temporary camps, will reduce the potential for birds to be attracted to the construction site (e.g., common raven [*Corvus corax*]), thus reducing the potential for mortality risk related to human-bird conflict.

Following the implementation of the mitigation measures, residual effects for change in mortality risk during construction are characterized as follows:

- **Direction is adverse:** Construction activities will increase bird mortality risk.
- **Likelihood is possible**: The residual effect could occur.
- **Magnitude is low:** A measurable change in the abundance of birds in the LAA is unlikely, although temporary local shifts in distributions in the LAA might occur.
- **Geographic extent is the LAA:** Residual effects will not extend into the RAA.
- **Timing is high sensitivity:** Although vegetation clearing will occur in the winter, construction will occur through the year, including during sensitive periods for birds.
- **Duration is medium- to long-term:** Direct effects will cease following the construction phase (i.e., up to 20 years) but indirect effects will persist into the operations and maintenance phase (i.e., > 20 years).
- **Frequency is multiple irregular event:** construction activities may result in direct and/or indirect bird morality, but potential mortalities are expected to occur infrequently at no set schedule following the implementation of mitigation measures.
- **Change is irreversible:** Direct effects will cease following the construction phase, but effects associated with indirect mortality risk will persist throughout the life of the Project.

20.4.3.3.2 Operations and Maintenance

A direct change in mortality risk is likely to occur through the presence of the highway and the associated traffic (i.e., through vehicle-bird collisions), which is generally an effect driven by both traffic volume and speed. Species most likely to be affected are those that that are attracted to the PDA where there is an increase in forage or prey availability (e.g., upland gamebirds, birds of prey). The highway will allow for increased traffic speeds (up to 80 km/h) which may increase bird mortality risk, but the widening of the ROW and maintenance and removal of dense brush along the highway ditches will limit the number of birds adjacent to highway and improve visibility of birds, which will reduce collision and mortality risk. Other maintenance activities will generally occur infrequently and will result in increased traffic volumes and/or the use of heavy machinery; these activities are anticipated to result in a negligible change in mortality risk.

An indirect change in mortality risk is likely to occur as the Project will provide year-round access to the LAA for hunters and by altering predator-prey dynamics. Linear features provide an efficient mechanism to move across the landscape that also provides relatively clear sightlines that are desirable to resource users and predators. There may be areas that were previously more difficult to access outside of the winter season which may experience increased hunting pressure once the Project is operational and harvested species are most at risk (e.g., waterfowl, upland gamebirds).

Following the implementation of the mitigation measures, residual effects for change in mortality risk during operations and maintenance are characterized as follows:

- **Direction is adverse:** Operations and maintenance activities will increase mortality risk.
- **Likelihood is possible**: The residual effect could occur.
- **Magnitude is low:** A measurable change in the abundance of birds in the LAA is unlikely.
- **Geographic extent is the LAA:** Residual effects will not extend into the RAA.
- **Timing is high sensitivity:** The Project will operate indeterminately, including during sensitive periods for birds, although temporary local shifts in distributions in the LAA might occur.
- **Duration is long-term:** Effects on mortality risk will persist during the operations and maintenance phase (i.e., > 20 years).
- **Frequency is multiple irregular event:** operations and maintenance activities may result in direct and/or indirect bird morality, but potential mortalities are expected to occur infrequently at no set schedule following the implementation of mitigation measures.
- **Change is irreversible:** The Project will operate indeterminately and effects will persist throughout the life of the Project.

20.4.4 Change in Bird Health

20.4.4.1 Effect Pathways

An exposure pathway must be present for there to be an increased risk to bird health, and includes the ingestion of soil, sediment, food, or water and/or direct contact with soil, sediments, or water that may contain contaminants. The effect pathways that may result in a change in bird health include:

- Deposition of rock and dust may release contaminants into the surrounding terrestrial and aquatic environment during extraction (e.g., blasting, stockpiling), crushing, transport, and road construction and operations and maintenance.
- Sedimentation and runoff from project activities may release contaminants into surface water, affecting aquatic flora and fauna.

20.4.4.1.1 Construction

During construction, a change in bird health in the LAA due to release of contaminants related to deposition of rock and dust associated with site preparation of the ROW, access, workspaces, blasting, stockpiling, and culvert installations (Table 20.8). In addition, construction associated with site preparation of the ROW, and quarry access roads including road cuts and culvert installations, will occur adjacent to aquatic habitats and have potential to reduce surface water quality in aquatic environments through sedimentation and runoff.

20.4.4.1.2 Operations and Maintenance

As described for the construction phase, there are activities during the operations and maintenance phase (e.g., quarry operations) that could adversely affect bird health due to potential release of contaminants into the surrounding terrestrial environment. During operation, the sedimentation and runoff exposure pathway is not anticipated to result in a change in bird health, but deposition of dust will persist. Maintenance activities and the use of the highway are the primary pathway for dust to enter the terrestrial and aquatic environments.

20.4.4.2 Mitigation

As discussed in Chapter 5, project routing and design have integrated the existing MVWR to the extent practicable, which will reduce potential project interactions with change in bird health. In addition to a project-specific WMMP that will be implemented during the construction and operations and maintenance phases, standard industry practices and mitigation measures will also be implemented and are presented in Table 20.9. Key mitigation measures to avoid or reduce changes in bird health include:

- The SCP will include procedures to prevent and respond to spills.
- Maintenance yards will have a liner or concrete installed under areas of vehicle storage and maintenance.
- Vehicles parked for more than 2 hours will use drip trays.
- Placement of embankment will occur primarily during winter (December 15 to April 1), during frozen conditions. If work is to be completed under non-frozen conditions, equipment will be equipped with mushroom shoes.
- A project-specific ESCP will be developed and implemented.
- Washing, refueling, and servicing machinery and storage of fuel and other materials for machinery will be conducted a minimum of 100 m from the high-water mark and in a manner to prevent any deleterious substances from entering the water.
- Blast rock will not enter a waterbody or watercourse.
- A dust control program using water will be implemented during construction and operations and maintenance.
- Equipment, wastes, and contaminated soils will be removed once construction is completed.

20.4.4.3 Residual Effects

20.4.4.3.1 Construction

During construction, there is potential for increased risk to bird health through the mobilization of sediment into aquatic habitats and dust deposition.

The Project will follow applicable regulatory requirements and apply mitigation measures for aquatic resource protection, which will reduce risks to birds and bird habitat. Residual effects are anticipated to be negligible.

Dust deposition is expected to result in minor and localized changes to vegetation and bird habitat adjacent to the PDA (i.e., within 40 m; Section 20.4.2.3), but dust deposition resulting from construction activities is not anticipated to contain chemicals of potential concern that could harm birds or bird habitat.

Harvested wildlife species in NWT, such as upland gamebirds, have been shown to have limited environmental contamination (Appendix 20A, Section 3.2.2.1; K'alo-Stantec, 2023) and construction of the Project is not expected to result in a change in bird health within the LAA.

Following the implementation of the mitigation measures, residual effects for change in bird health during construction are characterized as follows:

- **Direction is adverse:** Construction activities will increase risks to bird health.
- **Likelihood is unlikely**: The residual effect is almost certainly not to occur.
- **Magnitude is negligible:** A measurable change in the abundance of birds in the LAA is not anticipated.
- **Geographic extent is the LAA:** Residual effects will not extend into the RAA.
- **Timing is high sensitivity:** Construction will likely occur through the year, including during sensitive periods for birds.
- **Duration is medium-term:** Effects will cease following the construction phase (i.e., up to 20 years).
- **Frequency is continuous:** Effects will occur throughout the construction phase.
- **Change is reversible:** Effect pathways associated with construction activities will cease following completion of project construction.

20.4.4.3.2 Operations and Maintenance

Dust deposition is expected to result in minor and localized changes to vegetation and bird habitat adjacent to the PDA (i.e., within 40 m; Section 20.4.2.3). However, given the lack of chemicals of potential concern contained within dust emissions and the amount of dust expected from 50 vehicles/day, it is unlikely to result in a measurable change in the health and condition of birds in the LAA. Additionally, this is consistent with determinations in other similar projects in the NWT (i.e., Tłı̨chǫ Highway [Golder, 2017]).

Harvested bird species in NWT have been shown to have limited environmental contamination (Appendix 20A, Section 3.2.2.1; K'alo-Stantec, 2023), and operations and maintenance of the Project is not expected to result in a change in bird health within the LAA.

Following the implementation of the mitigation measures, residual effects for change in bird health during operations and maintenance are characterized as follows:

- **Direction is adverse:** Operations and maintenance activities can increase risk to bird health.
- **Likelihood is unlikely**: The residual effect is almost certainly not to occur.
- **Magnitude is negligible:** A measurable change in the health and condition of wildlife in the LAA is not anticipated.
- **Geographic extent is the LAA:** Residual effects will not extend into the RAA.
- **Timing is high sensitivity:** The Project will operate indeterminately, including during sensitive periods for birds.
- **Duration is long-term:** Effects on bird health will persist during the operations and maintenance phase (i.e., > 20 years).
- **Frequency is continuous:** Effects will occur throughout the operations and maintenance phase.
- **Change is irreversible:** The Project will operate indeterminately and effects will persist throughout the life of the Project.

20.4.5 Summary of Residual Effects

Table 20.14 summarizes the residual effects on bird and bird during the construction and operations and maintenance phases of the Project.

Table 20.14 Residual Effects on Bird and Bird Habitat

Residual Effect	Residual Effects Characterization*								
	Project Phase	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in Habitat	C	A	CE	L	LAA	HS	MT-LT	C	I
	O	A	P	L	LAA	HS	LT	C	I
Change in Mortality Risk	C	A	P	L	LAA	HS	MT-LT	IR	I
	O	A	P	L	LAA	HS	LT	IR	I
Change in Bird Health	C	A	U	N	LAA	HS	MT	C	I
	O	A	U	N	LAA	HS	LT	C	I

KEY

*See Table 20.3 for detailed definitions

Project Phase
C: Construction
O: Operations and maintenance

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
N: Negligible
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirements related to fish and wildlife, and consideration of engagement input and incorporation of Traditional Knowledge.

The design of the Project and mitigation measures for protection of birds and bird habitat will respect the values of the Petiniʔah (Bear Rock) CZ, Mio Lake CZ, Norman Range SMZ, K'ąąlǫ Tué (Willow Lake Wetlands) SMZ and Deh Cho (Mackenzie River) SMZ, as areas with important bird habitat.

20.5 Assessment of Cumulative Effects on Birds and Bird Habitat

Project residual effects described in Section 20.4 are likely to interact cumulatively with residual environmental effects from other physical activities including past, present, and reasonably foreseeable projects.

The effects of past and current projects contribute to baseline conditions upon which Project effects are assessed. Cumulative effects are described as those resulting from residual Project effects combined with the effects of past, present, and reasonably foreseeable projects and activities.

Future projects that are reasonably foreseeable are those that: (a) have obtained the necessary authorizations to proceed or are in the process of obtaining the required authorization, or (b) have been publicly announced with the intention to seek the necessary authorizations to proceed.

Two conditions must be met to initiate an assessment of cumulative effects on a VC:

- The Project is assessed as having measurable adverse residual environmental effects on a VC.
- The adverse residual effects from the Project overlap spatially and temporally with measurable residual effects of other physical activities on a VC.

If either condition is not met, the assessment of cumulative effects is not warranted because the Project is not considered to interact cumulatively with other projects or activities. Except for change in bird health, both conditions apply for change in habitat and mortality risk and a cumulative effects assessment is presented below.

The Project is predicted to result in no measurable residual effects on bird health (Table 20.14); and therefore, the Project is not expected to interact cumulatively with residual effects from other physical activities (past, present and reasonably foreseeable). Although, changes in air and water quality can result in changes in the quality of food sources (e.g., plants, fish) consumed by birds, the conclusions in the cumulative effects assessments for air quality (Volume 4, Chapter 12, see Section 12.5 of the DAR) and surface water and sediment quality (Volume 4, Chapter 16, see Section 16.5) indicate that there is no potential for cumulative effects on air or surface water quality; and therefore, there is no potential for cumulative effects on bird health due to changes in air or water quality. In the absence of cumulative effects pathways, bird health will not be further assessed.

20.5.1 Residual Effects Likely to Interact Cumulatively

The project and activity inclusion list (Table 20.15) identifies known past, present, and reasonably foreseeable projects and physical activities that could interact cumulatively with the residual effects. Chapter 4 of the DAR presents the names, proponents, use or activity, descriptions, status, and location of these projects and activities.

Table 20.15 Projects with the Potential to Contribute to Cumulative Effects in the RAA

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects		
	Change in Habitat	Change in Mortality Risk	Change in Bird Health
Past and Present Physical Activities and Resource Use (Base Case)			
Geotechnical	–	–	–
Oil, Gas & Seismic*			
Tulita 2D Seismic Program	✓	✓	–
EL 466 Drilling Program	✓	✓	–
Windy Island Drilling Program	✓	✓	–
Summit Creek Drilling Program	✓	✓	–
Slater River Project	✓	✓	–
Little Bear Staging Area	✓	✓	–
Infrastructure			
Mackenzie Valley Winter Road, including bridges and bridge-sized culverts	✓	✓	–
Canyon Creek All Season Access Road	✓	✓	–
Norman Wells Pipeline	✓	✓	–
Mackenzie Valley Fibre Link	✓	–	–
Délı̨nę Winter Road	✓	–	–
Mackenzie Highway No.1	✓	✓	–
Prohibition Creek Access Road	✓	✓	–
Quarries and Borrow Sources			
HRN Quarry	✓	✓	–
Little Bear River Quarry	✓	✓	–

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects		
	Change in Habitat	Change in Mortality Risk	Change in Bird Health
Mining & Exploration			
Wrigley Zinc Property Drilling Program	✓	–	–
Municipal Operations, including water, waste, power, and community development			
Wrigley Municipal Activities	✓	✓	–
Tulita Municipal Activities	✓	✓	–
Norman Wells Municipal Activities	✓	✓	–
Project-Related Physical Activities (Project Case)			
Mackenzie Valley Highway Project	✓	✓	–
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)			
Quarries			
Dhu-1 Quarry	✓	✓	–
Infrastructure			
Great Bear River Bridge	✓	✓	–
Oil and Gas			
Enbridge Maintenance Camp	✓	✓	–

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = Includes support activities such as production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas.

Change in bird health is not expected to interact cumulatively with other projects or activities because there is no measurable change in bird health due to the Project (Table 20.14).

20.5.2 Change in Habitat

20.5.2.1 Cumulative Effects Pathways

Potential cumulative effects on bird habitat due to reasonably foreseeable activities have similar effects pathways as those identified for the Project (see Section 20.4.2.1) including direct loss or alteration of habitat from vegetation clearing and indirect effects due to sensory disturbance (e.g., noise, artificial light), dust deposition, edge effects, and fragmentation generated during project construction and operations and maintenance of the Project.

20.5.2.2 Mitigation for Cumulative Effects

Mitigation measures and regional initiatives applicable to limiting cumulative effects on bird habitat, including for SAR, within the RAA (including other reasonably foreseeable projects) include the following:

- Adherence to the project-specific WMMP and other environmental management and monitoring plans used to protect and monitor the environment during Project construction and operations and maintenance, including the:
  - ESCP
  - Permafrost Protection Plan (PPP)
  - SCP
  - Waste Management Plan (WMP)
  - Quarry Development Plans

20.5.2.3 Cumulative Effects

Past and present activities including oil and gas development (e.g., Norman Wells Pipeline), the MVWR and other winter roads, quarries and borrow sources, mining and exploration activities as well as municipal and community development have resulted in the loss of bird habitat in the RAA. These past and current projects and activities reflect the existing (Baseline) conditions in the RAA. Although these projects and activities have altered the regional landscape and contributed to existing cumulative effects on bird habitat, the amount of existing anthropogenic disturbance (i.e., exposed land) in the Dehcho RAA (1.4%) and Sahtu RAA (1.5%) is relatively low (see Table 20.7). At Baseline, the Dehcho Region RAA contains an abundance of wildlife habitat dominated by coniferous forest (43.6%), wetlands (19.8%), and open water (19.3%) whereas the Sahtu Region RAA contains primarily coniferous forest (28.7%), wetlands (25.2%), and shrubland (20.6%) (Table 20.7). The Prohibition Creek Access Road is under construction and will contribute an additional 77.8 ha of direct habitat loss in the RAA.

Reasonably foreseeable activities and projects will result in additional direct habitat loss and alteration as well as sensory disturbance (e.g., noise), which will contribute to cumulative effects on bird habitat including SAR/SOCC in the RAA. Specifically, the Dhu-1 Quarry (including camp and winter access road) will result in a direct loss of 23 ha, and Great Bear River Bridge, 46.5 ha. The estimated project development area for the Enbridge Maintenance Camp is not available. Overall, the future projects are relatively small in spatial scale and some of these projects such as the Great Bear River Bridge at least partially overlap the existing MVWR, which will reduce cumulative effects on bird habitat.

The Project will contribute to cumulative effects on bird habitat, however, the change in habitat (2,315.2 ha) represents a 0.2% decrease from the existing condition in the RAA (1,010,983.5 ha), which includes 1,104.9 ha of exposed land and existing anthropogenic disturbances (i.e., existing MVWR and quarries) (see Table 20.11). The Project is anticipated to contribute 1,404.9 ha of new exposed land cover in the RAA, a 7.5% increase from the existing condition (15,970.4 ha).

Overall, the Project's contribution to cumulative change in bird habitat is relatively small representing < 0.1 to 0.7% from the existing condition depending on the species or species group (Table 20.12). Similarly, for species assessed qualitatively (e.g., bank swallow, barn swallow), the Project is expected to result in a low magnitude of change in habitat availability within the RAA relative to the existing condition.

20.5.3 Change in Mortality Risk

20.5.3.1 Cumulative Effects Pathways

Potential cumulative effects on bird mortality risk due to reasonably foreseeable activities have similar effects pathways as those identified for the Project (Section 20.4.3.1). Reasonably foreseeable activities would include site preparation activities (e.g., vegetation clearing, earthworks) and future road and bridge development, which can result in increased mortality risk including traffic-related mortality, and increased access opportunities for hunters and predators.

Notable past and present activities and projects that contribute to cumulative effects of mortality risk in the LAA and RAA are the Norman Wells Pipeline (inspections and maintenance), Highway No.1, Canyon Creek All Season Access Road and municipal operations.

20.5.3.2 Mitigation for Cumulative Effects

Mitigation measures and regional initiatives applicable to limiting cumulative effects on mortality risk within the RAA include the following:

- A WMMP will be developed and implemented. The WMMP will contain detailed monitoring and mitigation measures to be implemented for the duration of the construction and operations of the Project.

- Vegetation clearing will be completed outside the migratory bird nesting period, which extends from May 1 to August 31. This considers Nesting Zone B8 (May 4 to August 22 for Zone B8; ECCC, 2018) and potential species at risk. Vegetation clearing will also consider the Critical Breeding Periods for Raptor Species of the Northwest Territories (Shank and Poole, 2016) to avoid disturbing species that breed prior to the migratory bird nesting period.
- Closure and reclamation will promote re-establishment of vegetation.
- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent practical.
- Speed limits will be posted on the public highway.

20.5.3.3 Cumulative Effects

Existing activities contribute to cumulative effects on bird mortality risk in the RAA. During construction and operations, reasonably foreseeable activities and projects have potential to contribute to increased bird mortality risk in the RAA including the Dhu-1 Quarry, the Great Bear River Bridge, the Prohibition Creek Access Road and the Enbridge Maintenance Camp. The reasonably foreseeable projects are expected to contribute to cumulative effects on bird mortality risk; however, these projects are comparatively small, involving limited amounts of clearing and vehicle traffic and the Prohibition Creek Access Road overlaps the existing MVWR, which will limit the amount of vegetation clearing associated with increased bird mortality risk. In addition, it is assumed pre-construction surveys and other site-specific mitigation (e.g., setbacks) will be implemented for future projects, which will reduce residual cumulative effects on bird mortality risk.

With mitigation, the residual cumulative effects on wildlife mortality risk from past, present, and reasonably foreseeable projects and physical activities, including the Project, are predicted to be low in magnitude. Residual cumulative effects will occur as multiple irregular events as reasonably foreseeable projects and physical activities go forward and will occur over the long-term during operations.

20.5.4 Summary of Cumulative Effects

The Project is located in a corridor within the Mackenzie Valley that is subject to disturbance from past and present activities and projects, including existing linear infrastructure. Since the Project proposes to use the existing MVWR ROW and watercourse crossing structures to the extent possible, cumulative effects on direct change in habitat are reduced and the Project's contribution to direct change in habitat is predicted to be low in magnitude. Indirect effects on habitat resulting from project noise and activity are expected to be localized and are also low in magnitude and irreversible, despite some areas being reclaimed after construction.

Similarly, the Project's contribution to cumulative change in mortality risk will be low in magnitude given implementation of mitigation, particularly given that PDA clearing will occur outside of the sensitive breeding period for birds.

Table 20.16 summarizes cumulative effects on birds and bird habitat.

Table 20.16 Summary of Cumulative Effects

Residual Cumulative Effect	Residual Cumulative Effects Characterization							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in Habitat	A	CE	L	RAA	HS	LT	IR	I
Contribution from the Project to the residual cumulative effect	The Project will result in the direct loss or alteration of 0.2% of bird habitat in the RAA compared to existing conditions. Similarly, direct habitat loss for SAR is expected to be low, ranging from < 0.1 to 0.7% compared to existing conditions, depending on the species or species group. With mitigation, the contribution from the Project to residual cumulative effects on bird habitat is expected to be low.							
Change in Mortality Risk	A	P	L	RAA	HS	LT	IR	I
Contribution from the Project to the residual cumulative effect	The Project will result in increased mortality risk due to vegetation removal during construction and vegetation maintenance (mowing) along the ROW during operations and maintenance. Mitigation measures (e.g., avoid vegetation clearing during bird nesting periods and pre-construction bird nest searches) will be completed to reduce mortality risk, as required. With mitigation, the contribution from the Project to residual cumulative effects on bird mortality risk is expected to be low.							

KEY

* See Table 20.3 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
No: Negligible
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
MS: Moderate sensitivity
HS: High sensitivity

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

20.6 Determination of Significance

20.6.1 Significance of Residual Effects

The Project will result in the direct loss or alteration of 2,315.2 ha (< 3.1%) of bird habitat within the LAA, including 1,104.9 ha of exposed lands that includes existing anthropogenic disturbances (i.e., existing MVWR and quarries) and provide limited suitability for most bird species. The Project will result in the direct loss or alteration of < 5.0% of habitat within the LAA for all bird SAR, except for common nighthawk (5.9 % change from the existing condition). Similarly, for species assessed qualitatively (e.g., bank swallow, barn swallow), the Project is expected to result in a low magnitude of change in habitat availability within the LAA compared to the existing condition. Common nighthawk are common in the LAA and readily nest in disturbed habitats (e.g., quarries and borrow sources) and following construction of the Project, some quarries and borrow sources will be reclaimed and will provide habitat for the species. Habitat within the RAA for common nighthawk will remain abundant. Indirect effects of habitat loss or alteration are expected to be greatest near active quarries and borrow sources but are generally localized and limited to within the LAA.

Vegetation clearing will occur outside of the nesting period for birds and the low traffic volume during operations and maintenance of the Project is unlikely to result in a notable increase in bird mortality risk, including for SAR/SOCC. Increased access opportunities for hunters may result in increased harvest rates of upland gamebirds and waterfowl, but harvested game species are generally abundant within the LAA.

With the application of avoidance and mitigation measures, residual effects on birds and bird habitat are not expected to threaten the long-term persistence or viability of SAR/SOCC or species of cultural or traditional importance and there are no conservation-based thresholds for species considered in this VC. In conclusion, the project effects on birds and bird habitat are not significant.

20.6.1.1 Significance of Cumulative Effects

The Project will result in the direct loss or alteration of 2,315.2 ha (< 0.2%) of bird habitat within the RAA, including 1,104.9 ha of exposed lands that are subject to existing anthropogenic disturbances (i.e., existing MVWR and quarries) and provide limited suitability for most bird species (Section 20.4.2.3). The Project will result in the direct loss or alteration of < 0.7% of habitat within the RAA for all bird SAR and for species assessed qualitatively (e.g., bank swallow, barn swallow); therefore, the Project is expected to result in a low magnitude of change in habitat availability within the RAA compared to the existing condition. Indirect effects of habitat loss or alteration are not expected to extend into the RAA. While the Project may interact cumulatively with several other, relatively small reasonably foreseeable projects within the RAA, the Project will contribute a small incremental change in habitat for birds. Habitat for birds, including migration, breeding, and winter habitat, will remain abundant in the RAA, including for SAR/SOCC.

The Project will interact cumulatively with past, present, and reasonably foreseeable projects and activities. However, vegetation clearing will occur outside of the nesting period for birds and the low traffic volume during operations and maintenance of the Project is unlikely to result in a notable increase in bird mortality risk, including for SAR/SOCC. Increased access opportunities for hunters may result in increased harvest rates of upland gamebirds and waterfowl, but harvested game species are generally abundant within the LAA.

With the application of mitigation and environmental protection measures, residual cumulative effects on birds and bird habitat are not expected to threaten the long-term persistence or viability of SAR/SOCC, or species of cultural or traditional importance. In conclusion, the cumulative effects on birds and bird habitat are not significant.

20.6.2 Project Contribution to Cumulative Effects

The Project will contribute a small incremental increase in both a change in habitat through vegetation clearing, sensory disturbance, dust deposition, edge effects, and fragmentation, and a change in mortality risk (vegetation clearing, bird-vehicle collisions, hunter access).

20.7 Prediction Confidence

The prediction confidence in the final determination of significance is considered moderate. This level of confidence is based on the factors listed, which includes assumptions as well as gaps and uncertainties discussed in Sections 20.7.1 and 20.7.2.

- The quantity and quality of data available, which includes limited Traditional Knowledge and traditional land and resource use information for portions of the LAA
- The conservative approach taken to assessment (Section 20.4.1.3)
- Professional judgement and experience with similar projects
- Effectiveness of mitigation measures, which reflect best industry practices and those used on similar highways Projects in the NWT (e.g., Tłı̨chǫ Highway)

Prediction confidence is expected to increase following the completion of pre-construction surveys and monitoring programs.

20.7.1 Assumptions

A conservative approach is used to address uncertainty in the environmental effects assessment, which increases confidence in the final determination of significance. The assessment used a habitat-based approach, which focuses on identifying the quantity and composition of land cover types (i.e., habitats) affected by the Project relative to the availability of those habitats in the LAA and RAA. This approach is considered conservative as it assumes that bird species are present if the habitat is available, which is not always the case (e.g., some birds may not be present in a habitat recently affected by fire until the habitat returns to its pre-fire state following the vegetation successional process that require several years). Additionally, land cover classes that represent

disturbed lands (i.e., exposed land) are included in the quantification of direct habitat loss (and comprise 47.8% [1,104.91 ha] of the PDA) despite providing limited value for most bird species. The PDA is conservatively assumed to be lost to birds but there are portions that will be reclaimed, and some species will use disturbed sites.

20.7.2 Gaps and Uncertainties

A systematic survey of raptor nests within the LAA in the Dehcho Region has yet to be completed and the number of nests with potential to interact with the Project is unknown. A pre-construction raptor nest survey (Section 20.8) in this area will help to inform mitigation measures to protect nesting raptors. The Project may increase harvest opportunities and mortality risk and the degree to which this may affect the populations of some species (e.g., upland gamebirds) within the LAA is uncertain. Completing a raptor nest survey and implementing the WMMP is expected to increase prediction confidence.

In addition, there is uncertainty related to the potential direct and indirect effects of climate change on bird distribution and abundance (Stralberg et al. 2015, Duclos et al. 2019, Micheletti et al. 2021). In the NWT, some bird species have been reported to be positively affected whereas others are negatively affected due to potential changes in climatic suitability, fire regimes, vegetation communities as well as forest growth and mortality (Micheletti et al. 2021).

20.8 Follow-up and Monitoring

Pre-construction bird surveys will be completed prior to vegetation clearing where the Project has the potential to interact with sensitive features such as raptor nests or bank swallow colonies in existing quarries. Monitoring programs will be implemented to evaluate if mitigation measures are implemented and operating as planned. These include monitoring in accordance with the terms and conditions of permit approvals and the development and implementation of a WMMP.

The GNWT will continue to refine the WMMP for this project throughout the EA process and is open to and interested in discussions with Indigenous Governments, Indigenous Organizations, and other affected parties on how best to incorporate their recommendations.

Migratory bird species at risk will be monitored to determine species presence and relative abundance during construction. Similar to avian baseline surveys completed to support the DAR, effect monitoring surveys will be designed to focus on migratory bird species at risk most likely to interact with the Project (e.g., bank swallow [*Riparia riparia*], barn swallow [*Hirundo rustica*]) using recommended survey protocols. Specific survey objectives, study design and monitoring methods will be determined in consultation with ECCC and GNWT-ECC.

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21.0 ASSESSMENT OF POTENTIAL EFFECTS ON BIODIVERSITY

Biodiversity is an important component of the environment that promotes social, economic, cultural, spiritual, and ecological benefits. In addition, there are international (United Nations Convention on Biological Diversity), federal (Canadian Biodiversity Strategy [Environment Canada {EC}, 2005]), and territorial (Northwest Territories Biodiversity Action Plan [Northwest Territories Biodiversity Team [NTBT], 2004]) initiatives that have been developed to enhance biodiversity conservation. A shared central goal in the federal and territorial initiatives is to conserve biodiversity and use biological resources in a sustainable manner.

Mammal and bird biodiversity is relatively high in the Mackenzie River (Deh Cho) valley and plant and wildlife biodiversity is highest in the Northwest Territories (NWT) where mixedwood forests provide habitat opportunities for a greater diversity of species (Aurora Research Institute, 2013).

This chapter provides a description of the changes to biodiversity from the construction and operations and maintenance of the Mackenzie Valley Highway Project (the Project) in consideration of the requirements outlined in the Terms of Reference (ToR; Mackenzie Valley Environmental Impact Review Board [MVEIRB], 2015 [Public Registry {PR}#66]), which are:

- Ecosystem and habitat loss
- Habitat fragmentation/barriers to movement and gene flow
- Ability of habitat or species to recover
- Response to edge effects
- Changes to species distribution and abundance
- Invasive/non-native species (hereafter referred to as alien and invasive alien species)
- Changes to special management areas and species of special management concern

In this chapter, these changes to the components of biodiversity are summarized from the assessment of potential effects on relevant valued components (VC) presented in: Chapter 18 (vegetation and wetlands); Chapter 19 (wildlife and wildlife habitat); Chapter 20 (birds and bird habitat); and Chapter 10 (caribou and moose). These changes are described in local and regional contexts and in relation to how the Project could result in potential changes to vegetation and wildlife (includes mammals, birds, and invertebrates) biodiversity using a habitat-based approach. Specifically, the biodiversity assessment considers 213 birds, 42 mammals, 4 invertebrates and 2 amphibians. A comprehensive list of mammal and amphibian species with potential to occur in the Local Assessment Area (LAA), including species at risk (SAR)/species of conservation concern (SOCC), are provided in Appendix 19A, Appendix A.2 (K'alo-Stantec, 2023a) and a list of birds is provided in Appendix 20A, Appendix A.2 (K'alo-Stantec, 2023b).

21.1 Residual Effects on Biodiversity

A significant adverse residual effect on biodiversity is one that, following the application of avoidance and mitigation measures, threatens the long-term persistence or viability of plant or animal SAR/SOCC (see Chapter 19 and Chapter 20). The assessment of potential effects on biodiversity considers the following changes. Pathways of effects are discussed within each section:

- Ecosystem and habitat loss
- Habitat fragmentation and barriers to movement
- Ability of habitat or species to recover
- Response to edge effects
- Changes to species distribution and abundance
- Alien and invasive alien species
- Changes to special management areas and species of special management concern

21.2 Ecosystem and Habitat Loss

Fire and anthropogenic disturbances affect the availability of large areas of secure, undisturbed habitat for boreal caribou in the NWT. Recent data published by ECCC estimates that, across their NWT range, 35% of boreal caribou habitat has been disturbed, with 28% from wildfires and 9% from anthropogenic sources (ECCC, 2020). Regionally, the percentage of undisturbed habitat in 2017 was approximately 79% in the Sahtu Region and 53% in the Southern NWT (i.e., the Dehcho and South Slave regions combined) (GNWT, 2019). The other portions of the NT1 range, the Inuvialuit, Gwich'in, and Wek'èezhìı regions, also have high amounts of undisturbed boreal caribou habitat (98%, 72%, and 66% respectively) (GNWT, 2019) (Section 10.2.2.1).

The Project will result in direct habitat loss and indirect habitat loss for wildlife and bird VCs as discussed in Chapter 10, Chapter 19, and Chapter 20. Direct habitat loss will occur through clearing and development of the Project Development Area (PDA) - the area of direct project disturbance or "footprint". Indirect habitat loss results from sensory disturbance, dust deposition, edge effects, and fragmentation.

21.2.1 Direct Habitat Loss

The Project will result in direct habitat loss within the PDA. Construction activities that require vegetation clearing and road placement will result in loss of upland and wetland habitats. Closure and reclamation of the Mackenzie Valley Winter Road (MVWR) and temporary borrow sources/ quarries, camps, and workspaces will be reclaimed to promote re-establishment of vegetation (Chapter 18 - vegetation and wetlands), which is expected to provide potential wildlife habitat as vegetation communities become established over time. The ability for these areas to support wildlife species will vary with successional stage and species-specific habitat requirements.

Construction of the Project will result in the direct loss of 2,315.2 hectares (ha) of land cover within the wildlife LAA (i.e., a 1 kilometre [km] buffer of the preliminary road alignment and a 2 km buffer around quarries and borrow source), which is a 3.1% decrease from existing conditions. However, 47.8% (1,104.91 ha) of this direct loss is exposed land that contains existing anthropogenic disturbances (i.e., existing MVWR, Norman Wells Pipeline, Mackenzie Valley Fibre Link, and borrow sources), which provide limited suitability for most wildlife species (Section 19.4.2.3).

Overall, construction of the Project will result in the direct loss of 1,210.3 ha of natural land cover for wildlife within the LAA, which represents a 2.1% decrease from existing conditions. Similarly, habitat loss for SAR and SOCC is anticipated to be relatively low. For example, the Project will result in an estimated direct loss of 2% of little brown myotis maternal roosting habitat, 2.9% of grizzly bear denning habitat, and 1.9% of olive-sided flycatcher habitat (Sections 19.4.2.3, 20.4.2.3). Although the Project will result in direct habitat loss for SAR/SOCC, project-related changes to habitat may benefit some species that take advantage of anthropogenic disturbances (Section 20.4.2.3.1.5).

Project routing and design have integrated the existing cleared MVWR right-of-way (ROW) to the extent practicable, which will reduce incremental ecosystem and habitat loss or alteration caused by the Project. For example, edge effects are already present along the entire length of the MVWR. Although there will be a small decrease in patch size for coniferous forest and shrubland (Section 18.4.2.3), core areas of large habitat patches will continue to be available in the LAA. In addition to a project-specific Wildlife Management and Monitoring Plan (WMMP) that will be implemented during the construction and operations and maintenance phases, standard industry practices and mitigation measures will be implemented to reduce the effects of habitat loss on ecosystem VCs. A list of key mitigation measures to reduce potential project effects on change in habitat (direct and indirect habitat loss) are provided.

Key mitigation measures to avoid or reduce direct habitat loss include:

- The area of direct ground disturbance will be limited by following the pre-existing Mackenzie Valley Winter Road (MVWR) road alignment to the extent possible.
- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent practical.
- Clearing will be limited to areas required for construction and safe operations.
- Project vehicles will be confined to existing roads and trails as much as possible to avoid disturbing vegetated areas.
- Riparian vegetation will be maintained whenever possible.
- The WMMP will outline how risks to migratory birds will be managed in accordance with ECCC's Guidelines to Reduce Risk to Migratory Birds (ECCC, 2021) if activities that could result in risk of harm cannot be avoided (e.g., pre-clearing nest surveys).
- Closure and reclamation will promote re-establishment of vegetation.

Operations and maintenance of the Project will not result in additional direct loss or alteration of habitat for vegetation and wildlife and some disturbed habitats may become habitat for vegetation and wildlife following reclamation and natural succession after construction.

21.2.2 Indirect Habitat Loss

An indirect loss or alteration of habitat is likely to occur adjacent to the PDA through sensory disturbance, dust deposition, edge effects, and fragmentation (Sections 10.4.2.1, 19.4.2.1, 20.4.2.1). Project-related sensory disturbance (i.e., noise and light) from most construction activities including equipment operation, infrastructure construction, and blasting has the potential to disturb wildlife and change the use of habitat around the PDA (e.g., habitat avoidance, fine-scale changes in individuals' movement and associated energetic costs). Vegetation clearing will result in an indirect alteration of habitats adjacent to the PDA by creating an unnatural transition (i.e., edge effects) between the PDA and adjacent habitat (Sections 10.4.2.3, 19.4.2.3, 20.4.2.1). Edge effects are discussed in Section 21.5. Dust deposition associated with project construction can affect vegetation composition adjacent to the PDA (e.g., Gill and Lantz, 2014), which may alter habitat use by wildlife. Indirect loss or alteration of habitat creates an area adjacent to the PDA that exhibits some degree of reduced ecological effectiveness, compared to the existing condition, that typically varies by effect pathway and vegetation and wildlife species. Measurable effects on wildlife outside of the LAA resulting from sensory disturbance are unlikely (Sections 19.4.2.3, 20.4.2.3); however, indirect habitat loss may occur in the larger Caribou and Moose LAA (Section 10.4.2.3.1.3).

The indirect loss or alteration of habitat created during construction is likely to persist adjacent to the PDA during operations and maintenance due to sensory disturbance and dust deposition associated with the presence and use of the highway by the public (i.e., continuation of edge effects and fragmentation). As a result, the ecological effectiveness of habitats adjacent to the PDA will be reduced (Section 19.4.2.3).

These indirect effects have the potential to result in a change in habitat and have been shown to result in fine-scale changes in wildlife movements (e.g., wolverine [Scrafford et al., 2018]). Additionally, the presence of the highway will maintain fragmentation and edge effects established during the construction phase. Although edge effects will be maintained due to maintenance activities within the ROW (i.e., periodic brushing and mowing every three years), the distance of edge influence in the adjacent forest may be reduced over time as vegetation communities respond to maintained edges (Harper et al., 2005, 2015, Section 18.4.2.3).

Indirect effects associated with sensory disturbance, dust deposition, edge effects, and fragmentation have primarily been mitigated based on the current preliminary alignment routing that largely follows the existing MVWR, where habitat is already subject to these disturbances and associated reduced ecological effectiveness and avoidance by wildlife. Construction of the Project will result in habitat alteration within the LAA by increasing the amount and duration (i.e., year-round at times) of these indirect effects.

Although there will direct and indirect loss of wildlife habitat in the LAA residual effects on vegetation and wildlife, including on SAR/SOCC, are predicted to be not significant. However, the Project will increase the amount of anthropogenic disturbance in the Caribou and Moose LAA, though relatively small, will contribute to an existing exceedance of a conservation-based threshold for boreal caribou (i.e., 65% undisturbed habitat). Therefore, residual effects on boreal caribou from change in habitat are predicted to be significant (Section 10.6.1.1).

21.2.3 Cumulative Effects on Biodiversity from Habitat Loss

Residual effects arising from past, present, and reasonably foreseeable activities have similar pathways of effects as those arising from the Project and have the potential to result in a cumulative increase in wildlife habitat loss or alteration during the construction and operations and maintenance of the Project. These effects pathways are the direct loss or alteration of wildlife habitat through vegetation clearing and indirect effects through sensory disturbance, dust deposition, edge effects, and fragmentation.

Notable past and present activities and projects that contribute to cumulative effects of habitat loss in the LAA and Regional Assessment Area (RAA i.e., a 15 km buffer of the PDA) are the Norman Wells Pipeline, the MVWR and other winter roads, and quarries and borrow sources. Reasonably foreseeable activities and projects are the Dhu-1 Quarry, the Great Bear River Bridge, and the Prohibition Creek Access Road Project that occur within the LAA and RAA. Although additive, the reasonably foreseeable projects are comparatively small, involving limited amounts of clearing and vehicle traffic, and their respective residual effects are anticipated to be minimal following the application of project-specific mitigation measures.

Mitigation measures and regional initiatives applicable to limiting cumulative effects on wildlife habitat within the RAA (including other reasonably foreseeable projects) include adherence to the project-specific WMMP and other management and monitoring plans used to protect and monitor the environment during the project construction, and operations and maintenance phases (see Section 21.2.1).

Development of the Project, including vegetation clearing, will result in a direct loss or alteration of 2,315.2 ha of habitat for wildlife, a 0.2% decrease from the existing condition in the RAA (1,010,983.5 ha). This includes 1,104.9 ha of exposed land that is subject to existing anthropogenic disturbances (i.e., existing MVWR and quarries). Past and present activities and projects have resulted in the direct loss or alteration of wildlife habitat in the RAA, including for SAR/SOCC.

Although residual cumulative effects on vegetation and wildlife including SAR/SOCC, are predicted to be not significant, the Project will contribute to an existing cumulative effect in the Caribou and Moose LAA and further contribute to an exceedance of a conservation-based threshold for boreal caribou (i.e., 65% undisturbed habitat). Therefore, residual cumulative effects on boreal caribou from change in habitat are predicted to be significant (Section 10.6.2.1).

21.3 Habitat Fragmentation/Barrier to Movement and Gene Flow

Construction of the Project has the potential to affect wildlife movement through the creation of fragmented habitats and physical and sensory barriers that may affect wildlife movement in the LAA. The ability to move between resource patches is important for a species' persistence and barriers can reduce access to key resources, reduce gene flow, lead to range shifts, and alter seasonal movement patterns and dispersal events (Ament et al., 2014; Nathan et al., 2008; Johnson et al., 1992). Increased noise levels can also result in decreased opportunity costs (i.e., time), increased exposure (Beyer et al., 2014), and increased energy expenditure, especially during winter when energy costs are relatively higher (Bradshaw et al., 1998; Saher and Schmiegelow, 2005). The extent to which construction activities alter wildlife movement in the LAA will vary by the duration, frequency, and intensity (e.g., noise level) of disturbance as well as by wildlife species (Shannon et al., 2016). Overall, the Project will contribute to existing habitat fragmentation through a small decrease in average and maximum patch size for some land cover types and an increase in perimeter to area ratio for all land cover types (i.e., edge) (see Chapter 18 - vegetation and wetlands).

21.3.1 Physical Barriers to Movement

In addition to widening the existing MVWR ROW (from 20 metres [m] to 60 m) for most of the length of the Project, there will be some creation of new highway ROW, in addition to quarries, borrow sources, and access roads, that contribute to increased habitat fragmentation. During construction, the physical presence of these features may present a barrier to wildlife but many of the sources of sensory disturbance will only occur seasonally. Habitat fragmentation also has the potential to increase wildlife mortality risk through increased access opportunities and hunting efficiency for hunters, trappers, and predators.

Effects associated with habitat fragmentation will persist into the operations and maintenance phase and the presence of the highway may create a physical barrier to wildlife movement. The associated highway traffic and other operations and maintenance activities also have the potential to reduce barrier permeability due to contributions of sensory disturbance. Sensory disturbances associated with the operations and maintenance of the highway, including the associated public vehicle traffic, will become year-round pathways of effects that have the potential to result in a change in wildlife movement (Sections 10.4.3.3, 19.4.3.3).

Project routing and design have integrated the existing MVWR ROW to the extent possible, which will reduce habitat fragmentation and the creation of new barriers to movement. In addition to a project-specific WMMP that will be implemented during the construction, and operations and maintenance phases, standard industry practices and mitigation measures will also be implemented.

Key mitigation measures to avoid or reduce change in movement include:

- A buffer strip of undisturbed vegetation of at least 30 m wide will be maintained between the highway ROW and other new areas to be cleared.
- Vegetation buffers will be used as visual barriers and to protect riparian vegetation, as appropriate.
- Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns.
- The height of snowbanks will be limited to the extent possible and to a height of less than 1 m.
- Construction and quarry development activities will adhere to the applicable recommended setbacks and timing restrictions for wildlife outlined in the WMMP, where possible.
- Closure and reclamation will promote re-establishment of vegetation.

21.3.2 Change in Movements

Construction of the Project has potential to result in the alteration of movement patterns, including traditional or seasonal movement corridors, over space and time for some wildlife species through sensory disturbance from vehicles, equipment, and personnel. A reduction in barrier permeability (i.e., the PDA may become more difficult to cross) is possible for less mobile species (e.g., small mammals, amphibians), or other wildlife species where roads and traffic volumes can affect movement including wolverine (Scrafford et al. 2018, Section 19.4.3.1.1) as well as moose and caribou (Section 10.4.3.1.1). Project routing that predominantly follows the MVWR has also reduced the potential for adverse effects on wildlife habitat resulting from habitat fragmentation; core areas of large habitat patches will continue to be available in the LAA. Additionally, aquatic habitats will remain connected through the construction of culverts and bridges and a change in movement for aquatic species (e.g., beaver [*Castor canadensis*]) is not anticipated.

Two existing quarries proposed for use on this Project overlap two muskox (*Ovibos moschatus*) important wildlife areas (IWAs) (i.e., areas that consistently contain a relatively high number of individuals) near Norman Wells. As such, there is potential for the Project to temporarily affect local movement of muskox during construction; however, proposed mitigation measures (timing and setback distances) are expected to reduce potential effects associated with sensory disturbance. Overall, construction will be completed in sections and effects associated with sensory disturbance are expected to be localized and short-term in any given location.

Operations and maintenance of the Project has potential to influence the movement of some wildlife species and result in the alteration of wildlife movement patterns, including traditional or seasonal movement corridors, as the presence of the highway and associated traffic will present year-round disturbance (i.e., estimated 50 vehicles/day). Wildlife currently interact with the existing MVWR, which might act as a permeable, semi-permeable or impermeable barrier depending on species-specific road avoidance behaviours. Although the Project will result in a small incremental increase in the width of the road, an increase in traffic volume at relatively low levels

can affect wildlife movement depending on species (Mace et al. 1996, Beyer et al. 2014, Scrafford et al. 2018).

Overall, the LAA will remain connected and relatively undisturbed, and the Project will contribute a small incremental increase in habitat fragmentation. Residual effects on vegetation and wildlife (including SAR/SOCC) associated with project-related habitat fragmentation and barriers to movement are predicted to be not significant (Sections 18.6, 19.6).

21.3.3 Cumulative Effects on Biodiversity from Habitat Fragmentation and Barriers to Movement

Residual effects arising from past, present, and reasonably foreseeable activities have similar pathways as those arising from the Project and have the potential to result in a cumulative barrier to wildlife movement and gene flow. These pathways include physical and sensory barriers.

Notable past and present activities and projects that contribute to cumulative effects on wildlife movement in the LAA and RAA (e.g., creation of linear infrastructure and semi-permeable barriers) are the Norman Wells Pipeline, the MVWR and other winter roads, Prohibition Creek Access Road, and quarries and borrow sources. Reasonably foreseeable activities and projects that have potential to interact with residual effects on wildlife movement include the Dhu-1 Quarry and the Great Bear River Bridge that occur within the LAA and RAA. Although additive, the reasonably foreseeable projects are comparatively small, involving limited amounts of clearing and sensory disturbance, and their respective residual effects are anticipated to be minimal following the application of project-specific mitigation measures Section 19.5).

The Project primarily follows the existing MVWR and given that reasonably foreseeable projects are relatively small, a measurable change in wildlife movement and gene flow in the LAA is not anticipated, although temporary local shifts in distributions in the LAA might occur. Cumulative effects extending into the RAA are not anticipated.

The Project will contribute a small incremental increase in habitat fragmentation and the creation of barriers associated with the construction and operation of the Project (Sections 10.4.2.1, 18.4.2.3, 19.4.2.3). Cumulative effects on vegetation and wildlife (including SAR/SOCC) associated with habitat fragmentation and wildlife movement are predicted to be not significant.

21.4 Ability of Habitat or Species to Recover

The Project will result in the direct and indirect loss or alteration of habitat for vegetation and wildlife. While most habitat will be permanently lost, closure and reclamation of the MVWR and temporary borrow sources/quarries, camps, and workspaces are expected to recover over time due to natural revegetation or reclamation activities designed to promote vegetation communities (see Chapter 18 - vegetation and wetlands). The recovery of vegetation communities will provide potential habitat for a variety of wildlife species depending on site conditions, successional stage and species-specific habitat associations (van Rensen et al., 2015; Wilson and Bayne, 2019).

Construction and operations and maintenance of the Project has the potential to affect the survival and recovery of SAR/SOCC by resulting in a change in habitat, movement, mortality risk, and wildlife health in the LAA. The RAA contains habitat for four mammal, three invertebrate, and two bird SAR, and one mammal, one invertebrate, and one bird SOCC.

A comprehensive assessment of project effects on SAR/SOCC was completed within each respective VC (Chapters 10, 19 and 20), and each respective significance definition considers how residual effects affect the long-term persistence or viability of SAR/SOCC. With the application of avoidance and mitigation measures, residual effects and residual cumulative effects on the wildlife and wildlife habitat, birds and bird habitat, and caribou and moose are not expected to threaten the long-term persistence or viability of SAR/SOCC, or species of cultural or traditional importance.

21.5 Response to Edge Effects

Construction in the PDA will result in the removal of upland and wetland habitats through vegetation clearing. This will result in an indirect alteration of habitats adjacent to the PDA by creating an unnatural transition (i.e., edge effects) between the PDA and adjacent habitat. Edge effects can include changes in microclimate (e.g., Murcia, 1995) and vegetation structure (e.g., Harper et al. 2005), which can in turn result in changes in the vegetation and wildlife community in those habitats. It can also result in increased mortality risk and reduced reproductive success for species, particularly birds, that inhabit edge habitats.

Dust deposition associated with project construction can affect vegetation composition adjacent to the PDA (e.g., Gill and Lantz, 2014), which may further alter habitat suitability for vegetation and wildlife. Indirect loss or alteration of habitat creates an area adjacent to the PDA that exhibits some degree of reduced ecological effectiveness, compared to the existing condition, that typically varies by effect pathway and vegetation and wildlife species.

During operations and maintenance, the presence of the highway will maintain fragmentation and edge effects that were established during the construction phase. Although edge effects will be maintained due to maintenance activities within the ROW (i.e., periodic brushing and mowing every three years), the distance of edge influence in the adjacent forest may be reduced over time as vegetation communities respond to maintained edges (Harper et al., 2005, 2015, See Chapter 18 - vegetation and wetlands). Closure and reclamation of the MVWR and temporary borrow sources/quarries, camps, and workspaces will promote re-establishment of vegetation

(Chapter 18), which is expected to provide potential wildlife habitat as vegetation communities become established over time. The ability for these areas to support wildlife species will vary with successional stage and species-specific habitat requirements.

Project routing and design have integrated the existing MVWR ROW to the extent practicable, which will reduce the additional incremental edge effects caused by the Project. In addition to a project-specific WMMP that will be implemented during the construction, and operations and maintenance phases, standard industry practices and mitigation measures will also be implemented.

Construction, and operations and maintenance of the Project will result in an adverse residual effect relating to edge effects on vegetation and wildlife that will result from vegetation clearing activities, particularly where the PDA intersects forested habitats. However, the existing MVWR and other exposed lands (e.g., quarries) have already created edge effects and the Project will contribute a minor additive increase because a large proportion of the PDA, as based on the current preliminary alignment routing, overlaps these previously disturbed lands. Additionally, dust deposition associated with project construction has the potential to alter habitats adjacent to the PDA. Effects of dust deposition on vegetation are likely to be limited to within 40 m of the PDA (see Section 18.4; Meininger and Spatt, 1988; Gleason et al., 2007).

Edge habitats typically alter vegetation and wildlife species composition but can increase species diversity, particularly for bird species, where transitional habitats occur. For example, the creation of a linear feature through a large patch of coniferous forest may reduce suitability for interior forest songbird species but the open or transitional habitats created may be suitable for several other species. Regardless, the creation of edge habitats alters the vegetation and wildlife community composition and may also increase habitat opportunities for alien and invasive alien species.

Overall, the LAA will remain relatively undisturbed, and the Project will contribute a small incremental increase in edge habitats. Residual effects on vegetation or wildlife (including SAR/SOCC) associated with project-related creation of edge habitat are predicted to be not significant.

21.5.1 Cumulative Effects on Biodiversity from Edge Effects

Residual effects arising from past, present, and reasonably foreseeable activities have similar pathways as those arising from the Project and have the potential to result in a cumulative increase in edge effects during the construction and operations and maintenance of the Project. Notable past and present activities and projects that contribute to cumulative edge effects in the wildlife LAA and RAA are the Norman Wells Pipeline, the MVWR and other winter roads, and quarries and borrow sources. Reasonably foreseeable activities and projects are the Dhu-1 Quarry, the Great Bear River Bridge, and the Prohibition Creek Access Road Project that occur within the LAA and RAA. Although additive, the reasonably foreseeable projects are comparatively small, involving limited amounts of clearing, and their respective residual effects are anticipated to be minimal following the application of project-specific mitigation measures.

Mitigation measures and regional initiatives applicable to limiting cumulative effects on vegetation and wildlife within the RAA (including other reasonably foreseeable projects) include adherence to the project-specific WMMP and other management and monitoring plans used to protect and monitor the environment during project construction and operations and maintenance.

The Project will contribute a relatively small incremental increase in the amount of edge habitat within the RAA. Highway routing will reduce the amount of new edge habitat created and over time edge habitats along the PDA are expected to soften as shrubs grow and some project components are reclaimed.

Overall, the RAA will remain relatively undisturbed, and the Project will contribute a small incremental increase in edge habitats. Cumulative effects on vegetation and wildlife (including SAR/SOCC) associated with edge effects are predicted to be not significant.

21.6 Changes to Species Distribution and Abundance

The construction and operation of linear features, such as highways, creates an unnatural disturbance that can alter the distribution and abundance of species through environmental effects associated with direct (e.g., vegetation clearing) and indirect (e.g., sensory disturbance, edge effects) habitat loss or alteration, altered movement patterns, and increased direct (e.g., vehicle collisions) and indirect mortality risk related to altered predator-prey dynamics and increased access for harvesters, which might increase based on year-round improved access (see Chapter 10). The GNWT will work with the Sahtu Renewable Resources Board and other resource managers to address uncertainty regarding the effects of increased access created by the Project on harvested resources in the study areas. This would include monitoring of harvest that can be used to identify the need for management actions to be taken by the appropriate resource management organization.

Project routing and design have integrated the existing MVWR ROW to the extent practicable, which will reduce effects on vegetation and wildlife. In addition to a project-specific WMMP that will be implemented during the construction, and operations and maintenance phases, standard industry practices and mitigation measures will also be implemented.

The wildlife VCs (i.e., wildlife and wildlife habitat, birds and bird habitat, and caribou and moose) considered how these project-related environmental effects alter the distribution and abundance of wildlife. In general, a measurable change in the abundance of wildlife in the LAA is not anticipated, although temporary local shifts in distributions in the LAA might occur (e.g., during periods of increased construction activity) which is characterized as a low magnitude effect.

Similarly, the vegetation VC considered how environmental effects relating to landscape diversity, community diversity, species diversity, and wetland function can result in a change in the distribution and abundance of vegetation and wetlands. In general, residual effects on vegetation and wetlands are not anticipated to extend beyond the vegetation LAA, however, the Project may result in the loss of plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties and effects are considered moderate to high magnitude. It is possible,

though unlikely, that occurrences of a plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties removed from the PDA are the only occurrences of that species in the LAA or RAA. This determination includes uncertainty in the occurrence of May Be At Risk plants and the potential use by Indigenous Governments, Indigenous Organizations, and other affected parties. Project effects are not expected to result in the local or regional loss of secure or non-native plants and although abundance will be reduced, species of these plants occurring in the LAA are expected to remain abundant.

A comprehensive assessment of project effects on vegetation and wildlife was completed and the respective significance definitions consider how residual effects affect the long-term persistence or viability of species (i.e., which includes the distribution and abundance of species within the LAA and RAA). With the application of avoidance and mitigation measures, residual effects and residual cumulative effects on the wildlife and wildlife habitat, birds and bird habitat, and caribou and moose are not expected to threaten the long-term persistence or viability of SAR/SOCC, or species of cultural or traditional importance.

21.7 Alien and Invasive Alien Species

For the purposes of the Developer's Assessment Report (DAR), alien species include plants, animals and other organisms that are introduced, deliberately or inadvertently, by humans into an ecosystem that is beyond their natural range (GNWT, 2020b; NWT CISPP, 2023). Invasive alien species are those with potential to threaten biodiversity (e.g., native ecosystems), the economy, or society (NWT CISPP, 2023). This does not include species that naturally occur but are undergoing range expansion.

Invasive alien species can adversely affect biodiversity by displacing native species (e.g., competition), introducing pathogens and disease, increasing predation, or altering habitats (e.g., forest defoliation) and ecosystem degradation occurs when native species or endemic populations decline or become extirpated or extinct (GOC, 2017).

21.7.1 Vegetation

Desktop review revealed records of 16 alien plant species and four invasive alien plant species in the RAA (Table B.1 in Appendix 18A). Specific locations of these occurrences are not available but are assumed to be along ditches adjacent to human infrastructure.

Habitat fragmentation (e.g., construction of linear features) generally results in a change in plant community composition, including providing invasive alien species with additional habitat which results in increased abundances of such species. Vehicles using newly constructed roads may spread non-native invasive species by bringing in seed in mud and plant material on tires. However, mitigation will be implemented during construction, which will include regular inspection for invasive alien plant occurrences and mowing to reduce introduction and spread of weeds in the PDA and surrounding natural vegetation (see Chapter 18).

21.7.2 Wildlife

Rock pigeon (*Columba livia*), European starling (*Sturnus vulgaris*), and house sparrow (*Passer domesticus*) are invasive alien species (i.e., introduced from outside North America) that occur within the LAA, but breeding habitats for these species are associated with anthropogenic habitats such as residential areas. The presence of invasive alien species may affect native bird species in these altered habitats. Although European starlings can compete for nesting sites with native cavity-nesting birds (e.g., woodpeckers), potential adverse effects on native birds varies by species and does not necessarily result in severe effects on all native cavity-nesting bird populations (Koenig, 2003).

There are 68 alien invertebrate species that inhabit the NWT but there are additional species that have yet to be assessed and are also alien species (Working Group on General Status of NWT Species, 2021). Local knowledge provided by Tulita Renewable Resources Council (TRRC) through a project-specific Traditional Land and Resource Use (TLRU) study indicated that different species of birds are starting to appear around Tulita that have not been observed in the past, specifically magpies (TRRC, 2022). However, TRRC study participants reported that Sahtu harvesters and land users in the Tulita area are not sure why this is occurring (TRRC, 2022).

While there are no mammal or amphibian species that would be considered invasive alien or non-native species that occur within the RAA, there are some mammal species that have exhibited relatively recent range expansion into the RAA. There have been reports suggesting changes to the number and type of prey species that were once absent or uncommon in the RAA, such as white-tailed deer (*Odocoileus virginianus*) and muskox. It is believed that the northerly range expansion of white-tailed deer is responsible for the increased number of cougar (*Puma concolor*) observations in the Dehcho Region, but these are not expected to occur within the LAA.

Overall, the LAA will remain relatively undisturbed and residual effects on vegetation or wildlife, including on SAR/SOCC, due to invasive/non-native species are predicted to be not significant.

21.8 Changes to Special Management Areas and Species of Special Management Concern

The assessment of potential effects on the wildlife and birds VCs (see Chapters 19 and 20) quantitatively evaluated direct habitat loss or alteration within the LAA on:

- Important Wildlife Areas (Wilson and Haas, 2012):
  - Dehcho beaver concentration areas (3.1% decrease compared to existing conditions)
  - Dehcho lynx concentration areas (3.7% decrease compared to existing conditions)
  - Sahtu muskox areas (3.1% decrease compared to existing conditions)
  - Sahtu rivers (i.e., important moose habitat) (3.0% decrease compared to existing conditions)

- Important Bird Areas (IBAs):
  - Middle Mackenzie River Islands IBA (4.3% decrease compared to existing conditions)
- Conservation Zones (CZs; from the Sahtu Land Use Plan [SLUPB, 2023]):
  - Petiniʔah (Bear Rock) CZ (Zone #32) (3.1% decrease compared to existing conditions)

The Project overlaps Special Management Zones (SMZs) for the Sahtu Deh (Great Bear River) SMZ (Zone #33) and the Deh Cho (Mackenzie River) SMZ (Zone #63), and the Project is anticipated to result in a relatively small amount of direct habitat loss within those SMZ compared to availability within the LAA. The Project protects and respects the values of the SMZ and CZs, as assessed in Chapter 10, 18, 19 and 20).

Overall, the Project is anticipated to have a low magnitude effect on special management areas.

21.9 Summary

The assessment of potential effects on the vegetation, wildlife, and birds VCs (see Chapters 10, 18, 19 and 20) specifically evaluated Project effects on SAR/SOCC and the determination of significance for each respective VC chapter predicted that adverse residual effects would be not significant, except for effects on boreal caribou from habitat loss, which are predicted to be significant as they contribute to an existing exceedance of a conservation threshold. The residual effects of the Project on biodiversity are predicted to be not significant because the Project will not threaten the long-term persistence or viability of plant or animal SAR/SOCC).

Overall, the Project largely follows the existing MVWR and other mitigation measures, such as reclamation of the MVWR and temporary borrow sources/ quarries, camps, and workspaces, will further reduce potential project effects on biodiversity in the RAA.

Given the similarities in effects pathways and factors contributing to effects on biodiversity as described in this chapter, residual effects associated with predicted ecosystem and habitat loss, habitat fragmentation and barriers to movement/gene flow, changes to species distribution and abundance, alien and invasive alien species, and changes to special management areas, residual and cumulative effects on biodiversity are predicted to be not significant.

21.10 References

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22.0 ASSESSMENT OF POTENTIAL EFFECTS ON HERITAGE RESOURCES

The *Mackenzie Valley Resource Management Act* (MVRMA) defines heritage resources as archaeological or historical sites; burial sites; artifacts and other objects of historical, cultural or religious significance; and historical or cultural records.

Heritage Resources are a Valued Component (VC) as these are unique and non-renewable resources that are tangible evidence of thousands of years of human history. These resources reinforce the link between modern communities and land use history. For Indigenous Governments and Indigenous Organizations, heritage resources can be considered one component of traditional land and resource use (TLRU), extending into the deep past. As a result, sharing information between TLRU, and heritage resources assessment teams provides a more comprehensive assessment of potential effects of a project on heritage resources. Archaeological site potential, in particular, is typically evaluated through landscape attributes, including terrain, geology, soils, fauna (fish, wildlife, birds), and vegetation. These features are incorporated into the evaluation of site potential as these attributes play major roles in where people have lived, harvested, and travelled for thousands of years.

Heritage resources are included in the Terms of Reference (ToR) for the Mackenzie Valley Highway Project (the Project), as issued by the Mackenzie Valley Environmental Impact Review Board (MVEIRB, 2015 [Public Registry {PR}#66]), as a subject of note of the human environment. This chapter summarizes information contained within the territorial sites database relative to known sites and heritage resource potential, which is presented in greater detail within the Heritage Resources Technical Data Report (TDR) for the Project, provided in Appendix 22A (K'alo-Stantec, 2022).

Precontact archaeological, historical, and traditional land use sites represent discrete episodes of past activities. They are non-renewable and can be removed or altered by project development. Precontact and historical archaeological resources are tangible expressions of past land use activities. The archaeological interpretation of the resources depends on site contents such as artifacts, buildings, or trails, but also on the spatial relationship of site contents to one another and to the landscape. They are constantly at risk of disturbance and disappearance through both natural processes over time and human use and development of the land. They are therefore fragile, ephemeral, and the product of unique processes and conditions of preservation. Once they have been disturbed, they cannot be replaced, recreated, or restored. Archaeological resources are finite in quantity.

Heritage resources can be affected by the Project through activities that cause surface and/or subsurface disturbance, including vegetation removal, topsoil stripping, and/or excavation, including blasting.

The assessment of potential effects on heritage resources concludes that if all requirements issued by the Territorial regulators and stipulated by the Sahtu Land Use Plan (SLUP) are fulfilled prior to project construction, the residual effects and cumulative effects on heritage resources are predicted to be not significant.

22.1 Scope of Assessment

22.1.1 Regulatory and Policy Setting

The Government of the Northwest Territories (GNWT) Guidelines for Developers for the Protection of Archaeological Sites in the Northwest Territories summarizes the relevant legislation and regulations.

Heritage Resources are protected and regulated under the Northwest Territories Archaeological Sites Regulations pursuant to the *Archaeological Sites Act* (S.N.W.T., 2014, c.9) which applies to all lands and waters other than those within the administration and control of His Majesty in right of Canada. The Regulations state that:

> *4. No person shall search for archaeological sites or archaeological artifacts, or survey an archaeological site, without a Class 2 or Class 2 permit.*
>
> *5. No person shall excavate, alter or otherwise disturb an archaeological site, or remove an archaeological artifact from an archaeological site without a Class 2 permit.*

Additional legislative protection is provided through the MVRMA, regulated through the Mackenzie Valley Land Use Regulations (MVLUR) and the *Historical Resources Act* (territorial). Under Part 5 of the MVRMA, any "impact on the environment" includes any effect on the social and cultural environment or on heritage resources. Two sections of the MVLUR are relevant to archaeological sites:

> *6 (a). Unless expressly authorized by a permit or in writing by an inspector, no permittee shall conduct a land use operation within 30 m of a known monument or a known or suspected historical, archaeological site or burial ground; and*
>
> *12. Where, in the course of a land-use operation, a suspected historical or archaeological site or burial ground is discovered, (a) the permittee shall immediately suspend operations on the site or burial ground and notify the Board or an inspector; and (b) the Board or inspector shall notify any affected First Nation and the department of the Government of the Northwest Territories responsible therefor of the location of the site or burial ground and consult them regarding the nature of the materials, structures or artifacts and any further actions to be taken.*

Specific to the areas to which the SLUP applies, the Project must meet the 13 general conformity requirements (CR) of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023). The SLUP's conformity requirements include consideration of effects of the Project on heritage resources and engagement input in CR#2:

> *"1) For all applications for land use activities, community organizations and potentially affected community members must be adequately engaged with respect to:*
>
> *…b) Potential impacts of the proposed activities on specific locations, including heritage resources, and other issues of concern identified in the engagement…"*
>
> *"2) The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge."* (SLUPB, 2023)

Requirements related to archaeological sites and burial sites are included in CR#4:

> *"1) Land use activities must not be located within 500 m of known or suspected burial sites, or within 150 m of known or suspected archaeological sites, unless measures are developed in cooperation with the Prince of Wales Northern Heritage Centre, affected communities, or, in the case of burial sites, with affected families where possible, to fully mitigate all impacts to the site.*
>
> *2) In areas where there is a high risk of impact to known or suspected archaeological sites, as determined by the Prince of Wales Northern Heritage Centre (PWNHC), an archaeological impact assessment must be conducted prior to commencement of the land use activity."* (SLUPB, 2023)

Additionally, per CR#14, the Project must be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 2023), including the following, which each require protection of archaeological and burial sites:

- Petiniɀah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)
- K'ąąlǫ Tué (Willow Lake Wetlands) Special Management Zone (SMZ) (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

22.1.2 Influence of Engagement

The GNWT has engaged with Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapter 2 (Consultation and Engagement), Chapter 3 (Traditional Knowledge), and Chapter 11 (culture and traditional land use). The GNWT has recently initiated Consultation with Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific TLRU studies, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to heritage resources, including habitation sites, spiritual sites, trails, and travel routes. This feedback has been considered and summarized in Table 22.1 and has been integrated into the assessment of potential effects of the Project on heritage resources that follows.

The SLUP speaks to the importance and protection of heritage resources, Consulting with Indigenous Governments and Indigenous Organizations, and engaging with affected parties relative to proposed development projects. It is accepted practice to engage and include Indigenous knowledge holders in field assessments for Archaeological Impact Assessments (AIAs). This has resulted in direct inclusion of TLRU information in the identification and interpretation of heritage resources. The GNWT has been engaging with affected parties and Consultation has recently been initiated with Indigenous Governments and Indigenous Organizations and will continue throughout the life of the Project. The information shared to date on this Project and previous projects will result in more informed archaeological practice. For instance, site interpretation and identification information included in the Northwest Territories Archaeological Sites Data Base has provided the basis for an initial estimate of TLRU sites within the Heritage Resources TDR (Appendix 22A; K'alo-Stantec, 2022).

It is expected that additional Consultation and engagement will occur relative to completion of an AIA for the Project. Possible activities include providing opportunities for input from Indigenous Governments and Indigenous Organizations to guide selection of field assessment target areas, inclusion of Indigenous knowledge holders and/or community members on field crews, and presentation of the results of the assessment to Indigenous Governments and Indigenous Organizations to provide guidance for site interpretation and mitigation. These opportunities will facilitate integration of Traditional Knowledge relative to the concerns addressed relative to burial sites, trails, historic cabins and campsites, historical sites, and spiritual and sacred sites.

Regulatory engagement was initiated early in the Project's conceptual development. Recent engagement with the Culture and Heritage Division, Department of Education, Culture, and Employment (ECE) includes the review of the two desktop Archaeological Overview Assessments (AOAs) as well as liaison relative to the 2021 AIA of select borrow and quarry sources. Given the approval of the two AOAs by the territorial Assessment Archaeologist, these results will form the basis for additional field assessments (i.e., AIAs) to occur once the Project's footprint becomes more certain during detailed design, and prior to construction.

Table 22.1 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
Engaged Indigenous Governments, Indigenous Organizations and specific other affected parties identified cultural and heritage use sites and areas.	Dessau, 2012 (PR#13); EBA, 2006; 5658 NWT Ltd. and GNWT, 2011 (PR#16); Golder, 2015; IMG-Golder Corporation, 2006; GNWT, 2018; NWRRC, 2023; SHPSJWG, 2000; SLUPB, 2023; TRRC, 2022	The GNWT has reviewed and considered the cultural and heritage use sites and areas identified by Indigenous Governments, Indigenous Organizations and specific other affected parties.	For information about cultural and heritage use sites and areas, see Section 22.2.2.1. See also Section 11.2.5 for additional information about cultural and heritage use sites and areas.
The Project has potential to affect previously recorded trails and travelways and navigability identified by Pehdzéh Kį First Nation and Sahtu Dene and Métis.	IMG-Golder, 2006; Dehcho First Nations, 2011; NWRRC, 2023; TRRC, 2022	The GNWT has identified mitigation measures to reduce the effects of the Project on heritage resources. A Heritage and Sites Protection Plan (HSPP) will be developed and implemented. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning.	For mitigation measures to reduce effects of the Project on heritage resources, see Table 22.5 See also: Section 22.4.2 Loss of Site Contents and Contexts Volume 5 for management plans.
Community engagement participants stated that there are burials sites, trails, historic cabins and campsites, historical sites, and spiritual and sacred sites located in the RAA. Participants expressed concern that they will be disturbed by the Project and noted that many of the areas are still in use.	August 2021 Engagement; April to July 2022 Engagement; November to December 2022 Engagement; November 2022 to February 2023 Engagement		
Community engagement participants requested that an archaeological monitoring plan be put in place for the Project.	November to December 2022 Engagement		

22.1.3 Potential Effects, Pathways and Measurable Parameters

Table 22.2 summarizes the potential effects of project activities on heritage resources and the pathways by which these activities may affect heritage resources. From a scientific perspective, heritage resources are evaluated largely based on site contents (e.g., material culture/artifacts; features such as hearths, pits, and trails; structures such as buildings) and the spatial relationship of material culture components to one another, to their environment, and to the landscape. These site contents and contexts can be affected by project activities that result in surface and/or subsurface effects. The Heritage Resources VC does not have a clear and defined parameters that can be applied to measure project effects because there is no measurable count of heritage resources (e.g., archaeological sites) that are contained within the assessment areas (defined in Section 22.1.4.1). Individual sites are of variable heritage value and each must be assessed individually to determine effects, rather than assessing effects on the comprehensive VC.

Table 22.2 Potential Effects, Effects Pathways and Measurable Parameters for Heritage Resources

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Loss of site contents and contexts	Direct loss or alteration of archaeological sites due to surface and subsurface disturbance	Not applicable

22.1.4 Boundaries

Spatial and temporal boundaries for the effects assessment are described in the sections that follow.

22.1.4.1 Spatial Boundaries

Three basic assessment areas are used to assess project effects on Heritage Resources and to provide a broader context. These are the Project Development Area (PDA), Location Assessment Area (LAA), and Regional Assessment Area (RAA). The TDR (Appendix 22A; K'alo-Stantec, 2022) also uses the Project Area to quantify known sites and areas of archaeological site potential, to allow for footprint changes as the Project design progresses. Accordingly, the Project Area is also defined. The preliminary highway alignment, LAA, and RAA are illustrated in Figure 22.1, relative to known archaeological sites on record with the Culture and Heritage Division, ECE.

- **Project Development Area (PDA):** the area of direct project disturbance within which physical works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 metres (m) wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sources with access roads on a 30 m ROW. Following completion of design, the evaluation of the effects of the Project on Heritage Resources can be completed on the PDA only.

- **Project Area:** This is the area to be used by the Project and includes the preliminary highway alignment route with a 100 m buffer on either side, as well as the temporary and permanent quarry and borrow sources with associated access roads. A wider area is applied to allow for footprint changes as project design progresses. Archaeological site locations recorded in the territorial database prior to the use of handheld global positioning system (GPS) units may be inaccurate, while site centrepoints provided within the database do not accurately reflect larger site areas. The wider study area provides a more inclusive sample of sites that may intersect with the Project.
- **Local Assessment Area (LAA):** This is the area within which project-related effects are expected to occur. This is the area within approximately 1 km of the PDA.
- **Regional Assessment Area (RAA):** This is the area within approximately 5 km of the PDA, intended to provide greater contextual information given that there are relatively few heritage resources recorded within the overall region. It is the same as the Regional Study Area (RSA) used to characterize existing heritage resources in K'alo-Stantec (2022); see Section 22.2.

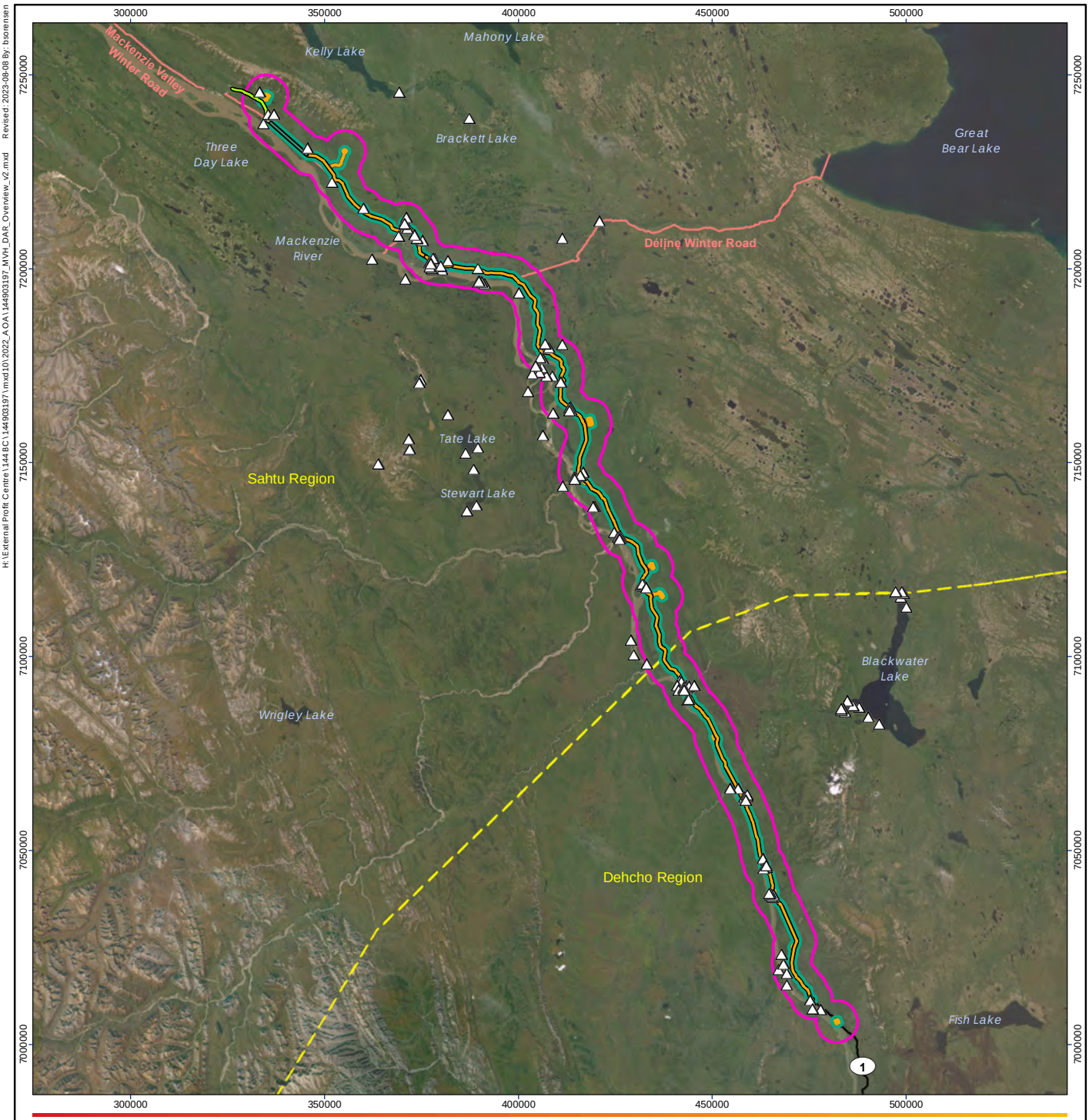
22.1.4.2 Temporal Boundaries

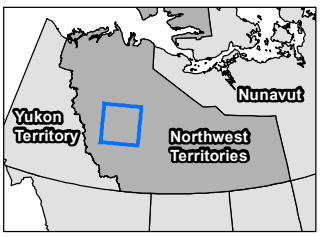
The potential effects of the Project on heritage resources are assessed relative to the following phases:

- **Construction Phase:** The Project will take approximately 10 years to construct, over a timeframe of up to 20 years. The schedule used for this assessment is conceptual and reflects a phased approach to construction, such that the Project is not likely to be constructed as a single, continuous project. The conceptual schedule assumes the highway will be constructed in three segments: Wrigley north to the Dehcho/Sahtu border (102 km); Tulita south to the Dehcho/Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (45 km).
- **Operations and maintenance phase:** The operations and maintenance phase of the Project will likely commence in a similarly staged approach once construction of a particular segment has been completed. The operations and maintenance phase does not have an end date as the Project will not be decommissioned.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, and borrow sources and quarries used only for construction are included within the construction phase.

Primary effects on heritage resources will occur during the construction phase. Assessments and mitigation must be completed prior to (e.g., AIA) or during (e.g., chance find protocol) construction of the Project to receive regulatory approval.





- Archaeological Site
- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Local Assessment Area
- Regional Assessment Area
- Northwest Territories Highway
- Winter Road
- Region Boundary

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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

144903197
Prepared by BSorensen on 2022-12-20
Revised by BSorensen on 2023-08-08

Client/Project
Client: Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
22.1

Title
Heritage Resources Assessment Areas and Recorded Sites

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Centre for Geomatics Government of the Northwest Territories, Government of Canada, Stantec
3. Background: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Imagery date 2021.
4. Archaeological Site Data provided by the Prince of Wales Northern Heritage Centre; (c) Government of the Northwest Territories, Education, Culture, and Employment

Disclaimer: Stantec assumes no responsibility for data supplied in electronic format. The recipient accepts full responsibility for verifying the accuracy and completeness of the data. The recipient releases Stantec, its officers, employees, consultants and agents, from any and all claims arising in any way from the content or provision of the data.

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22.1.5 Residual Effects Characterization

Surface disturbance, such as vegetation removal and vehicle traffic, has potential effects on surface and/or near-surface archaeological sites. Subsurface disturbance during activities such as stripping, grading, and excavation has potential to affect archaeological sites. The potential effects on heritage resources include the loss of site contents and contexts. Heritage resources may be of significance not only from a scientific, archaeological perspective but from the perspective of local and Indigenous Governments and Indigenous Organizations, because they are tangible reflections of TLRU.

Heritage resources are spatially fixed and defined, non-renewable resources. Site-specific effects are regulated at the territorial level. Project-specific effects on heritage resources are continually mitigated to the standards established by territorial regulators. In this context, after implementation of the required mitigation measures issued by the regulatory agency, there are no residual effects from a scientific perspective. Consulting with Indigenous Governments and Indigenous Organizations and engaging with affected parties can provide site-specific mitigation measures. After implementation of these mitigation measures as provided by Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils, there should be no residual effects from the Project on heritage resources from the perspective of Indigenous Governments and Indigenous Organizations. As a result, there is no further characterization of residual effects on this VC.

22.1.6 Significance Definition

There are no formal thresholds for determining heritage value of heritage resources as a single, comprehensive VC. Effects on these resources must be approved by the territorial regulatory agency and/or Minister (Department of Education, Culture and Employment, Culture and Heritage Division).

While site-specific recommendations for project approval and/or additional work are formulated by a Senior Archaeologist and presented in AOA and/or AIA reports submitted to the territorial regulators at GNWT-ECE, the final requirements are stipulated based on regulatory review.

Heritage values as outlined in the permit reports are considered on a site-by-site basis, but there are no guidelines or standards for loss as defined for the VC as a single entity. Mitigation requirements and/or project approvals are determined by the territorial heritage regulators based primarily on individual site integrity and perceived scientific value based on data collected during an AIA. Concerns raised during Consultation or engagement have the potential to influence or alter the final dispensation of individual sites within this VC.

22.2 Existing Conditions for Heritage Resources

This section includes a brief overview of the existing conditions for heritage resources, including information on known sites on record with ECE and areas of archaeological site potential. Greater detail on existing conditions is provided in the Heritage Resources TDR (Appendix 22A; K'alo-Stantec, 2022).

22.2.1 Methods

Information on known sites on record was requested from the Culture and Heritage Division at the PWNHC through an Archaeological Sites Data Base Access Request. This information was updated through a site data licence acquired in May 2022. This request was submitted for the RSA as outlined in the Heritage Resources TDR (Appendix 22A; K'alo-Stantec, 2022).

Portions of the LAA and Project Area have been subject to previous AOAs and AIAs; these reports (with associated GIS data, site forms, and field notes) were accessed, where available.

Palaeontological resources are not protected under territorial legislation. Palaeontological locations are identified when recorded within the territorial Archaeological Sites Database.

Where available, TLRU information is integrated; many of the archaeological sites on record reflect relatively recent ("contemporary") and historic local community use. The archaeological site information provided through the Culture and Heritage Division is reviewed relative to community use. Sites which definitively or possibly reflect TLRU were identified.

Areas of archaeological potential were reviewed primarily through two recent AOAs. The first is an AOA of MVWR upgrades from Prohibition Creek to Mount Gaudet (Krahulic, 2020). The second is an AOA of 39 proposed granular and bedrock sources along the project alignment (Peach, 2021). These two AOAs involved review of previous AOAs (where available), AIAs, and associated spatial data, field notes, maps, and site forms. These AOAs form the basis of the current assessment because they represent recent and comprehensive desktop assessments of the project highway corridor. Based on the results of the AOAs, the GNWT has initiated AIAs in high potential areas such as borrow and quarry sources. The reports of these AIAs are not yet approved by the regulator at the time of submission of the DAR.

Baseline data is summarized in the Heritage Resources TDR (Appendix 22A; K'alo-Stantec, 2022).

22.2.2 Overview

The Mackenzie Valley corridor has been subject to archaeological desktop studies (AOAs) as well as field assessments (AIAs) since the early 1970s. Each of these studies has addressed slightly different footprints related primarily to proposed roadway expansions, the Mackenzie Gas Project and, more recently, the Mackenzie Valley Fibre Link. These AIAs have resulted in the identification of archaeological sites and other heritage resources and have contributed to the evaluation of archaeological site potential. The recent AOAs (Krahulic, 2020; Peach, 2021) have incorporated the results of these AIAs to identify data gaps between the Project and previous field assessments and in the evaluation of resource potential within these unassessed areas.

Evaluations of archaeological site potential were based largely on landscape attributes drawn from National Topographic System (NTS) maps, satellite imagery, and Arctic Digital Elevation Model (DEM) data. Areas of existing anthropogenic disturbance were used in the evaluation of archaeological site potential given the importance of site integrity as a key attribute in evaluating heritage value of a site and therefore assessing the likelihood of effects on sites of high heritage value.

A total of 133 sites are currently on record with the Culture and Heritage Division within the RSA. Sites can range in size from a point (e.g., one isolated artifact) to a large campsite, village, trading post, or trail. This range in site size and in the differing accuracy of locational data due to decades of site records means that the likelihood of spatial overlap between a resource and the Project is approximate. As a result, potential project effects on known heritage resources must be considered with caution.

Of the 133 sites within the RAA, 50 of these lie within the Local Study Area (LAA; see Appendix 22A; K'alo-Stantec, 2022) and 13 fall within the PDA. Until a final footprint/PDA has been defined, the likelihood of effects on the majority of these recorded sites is unknown.

Of these 133 sites within the RSA, 63 may reflect TLRU based on the available site descriptions. Five of these sites are recorded as consisting of or including graves/burials.

Areas of particular site density are at the confluences of the Mackenzie River (Deh Cho) and Ochre River, White Sand Creek, Dam Creek, Blackwater River, Steep Creek, Saline River, Little Smith Creek, Big Smith Creek, and Great Bear River.

A total of 33 areas of high archaeological site potential have been identified within the 2020 AOA footprint (Krahulic, 2020). Nine areas of high archaeological site potential have been identified within the 2021 AOA footprint for borrows, quarries, and associated access within the Project Area. Additionally, previously unknown sites may be recorded in these areas of high archaeological site potential during the AIA field assessment. Previously unknown sites may be encountered during project construction.

22.2.2.1 Cultural and Heritage Use Sites and Areas Identified by Indigenous Governments, Indigenous Organizations, and Other Affected Parties

Cultural and Heritage use sites and areas were identified through a review of publicly available literature and project-specific TLRU studies by the Norman Wells Renewable Resources Council (NWRRC) and Tulita Renewable Resources Council (TRRC), and during engagement feedback provided by Indigenous Governments, Indigenous Organizations, and specific other affected parties. They are described in Table 22.3. For further details, including a figure mapping traditional trails and travelways, spiritual, heritage, and habitation sites, and other cultural sites and areas within the TLRU LAA and TLRU RAA see Chapter 11 (Figure 11.7).

Table 22.3 Cultural and Heritage Use Sites and Areas Identified by Indigenous Governments, Indigenous Organizations, and Other Affected Parties

Location	Within TLRU LAA	Within TLRU RAA[5]	Identified By
Spiritual and Cultural Use Sites and Areas			
Bear Rock (Petınıʔah)	✓*	-	Sahtu Region; Sahtu Dene and Métis; TRRC; NWRRC
Mackenzie River (Deh Cho)	✓*	-	Pehdzéh Kı̨ First Nation; Dehcho First Nations
Pehdzéh Kı̨ N'deh area[1]	✓*	-	Pehdzéh Kı̨ First Nation; Dehcho First Nations
Blackwater River (between MVWR kilometre marker [KM] 783 and 785)	✓*	-	Pehdzéh Kı̨ First Nation; Dehcho First Nations
Tulita	✓*	-	Sahtu; Shúhta Got'ı̨nę
Blackwater Creek	✓*	-	Dehcho First Nations; Pehdzéh Kı̨ First Nation
Great Bear River Watershed	✓	✓	Sahtu Dene and Métis; TRRC
Great Bear River Bridge (area)	✓	-	Sahtu Dene and Métis
Mount Gaudet (in Pehdzéh Kı̨́Ndeh)	-	✓	Pehdzéh Kı̨́First Nation
Heritage Resources			
Mackenzie River (Deh Cho)	✓*	-	Sahtu Region knowledge holders and land users; Pehdzéh Kı̨ First Nation; Dehcho First Nations
Blackwater River	✓*	-	Pehdzéh Kı̨ Fist Nations; Dehcho First Nations
Pehdzéh Kı̨ N'deh area[2]	✓*	✓	Pehdzéh Kı̨ First Nation; Dehcho First Nations

Location	Within TLRU LAA	Within TLRU RAA[5]	Identified By
Ochre River	✓	-	Pehdzéh Kį First Nation; Dehcho First Nations
Hodgson Creek (Near Wrigley)	✓*	-	Pehdzéh Kį First Nation
Prohibition Creek	✓	-	Sahtu Dene and Métis
Great Bear River	✓	-	Sahtu Dene and Métis
White Sand Creek	-	✓	Pehdzéh Kį First Nation; Dehcho First Nations
Vermilion Creek	✓	✓	Pehdzéh Kį First Nation; Dehcho First Nations
Steep Creek	✓	-	Sahtu Region knowledge holders and land users (SRRB)
Saline River	✓	-	Sahtu Region knowledge holders and land users (SRRB)
Little Smith Creek	-	✓	Sahtu Region knowledge holders and land users (SRRB)
Archaeological Site behind Bear Rock (Petınıɂah)	✓		NWRRC
Habitation Sites			
Pehdzéh Kį N'deh area[3]	✓*	-	Pehzdeh Ki First Nation; Dehcho First Nations
Great Bear River (around Bear Rock [Petınıɂah])	✓	-	Elders in the K'ásho Got'ıne and Tuilita regions; TRRC; NWRRC
Proposed Great Bear River Bridge (area) (camping)	✓*	✓	TRRC
Mackenzie River (Deh Cho)	✓	-	Sahtu Dene and Métis; Pehdzéh Kį First Nation; Dehcho First Nations
Blackwater River	-	✓	Pehdzéh Kį First Nation; Dehcho First Nations
Ochre River	-	✓	Pehdzéh Kį First Nation; Dehcho First Nations
Four Mile Creek (camping area)	✓*	-	TRRC
Tulita	✓*	-	TRRC
Cabins in Tulita (along the MVWR)[4]	✓*	-	TRRC
White Sand Creek	✓*	-	Pehdzéh Kį First Nation; Dehcho First Nations
Dam Creek	-	✓	Pehdzéh Kį First Nation; Dehcho First Nations

Location	Within TLRU LAA	Within TLRU RAA[5]	Identified By
Wrigley	✓	-	Pehdzéh Kį First Nation
Cabin along the Project KM 772 to 774	✓*	-	Project-specific engagement program
Cabins (Locations confidential)	✓	-	Project-specific engagement program
Bluefish Creek (fish camp area)	-	✓	NWRRC
Near Bluefish Creek (cabin)	-	✓	NWRRC
Canyon Creek (cabin)	-	✓	NWRRC
Prohibition Creek (cabin)	-	✓	NWRRC
Birch Creek (across from Twenty Mile Island) (cabin)	-	✓	NWRRC
Vermilion Creek (safety cabin/camping area)	✓	✓	NWRRC
Vermilion Creek (cabin)	-	✓	NWRRC
Twelve Mile Point (cabin)	-	✓	NWRRC

Notes:

* May occur within PDA

[1] Pehdzéh Kį N'deh area as described in Dessau (2012)

[2] Pehdzéh Kį N'deh area as described in Dessau (2012)

[3] Pehdzéh Kį N'deh area as described in Dessau (2012)

[4] Specific locations were not identified

[5] Occurs within the RAA outside the LAA and PDA

Sources: Dessau, 2012 (PR#13); EBA, 2006; Golder, 2015; IMG-Golder Corporation, 2006; GNWT, 2018; NWRRC, 2023; SHPSJWG, 2000; SLUPB, 2023; TRRC, 2022; project-specific engagement program (2021-2023)

Pehdzéh Kį First Nation identified spiritual sites in the Pehdzéh Kį N'deh area and a spiritual site associated with hunting moose in the Mackenzie Valley (south of Blackwater Creek) (Dessau, 2012 [PR#13]).

Pehdzéh Kį First Nation and Dehcho First Nations identified burial sites, which are located on both sides of the Mackenzie Valley Winter Road (MVWR) just north of Blackwater River and east of Mackenzie River (Deh Cho), hereafter referred to as Mackenzie River (between Mackenzie Valley Winter Roads KM 783 and 785) (Dessau, 2012 [PR#13]).

Bear Rock (Petınıɂah) is reported as one of the most sacred sites, associated with the story of Yamoria, for Sahtu Dene and Métis and has cultural value, and Sahtú Deh (Great Bear River watershed) in its entirety is considered an important heritage resource. (EBA, 2006; NWRRC, 2023, TRRC, 2022).

Pehdzéh Kį First Nation indicated that their traditional hunting grounds in the vicinity of White Sand Creek are located near concentrations of archaeological sites; historic camps, cabins, historic traps, historic trails, trading posts, and graves have been identified at the confluence of Hodgson Creek and Mackenzie River, as well as at Vermilion Creek South around Wrigley; and Pehdzéh Kį N'deh area, which contains the Old Wrigley town site, as well as burial sites and traditional travel routes near its western boundaries (Dessau, 2012 [PR#13]).

Pehdzéh Kį First Nation and Dehcho First Nations noted that there are historical cabins along Mackenzie River (north and south of Wrigley) accessible by land and water that are often used seasonally by local trappers (IMG-Golder Corporation, 2006).

Sahtu Dene and Métis reported that the Deh Cho (Mackenzie River) SMZ (Zone #63) includes archaeological and burial sites and Mackenzie River is a symbolic focal point of Sahtu Dene and Métis culture and history, containing important heritage harvest and subsistence use locations for Indigenous people in and outside of the Sahtu Region (SLUPB, 2023; 5658 NWT Ltd. and GNWT, 2011 [PR#16]).

Through the project-specific engagement program and in publicly available literature, participants identified Fish Lake[1] as a sacred burial site which should not be disturbed.

NWRRC study participants advised that there are no known archaeological sites in the TLRU study area; however, participants noted that old tools, such as flints, have been found along the river going into Fort Good Hope (NWRRC, 2023). NWRRC study participants noted that previous archaeological excavations occurred behind Bear Rock (Petınıʔah), but it is unknown if any artifacts or resources were recovered (NWRRC, 2023).

Pehdzéh Kį First Nation identified lookout towers: one is located in the northwest corner, one west of Fish Lake, and one on the east bank of the Mackenzie River north of Wrigley (IMG-Golder Corporation, 2006).

Cabins were identified through project-specific TLRU studies, including: along the MVWR (near Tulita), along the MVWR between KM 772 and 774, (near) Bluefish Creek, Canyon Creek, Prohibition Creek, Birch Creek (across from Twenty Mile Island), Vermilion Creek, Twelve Mile Point (NWRRC, 2023; TRRC, 2022). NWRRC study participants identified a safety cabin at Vermilion Creek (NWRRC, 2023).

Sahtu Dene and Métis have identified historic camps, cabins, graves, historic features; historic trails have been identified by Sahtu knowledge holders and land users along the terraces of Steep Creek, Saline River, Little Smith Creek, and various locations along the previous proposed highway route (5658 NWT Ltd. and GNWT, 2011 [PR#16]; IMG-Golder Corporation, 2006).

Study participants of the NWRRC and TRRC TLRU identified camping sites at Bluefish Creek, Vermilion Creek, Four Mile Creek, around Great Bear River (around Bear Rock [Petınıʔah]), and around the proposed Great Bear River Bridge (NWRRC, 2023; TRRC, 2022).

[1] Fish Lake is a common lake name and may refer to Trout Lake

Pehdzéh Kį First Nation in the Dehcho Region reported traditional travel routes near the Pehdzéh Kį N'deh area western boundary, and several cabins and traplines in the area around the lakes connecting Wrigley by traditional trails, several of which are found along the MVWR (Dessau, 2012 [PR#13]; IMG-Golder Corporation, 2006). Pehdzéh Kį First Nation and Dehcho First Nations indicated that historic trails have been identified at the confluence of Hodgson Creek and Mackenzie River, and trails are found around Vermilion Creek South and along Blackwater and Ochre rivers (Dessau, 2012 [PR#13]).

Participants of the TRRC study identified several trails, accessible from the community of Tulita and from Four Mile Creek, which lead to important harvesting, hunting, and other areas of interest to Tulita community members (TRRC, 2022). Participants of the NWRRC study reported that there is an old cutline connecting Kelly Lake to Bluefish Creek that is now used as skidoo trail; a dogsled trail head starts at Sucker Creek; a walking trail that connects Prohibition Creek to Canyon Creek; a trail that connects Bluefish Creek to Kelly Lake; an old trail connects Twenty Mile Island to Sucker Creek; and a trail around Windy Island, which connects the island to the mainland (used for harvesting sheep on Windy Island) (NWRRC, 2023).

Both TRRC and NWRRC study participants identified that the existing Norman Wells pipeline ROW is used as a skidoo trail and access trail for harvesting wildlife along the ROW, and that the MVWR is used for harvesting and hunting on a drive-by basis when wildlife are available (most often when travelling from Tulita to Norman Wells) during the winter or when the MVWR is open (NWRRC, 2023; TRRC, 2022). Sahtu Dene have noted that the Sucker Lake/Three Day Lake (DehdéleĮǫ Tué) area is the location of traditional trails to the mountains and traditional trails are present at Petiniʔah (Bear Rock) CZ (Zone #32). Great Bear River has been the most well-used travel route to Great Bear Lake and is part of many traditional stories and place names. (Dessau, 2012 [PR#13]; IMG-Golder Corporation, 2006; TRRC, 2022; NWRRC, 2023; Golder, 2015).

Pehdzéh Kį First Nation previously stated that, given the importance of traditional practices in the areas surrounding the Project, the cultural value of these areas may be affected, resulting in a diminished historical and social identity for the community, which maintains right and title within their asserted traditional territory (IMG-Golder Corporation, 2006).

22.3 Project Interactions with Heritage Resources

Potential interactions between project activities and heritage resources are identified by a check mark in Table 22.4. These potential interactions are discussed in Section 22.4, in the context of effects pathways as well as standard and project-specific mitigation. Heritage Resources are non-renewable resources which are immoveable and spatially defined. Activities that result in surface and/or subsurface disturbance, such as those involving clearing, excavation, or blasting have the potential to affect known and/or potential heritage resources through the loss of site contents and/or site contexts. These effects will occur during the construction phase. They are not limited or defined by season of activity.

Table 22.4 Project-Environment Interactions with Heritage Resources*

Physical Activities	Timing	Environmental Effect
		Loss of site contents and contexts
Construction Phase		
Mobilization of equipment, materials, and fuel, resupply, and demobilization	Summer and winter	–
Establishment and operation of camps	Year-round	✓
Site preparation of ROW, access, and workspaces	Winter	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	✓
Material haul	Year-round	–
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓
Culvert installations	Summer or winter	✓
Road base placement, compaction, and surfacing	Summer	✓
Water withdrawal to support construction activities	Year-round	–
Closure and reclamation of MVWR and temporary borrow sources/quarries, camps, and workspaces	Summer	✓
Employment and contracted goods and services[1]	Year-round	–
Operations and Maintenance Phase		
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	–
Material haul and stockpiling	Summer	–
Operation of, and activities at, maintenance yards	Year-round	–
Water withdrawal for dust control	Summer	✓
Employment and contracted goods and services[1]	Year-round	–
Presence and public use of the highway	Year-round	–
Highway and access road maintenance including snow clearing, repair, grading, dust control	Year-round	-
Vegetation control	Summer	-
Bridge and culvert maintenance	As needed	-

Notes:

✓ = Potential interaction

– = No interaction

[1] Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, "Employment and contracted goods and services" have been introduced as an additional component under each project phase.

22.4 Assessment of Residual Effects on Heritage Resources

Based on potential project interactions with the environment identified in Table 22.4, the Project may affect heritage resources. Potential effects, effect pathways, and mitigation measures that will reduce or eliminate the effects on heritage resources are identified in Table 22.5.

As discussed in Section 22.1.5, with implementation of mitigation measures issued by the regulatory agency, there are no residual effects from a scientific perspective. After implementation of these and other mitigation measures as may be provided by Indigenous Governments, Indigenous Organizations, and other affected parties, there should be no residual effects from the Project on heritage resources from the perspective of Indigenous Governments, Indigenous Organizations, and other affected parties.

Table 22.5 Potential Effects and Mitigation Measures for Heritage Resources

Effect Name	Effect Pathway	Mitigation Measures
Loss of site contents and contexts	Surface and subsurface ground disturbance can affect archaeological sites, artifacts, and features.	The GNWT will submit project information to GNWT-ECE as required by regulation
		The GNWT will complete and comply with requirements as issued by GNWT-ECE for mitigating effects on heritage resources
		The GNWT will develop a Heritage and Sites Protection Plan.
		The area of direct ground disturbance will be limited by following the pre-existing Mackenzie Valley Winter Road (MVWR) road alignment to the extent possible.
		The highway route will be aligned to existing MVWR watercourse crossing structures (bridges and bridge-sized culverts) to reduce new disturbance in and near watercourses.
		The GNWT will investigate and/or mitigate 'known and suspected sites' as identified by Indigenous Governments and Indigenous Organizations during Consultation, affected parties during engagement, and/or through TLRU studies.
		In areas designated in the Sahtu Land Use Plan, land use activities will not be located within 500 m of known or suspected burial sites, or within 150 m of known or suspected archaeological sites, unless measures are developed in cooperation with the Prince of Wales Northern Heritage Centre, affected communities, or in the case of burial sites, with affected families where possible, to fully mitigate all impacts to the site.
		The GNWT will develop and maintain compliance with a chance find protocol (including worker education) for cultural materials and sites identified during construction.

22.4.1 Analytical Assessment Techniques

Heritage value is assessed individually for each site rather than for the single, comprehensive VC. The relative interpretive potential of a heritage resource must be determined to understand the ways in which it will affect the Project and to formulate the mitigation measures that will be used to resolve or reduce any project conflicts. Site content and context are applied as indicators of interpretive capacity and each site is evaluated in a pre-effect setting from the perspective of scientific value. Community value will also contribute to the evaluation of a heritage resource.

The basic attributes of scientific value are the capacity of an archaeological site to contribute to the current understanding of cultural or natural history and development and its potential to address current research problems within the discipline. Scientific value can be applied to precontact, historic, or palaeontological concerns. Although site integrity is the primary indicator of scientific value, several other factors are also considered. Scientific value is the primary method for assessing interpretive potential at most historic resource sites.

22.4.2 Loss of Site Contents and Contexts

Anticipated loss of site contents and contexts was determined through the consideration of project activities and the likelihood of each activity to result in surface or subsurface disturbance. These activities have the potential to affect known and as yet unidentified heritage resources. There are known heritage resources within the PDA, Project Area, and LAA; there are also areas of evaluated high site potential. There are no formal thresholds for determining heritage value of archaeological resources as a single, comprehensive VC; heritage value from a scientific/regulatory perspective and from an Indigenous/TLRU perspective has not yet been incorporated into the assessment. This will be included on an ongoing basis as the Project progresses, as territorial regulatory requirements are issued and fulfilled, Consultation with Indigenous Governments and Indigenous Organizations occurs, and engagement activities with affected parties occur.

22.4.2.1 Effects Pathways

Surface disturbance, such as vegetation removal and off-road travel, have potential to affect surface and/or near-surface archaeological sites. Subsurface disturbance during activities such as stripping, grading, blasting and excavation have potential to affect subsurface archaeological sites.

22.4.2.2 Mitigation

Mitigation measures relative to the Project include the submission of the TDR (K'alo-Stantec, 2022) and Developer's Assessment Report (DAR) to the Culture and Heritage Division, ECE. It is expected that the Territorial regulators for Heritage Resources will review the project information and issue requirements intended to initiate a staged process of mitigating project effects. These requirements are expected to include completion of:

- An AOA to identify assessment gaps relative to a final footprint/PDA
- An AIA prior to construction in areas with known or suspected high archaeological potential

Fulfilling these requirements will contribute to the mitigation of project effects. Additional requirements may be issued by the Territorial regulators for heritage resources identified during the AIA completion. These requirements may include avoidance of sites through project redesign or fencing/protection during construction, archaeological mitigative excavation, controlled surface collection of cultural materials, historic structure recording, archival/documentary research, construction monitoring, or other mitigative approaches. Similar requirements of 'known and suspected sites' as identified by Indigenous Governments and Indigenous Organizations during Consultation, affected parties during engagement, and/or through TLRU studies will also serve to mitigate project effects.

Mitigation measures will be developed in cooperation between the ECE regulators, Indigenous Governments and Indigenous Organizations, and/or families (in the case of known or suspected burials) to fully mitigate effects on known and/or suspected burials and sites, as per the SLUP conformity requirements. Preferred measures are avoidance of effect, with buffers of 500 m for burial sites and 150 m for archaeological sites. The final mitigation measure is the development and application of a chance find protocol for cultural materials, features, and sites during project construction. A workers' education program can be developed to further the objectives of the chance find protocol. Chance finds may result in additional requirements issued by the territorial regulators.

22.4.2.3 Residual Effects

Site-specific recommendations are typically formulated by a Senior Archaeologist and presented in AOA/AIA reports submitted to the territorial regulators; final requirements are stipulated based on regulatory review, as described. These agencies issue project approvals under territorial legislation. As such, Project-specific effects on heritage resources are continually mitigated to the standards established by the territorial regulators. In this context, after implementation of the required mitigation measures issued by the regulatory agency, there is no residual effect from the Project on heritage resources from a scientific perspective. Engagement activities with affected parties and Consultation with Indigenous Governments and Indigenous Organizations can, however, provide suggested site-specific mitigation measures. Assuming implementation of these mitigation measures as provided by Indigenous Governments, Indigenous Organizations, and other affected parties, there should be no residual effects from the Project on heritage resources from the perspective of Indigenous Governments, Indigenous Organizations, and other affected parties.

With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirements related to archaeological sites and burial sites, and consideration of engagement and Consultation input and incorporation of Traditional Knowledge. The design of the Project and mitigation measures for protection of heritage resources will protect the archaeological sites and burial sites of the Petiniɂah (Bear Rock) CZ, Mio Lake CZ, Norman Range SMZ, K'ąąlǫ Tué (Willow Lake Wetlands) SMZ and Deh Cho (Mackenzie River) SMZ.

22.5 Determination of Significance

22.5.1 Significance of Residual Effects

If all requirements issued by the territorial regulators and via the SLUP are fulfilled prior to project construction, the territorial government considers there to be no significant residual effects for heritage resources. Requirements may include additional desktop and field assessments (AOAs, AIAs), mitigation, and Consultation with Indigenous Governments and Indigenous Organizations, continued engagement opportunities, as well as development and implementation of a chance find protocol.

22.5.2 Significance of Cumulative Effects

If all requirements issued by the territorial regulators and via the SLUP are fulfilled prior to project construction, the territorial government considered there to be no significant cumulative effects for Heritage Resources.

22.6 Prediction Confidence

Provided that regulatory requirements issued by territorial regulators for the Project have been fulfilled and approval is obtained under territorial heritage legislation, confidence in the VC assessment is ranked as high.

22.6.1 Assumptions

The key assumption is that the current regulatory environment (legislation, systems and processes, mitigative options) will continue throughout the life of the Project construction.

22.6.2 Gaps and Uncertainties

The key gap reflects the nature of the heritage resources database, which is incomplete as the majority of heritage resources are unknown. Once a final PDA is defined, it is expected that an AIA will be completed to fulfil requirements of the Culture and Heritage Division of ECE relative to the Project. Completion of the AIA and any subsequently issued regulatory requirements to mitigate project effects (e.g., archaeological excavation, controlled surface collection of artifacts, detailed mapping/recording of historical structures, documentary/archival research) will provide additional information and fill some gaps within the project-specific heritage resources database. Archaeological assessment is always limited to a sample of the overall PDA, however, and it is not possible to identify every resource within the PDA.

Uncertainties include the effects of the gaps and assumptions, as well as additional TLRU information. These uncertainties will be resolved during the application of identified mitigation measures.

22.7 Follow-up and Monitoring

There are no commitments for follow-up or monitoring relative to Heritage Resources at this time. However, early engagement with Indigenous Governments, Indigenous Organizations, and other affected parties has resulted in a recommendation for a monitoring program. Without additional detail, the nature of the monitoring program—whether during the construction or operations and maintenance phases or both—is unknown. Further engagement as well as Consultation with Indigenous Governments and Indigenous Organizations is recommended to consider and develop a monitoring program. Territorial heritage regulators at ECE may also require a monitoring program; this will not be known until regulatory review of the AIA final permit report has been completed and a response issued.

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APPENDIX 12A

Air Quality, Greenhouse Gas Emissions and Climate Baseline Technical Data Report

Mackenzie Valley Highway Project
Technical Data Report—Air Quality, Greenhouse Gas Emissions and Climate Baseline

Prepared for:

Government of the Northwest Territories

Prepared by:

K'alo-Stantec Limited

December 2022

Project No.: 144903025

K'alo-Stantec

Limitations and Sign-off

This document entitled Mackenzie Valley Highway Project Technical Data Report—Air Quality, Greenhouse Gas Emissions and Climate Baseline was prepared by K'alo-Stantec Limited ("K'alo-Stantec") for the account of Government of the Northwest Territories (the "Client") to support the regulatory review process for its Developer's Assessment Report (DAR) (the "Application") for the Mackenzie Valley Highway Project (the "Project"). In connection therewith, this document may be reviewed and used by the Department of Infrastructure (INF) for the Government of the Northwest Territories participating in the review process in the normal course of its duties. Except as set forth in the previous sentence, any reliance on this document by any other party or use of it for any other purpose is strictly prohibited. The material in it reflects K'alo-Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between K'alo-Stantec and the Client. The information and conclusions in the document are based on the conditions existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, K'alo-Stantec did not verify information supplied to it by the Client or others, unless expressly stated otherwise in the document. Any use that another party makes of this document is the responsibility and risk of such party. Such party agrees that K'alo-Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other party as a result of decisions made or actions taken based on this document.

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Executive Summary

The Government of the Northwest Territories (GNWT) Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the "Project") that extends the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells. The Project includes construction of approximately 281 kilometres (km) of new all-season highway and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT).

This technical data report presents detailed data and analysis for baseline ambient air quality, greenhouse gas (GHG) emissions, and existing and forecasted climate conditions in the study area. The report includes results from traditional knowledge and traditional use studies that have been completed in the Sahtu Region and the Dehcho Region in the last two decades.

Existing criteria air contaminants (CAC) emissions for NT originate from a variety of sources, including human and natural. Criteria Air Contaminant emissions are reported annually by industries for all of Canada as part of the National Pollutant Release Inventory. There are no major industrial sources of air contaminants near the Project.

All measured air contaminants (except the particulate matter (PM_{10}) concentrations) are below the applicable Northwest Territories Ambient Air Quality Standards (NWT AAQS) or the Canadian Ambient Air Quality Standards (CAAQS). Particulate matter sources near the Norman Wells station include forest fire smoke as well as dust/sand from gravel and sand roads, which are exposed after being snow covered during the winter months. There may also be local sources that have contributed in 2019.

When baseline CAC concentrations are compared against the four color-coded management levels of the federal Air Quality Management System (AQMS), all CACs concentrations fall into the green category (lowest concentration of air pollutants, requiring the lowest level of air quality management) with the exception of the maximum 24-hour average and annual average of $PM_{2.5}$ concentrations and the maximum 98th percentile of the daily one-hour average nitrogen dioxide (NO_2) concentration, which both fall into the yellow category (second lowest level of air quality management). The green and the yellow category both indicate that concentrations are well below the maximum levels.

Historical climate data from 1981-2010 was obtained from the Norman Wells station, near the northern end of the Project and the Fort Simpson station, located approximately 200 km southeast of the southern end of the Project (Wrigley, NT). The prevailing climate conditions include short warm summers and long, cold winters. Annual average temperatures range from -2.8 degree Celsius (°C) at Fort Simpson to -5.8°C at Norman Wells. Annual total precipitation values are low; most of the rain occurs during the summer months and peak snowfall occurs from October to December. Winds are usually light, below 3 metres per second at both locations. The prevailing wind directions at Norman Wells are from the west and east. At Fort Simpson, the dominant wind directions are north, northwest, and southeast. Visibility at both locations is usually greater than 9 km for most times of the year. Low visibility (i.e., less than 1 km), if it occurs, occurs mostly during the fall months.

Climate in the NT has and is expected to continue to change due to global warming induced by anthropogenic activities emitting GHGs. This change in climate is anticipated to occur more rapidly for northern countries than for the rest of the continental climate in North America. Canada overall is warming twice as fast as the rest of the world, on average; however, the north of Canada has been warming at a rate three times the global average (Government of Canada, 2019). Climate prediction data under the highest GHG emissions scenario (representative concentration pathway (RCP) 8.5) indicate that the trends measured from the last two decades are going to continue. By 2100, the annual average temperature at Norman Wells is forecasted to increase to 1.3°C and total precipitation is predicted to increase by 28% when compared to the average total precipitation measured during 1951-1980.

The climate is changing with increasing global GHG concentrations. The NT reported annual GHG emissions are considered small: they only account for 0.2% of the federal reported total. The largest source of GHG emissions in NT are from the energy sector (e.g., mining, commercial and institutional, domestic aviation, and road transportation).

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Abbreviations

%	percent
µg/m^3	micrograms per cubic metre
µm	micrometre
AQMS	Air Quality Management System
BC AAQO	British Columbia Ambient Air Quality Objectives
CAAQS	Canadian Ambient Air Quality Standards
CAC	criteria air contaminant
CCME	Canadian Council of Ministers of the Environment
cm	centimetre
CO	carbon monoxide
CO_2e	carbon dioxide equivalent
D1HM	daily maximum 1-hour average concentrations
DAR	Developer's Assessment Report
ECCC	Environment and Climate Change Canada
GHG	greenhouse gas
GNWT	Government of the Northwest Territories
GNWT-ENR	Government of the Northwest Territories - Environment and Natural Resources
INF	Department of Infrastructure
km	kilometre
KM	kilometre marker
kPa	kilopascal
kt	kilotonne
LSA	Local Study Area
m	metre
m/s	metres per second
mm	millimetre
Mt	megatonne
MVH	Mackenzie Valley Highway

MVRMA ..... *Mackenzie Valley Resource Management Act*
MVWR ..... Mackenzie Valley Winter Road
NAPS ..... National Air Pollution Surveillance
NO ..... nitric oxide
NO_2 ..... nitrogen dioxide
NO_x ..... nitrogen oxide
NPRI ..... National Pollutant Release Inventory
NT/NWT ..... Northwest Territories
NWT AAQS ..... Northwest Territories Ambient Air Quality Standards
O_3 ..... ozone
ON AAQC ..... Ontario Ambient Air Quality Criteria
PM ..... particulate matter
PM_{10} ..... Particulate Matter aerodynamic diameters less than 10 µm
$PM_{2\,5}$ ..... Particulate Matter aerodynamic diameters less than 2.5 µm
RCP ..... representative concentration pathway
RSA ..... Regional Study Area
SO_2 ..... sulphur dioxide
SO_x ..... sulphur oxides
tCO_2e ..... tonnes of carbon dioxide equivalent
TDR ..... Technical Data Report
the Project ..... Mackenzie Valley Highway Project
ToR ..... Terms of Reference
TSP ..... total suspended particulate
UNFCC ..... United Nations Framework Convention on Climate Change
VOC ..... volatile organic compounds

Glossary

Air Quality Objectives (AQO)	Regulatory criteria for air quality are a suite of ambient air quality criteria that have been developed provincially and nationally to inform decisions on the management of air contaminants.
Criteria Air Contaminants (CACs)	Emissions of criteria air contaminants contribute to poor air quality and human health issues.
Local Study Area (LSA)	The Project footprint and a buffer on either side of the road alignment that considers the extents of the Project's dispersion of air emissions which are primarily dust from the movement of the vehicles over the unpaved road surface.
Regional Study Area (RSA)	The Project footprint and double of the LSA buffer (defined above). This is to account for the other existing and future physical activities that may act cumulatively with the Project air emissions.

1 Introduction

The Government of the Northwest Territories (GNWT) Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the "Project") that will extend the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells to replace the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT; Figure 2.1).

The Project is subject to an environmental assessment and the requirements of Part 5 of the *Mackenzie Valley Resource Management Act* (MVRMA). This technical data report (TDR) presents the existing (baseline) conditions for air quality, greenhouse gases (GHG) emissions, and climate to support development of the Developer's Assessment Report (DAR) as required by the Terms of Reference (ToR) (MVEIRB, 2015).

The required elements specified in the ToR with respect to climate are to describe the existing or baseline climate conditions and climatic variability and trends for:

- location of recording stations and length of record (for air quality measurements see Section 4.1.2; for climate measurements see Section 4.3)
- prevailing climatic conditions, seasonal variations, predominant winds including direction and velocity, temperature, and precipitation (snowfall, snow depth, rain, fog, wind) (see Section 4.3)
- spatial and temporal boundaries for the description of climate (see Section 4.3)
- any current climate-related extreme events that may affect the highway, and frequency of occurrence (to be assessed in the DAR section that describes the potential effects of the environment on the Mackenzie Valley Highway [MVH] Project) (see Section 4.3)

In particular, the baseline or existing information presented for climate should:

- define the variability/trends within the "current" climate normal period and within the historical period of instrument record (see Section 4.3)
- discuss the contribution of traditional knowledge to the understanding of climate conditions and variability (see Section 3.1)
- identify the location of recording stations and length of record for any meteorological data presented (for air quality measurements see Section 4.1.2, for climate measurements see Section 4.3)

Specific to air quality, this ToR describes existing air quality in the highway area, including airsheds, emission sources, seasonal variations, existing and historical air quality, and visibility (as related to highway safety such as known fog areas).

2 Study Area

The Project is in the Mackenzie Valley region of the NT between the current terminus of the existing all-weather highway in Wrigley (Highway #1, kilometre marker [KM] 690) and Norman Wells (KM 1011 of MVWR). The highway portion of the Project parallels the Mackenzie River to its east and passes through the community of Tulita (KM 938) (Figure 2.1).

The study area has long cold winters and short cool summers. Solar radiation on the earth's surface and in atmosphere is the key driver for the climate in the study area. The strength of this radiation is determined primarily by latitude. Snow cover, clouds and large variations in daylight and sun elevation are also factors. The sun's heat is the driving force for the movement of masses of air. During winter, the air flows from the polar region. The Mackenzie Mountains protect this polar air mass from the milder, moister Pacific air. In summer, the air circulation pattern changes. The Arctic air retreats, allowing low pressure systems to gain access from the southwest. Along with this change, the air flow from the south combines with the long hours of sunlight to make the Mackenzie Valley the warmest region for its latitude in all of Canada. Temperature inversions (i.e., warmer air on top of colder more dense air) are common in the Mackenzie Valley. Precipitation is restricted partly due to the rain shadow effect of the Mackenzie Mountains. Precipitation decreases at the more northern latitudes. Overall, the climate patterns are subject to the influences of the Mackenzie Mountains and the annual fluctuations in the incoming solar radiation and sun elevation (Auld and Kershaw, 2009).

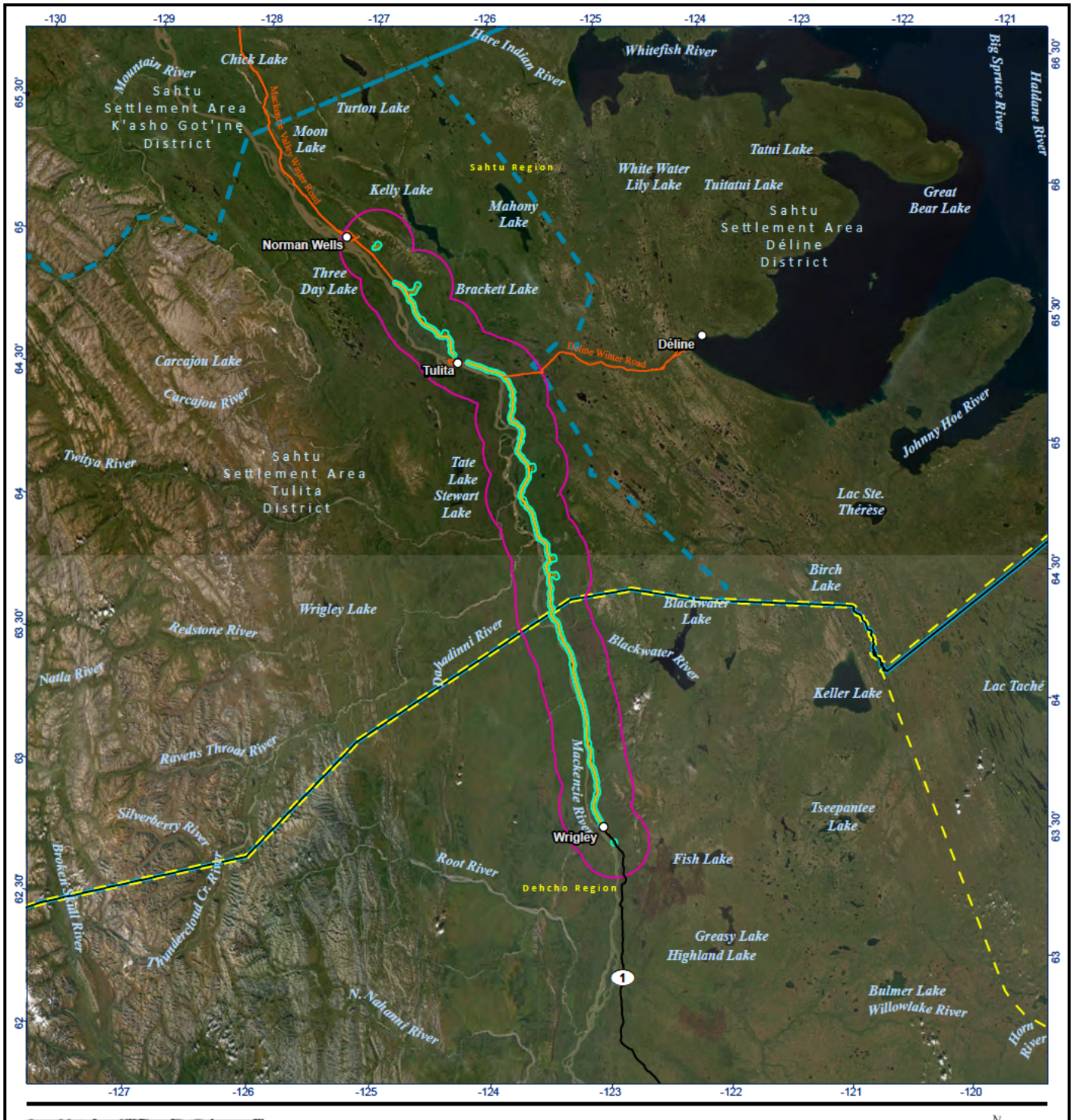
2.1 Local and Regional Study Area

The local and regional study areas presented in this TDR are the areas where data was compiled/collected to allow for an understanding of the environment in support of the project-specific effects assessment and the cumulative effect assessment. Long term air quality and climate monitoring records are available in Norman Wells, and these are sufficient to describe climate in the northern section of the study areas (defined below). Existing air quality and climate information for the southern portion of the study areas is available at Fort Simpson, which is located approximately 200 km southeast of Wrigley along the Mackenzie Highway.

The local study area (LSA) for air quality and climate is a 15 km buffer around the centerline of the highway alignment and around the footprint of the proposed borrow sources. The size of the LSA is consistent with recent environmental assessment and DARs for road projects in the same region (e.g., Prairie Creek All Season Road and the Inuvik-Tuktoyaktuk Highway). It coincides with the maximum geographic extent to which the air emissions, mostly particulate matter (PM) or "fugitive dust", from the MVH road traffic is expected to blow or disperse until the concentrations are undiscernible from the background PM concentrations. Most of the fugitive dust generated by unpaved road traffic is total suspended particulate (TSP) and the larger sized PM (PM_{10}) that falls to the ground at short distances from the source under the influence of gravity.

The size of the regional study area (RSA) also considered the dispersion of other types of air emissions (e.g., gaseous contaminants) from the various phases of the Project. The RSA is a 30 km (double the size of the LSA) buffer around the centerline of the highway alignment and around the footprint of the proposed borrow sources. The RSA accounts for other existing and future physical activities that may act cumulatively with the air emissions from the Project. Physical activities located beyond the 30 km buffer are not expected to interact with project residual air quality effects due to air dispersion over distance.

Figure 2.1 shows a map of the air quality LSA and RSA.



Notes

1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
   World Imagery: Earthstar Geographics
   World Hillshade: Esri, USGS

Project Location
Wrigley to Norman Wells, NWT

Prepared by AJ on 2023-03-07
TR by AT on 2023-03-07

Client/Project
144903025-0018 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
2.1

Title
Local and Regional Study Areas

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3 Review of Existing Data

Several information sources were reviewed for existing conditions of air quality, GHG emissions, and climate. In most cases, the long-term records are available from monitoring stations that are maintained and operated by the GNWT or Environment and Climate Change Canada (ECCC). The information sources were reviewed and approved by members of the Government of the Northwest Territories - Environment and Natural Resources (GNWT-ENR) air quality and climate change teams (Fischer, 2020, pers. comm.; Rudkevitch, 2020, pers. comm.).

3.1 Traditional Knowledge and Traditional Use

Traditional knowledge of the study area has been passed on between generations for centuries through a variety of means, including legends, stories, songs, dances, and experience (Auld and Kershaw, 2009). The knowledge continues to be relevant today because the traditions and activities (such as hunting, trapping, and fishing) are still practiced.

Traditional knowledge studies have been completed in the Sahtu Region and the Dehcho Region in the past two decades. Traditional knowledge obtained through the review of publicly available studies has been incorporated into the description of the existing air quality, GHG emissions, and climate conditions for the Project. When additional information related to atmospheric environment traditional knowledge and traditional use becomes available, it will be included in the DAR.

3.1.1 Methods

The following studies were reviewed for traditional knowledge and traditional use related to air quality, GHG emissions, and climate:

- The draft report on Renewable Resource Assessment of the Pehdzeh Ki Ndeh Area of Interest (IMG-Golder Corporation, 2006).
- Traditional Knowledge Assessment of Boreal Caribou (Mbedzih) in the Dehcho Region (Dehcho First Nations, 2011).
- Mackenzie Valley Highway Extension Pehdzeh Ki Ndeh – Dehcho Region. Project Description Report. Prepared for Government of the Northwest Territories, Department of Transport. (Dessau, 2012)
- Boreal Caribou Traditional Knowledge Collection Study: The Sahtu Settlement Area. Edited by Andrea Hrynkiw and Glen Guthrie and McDonald. For the Canadian Wildlife Service, Environment Canada. (McDonald, 2010)
- 5658 NWT Ltd. and the Government of the Northwest Territories. 2011. Project Description Report for Construction of the Mackenzie Valley Highway Tulita District, Sahtu Settlement Area. (5658 NWT Ltd. and GNWT, 2011)
- Central Mackenzie Surface Water and Groundwater Baseline Assessment. Report 1: Technical State of Knowledge. Report Number: 1401835 Final Report 1. May 21, 2015. (Golder, 2015)

3.1.2 Results

IMG-Golder Corporation (2006) indicated that:

- Commercial fishing efforts in the region are likely to be faced with restricting factors such as cold climate.
- There have been successful efforts to produce vegetable and even grain crops in the mid-1900s in area's challenging climate at the communities of Aklavik and Inuvik in the Mackenzie Delta.
- Meteorological data from the climate station at the Wrigley Airport (operated by ECCC) would be useful for studying the feasibility of incorporating wind-energy electricity to replace diesel generator derived electricity.

Dehcho First Nations (2011) indicated that:

- The Dehcho region is clearly getting warmer and wetter overall, with more rainfall in August and September and even into October. This change is creating more incidences of ice crusting along the ground which may make it more difficult for boreal caribou to forage for ground lichens. Sudden thaws and melting during winter months also create crusts on the snow that make it difficult for boreal caribou to move around and escape predators. In some instances, frost heaves that harbor lichens are diminishing or melting entirely, which reduces availability of this particularly rich habitat site. Wetter summers and falls are resulting in higher water levels on small rivers and streams, increasing boat access (particularly jet boat access) into boreal caribou habitat areas previously difficult to access at these times of year.
- Climate change does not yet appear to be affecting ground or hanging lichens, although some monitoring of future changes to lichen due to climate change should be undertaken.
- Recent changes in climate are significant which include warmer temperatures, increased rain in November, milder winters and increasing summer storms. Boreal woodland caribou food sources are affected by precipitation. During colder times, food becomes less accessible because it is covered by more snow, making it harder for caribou to access.
- More detailed analysis of critical habitat characteristics (with a focus on boreal caribou calving and over-wintering habitat as well as lichen availability, quality, density, and vulnerability) is needed in the context of development, airborne pollution, and climate change. These recommendations were to be considered by the Canadian Wildlife Service in its development of a National Recovery Strategy and Action Plan.
- Global climate change may be impacting caribou populations in a variety of ways
- Forest fire prevalence has increased since the 1960s, with one possible factor begin increased lightning strikes
- An interviewee indicated that climate change is affecting the way people use the land: freeze up is later and at a different place than before, making conditions unsafe for travel
- Fall rain and freezing rain during early winter was mentioned by several of the people who were interviewed. The freezing rain causes a thicker crust to form on the ice, making it difficult for the caribou to travel.

- The crust on the snow can also happen with warm winter winds, although it is unclear if these winds are related to climate change or happen with some regularity
- Not all interviewees agreed that climate change was the root of the changes seen on the land. Some wondered if natural cyclical weather patterns were the reason for the freezing rain conditions seen recently and causing trouble for caribou

The Pehdzeh Ki/ Dehcho First Nations indicated that:

- During the Wrigley Community Consultation (January 25-26th, 2012) the additional concerns that were identified included more dust, contaminants hauled through the land, and more pollution on the road (Dessau, 2012)

Sahtu participants indicated that:

- Weather plays a significant role in the health and well-being of boreal woodland caribou. Increasing extremes in annual temperatures and flooding negatively impact herds (McDonald, 2010).
- Warmer temperatures, melting permafrost and other environmental changes create concerns related to the environment (5658 NWT Ltd. and GNWT, 2011).

The Golder study (2015) indicated that:

- Community members have reported that winds in the area are stronger than in the past, and southerly winds have become more frequent.

3.2 Literature Review

The following information sources were reviewed for existing information related to air quality, GHG emissions, and climate:

- Mackenzie Gas Project (MGP) Environmental Impact Statement (EIS) Volume 3: Biophysical Baseline Part A Environmental Setting, Air Quality and Noise (IORVL, 2004)
- Environmental Impact Statement (EIS) for Construction of the Inuvik to Tuktoyaktuk Highway, NT (Kiggiak – EBA, 2011)
- National Inventory Report (NIR) 1990-2019: Greenhouse Gas Sources and Sinks in Canada, Part 3 (ECCC, 2022a)
- Northwest Territories Air Quality Report 2018 (GNWT, 2018)
- National Air Pollution Surveillance (NAPS) Program Information web site (ECCC, 2022b)
- Canada's Changing Climate Report (Government of Canada, 2019)
- Guidelines for Ambient Air Quality Standards in the Northwest Territories (GNWT, 2014)
- Canadian Ambient Air Quality Standards (CAAQS) (CCME, 2022)
- Climate Data for a Resilient Canada (ECCC, 2019a)

- National Pollutant Release Inventory (NPRI) online datasets for the latest available years (2017 to 2019) (Government of Canada, 2022a)
- Canadian Climate Normals (ECCC, 2022c)
- Online forest fire maps (Natural Resources Canada, 2022)

3.2.1 Methods

The ToR were reviewed to determine the specific existing air quality and climate data that were relevant to the Project. The most appropriate sources for the existing information were identified during discussions with the GNWT-ENR staff for air quality, climate, and climate change (Fischer, 2020, pers. comm.; Rudkevitch, 2020, pers. comm.).

3.2.2 Results

Following discussions with GNWT-ENR staff it was determined that the acceptable sources of ambient air quality information are the latest available Northwest Territories Air Quality Report (GNWT, 2018) and the NAPS program information web site (ECCC, 2022b). The NAPS website provided ambient air quality results for the Norman Wells station. The ECCC NPRI online program information website was the acceptable source of data for criteria air contaminant (CAC) emissions for 2017 to 2019 in the NT (Government of Canada, 2022a). The acceptable source of data for the GHG emissions in the NT is the latest edition of the ECCC National Inventory Report (ECCC, 2022a). The acceptable source of data relating to climate normals is the online ECCC climate normal web site (ECCC, 2022c). The acceptable sources of information related to the climate change predictions applicable to the Project are the Climate Data for a Resilient Canada online tool (ECCC, 2022d) and Canada's Changing Climate Report (Government of Canada, 2019).

The detailed results of data analysis from these sources define the Project's existing conditions for ambient air quality, CAC emissions, GHG emissions, current climate conditions, and the predictions for future climate conditions. These are summarized in Section 4.

4 Key Results and Findings

This section summarizes results of ambient air quality monitoring (see Section 4.1.2), reported existing CAC emissions (see Section 4.1.3), reported GHG emissions (see Section 4.2), and climate normals (see Section 4.3) for the study area. In addition to the historical climate description, this section also includes projections for future climate (see Section 4.4).

4.1 Air Quality

Ambient air, the air in the outdoor environment, mainly contains nitrogen, oxygen, a small amount of carbon dioxide and water vapor. Ambient air, however, also contains a small amount of PM and several other chemicals (also called pollutants). Naturally occurring chemicals and PM are considered part of background levels for air quality.

Air quality is defined as the ambient concentrations of pollutants, defined as the amount of a pollutant in a defined volume of air, usually expressed in micrograms per cubic metre ($\mu g/m^3$). Air quality changes are a result of CAC emissions released from natural or anthropogenic sources, and local meteorological conditions influencing air dispersion (e.g., wind speed, atmospheric stability, and precipitation). The assessment of air quality is valuable for its importance to the health and well-being of people, wildlife, vegetation, and other biota of ecosystems.

This baseline report describes the following CAC pollutants: sulphur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter (inhalable $PM_{2.5}$, coarse PM_{10}, and TSP), ground level ozone (O_3), and carbon monoxide (CO). These CACs are selected because they are included in Northwest Territories Ambient Air Quality Standards (NWT AAQS) or related standards.

The following sections outline the regulatory objectives applicable to air quality in the study area (Section 4.1.1), summarize current air quality concentrations representative of the study area (Section 4.1.2), and list the current emissions released as they are reported to NPRI (Government of Canada, 2022a) (Section 4.1.3).

4.1.1 Air Quality Regulatory Objective

Air quality objectives are a suite of ambient air quality criteria that have been developed provincially and federally to inform decisions on the management of air contaminants. In the NT, the NWT AAQS are used (GNWT-ENR, 2014). Note that the NWT AAQS do not have a standard for PM_{10}. For this review, 50 $\mu g/m^3$ criteria from other jurisdictions (e.g., British Columbia and Ontario) is adopted (see Table 4.1).

Federally, the Canadian Ambient Air Quality Standards (CAAQS) are used to manage air quality such that human health is protected and clean air remains clean. This is managed through the federal Air Quality Management System (AQMS) (CCME, 2022). The Canadian Council of Ministers of Environment (CCME) have stated that achievement of the CAAQS is determined on an airshed and air zone basis, which cover broad geographical areas. They are regional ambient standards. They are not intended to be

applied to individual projects and facilities and are not intended to be used as fenceline standards (CCME, 2019). A fenceline is generally defined as the perimeter of a disturbed area where public access is restricted (BC ENV, 2015). The CAAQS are used by provinces and territories to guide air zone management actions intended to reduce ambient concentrations below the CAAQS and prevent CAAQS exceedances.

Under the federal AQMS, air quality management actions are assigned based on ambient pollutant concentrations within an air zone. Concentration levels are categorized into four management levels associated with specific management actions. This helps to ensure that the CAAQS are not seen as a pollute-up-to levels. The highest level (i.e., red) indicates that concentrations are at or exceeding the CAAQS and require action plans for improvement, the middle management levels (orange and yellow) indicate the need for continuous improvement and action plans to improve air quality. Finally, the lowest management level (green) is considered the baseline; the least impacted or influenced by anthropogenic sources and little action to improve air quality is needed; however, monitoring is ongoing. Suggested air quality management actions are provided for each management level and include, air quality monitoring, emission inventories, stakeholder engagement, developing air zone management plan, implementation plan, reporting, and public education (Table 4.2). In 2025, the CAAQS will become more stringent. There is a slight change in the upper bounds of the red and orange management levels for the 2025 CAAQS (CCME, 2022).

Table 4.1 Applicable Regulatory Criteria

Parameter	NWT AAQS (µg/m^3)	CAAQS 2020 (µg/m^3)	CAAQS 2025 (µg/m^3)	Other Criteria (µg/m^3) (BC AAQO; ON AAQC)
Sulphur Dioxide (SO_2)				
Maximum of 1-hour average	450	-	-	-
Statistics of 1-hour average [a]	-	183	170	-
Maximum of 24-hour average	150	-	-	-
Annual average	30	13	10	-
Nitrogen Dioxide (NO_2)				
Maximum of 1-hour average	400	-	-	-
Statistics of 1-hour average [b]	-	113	79	-
Maximum of 24-hour average	200	-	-	-
Annual average	60	32	23	-
Fine Particulate Matter ($PM_{2.5}$)				
Statistics of 24-hour average [c]	28	27	-	-
Statistics of Annual average [d]	10	8.8	-	-
Coarse Particulate Matter (PM_{10})				
Maximum of 24-hour average	-	-	-	50
Total Suspended Particulate (TSP)				
Maximum of 24-hour average	120	-	-	-
Maximum of Annual average	60	-	-	-
Ground Level Ozone (O_3)				
Statistics of 8-hour average [e]	126	122	118	-

Parameter	NWT AAQS ($\mu g/m^3$)	CAAQS 2020 ($\mu g/m^3$)	CAAQS 2025 ($\mu g/m^3$)	Other Criteria ($\mu g/m^3$) (BC AAQO; ON AAQC)
Carbon Monoxide (CO)				
Maximum of 1-hour average	15,000	-	-	-
Maximum of 8-hour average	6,000	-	-	-

Notes:

$\mu g/m^3$: micrograms per cubic metre

All ambient air quality measurements will be referenced to standard conditions of 25°C and 101.3 kPa.

"-" not applicable

[a] Achievement based on the 3-year average of the annual 99th percentile of the SO_2 D1HM.

[b] Achievement based on the 3-year average of the annual 98th percentile of the NO_2 D1HM.

[c] Achievement based on the 3-year average of the annual 98th percentile of the daily 24-hour average concentrations.

[d] Achievement based on the 3-year average of the daily 24-hour average concentrations.

[e] Achievement based on the 3-year average of the annual 4th highest of the daily maximum 8-hour average ozone concentrations.

Sources:

NWT AAQS: GNWT-ENR (2014).

CAAQS: CCME (2022).

BC AAQO (British Columbia Ambient Air Quality Objectives): Government of BC (2021)

ON AAQC (Ontario Ambient Air Quality Criteria): Ontario Ministry of Environment (2020)

Table 4.2 Canadian Ambient Air Quality Standards Air Quality Management Levels

Air Quality Management Levels	8-hour Ozone ($\mu g/m^3$)		24-hour $PM_{2.5}$ ($\mu g/m^3$)		Annual $PM_{2.5}$ ($\mu g/m^3$)		1-hour Sulphur Dioxide ($\mu g/m^3$)		Annual Sulphur Dioxide ($\mu g/m^3$)		1-hour Nitrogen Dioxide ($\mu g/m^3$)		Annual Nitrogen Dioxide ($\mu g/m^3$)	
	2020	2025	2015	2020	2015	2020	2020	2025	2020	2025	2020	2025	2020	2025
Red	>122	>118	>28	>27	>10.0	>8.8	>183	>170	>13	>10	>113	>79	>32	>23
Orange	>110 and ≤122	>110 and ≤118	>19 and ≤28	>19 and ≤27	>6.4 and ≤10.0	>6.4 and ≤8.8	>131 and ≤183	>131 and ≤170	>8 and ≤13	>8 and ≤10	>58 and ≤113	>58 and ≤79	>13 and ≤32	>13 and ≤23
Yellow	>98 and ≤110		>10 and ≤19		>4.0 and ≤6.4		>79 and ≤131		>5 and ≤8		>38 and ≤58		>4 and ≤13	
Green	≤98		≤10		≤4.0		≤79		≤5		≤38		≤4	

Source: CCME website: https://ccme.ca/en/air-quality-report#slide-7

4.1.2 Measured Air Quality

The NAPS program is the main source of monitored ambient air quality data in Canada. The program began in 1969 and consists of more than 250 monitoring stations across Canada. The goal of NAPS is to provide accurate and long-term air quality data of a uniform standard across Canada (Government of Canada, 2022b). The GNWT operates four continuous monitoring stations as part of NAPS: Fort Smith, Yellowknife, Norman Wells, and Inuvik (ECCC, 2022b).

Data from the Norman Wells and Fort Smith monitoring stations are used to describe the existing ambient air quality in the study area (Table 4.3). The Norman Wells station is used because it is located within the study area, at its northern end, and hence considered most representative. Since the Norman Wells station does not monitor CO concentrations, representative data from the Fort Smith monitoring station is used for CO only. The Fort Smith station is located 960 km southeast of Norman Wells; however, it is considered representative of the project site based on similarity of nearby emissions sources and meteorological conditions that influence air dispersion. This station was selected for the conservative use of the highest measured CO concentrations in 2018 of all the NAPS station in NT.

Table 4.3 NAPS Ambient Air Quality Monitoring Stations near the Project

NAPS Monitoring Station	ID	Latitude	Longitude	Elevation	Monitoring Variables
Norman Wells[1]	129102	65.279	-126.813	60 m	SO_2, NO_2, NO, NO_x, O_3, $PM_{2.5}$, PM_{10}
Fort Smith[1]	129601	60.005	-111.893	680 m	CO

Note:
[1] The Norman Wells and the Fort Smith stations have been operational since 2006 and 2015, respectively.
Source: ECCC (2022b)

Measured ambient concentrations of the CACs from the Norman Wells and Fort Smith stations are listed in Table 4.4 and compared against the air quality objectives. Achievement for each parameter and time averaging interval is as described in the notes section of Table 4.1. Note that the statistical forms for the time averaging intervals vary slightly between some NWT AAQS and the CAAQS. For example, the achievement of the NWT AAQS SO_2 1-hour average value of 450 µg/m^3 is based on the maximum 1-hour average value measured within a year, whereas the achievement of the CAAQS 1-hour average of 183 µg/m^3 is based on the 3-year average of the annual 99th percentile of the SO_2 D1HM.

Except for one CAC, the measured CAC concentrations are well below the applicable federal and territorial criteria. This is expected because the area is relatively undeveloped with very few anthropogenic sources and activities that could affect the quality of air. The exception is spike concentrations of PM_{10}, which can be related to nearby forest fires or dust and sand sources close to the monitoring station, especially during the summer. The seasonal trends for the gaseous air contaminants are documented in the 2018 Air Quality Report prepared by GNWT (GNWT, 2018). The following sections provide more detail for each of the pollutants.

Table 4.4 Summary of Existing Air Quality at Noman Wells

Parameter	Existing Air Quality Concentration (µg/m³)	NWT AAQS (µg/m³)	CAAQS 2020 (µg/m³)	CAAQS 2025 (µg/m³)	Other Criteria (µg/m³) (BC AAQO; ON AAQC)
Sulphur Dioxide (SO_2)					
Maximum of 1-hour average	2.1	450	-	-	-
Statistics of 1-hour average [a]	2.5	-	183	170	-
Maximum of 24-hour average	1.6	150	-	-	-
Annual average	0.5	30	13	10	-
Nitrogen Dioxide (NO_2)					
Maximum of 1-hour average	48.0	400	-	-	-
Statistics of 1-hour average [b]	41.1	-	113	79	-
Maximum of 24-hour average	17.7	200	-	-	-
Annual average	3.2	60	32	23	-
Fine Particulate Matter ($PM_{2.5}$)					
Statistics of 24-hour average [c]	15.0	28	27	-	-
Statistics of Annual average [d]	4.6	10	8.8	-	-
Coarse Particulate Matter (PM_{10})					
Maximum of 24-hour average	162.0	-	-	-	50
Total Suspended Particulate (TSP)					
Maximum of 24-hour average	-	120	-	-	-
Maximum of Annual average	-	60	-	-	-
Ground Level Ozone (O_3)					
Statistics of 8-hour average [e]	86.3	126	122	118	-
Carbon Monoxide (CO)					
Maximum of 1-hour average	2,164 [f]	15,000	-	-	-
Maximum of 8-hour average	1,099 [f]	6,000	-	-	-

Notes:

µg/m³: micrograms per cubic metre

All ambient air quality measurements will be referenced to standard conditions of 25°C and 101.3 kPa.

"-": not applicable

Converted based on ppbv (parts per billion by volume) (parts per million by volume (ppmv) used for CO only) using conversion factors at standard conditions of 25°C and 101.3 kPa.

[a] Achievement based on the 3-year average of the annual 99th percentile of the SO_2 D1HM.

[b] Achievement based on the 3-year average of the annual 98th percentile of the NO_2 D1HM.

[c] Achievement based on the 3-year average of the annual 98th percentile of the daily 24-hour average concentrations.

[d] Achievement based on the 3-year average of the annual average of the daily 24-hour average concentrations.

[e] Achievement based on the 3-year average of the annual 4th highest of the daily maximum 8-hour average ozone concentrations.

[f] There are no CO measurements at Norman Wells station, therefore the maximum of 2019 measurements from the Fort Smith NAPS station in NT is presented

Sources: As detailed in the notes of Table 4.1

4.1.2.1 Sulphur Dioxide

Sulphur dioxide is part of sulphur-containing gases called sulphur oxides (SO_x). Sulphur dioxide has a strong odor and is mainly emitted from the combustion of fossil fuels that contain sulphur, but also from natural gas processing, oil refineries and other industrial activities. Forest fires and volcanic eruptions can be a source of natural SO_2 however human activity is the main source of SO_2 emissions. Sulphur dioxide is considered harmful to humans' respiratory system. Sulphur dioxide also contributes to acid deposition and smog, and it can aid in the formation of secondary $PM_{2.5}$ through chemical reactions (GNWT, 2018; CCME, 2017).

All measured SO_2 values are less than the NWT AAQS and CAAQS. The 24-hour and annual average SO_2 values are low at 1.6 µg/m^3 and 0.5 µg/m^3, respectively. The measured 1-hour average value is 2.1 µg/m^3 when calculated for the NWT AAQS, and 2.5 µg/m^3 when calculated for the CAAQS (i.e., 3-year average of the annual 99th percentile of the SO_2 D1HM) (Table 4.4).

These ambient SO_2 concentrations fall into the green category of the AQMS management levels. The green management category has the least requirements of the four management categories. Little action is needed to improve the air quality and maintaining good air quality is achieved through proactive air management measures that include continuous air quality monitoring, reporting, and public education (CCME, 2019).

4.1.2.2 Nitrogen Dioxide

Nitrogen dioxide (NO_2) belongs to a group of gases that is called nitrogen oxides (NO_x). Nitric oxide (NO) is another one of this group. Both these emissions (NO_2 and NO) are formed when fossil fuels are combusted (e.g., vehicles, industries, heating). During combustion, mainly NO is emitted, however, once released in the air it converts to NO_2. Nitrogen dioxide is also linked to formation of ozone, secondary PM, and acid rain. Nitrogen dioxide is harmful to humans and can cause adverse respiratory effects (GNWT, 2014; CCME, 2017).

All measured NO_2 values are less than the NWT AAQS and CAAQS. The 24-hour and annual average NO_2 values are low at 17.7 µg/m^3 and 3.2 µg/m^3, respectively. The measured 1-hour average value is 48.0 µg/m^3 when calculated for the NWT AAQS, and 41.1 µg/m^3 when calculated for the CAAQS (i.e., 3-year average of the annual 98th percentile of the NO_2 D1HM) (Table 4.4).

The annual measured NO_2 value falls into the green category of the AQMS management levels. However, the 98th percentile of the daily one-hour maximum concentration falls into the yellow category (Table 4.2). The yellow air quality management level has more suggested actions to maintain good air quality than the green category. In addition to all the management actions of the green category, the yellow category adds the following action items: compiling an emission inventory, stakeholder engagement, developing an air zone management plan and prepare air zone specific reports (CCME, 2019).

4.1.2.3 Particulate Matter

Particulate matter is divided by size: fine particulate matter is $PM_{2.5}$, whereas coarse PM is called PM_{10}. $PM_{2.5}$ is potentially dangerous to humans as they can easily be inhaled and can aggravate existing pulmonary and cardiovascular disease. PM_{10} is associated with dust and can be a nuisance. Particulate matter further can also degrade visibility and it is a major contributor to smog. Particulate matter is either solid or liquid particles. Sources of $PM_{2.5}$ in the NT include industrial activities, heating, vehicle emissions and forest fires. Besides being directly emitted (primary PM), PM can form due to reaction of precursor pollutants (secondary PM) (CCME, 2017). The following sections report on measured ambient concentrations of $PM_{2.5}$ and PM_{10}.

Fine Particulate Matter $PM_{2.5}$

The $PM_{2.5}$ maximum 24-hour average and annual average from the Norman Wells monitoring station are less than the NWT AAQS. Regarding the CAAQS air quality management levels, the annual average $PM_{2.5}$ value of 4.6 µg/m^3 and the maximum 24-hour average $PM_{2.5}$ value of 15.0 µg/m^3 fall into the yellow AQMS management level and could indicate an ongoing need to improve air quality, such as management plans and stakeholder engagements (CCME, 2019). However, as the next section will show, shorter term peaks of $PM_{2.5}$ are often influenced by forest fire smoke, especially during summer, and not due to direct human activities. Further in-depth analysis of $PM_{2.5}$ data is provided below.

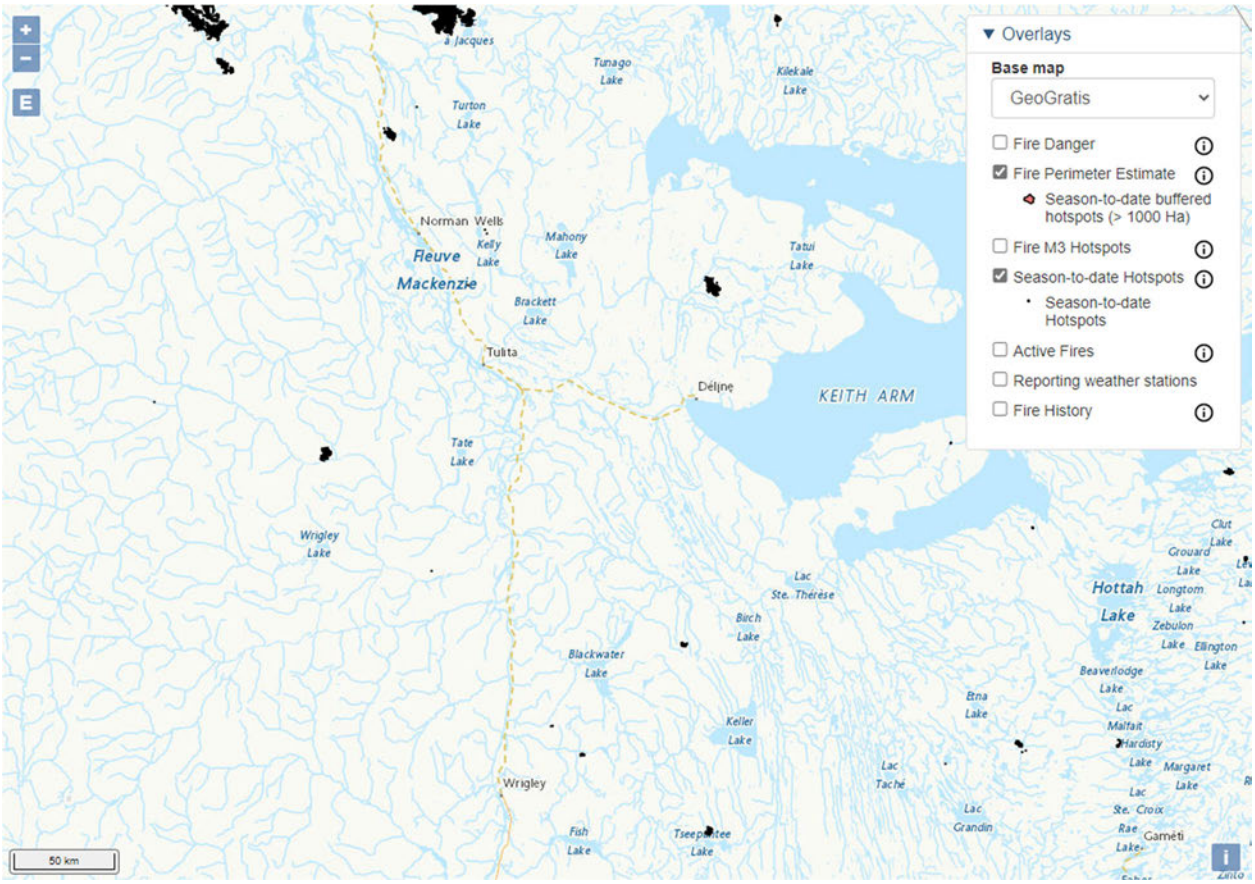
Daily $PM_{2.5}$ data from the Norman Wells NAPS station for 2017 until 2019 has been plotted in Figure 4.1. Each figure presents data for one year. Daily averages were calculated from the hourly data if at least 18 hours of data were available per day. Days with less valid hours are not shown in the graph (18 hours represent 75% data completeness following guidance from CCME, 2011).

For context purpose the 24-hour $PM_{2.5}$ NWT AAQS of 28 µg/m^3 is also shown in the figures. It is for context purpose only, as this achievement is based on the 3-year average of the annual 98th percentile of the daily 24-hour average concentrations. Data in each figure is from one year and only a straight average of the hourly values per day. Daily $PM_{2.5}$ average concentrations are greater than the NWT AAQS in August 2017, and July and August 2019. No concentrations greater that the NWT AAQOs were recorded in 2018.

The interactive fire map from Natural Resources Canada (2022) confirmed the presence of fires in the Sahtu and Dehcho regions in July and August 2017 and 2019, which corresponds to the period with peaks in $PM_{2.5}$ concentration. This suggests that the higher levels of $PM_{2.5}$, specifically during the summer months, may be attributable to forest fire smoke, although it may be due to other local sources given the distance from the fires to Norman Wells (approximately 50 km in 2016 and 100 km away in 2019). Figure 4.2, Figure 4.3 and Figure 4.4 show the summarized season-to-date fire perimeter estimate and season-to-date hotspots near the end of the fire season around September from 2017 to 2019. The figures show that the year 2017 had more fire activity than 2018 and 2019.

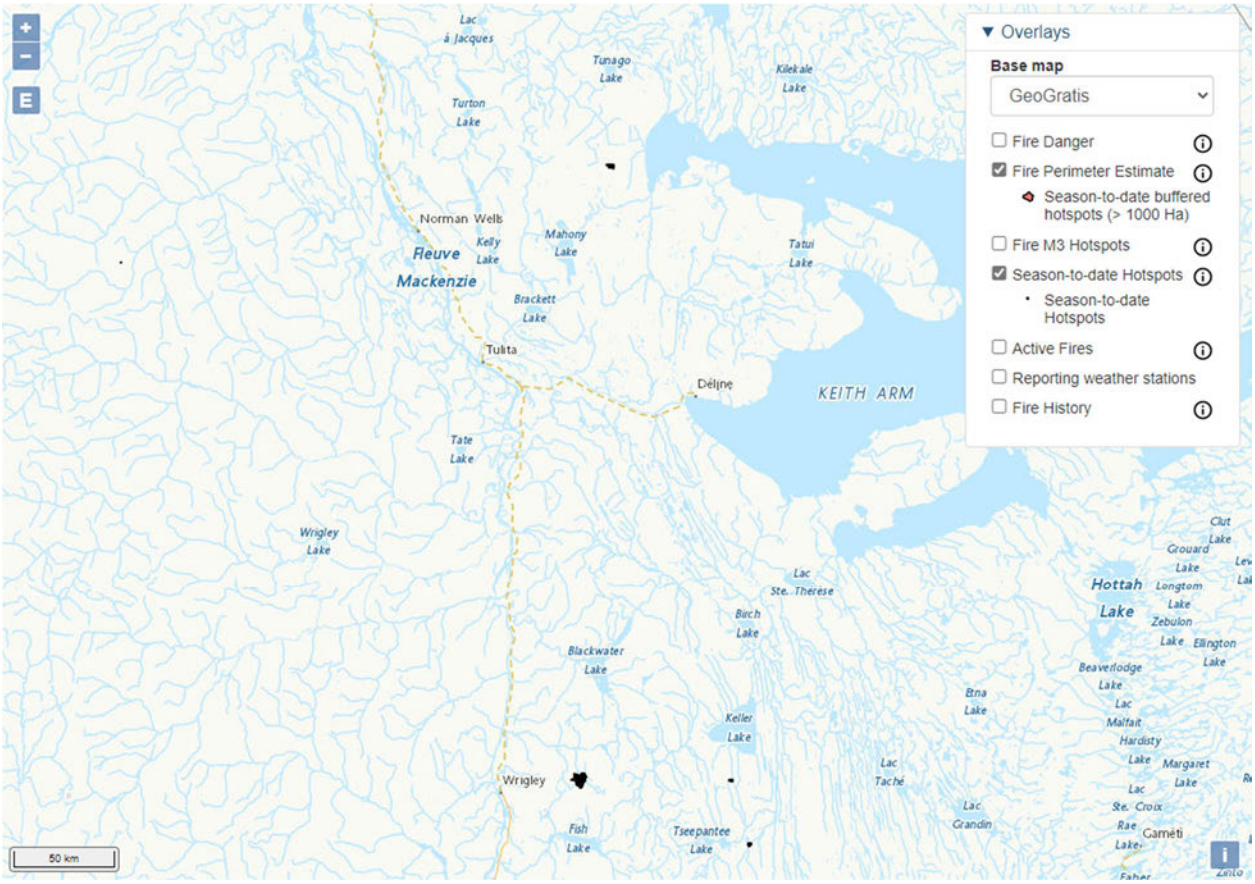
Figure 4.1 Daily Average $PM_{2.5}$ Concentration at Norman Wells in 2017-2019

Figure 4.2 Forest Fire Interactive Map in the Sahtu and Dehcho Regions - 2017



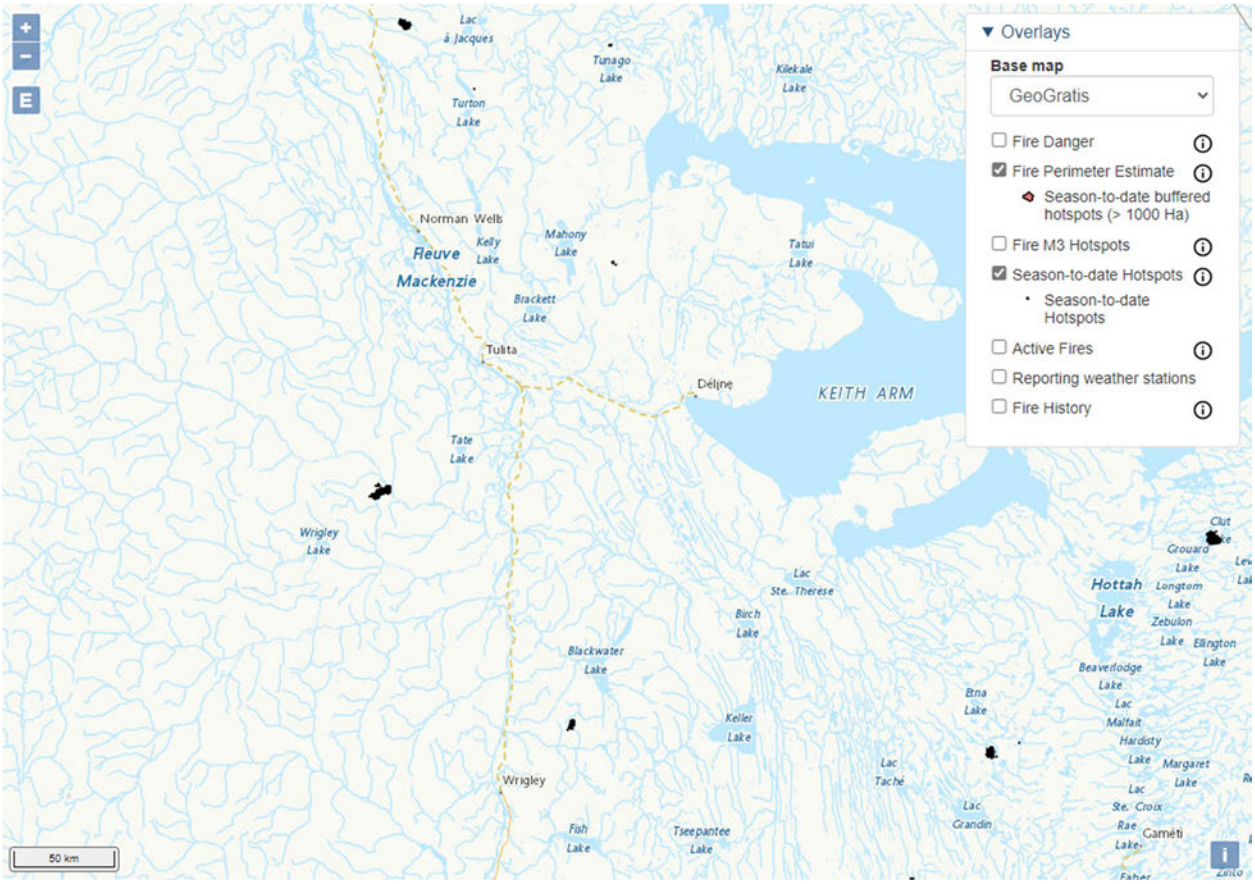
Source: Natural Resources Canada (2022)

Figure 4.3 Forest Fire Interactive Map in the Sahtu and Dehcho Regions - 2018



Source: Natural Resources Canada (2022)

Figure 4.4 Forest Fire Interactive Map in the Sahtu and Dehcho Regions - 2019



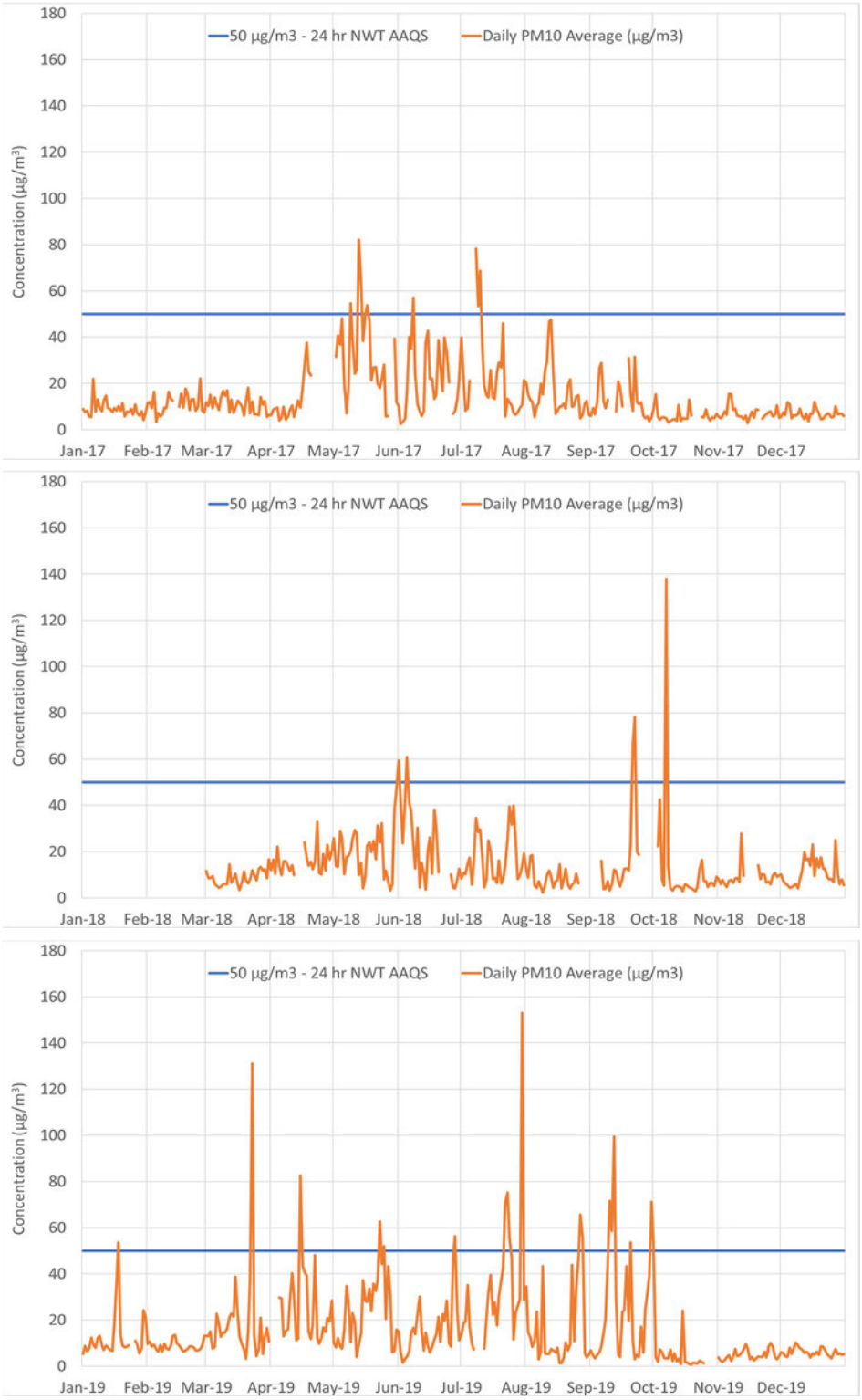
Source: Natural Resources Canada (2022)

Coarse Particulate Matter PM_{10}

Measured PM_{10} data showed that the maximum 24-hour average of 162 µg/m^3 exceeded the 50 µg/m^3 criteria from other jurisdictions (British Columbia Ambient Air Quality Objectives [BC AAQO], Ontario Ambient Air Quality Criteria [ON AAQC]) (Table 4.1).

Daily PM_{10} concentrations for the years 2017 to 2019 are plotted in Figure 4.5. Each graph presents data for one year. Daily averages were calculated from the hourly data if at least 18 hours of data were available per day, where 18 hours of data was not available information is shown as gaps in the graphs.

Figure 4.5 Daily Average PM_{10} Concentration at Norman Wells in 2017-2019



A main source of PM_{10} includes road dust. Exceedances of the BC AAQO of 50 µg/m^3 are observed during the spring and summer months of all three years. This coincides with the time after the snow has melted and sand and gravel roads are exposed. Vehicles or wind cause dust to form on roads. Since there are many gravel roads in the vicinity of Norman Wells, this is likely the main reason for fluctuating concentrations and exceedances of the AAQO throughout the spring and summer months (GNWT, 2018).

Like $PM_{2.5}$, PM_{10} can also be an indicator for forest fires. If the forest fire is occurring nearby the monitoring station, then PM_{10} level can also spike due to larger ash particles falling out of the air near the station. Exceedances of the BC AAQO of 50 µg/m^3 of PM_{10} are observed during the spring and summer months during 2017, and during summer and fall 2018. Exceedances are also more numerous in 2019 than in the previous two years. As the $PM_{2.5}$ concentrations are showing peaks at the same time as the PM_{10} peaks for July 2019 (compare Figure 4.1 and Figure 4.4), forest fires or other combustion activity may be the source in that case; however, the $PM_{2.5}$ concentrations are not showing peaks at the same time for the other periods, and therefore combustion activities are likely not the source.

Discussions with the air quality branch of the GNWT-ENR have confirmed that the peaks up to the period of 2018 are valid and are not erroneous data. They are most likely due to local industrial activity nearby the Norman Wells monitoring station (McKay, 2020, pers. comm.).

4.1.2.4 Total Suspended Particulate

Total suspended particulate combines airborne solid and liquid particles of different sizes, also referred to as “dust”. It represents a somewhat outdated regulatory measure as $PM_{2.5}$ and PM_{10} particles are included when amounts of TSP are discussed. Most regulatory air quality standards and objectives are focusing on $PM_{2\,5}$ and PM_{10} instead of TSP. Note that TSP is not monitored at the Norman Wells or Inuvik station. Since this assessment focuses on $PM_{2.5}$ and PM_{10} measurements and compares them against CAAQS and BC AAQS, no further analysis is required on TSP.

4.1.2.5 Ozone

Ground level O_3 is the same gas as the stratospheric O_3, however at ground level it is considered dangerous as it can cause human health concerns. Ground level ozone is not directly emitted but rather formed during chemical reactions with so-called precursor pollutants (e.g., volatile organic compounds [VOC] and NO_x) and with sunlight. Therefore, O_3 is called a secondary pollutant. Ozone is also a contributor to smog, and it acts as a GHG. Ozone is harmful to humans, specifically to the respiratory system (GNWT, 2014; CCME, 2017).

The measured ozone level of 86.3 µg/m^3 at the Norman Wells station, based on the 3-year average of the annual 4th highest of the daily maximum 8-hour average ozone concentrations, is below the NWT AAQS of 126 µg/m^3 and the CAAQS of 122 µg/m^3 and falls into the green AQMS management level. The green management level indicates that there is little concern regarding ozone concentrations and only little action is required according to the air quality managements actions including continuous air quality monitoring, reporting and public education (CCME, 2019).

4.1.2.6 Carbon Monoxide

CO usually forms during incomplete combustion of hydrocarbon fuels (e.g., diesel, gasoline) and is emitted from vehicle tailpipes. Other sources of CO are from wood combustion, for example, by the forestry industry, by residential heating by wood, and by forest fires. Carbon monoxide is an odorless gas and highly toxic to humans (GNWT, 2014). High concentrations of CO generally occur in areas with heavy traffic congestion (cities) due to vehicle exhaust (US EPA, 2018).

Since the pollutant CO is not measured at the Norman Wells station, data from the Fort Smith station has been assessed. Fort Smith is the location in the Northwest Territories with the most conservative monitoring results for CO and it is in a similar remote northern environmental setting as Norman Wells and neither location experiences heavy traffic congestion. The 1-hour and 8-hour maximum concentrations of 2,164 µg/m^3 and 1,099 µg/m^3 are well below the NWT AAQS of 15,000 µg/m^3 and 6,000 µg/m^3, respectively. There are no federal air quality objectives for CO emissions.

4.1.3 Existing Emissions

As mentioned earlier, air quality is impacted by releases of pollutants (e.g., gases and particles) to the atmosphere from a specific source. A source can be a human activity (e.g., industrial facilities, transportation, and home heating, among others) or a natural activity (e.g., forest fires) (CCME, 2017).

Existing pollutant releases to air are monitored by ECCC on an annual basis through the NPRI. All Canadian industrial, commercial, and institutional facilities must report on their releases, disposals, and transfers of a predetermined list of pollutants and other substances of concern if they meet the reporting threshold. Emissions are inventoried on a per-emitter basis (e.g., individual facilities). This inventory is nationwide and publicly accessible (Government of Canada, 2022a). Reporting industries include, mines, oil and gas operations, power plants and manufacturing facilities. Table 4.5 lists the reported CAC releases to the atmosphere in NT for 2017, 2018 and 2019. Most of the reported CAC emissions have been decreasing since 2017, except for the Coarse Particulate Matter (PM_{10}) and the TSP.

Table 4.5 Summary of Emissions Reported in 2017, 2018 and 2019 NPRI for Northwest Territories

Substance Name	Total Air Emissions (2017) (tonne)	Total Air Emissions (2018) (tonne)	Total Air Emissions (2019) (tonne)
sulphur dioxide (SO_2)	257	261	211
nitrogen dioxide (NO_2)	7,735	7,707	7,277
fine particulate matter ($PM_{2.5}$)	339	361	318
coarse particulate matter (PM_{10})	383	517	482
total suspended particulate (TSP)	412	687	646
carbon monoxide (CO)	1,866	1,732	1,711

Note:
Emissions are presented when the NPRI inventory for each year is filtered for the NT economic region
Source: Government of Canada (2022a).

There are no major industrial sources of air contaminants in the study area, as confirmed by the NPRI inventory (Government of Canada, 2022a). There are, however, smaller industrial facilities in the study area. Reporting industrial facilities in the study area include NWT Power Corporation generating stations (Norman Wells, Tulita, and Wrigley), Enbridge Pipelines facilities (between Norman Wells and Wrigley), and Imperial Oil Resources producing wells and a central processing facility (Norman Wells). Besides these small industrial sources, other emission sources in the study area include aviation activities, community sources (such as traffic and heating), and natural sources (such as forest fires).

4.2 GHG Emissions

Greenhouse gas emissions are federally and provincially/territorially managed in Canada. Industrial facilities that emit more than 10,000 tonnes of carbon dioxide equivalent (tCO_2e) per year are required to report their annual GHG emissions to the federal government to the GHG Reporting Program (Government of Canada, 2020a). Emissions included in these reports are included in the national GHG inventories. Every year, Canada prepares and submits a national GHG inventory to the United Nations Framework Convention on Climate Change (UNFCC) on anthropogenic (human-caused) emissions by sources, removals by sinks, and annual emissions estimates dating back to 1990. The national GHG inventory report presents emissions at the provincial and territorial level in the following four categories: energy, industrial processes and product use, agriculture, and waste. See Table 4.6 for annual GHG emissions reported in NT in comparison to Canadian total GHG emissions.

Table 4.6 Summary of GHG Emissions for Northwest Territories

Greenhouse Gas Categories	Selected Years (kilotonne (kt) CO_2e)							
	1999	**2005**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Energy	1,220	1,570	1,470	1,680	1,560	1,260	1,350	1,310
Industrial Processes and Product Use	9	20	28	27	27	26	28	29
Agriculture	-	-	-	-	-	-	-	-
Waste	38	39	36	36	37	38	39	40
Total NT	**1,260**	**1,630**	**1,530**	**1,740**	**1,620**	**1,320**	**1,420**	**1,380**
Total Canada	**710,000**	**739,000**	**723,000**	**723,000**	**707,000**	**716,000**	**728,000**	**730,000**
NT as percentage of Canada	0.18%	0.22%	0.21%	0.24%	0.23%	0.18%	0.20%	0.19%

Notes:
"-" indicates no emissions.
The total does not match the sum of energy, industrial processes and product use, agriculture, and waste due to rounding
Source: ECCC (2022a).

Canada's total emissions for 2019 were 730 megatonnes (Mt) of CO_2e. Emissions from NT account for a small portion of this, 1,380 kilotonnes (kt) of CO_2e, which is about 0.19% of the federal total. Since the total annual GHG emissions from NT are small, the change in emissions from year to year can appear quite large. For example, emissions dropped by about 20% from 2016 to 2017. These changes are mostly due to factors such as increasing or decreasing use of off-road diesel for large construction projects or the utilization of aviation fuel for mining exploration and fighting wildfires. Changes in these main activities can alter the year-to-year total noticeably.

The energy sector makes up most of the annual emissions in the NT. In 2019, emissions from the energy sector attributed for 95% of the total reported emissions. The largest contributors to the energy category in 2019 were road transportation (612 kt CO_2e: 44%), mining (192 kt CO_2e: 14%), aviation (146 kt CO_2e: 11%), other transportation (93 kt CO_2e: 7%), and commercial and institutional (69 kt CO_2e: 5%).

Despite the NT's low total GHG emissions, if the emissions are assessed on a per capita basis, then NT (30.8 tCO_2e/capita in 2019) is well above the national average (19.4 tCO_2e/capita in 2019). These high per capita emissions are mainly due to a low population number, long distances between communities, energy-intensive resource industry, reliance on diesel power generation and long, cold winters (GNWT, 2020).

A Climate Lens Assessment has been completed for the Project, the intent this Infrastructure Canada's program is to "incent behavioral change and consideration of climate impacts into the planning of infrastructure projects with a view to implementing Canada's mid-century goals of a clean growth low-carbon economy" (Infrastructure Canada, 2018). A GHG Mitigation Assessment (Part I of a Climate Lens Assessment) and Climate Change Resilience Assessment (Part II of the Climate Lens Assessment) have been prepared for the Project. Part I estimates the expected GHG emissions associated with the Project and estimates the potential changes in GHG emissions associated with the Project compared to a functionally equivalent baseline scenario. Part II identifies the climate risks to the Project at a broad systems-level based on a future climate scenario and provides an understanding of the climate impacts on the Project over its construction and operational life. Part II is intended to inform the design team of projected changes in climate and associated risks to consider at the project's detailed design stage. Further details are provided in the DAR.

4.3 Climate

Climate is defined as the weather conditions prevailing in an area over a long period of time, typically 30 years. If weather variables such as temperature, precipitation and wind are averaged over such a long time, they can summarize the average climatic condition of a particular location. To describe the average climate in the study area, the 30-year Canadian Climate Normals data from 1981-2010 were assessed. These are the most recent climate normals data available. Although there is data available prior to 1981, the most recent climate normal information is sufficient to quantify the baseline climate conditions. The stations nearest to the Project with climate normals data available are operated by ECCC and are shown in Figure 2.1:

- The Norman Wells Airport station (ID: 2202800), located at 65°16'57" N, 126°48'01" W, at an elevation of 73 meters (m). This station is located at the airport in the town of Norman Wells in the northern portion of the study area.
- The Fort Simpson Airport station (ID: 2202101), located at 61°45'37" N,121°14'12" W at an elevation of 169 m. This station is located at the airport south of the town of Fort Simpson, roughly 200 km southeast of Wrigley.

Both stations monitor temperature, precipitation, wind speed and direction and visibility. Climate normals data from 1981-2010 for Norman Wells and Fort Simpson are shown in Table 4.7 and Table 4.8. See the following sections for a detailed summary.

4.3.1 Air Temperature

In general, the climate in NT can be described as subarctic, which usually involves short warm summers and long, cold winters (Phillips, 1990). Measured climate normal temperature data confirm this annual temperature pattern. Daily average temperatures are below 0°C for 7 months at Norman Wells and Fort Simpson station with the coldest month being January, where daily average temperatures reach as low as -24.2°C at Fort Simpson and -26.1°C at Norman Wells. Summer months (June, July, and August) average daily temperatures reach the high teens, with the warmest month being July with average temperatures of 17.1°C and 17.4°C, respectively, at the two stations. Extreme temperatures have a range from -53.3°C (February 3, 1968) to 36.6°C (July 25, 1994) at Fort Simpson and -54.4°C (February 4, 1947) to 35.0°C (July 14, 1989) at Norman Wells. In general, the temperature data indicates that the climate near Fort Simpson is warmer than at Norman Wells (annual average temperature of -2.8°C versus -5.1°C). Annual daily minimum, average and maximum temperatures are shown graphically in Figure 4.6 for both stations.

Table 4.7 Climate Normal Data, Norman Wells Airport Station a, NT (1981-2010)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
Daily Average (°C)	-26.1	-24	-18.4	-5.1	6.4	15	17.1	13.8	6.6	-4.7	-18.7	-23.4	-5.1
Standard Deviation	4.5	3.9	3.5	3.1	2.3	1	1.5	1.6	1.9	2.4	4	3.6	1.1
Daily Maximum (°C)	-22.2	-19.5	-12.5	1	12.1	20.7	22.5	19	11	-1.6	-15.2	-19.6	-0.4
Daily Minimum (°C)	-29.9	-28.4	-24.2	-11.1	0.6	9.3	11.5	8.4	2	-7.7	-22.2	-27.1	-9.9
Extreme Maximum (°C)	12.4	7.9	11.1	20	31.3	33.5	35	32.4	27.1	21	13.3	5.7	35
Extreme Minimum (°C)	-52.2	-54.4	-46.1	-37.2	-17.8	-2.8	-1.1	-6.1	-15.7	-31.7	-42.8	-47.8	-54.4
Precipitation													
Rainfall (mm)	0.2	0	0.1	1.2	13.3	42.4	41.8	41.1	26.7	4.6	0	0.2	171.7
Snowfall (cm)	21.1	19.9	14.4	12.8	6.4	0.4	0	0.7	6.9	27.3	26	25.9	161.5
Snow Water Equivalent (mm)	15.4	14.9	10.6	9.9	5.7	0.3	0	0.7	6.4	22.1	18.7	18	122.7
Precipitation (mm)	15.6	14.9	10.7	11.1	19	42.7	41.8	41.8	33.1	26.7	18.7	18.2	294.4
Extreme Daily Rainfall (mm)	3	0.9	5.6	12.4	19.6	45.1	49.3	48.5	42.8	21.4	5.8	2	
Extreme Daily Snowfall (cm)	23.1	27	13	28.4	20.6	15	2	7.6	16.8	18.8	16.8	17	
Extreme Daily Precipitation (mm)	24.6	20.6	9.6	26.7	20.6	45.1	49.3	48.5	50.8	21.8	16.5	17	
Wind													
Maximum Hourly Speed (m/s)	22.2	20.6	18.3	18.9	16.4	18.1	16.9	22.2	19.4	17.5	18.6	20.0	22.2
Direction of Maximum Hourly Speed	W	NW	SE	W	NW	NW	NW	W	NW	NW	NW	E	W

Note:

[a] Location: 65°16'57.000" N, 126°48'01.000" W; Elevation: 72.5m. Climate Station ID: 2202800

Source: ECCC (2022c)

Table 4.8 Climate Normal Data, Fort Simpson Airport Station [a], NT (1981-2010)

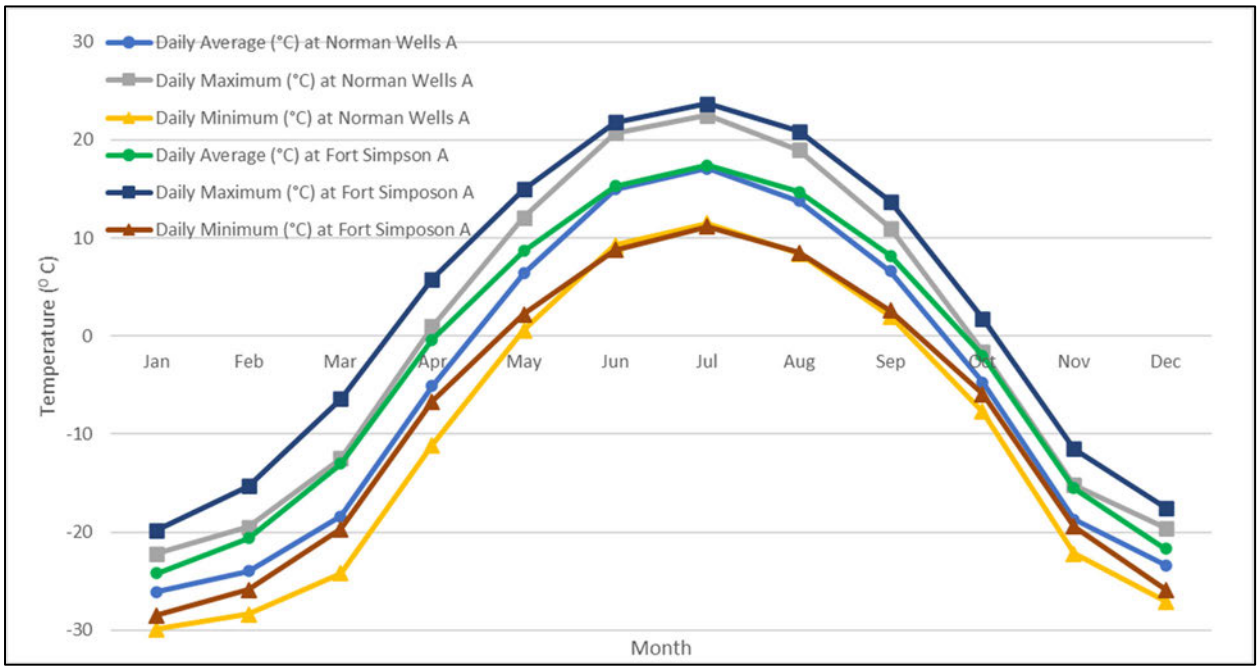
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
Daily Average (°C)	-24.2	-20.6	-13	-0.4	8.7	15.3	17.4	14.7	8.2	-2	-15.5	-21.7	-2.8
Standard Deviation	4.6	3.5	3.6	2.6	2.2	1.1	1.2	1.6	2	2	3.8	3.6	4.1
Daily Maximum (°C)	-19.8	-15.3	-6.4	5.8	15	21.8	23.7	20.9	13.7	1.8	-11.5	-17.5	2.7
Daily Minimum (°C)	-28.5	-25.9	-19.7	-6.7	2.2	8.8	11.2	8.5	2.6	-5.9	-19.4	-25.9	-8.2
Extreme Maximum (°C)	13.2	14.4	16.1	25.5	32.8	33.9	36.6	35.4	30	24.9	12.2	14.5	36.6
Extreme Minimum (°C)	-50	-53.3	-42.2	-38.3	-17.5	-2.2	-1.1	-3.7	-20.6	-27.7	-41.7	-50.6	-53.3
Precipitation													
Rainfall (mm)	0.2	0	0.1	2.5	21	51.2	61.1	60.9	28.5	12.9	0.1	0	238.6
Snowfall (cm)	27.4	24.2	19	17.4	7.6	0.1	0	0.5	4.2	29	33.4	24.3	187
Snow Water Equivalent (mm)	18.7	17.6	15.3	14.5	8.4	0.1	0	0.5	3.7	26.5	24.7	19.1	149
Precipitation (mm)	18.9	17.6	15.4	17	29.4	51.3	61.1	61.4	32.2	39.4	24.8	19.1	387.6
Extreme Daily Rainfall (mm)	2.4	0.8	2.6	10.7	30.8	85.8	57.2	52.4	42.4	45.9	4.3	0	
Extreme Daily Snowfall (cm)	13.5	27	19.3	33.8	29.5	1.8	0	15.2	14.6	22.8	30.4	16.2	
Extreme Daily Precipitation (mm)	12.7	14.2	18.8	38.4	30.8	85.8	57.2	52.4	42.4	45.9	27	13.3	
Wind													
Maximum Hourly Speed (m/s)	12.8	16.4	13.9	15.6	16.4	12.8	13.3	18.3	18.1	13.9	12.8	13.3	18.3
Direction of Maximum Hourly Speed	NW	NW	N	SW	N	NW	S	SW	NW	N	N	NW	SW

Note:

[a] Location: 61°45'37.000" N, 121°14'12.000" W; Elevation: 169.2m. Climate Station ID: 2202101

Source: ECCC (2022c)

Figure 4.6 Summary of Daily Temperatures at Norman Wells Airport and Fort Simpson Airport (1981 to 2010)



4.3.2 Precipitation

Precipitation includes rain and snowfall, with rain occurring mostly from May to September and snow from October to April for both stations. Most of the annual rain occurs during the three summer months (June, July, and August). At both climate stations, roughly 70% of the annual rainfall occurs during these months. For snowfall, the peak snow months for both climate stations are October to December; roughly 50% of the total annual snowfalls occurs during these months. However, for those peak months (October to December) the total amount of precipitation (rain and snow) is relatively low, when compared to the Canadian precipitation climatology (Government of Canada, 2020b).

Recorded extreme daily rainfall amounts range from 49.3 millimetres (mm; July 19, 1967) at Norman Wells in July to 85.8 mm (June 30, 1988) at Fort Simpsons in June. Extreme daily snowfall values are 28.4 centimetres (cm; April 29, 1972) at Norman Wells and 33.8 cm (April 25, 1981) at Fort Simpson, both recorded in the month of April.

Annual total rainfall at Fort Simpson is higher than at Norman Wells (238.6 mm versus 171.7 mm); whereas annual total snowfall is similar between the two stations with Fort Simpson recording 187 cm and Norman Wells 161.5 cm. Annual rainfall, snow water equivalent and total precipitation values are shown graphically in Figure 4.7 and Figure 4.8. Snow water equivalent values are obtained by deducting monthly rainfall values from monthly precipitation values. The snow water equivalent describes the depth of water that would result if the snow were melted instantaneously.

Figure 4.7 Summary of Monthly Precipitation at Norman Wells Airport (1980 to 2010)

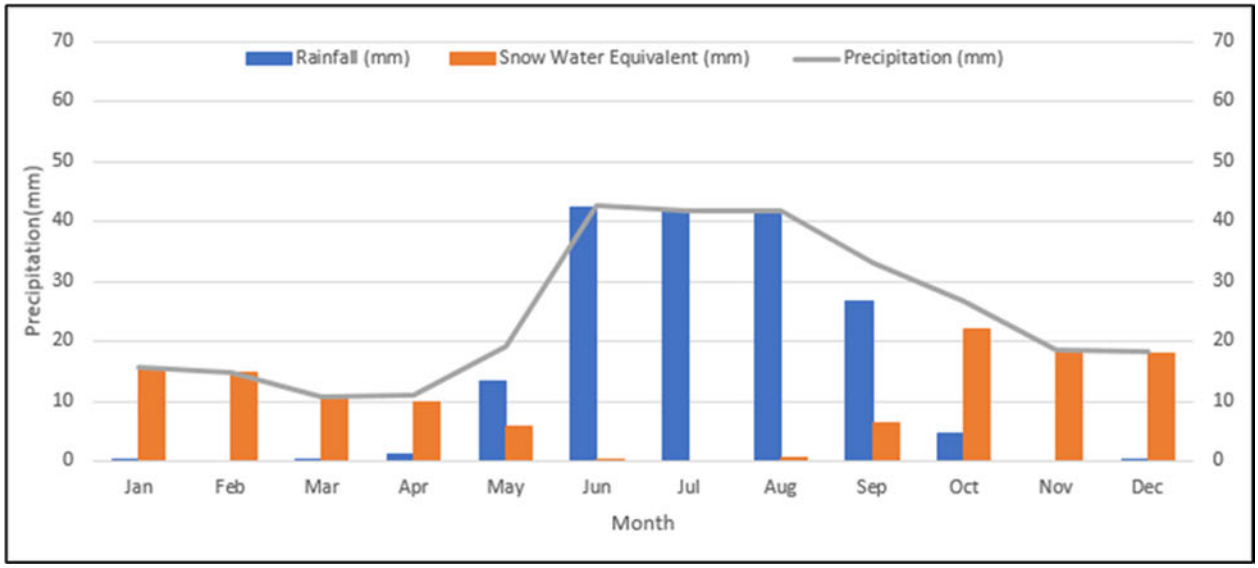
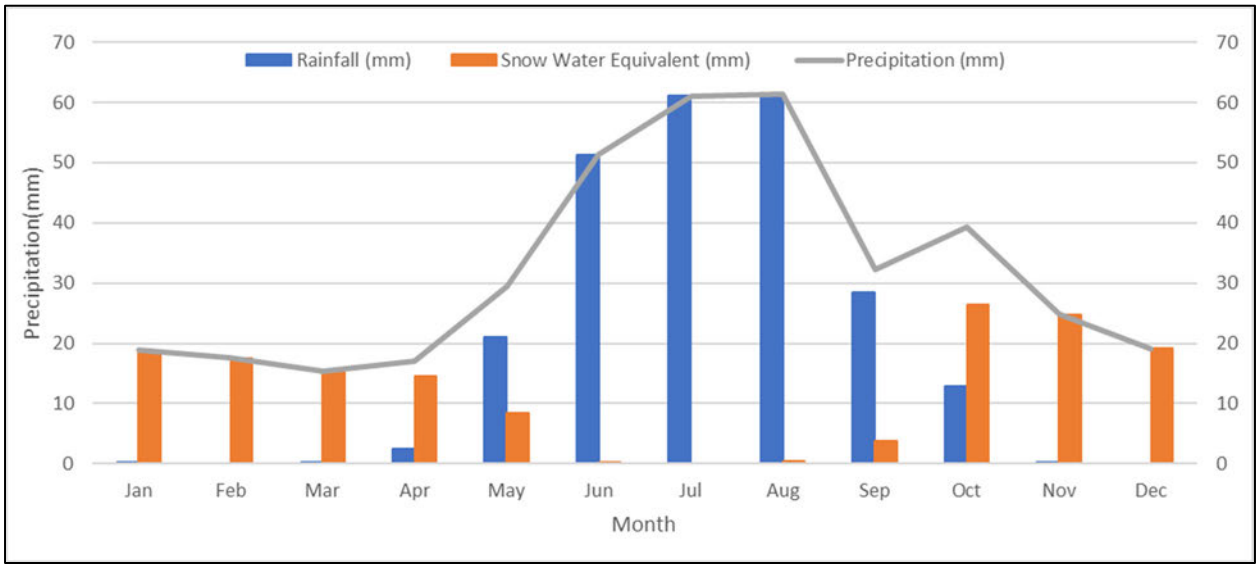


Figure 4.8 Summary of Monthly Precipitation at Fort Simpson Airport (1980 to 2010)



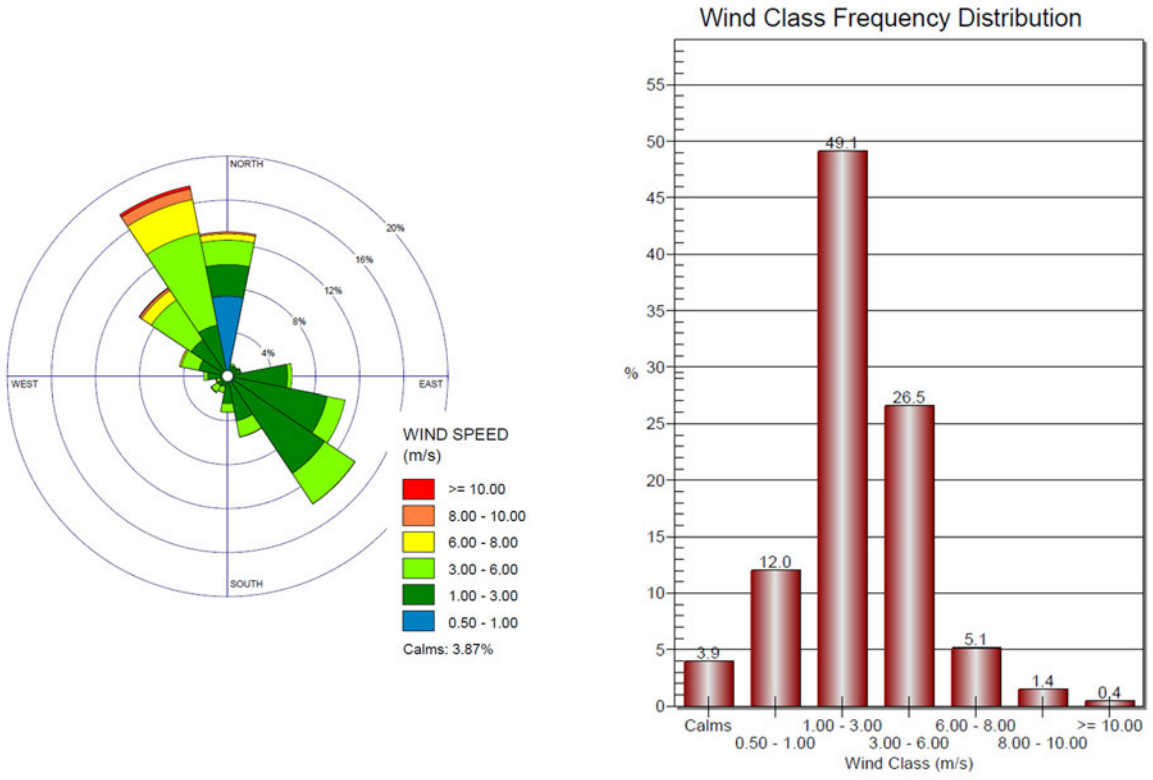
4.3.3 Wind Speed and Direction

Wind roses and wind class frequency distribution are shown in Figure 4.9 and Figure 4.10. Wind roses summarize graphically how wind speed and direction are typically distributed. The length of each spoke indicates how frequent that the wind blows from a particular direction, with the color showing the wind speed frequency associated with each direction. The wind class frequency distribution is shown in the same figures.

At Fort Simpson, 91.5% of the hourly wind speeds recorded are below 6 m/s. Most of the time (i.e., 49.1%), wind speeds are between 1 metre per second (m/s) to 3 m/s. Only 0.4% of all the hourly wind speeds are higher than 10 m/s. Prevailing wind directions are north-northwest, north, and southeast. Stronger winds (i.e., wind speed greater than 10 m/s) tend to be from the northerly directions (Figure 4.9).

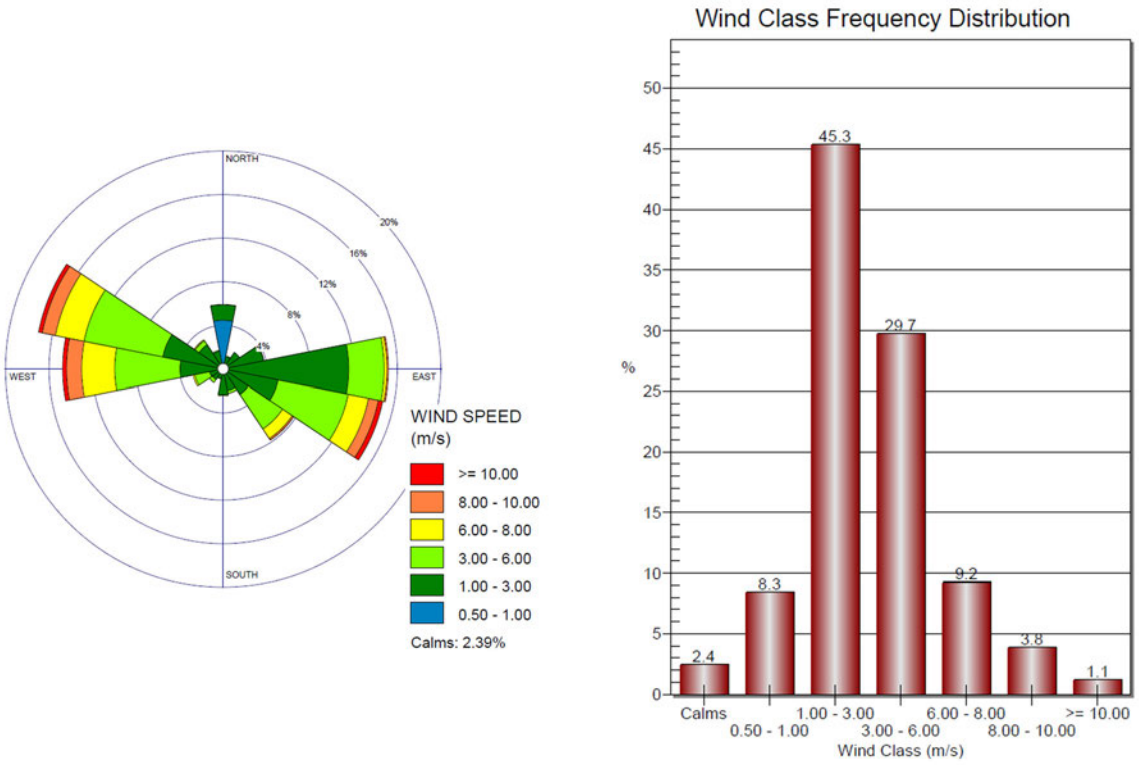
Wind speeds are greater at Norman Wells compared to Fort Simpson. At Norman Wells, 85.7% of the hourly wind speeds recorded are below 6 m/s, 13.2% of the wind speeds are between 6 m/s and 10 m/s, and 1.1% of the hourly wind speeds are above 10 m/s. Prevailing wind directions are east-southeast, east, west-northwest, and west, with strong winds (i.e. wind speed greater than 10 m/s) coming from east-southeast, west-northwest, and west directions (Figure 4.10).

Figure 4.9 Summary of Hourly Wind Speeds at Fort Simpson Airport (2021)



Source: ECCC Historical Data (2022e)

Figure 4.10 Summary of Hourly Wind Speeds at Norman Wells Airport (2021)



Source: ECCC Historical Data (2022e)

4.3.4 Visibility

Visibility describes the distance at which an object of suitable size can be seen and identified. Atmospheric visibility can be impacted by precipitation, fog, haze, or other suspended particles in the air such as snow or dust (Government of Canada, 2020c). Visibility, as recorded in the climate normals, is separated into three categories: less than 1 km, between 1 km and 9 km and more than 9 km (ECCC, 2022c).

Visibility at Norman Wells and Fort Simpson is similar, with roughly 8,000 hours out of a possible 8,760 hours a year having a visibility of more than 9 km. This is 92% of the year. The highest frequency of high visibility (greater than 9 km) is for the summer months (700.8 hours for Norman Wells and 703.1 hours for Fort Simpson). For approximately 70 hours per year, the visibility is less than 1 km for both stations, with most of these hours occurring during the fall months (Table 4.9 and Table 4.10).

Table 4.9 Summary of Monthly Average Visibility, Norman Wells A Station, NT (1981-2010)

Parameter	Average				
	DJF	MAM	JJA	SON	Annual
Visibility (hours with)					
< 1 km	6.9	1	4.5	10.1	67.4
1 to 9 km	86.2	30.7	30.8	108.5	768.5
> 9 km	628.8	696.3	700.8	617.4	7,929.6

Notes:
DJF=December, January, and February; MAM=March, April, May; JJA=June, July, August; SON=September, October, November.

Table 4.10 Summary of Monthly Average Visibility, Fort Simpson A Station, NT (1981-2010)

Parameter	Average				
	DJF	MAM	JJA	SON	Annual
Visibility (hours with)					
< 1 km	4.5	2.8	4.6	11.2	68.8
1 to 9 km	76.6	25.7	28.3	98.2	686.4
> 9 km	640.9	699.6	703.1	626.6	8,010.5

Notes:
DJF=December, January, and February; MAM=March, April, May; JJA=June, July, August; SON=September, October, November.

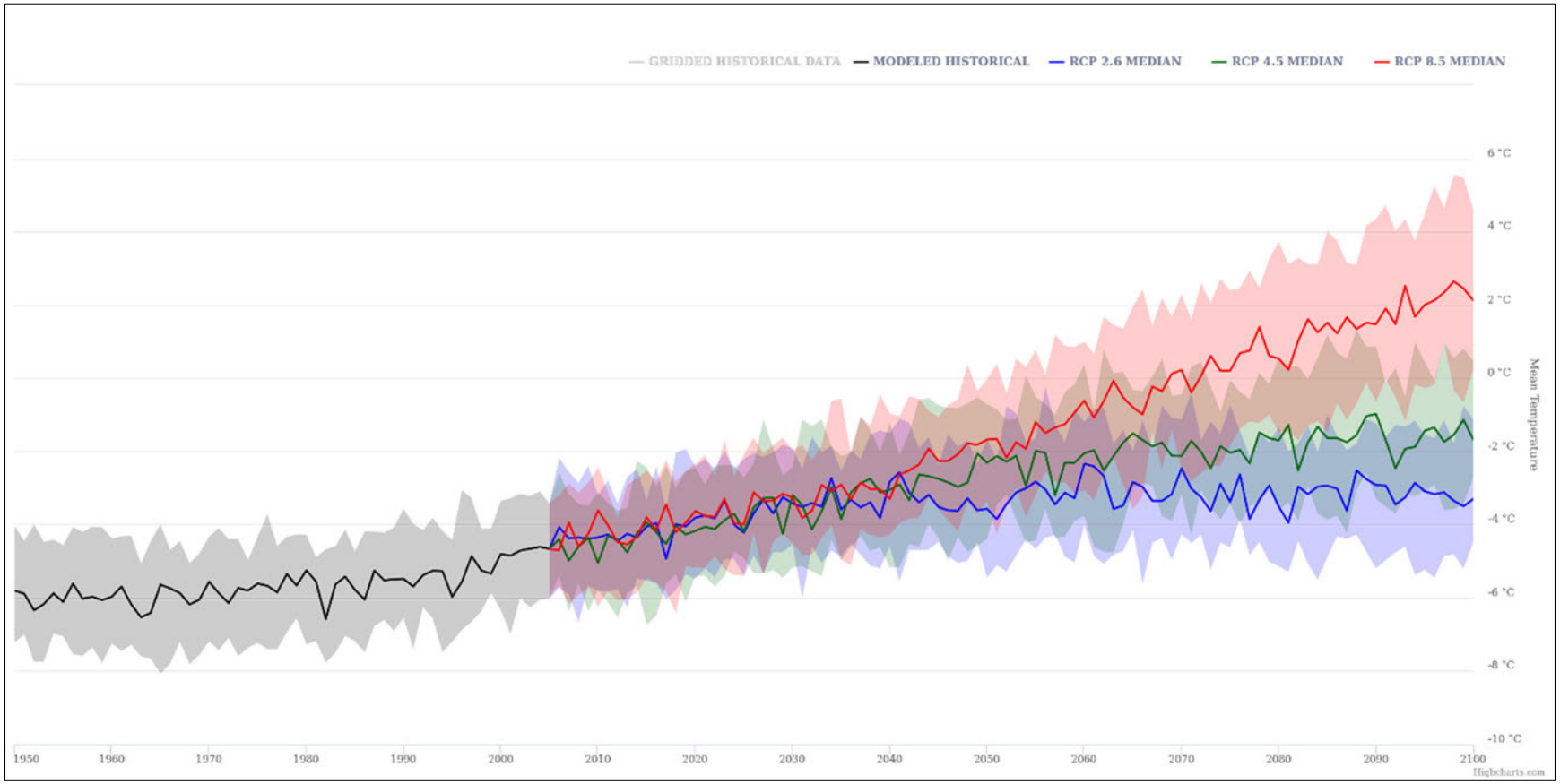
4.4 Climate Change

Climate change is defined as the long-term continuous increase or decrease of any statistical form of climatic variables such as temperature and precipitation. The statistical form can be mean, variability or extreme (ECCC, 2022d).

Climate change is observed at a more rapid rate in the Arctic regions than in southern regions around the world. This is apparent in the temperature changes over the last three decades in the NT compared to temperature changes observed in the rest of North America. Specifically, the Mackenzie Valley is considered a warming hotspot. Greatest warming and increases in precipitation are observed during the winter months. This trend is expected to continue in the future (Government of Canada, 2019).

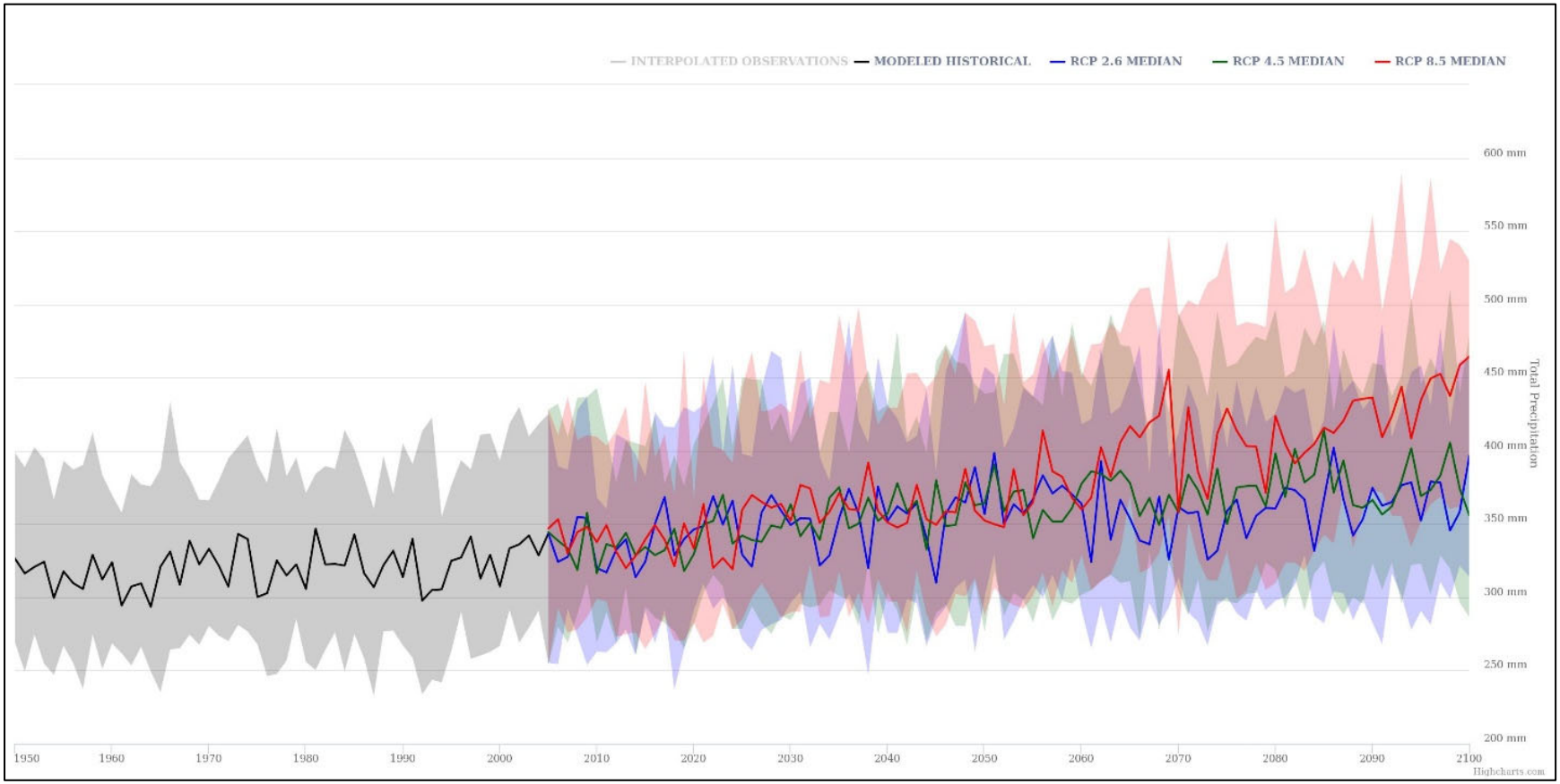
Climate change predictions for Norman Wells shown in Table 4.11, Figure 4.11, and Figure 4.12 were obtained from ClimateData (ECCC, 2022d). ClimateData is a collaboration between ECCC and several climate modelling institutes across Canada, providing climate forecast data for all of Canada. Although there are many sources of regional meteorology and climate information (e.g., GNWT-ENR Forest Management Division fire weather stations, Geological Survey of Canada, regional research stations), ClimateData is widely recognized as a reliable source of climate change forecast information.

Figure 4.11 Norman Wells Climate Change Projection for Average Annual Temperature



Source: Figure sourced from ECCC (2022d)

Figure 4.12 Norman Wells Climate Change Projection for Annual Total Precipitation



Source: Figure sourced from ECCC (2022d)

Table 4.11 Climate Change Predictions for Norman Wells

Parameter	Climate Change Prediction				
	1951-1980	1981-2010	2021-2050	2051-2080	2071-2100
Annual Average Temperature (°C)	-5.8	-5.2	-2.9	-0.5	1.3
Annual Total Precipitation (mm)	328	294	358	393	419

Note:
The future projections represent the median under the RCP8.5 scenario (high emission scenario) for Norman Wells. Past data for 1951-1980 and for 1981-2010 is based on measured climate normal data.

Source: Future climate predictions from ClimateData (ECCC, 2022d), historical climate data information from climate normal for Norman Wells from ECCC (2022c)

Data from ClimateData is based on 24 climate models used to simulate global climate response to varying concentrations of GHGs. These varying concentrations are represented by three scenarios: the so-called representative concentration pathways (RCP). These pathways consider different assumptions regarding demographic and socioeconomic development or technological change. The three scenarios are low emission scenario RCP2.6, moderate emission scenario RCP4.5, and high emission scenario RCP8.5. For this assessment, the RCP8.5 scenario is assumed to occur, which results in the highest level of global warming and climate change. This scenario assumes that GHG concentrations will continue to increase in the atmosphere at the same rate as they are now, leading to the highest GHG concentration in the atmosphere for the various RCPs.

Measured annual average temperature values for the 1951-1980 period for Norman Wells were -5.8°C. For the most recent climate normals period from 1981-2010, the annual average temperature was 0.6°C warmer, reaching -5.2°C (ECCC, 2022c). Under a high emissions scenario, this value is expected to increase further. For the period of 2021-2050 the annual average temperature is forecasted to be -2.9°C, -0.5°C for the period of 2051-2080, and 1.3°C for the last thirty years of this century. This indicates a change from a negative annual average temperature to a positive temperature (Table 4.11) (ECCC, 2022d).

Similarly, annual total precipitation values are forecasted to increase to 358 mm for 2021-2050, to 393 mm for 2051-2080 and to 419 mm for 2071-2100. This indicates a 28% increase for the period of 2071-2100 when compared to the average value from 1951-1980 of 328 mm (Table 4.11) (ECCC, 2022c). Forecasted annual total precipitation and annual average temperature for Norman Wells are also shown graphically in Figure 4.11 and Figure 4.12. Data shown as a grey line is historical modelled data for Norman Wells from 1950-2005. Data in color represents forecasted data based on the three RCPs in the future until 2100. The shaded area in the graphs represent the 90th percentile and the 10th percentile of the model results. The bold line in the middle of the shading indicates the median value of all the climate models, which indicates half of the model predictions are above the median line and half are below (ECCC, 2022d).

For more information on how a changing climate may affect the Project, refer to the Effects of the Environment on the Project section/chapter in the MVH DAR. For additional information on how a changing climate may impact other physical environments, see the individual technical data reports (e.g., Technical Data Report, Soils, Vegetation, Terrain, and Permafrost).

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5.2 Personal Communications

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APPENDIX 13A

Acoustic Environment Baseline Technical Data Report

Mackenzie Valley Highway Project Technical Data Report—Acoustic Environment Baseline

Prepared for:

Government of the Northwest Territories

Prepared by:

K'alo-Stantec Limited

December 2022

Project No.: 144903025

K'alo-Stantec

Limitations and Sign-off

This document entitled Mackenzie Valley Highway Project Technical Data Report—Acoustic Environment Baseline was prepared by K'alo-Stantec Limited ("K'alo-Stantec") for the account of Government of the Northwest Territories (the "Client") to support the regulatory review process for its Developer's Assessment Report (DAR) (the "Application") for the Mackenzie Valley Highway Project (the "Project"). In connection therewith, this document may be reviewed and used by the Department of Infrastructure (INF) for the Government of the Northwest Territories participating in the review process in the normal course of its duties. Except as set forth in the previous sentence, any reliance on this document by any other party or use of it for any other purpose is strictly prohibited. The material in it reflects K'alo-Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between K'alo-Stantec and the Client. The information and conclusions in the document are based on the conditions existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, K'alo-Stantec did not verify information supplied to it by the Client or others, unless expressly stated otherwise in the document. Any use that another party makes of this document is the responsibility and risk of such party. Such party agrees that K'alo-Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other party as a result of decisions made or actions taken based on this document.

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Executive Summary

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the "Project") that will extend the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells to replace the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT).

This technical data report (TDR) presents detailed technical data and analysis of the baseline acoustic environment for the Project.

Data and information reviewed for this report included traditional knowledge (TK) and traditional use (TU) information pertaining to acoustic environment. Traditional knowledge relevant to this TDR specifically focused on caribou behavioral responses to noise. The reviewed TK and TU indicates that interviewees generally agreed that caribou are not necessarily impacted by construction equipment or vehicular traffic and become accustomed over the years; however, not all interviewees agreed with this.

Other documents reviewed included the baseline noise survey results conducted in the area from the Mackenzie Gas Project (as reported in 2004) and Enbridge Pipelines Project. Based on the average measurement results from these projects, the baseline day-night sound level (L_{dn}) for the Mackenzie Valley Highway (MVH) Project is assumed to be 38 dBA (A-weighted decibels). The measurement locations in the Mackenzie Gas Project and Enbridge Pipelines Project are representative of remote areas without any development, similar to the acoustic local study area (LSA) and regional study area (RSA) for the MVH Project baseline noise levels are assumed the same for the project footprint along the proposed highway route and near the proposed borrow sources.

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Abbreviations

ATV	all-terrain vehicle
BC OGC	British Columbian Oil and Gas Commission
DAR	Developer's Assessment Report
dB	decibel
dBA	A-weighted decibels
GNWT	Government of the Northwest Territories
HC	Health Canada
INF	Department of Infrastructure
km	kilometre
L_d	daytime sound level
L_{dn}	day-night sound level
L_{max}	maximum sound level
L_n	nighttime sound level
LSA	Local Study Area
m	metre
MVH	Mackenzie Valley Highway
MVRMA	*Mackenzie Valley Resource Management Act*
MVWR	Mackenzie Valley Winter Road
NT	Northwest Territories
RSA	Regional Study Area
TDR	Technical Data Report
the Project	Mackenzie Valley Highway Project
TK	traditional knowledge
ToR	Terms of Reference
TU	traditional use

Glossary

A-Weighting Sound (dBA)	A weighting of the frequencies in a sound that approximates the response of the human ear to frequencies in moderately loud sounds (sound pressure levels in the range of 45-65 dBA).
Daytime	A time period from 7:00 AM to 10:00 PM
Daytime Sound Level (L_d)	L_d - Daytime period equivalent sound level (15 hours from 7:00 AM to 10:00 PM)
Day-night Sound Level (L_{dn})	L_{dn} - An equivalent continuous sound level taken over 24 hours, with the night-time (10:00 PM to 7:00 AM) sound contributions increased by 10 decibels (dB). A 10 dB penalty added to the nighttime period to account for the increased sensitivity to noise during the night.
24-hour equivalent Sound Level (LA_{eq}-24hr)	An energy-average sound level taken over a 24-hour period of time. It represents the average sound pressure encountered for the period. L_{eq} is usually A-weighted. An L_{eq} value expressed in A-weighted dB (dBA) is a good, single value descriptor of the annoyance of noise.
Decibel (dB)	A logarithmic unit of measurement that expresses the magnitude of sound pressure level relative to reference level (20 micro-Pascals). It is dimensionless unit since it expresses the ratio of two quantities with the same unit.
MVH Project Area (Project Area)	The area to be utilized by the Project and includes the proposed alignment of the MVH between Wrigley and Norman Wells and a 100 m buffer on either side. It also includes the temporary and permanent borrow sources and associated access roads.
Nighttime	A time period from 10:00 PM to 7:00 AM.
Nighttime Sound Level (L_n)	Ln - Nighttime period equivalent sound level (9 hours from 10:00 PM to 7:00 AM).

Noise	Unwanted sound.
Sound	Acoustic energy added to the ambient air in the form of fluctuating pressure.

1 Introduction

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the "Project") that will extend the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells to replace the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT; Figure 1.1).

The Project is subject to an environmental assessment and the requirements of Part 5 of the *Mackenzie Valley Resource Management Act* (MVRMA). As part of the environmental assessment process, the Developer's Assessment Report (DAR) assesses how development of the proposed Project could affect the acoustic environment.

This technical data report (TDR) presents the existing conditions (baseline) for the acoustic environment to support development of the DAR as required by the Terms of Reference (ToR; MVEIRB, 2015).

The required elements specified in the ToR with respect to baseline conditions include describing the existing acoustic environment "along the proposed highway route", including noise sources, types and boundaries, and any relevant standards, guidelines, or objectives. This report describes the existing acoustic environment within the acoustic local and regional study areas.

Relevant territorial, provincial, and federal noise guidelines are discussed in this TDR with the focus on their purpose and use in determining baseline sound levels.

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Quarry
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0029 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
1.1

Title
Project Location, Local Study Area, and Regional Study Area

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

2 Regulatory Framework

The GNWT has developed guidelines that, along with legislation, regulations and policies, help manage the environment in the NT. However, there is no dedicated regulation or guideline that regulates the acoustic environment.

In the absence of territorial noise regulations, noise guidelines from Alberta and British Columbia are included to provide additional information for the estimation of baseline sound levels for the Project.

In addition to provincial noise guidelines, federal noise guidance such as the Health Canada (HC) Guidance for Evaluating Human Health Impacts in Environmental Assessment: Noise (HC, 2017) can be referenced for noise assessment of large infrastructure projects. The HC document provides generic guidance on predicting health risks related to sound predicted in federal environmental assessments of proposed major resource and infrastructure projects. The guidance includes recommendations for estimating baseline sound levels.

3 Noise Descriptors

The noise descriptors commonly used in federal and provincial guideline documents are the daytime (L_d), nighttime (L_n), day-night (L_{dn}) and maximum (L_{max}) sound levels. L_d and L_n are the continuous equivalent (energy-averaged) sound levels calculated over the daytime (07:00 AM – 10:00 PM) and nighttime (10:00 PM – 07:00 AM) periods, respectively. L_{dn} is the day-night average sound level over a 24-hour period with 10 decibels (dB) penalty added to nighttime sound level because of increased sensitivity to nighttime noise.

Health Canada guidance widely uses L_d, L_n and L_{dn} parameters for estimation of baseline noise levels and assessment of the effects of project-related noise from construction activities and project operation. This baseline TDR uses the same parameters to describe the Project's baseline acoustic environment.

4 Study Area

The Project is located in the Mackenzie Valley region of the NT between the current terminus of the existing all-weather highway in Wrigley (Northwest Territories Highway #1) and Prohibition Creek (approximately 28 km south of Norman Wells). The Project highway alignment parallels the Mackenzie River to its east and passes through the community of Tulita. The Project is located in sparsely populated areas except those parts of the highway alignment near the communities of Wrigley, Tulita and Norman Wells. The existing acoustic environment is dominated mostly by the sounds of natural environment such as wind, rainfall, running water and wildlife. Noise contributions from human activity are present near the settlements of Wrigley, Tulita and Norman Wells and along the footprint of the existing Mackenzie Valley Winter Road. These human activities are transient in nature and include local traffic, operation of off-road vehicles and snow-machines, helicopter, and aircraft flyovers.

The local and regional study areas presented in this TDR are the areas where data were compiled/collected to allow for an understanding of the environment in support of the project-specific effects assessment and the cumulative effect assessment.

The local and regional study areas (LSA and RSA respectively) presented in this TDR partially overlap with the local and regional study areas of Mackenzie Gas Project (IORVL, 2004). As part of Mackenzie Gas Project environmental impact studies (IORVL, 2004) and Enbridge Pipelines Project (Enbridge, 2018), baseline sound surveys were conducted near Norman Wells and at other remote locations with acoustic environments similar to the LSA and RSA. The baseline sound survey results obtained at these remote locations are considered representative of the acoustic LSA and RSA because of the similar acoustic environment. In addition, noise effects near the existing MVWR during the four months of operation is referenced from the Mackenzie Valley Highway Extension Pehdzeh Ki Ndeh – Dehcho Region Project Description Report (Dessau, 2012).

4.1 Local Study Area

The LSA for the characterization of existing conditions is a 1.5 km buffer around the centerline of the highway alignment and quarry/borrow access roads and 1.5 km buffer around the footprint of the proposed quarry/borrow sources. Potential quarry/borrow sources in Sahtu Region and in the Dehcho Region are shown in Figure 1.1. Project-related noise effects are expected to occur within the LSA; outside the LSA, noise effects are expected to be negligible due to natural atmospheric attenuation and ground absorption. Project residual noise effects are not expected to extend beyond the LSA. Figure 1.1 shows the spatial boundaries of the acoustic environment LSA.

4.2 Regional Study Area

The RSA for the characterization of existing conditions was set as a 3 km (double of LSA) buffer around centerline of the highway alignment and 3 km buffer around the footprint of the proposed quarry/borrow sources. Potential quarry/borrow sources in Sahtu Region and in the Dehcho Region are shown in Figure 1.1. The RSA is to account for other existing and future physical activities that may have effects that act cumulatively with the project effects and to provide context for project specific effects and cumulative effects. Physical activities located beyond the 3 km buffer are not expected to interact with project residual acoustic effects due to natural atmospheric attenuation and ground absorption. Figure 1.1 shows the spatial boundaries of the acoustic environment RSA.

5 Review of Existing Data

This section of TDR presents a summary of baseline sound level information obtained from past projects and Health Canada guidance. It also presents a summary of traditional knowledge and traditional use related to the acoustic environment.

5.1 Traditional Knowledge and Traditional Use

The Traditional Knowledge Assessment of Boreal Caribou (Mbedzih) in the Dehcho Region (Dehcho First Nations, 2011) report was reviewed for traditional knowledge (TK) and traditional use (TU) related to the acoustic environment. This report presents TK related to caribou behavior, specifically caribou responses to noise. The TK and TU information provided in the report is based on interviewee responses to noise and light disturbance related questions. The interview questionnaire asked the following noise and light disturbance related questions:

1. Have you observed noise or light disturbance from aircraft, skidoos, all-terrain vehicles (ATVs), or industry affecting woodland caribou in your area?
2. If so, how is it affecting the caribou?
3. Do you notice areas where it is more of a problem?
4. Do you have suggestions for how to address this?

The findings described below do not give a strong indication of the existing anthropogenic noise in the LSA; however, they provide information on the possible impact of the noise related to project activities on wildlife.

The report (Dehcho First Nations, 2011) summarizes that: “Interviewees generally agreed that woodland caribou, like most animals, will not necessarily be impacted by machines or industrial noise such as graders or pumping stations, or a skidoo driven at a reasonable pace”.

Some of the interviewees indicated that: “in the past, animals including caribou and moose were more likely to be frightened by industrial or vehicular noises but have become accustomed over the years”. Not all interviewees agreed that caribou become accustomed to anthropogenic noise. There were some interviewees who feel that industrial and vehicular noise would be negative for the caribou and cause them to flee.

Boreal Caribou TK Collection Study (McDonald et al., 2010) for the Sahtu Settlement Area was also reviewed for TK and TU information related to the acoustic environment. The study acknowledges that noise from general construction activities and from construction traffic is a major disturbance factor for the boreal woodland caribou. According to the study: “*caribou prefer old growth areas and have a tendency to stay away from winter roads because of noise pollution*”. That study recommends that any development should not occur during the calving season or near caribou habitat.

Project activities (construction and operation) have potential to impact other important harvested species, such as moose. The reviewed TK and TU information for the Dehcho Region (Dehcho First Nations, 2011) and the Sahtu Settlement Area (McDonald et al., 2010) is focused on the impacts of human-induced changes to caribou habitat as an important harvested species. That TK and TU information does not provide any specific data on the impacts of increased anthropogenic sound levels to the habitats of other harvested species, such as moose. There is currently a gap in information related to harvested species other than caribou.

5.2 Mackenzie Gas Project and Enbridge Pipelines Project

Baseline sound surveys were conducted for two projects located near the Project area. The LSA and RSA presented in this TDR partially overlap with the LSA and RSA of the Mackenzie Gas Project (IORVL, 2004), and the Enbridge Pipelines Project (Enbridge, 2018) is located approximately 200 km south of the acoustic environment LSA. Baseline sound surveys were conducted near Norman Wells, Niglintgak, and Inuvik Area for the Mackenzie Gas Project, and near Fort Simpsons for the Enbridge Pipelines Project. The baseline sound survey results obtained at these locations are considered representative of the acoustic LSA and RSA for the Mackenzie Valley Highway (MVH) Project because of the similar acoustic environment for remote areas without any development. Further, the Norman Wells survey location is within the acoustic RSA. Baseline sound survey results based on the Mackenzie Gas Project and Enbridge Pipelines Project are provided in Table 5.1. The summer L_{dn} are higher than the winter L_{dn} for the Niglintgak and Inuvik Area Facility locations. The range of values in the results indicate variability due to season and locations. The estimated average baseline sound level is 34 A-weighted decibels (dBA) and 31 dBA, based on the logarithmic average of measured L_d and L_n for all locations. The equivalent L_{dn} of 38 dBA is based on the L_d of 34 dBA and L_n of 31 dBA.

Table 5.1 Baseline Sound Survey Results – Mackenzie Gas Project and Enbridge Pipelines Project

Reference Project	Sound Survey Location and Time	Daytime L_d (dBA)	Nighttime L_n (dBA)	Day-Night L_{dn} (dBA)
Mackenzie Gas Project	Winter Sound Levels at Niglintgak. Nov 30 – Dec 1, 2002	37	33	40
	Summer Sound Levels at Niglintgak. July 6 – 7, 2003	38	36	43
	Winter Sound Levels at the Inuvik Area Facility. Dec 3 – 4, 2002	21	19	26
	Summer Sound Levels at the Inuvik Area Facility. July 5 – 6, 2003	33	25	34
	Summer Sound Levels at Norman Wells. July 10 – 11, 2003	32	32	38
Enbridge Pipelines Project	Spring Sound Levels at Fort Simpsons. April 2 – 4, 2018	27	22	29
	Average baseline sound level	34	31	38

5.3 Mackenzie Valley Winter Road

Baseline sound level information for MVWR was reviewed in project description documents for the Dehcho Region (Dessau, 2012) and Sahtu Region (5658 NWT Ltd. and GNWT, 2011).

The MVH highway alignment largely follows the route of the existing MVWR, which is used only during winter for a 4-month period (Dessau, 2012). In winter months, the traffic noise from MVWR is not continuous due to low traffic volume: the annual average number of vehicles travelling on the MVWR is 50 to 99 vehicles according to GNWT Department of Transportation data for 2006 (Dessau, 2012). Based on approximate traffic volume, the project description for Dehcho Region estimates that LA_{eq}-24hr levels within narrow strip around the MVWR (approximately 25 metres [m] from road centerline) are 50 dBA (Dessau, 2012).

The project description for the Sahtu Settlement Area (5658 NWT Ltd. and GNWT, 2011) states that the highway construction noise is expected to have limited, localized, and temporary impacts in the vicinity of the MVWR. Heavy equipment and truck movements and blasting are the known major sources of the noise associated with highway construction. The project description for Sahtu Settlement Area estimates that the noise levels associated with dump trucks and haul trucks are typically within 78 dBA to 82 dBA range at 15-meter distance from the trucks. The project description for Sahtu Settlement Area does not estimate the noise levels associated with the highway traffic volumes.

5.4 Provincial Noise Guidelines

Comparable noise guidelines from other provinces include the Alberta Energy Regulator Directive 038: Noise Control (AER, 2007), Alberta Utilities Rule 012: Noise Control (AUC, 2021) and British Columbia Oil and Gas Commission (BC OGC) Noise Control Best Practices Guideline (BC OGC, 2021).

In absence of ambient sound level measurements, these provincial guidelines recommend that the average rural ambient sound level can be assumed equal to approximately L_d of 45 dBA and L_n of 35 dBA. The daytime adjustment recognizes that daytime ambient sound levels are commonly 10 dB higher than nighttime levels. The equivalent L_{dn} value would be 45 dBA, based on the L_d of 45 dBA and L_n of 35 dBA. All three provincial guidelines indicate that the recommended ambient sound level for rural area may not apply in a pristine area. Pristine area is defined as a natural area that might have a dwelling but no industrial presence, including energy, agricultural, forestry, manufacturing, recreational or other industries that affect the noise environment.

5.5 Health Canada

Health Canada guidance recommends that the standard approach for baseline sound determinations is direct measurement (HC, 2017). However, the guidance also provides alternative approaches to estimate baseline levels in different community types. For quiet rural communities, HC noise guidance suggests the estimated baseline sound level L_{dn} to be 45 dBA or less. Quiet rural communities are described as community with dwelling units more than 500 m from heavily travelled roads and/or rail lines and not subject to frequent aircraft flyovers. The guidance also includes one conservative (i.e., most protective) approach which is to consider a reasonable worst-case scenario and assume L_{dn} baselines of 35 dBA for rural areas.

6 Key Results and Findings

The measured and estimated daytime and nighttime baseline sound level for period without MVWR operation are summarized in Table 6.1 for comparison.

Table 6.1 Baseline Sound Level Summary

Source	Daytime L_d (dBA)	Nighttime L_n (dBA)	Day-Night L_{dn} (dBA)
Mackenzie Gas Project and Enbridge Pipelines Project average baseline sound levels	34	31	38
Alberta and British Columbia noise guidelines	45	35	45
Health Canada noise guidance – quiet rural communities	45	35	45
Health Canada noise guidance – most protective approach	35	25	35

Most areas within the LSA and RSA are considered remote without any development. Anthropogenic sounds from human activities are present at certain segments of the LSA and RSA (near the settlements of Wrigley and Tulita and Norman Wells, and along the MVWR). The acoustic environment within most of the acoustic LSA and RSA of the MVH Project is expected to be dominated by natural sounds.

The measurement locations in the Mackenzie Gas Project and Enbridge Pipelines Project, described in Section 5.2, are representative of remote areas without any development, similar to the Project acoustic environment LSA and RSA. The baseline sound level L_{dn} for the MVH Project is assumed to be 38 dBA, based on the average measurement results from the Mackenzie Gas Project and Enbridge Pipelines Project. The MVH Project baseline noise levels are assumed to be the same along the proposed highway route as they are near the proposed quarry/borrow sources.

The HC noise guidance and provincial noise guidelines recommend the L_{dn} of 45 dBA for rural communities. However, measurement results from the Mackenzie Gas Project indicate lower baseline sound levels. HC guidance recommends measured baseline data in areas with similar acoustical environments. The Mackenzie Gas Project and Enbridge Pipelines Project measurement results are considered to be more representative than the most protective baseline sound level value of 35 dBA L_{dn}.

During the four months of MVWR operation, it was estimated that L_{24hr} levels within narrow strip around MVWR (approximately 25 m from road centerline) are 50 dBA (Dessau, 2012).

During construction phase, the noise from construction activities within the LSA will affect ambient sound levels. During the operation stage, the ambient sound levels will be affected by increased traffic volume.

7 Closure

This TDR was prepared for the sole benefit of GNWT to describe existing conditions related to acoustic environment within the Project LSA and RSA. If you have any questions, please do not hesitate to contact the undersigned.

Respectfully submitted,

K'alo-Stantec Limited

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APPENDIX 13B

Effect Parameter Noise Maps

Figure 13B.1 Noise Map - Construction Phase – Construction Mobilization - Short-Term Community Annoyance (L_{dn})

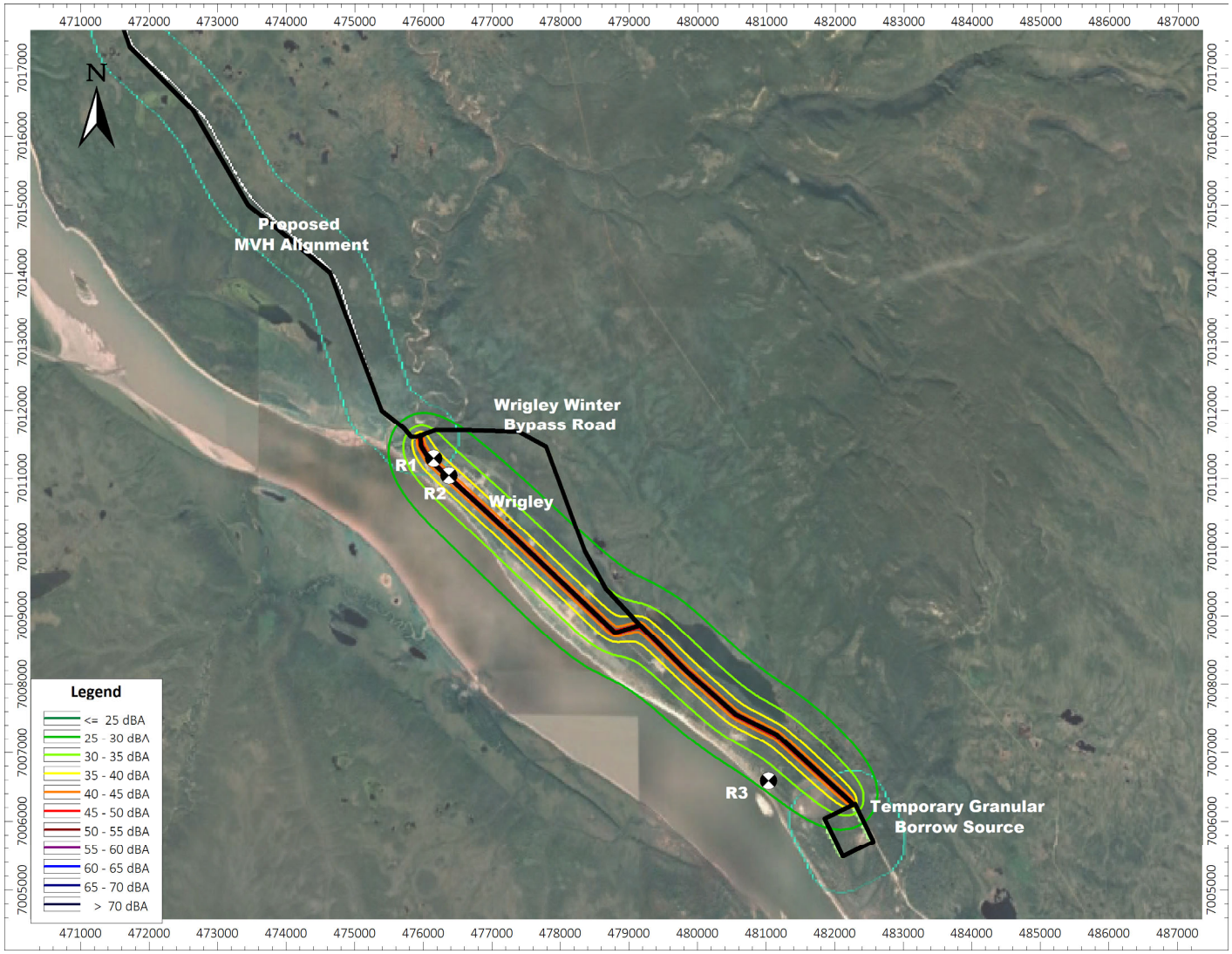


Figure 13B.2 Noise Map - Construction Phase – Road Construction - Short-Term Community Annoyance (L_{dn}) - First Day

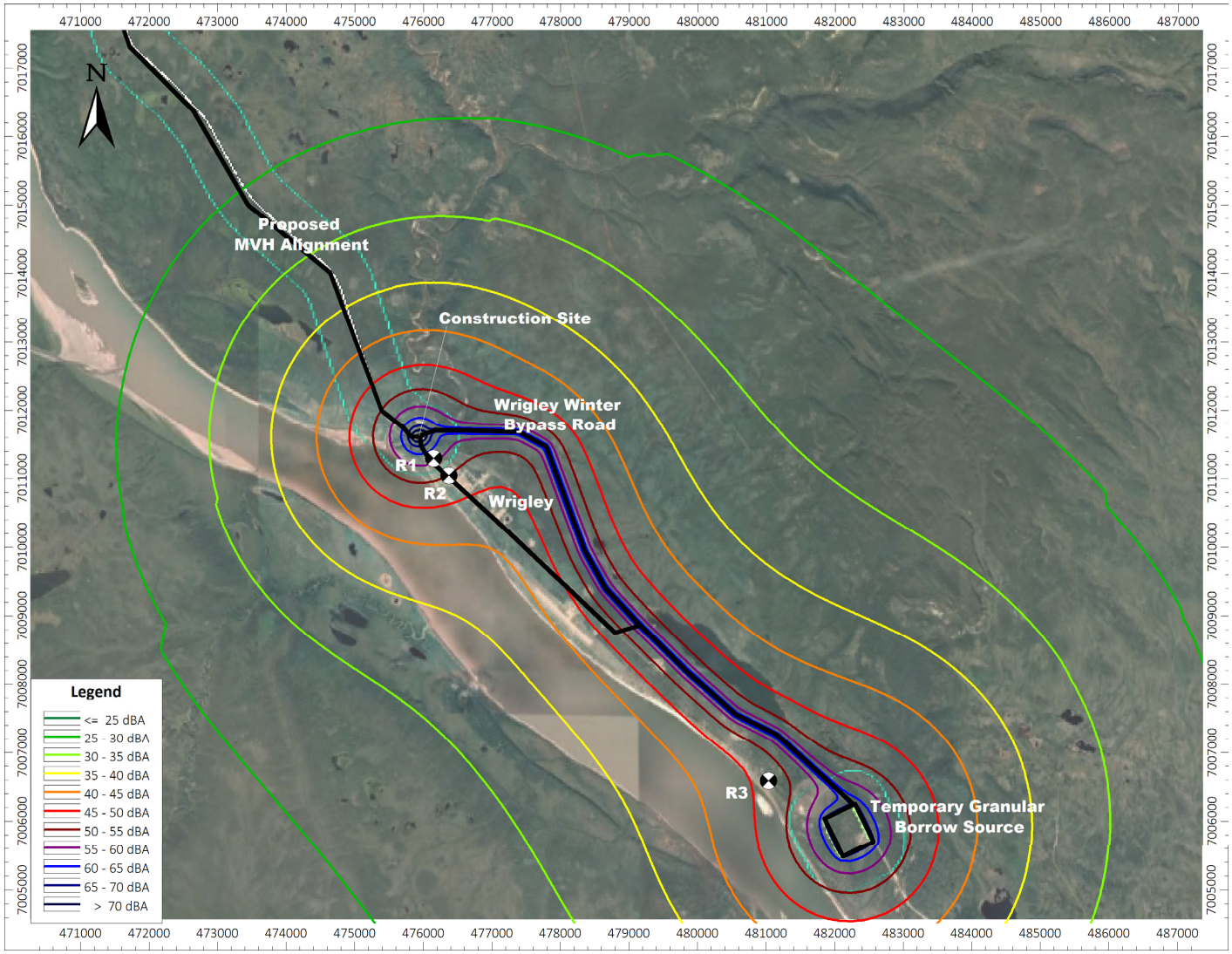


Figure 13B.3 Noise Map - Construction Phase – Road Construction - Short-Term Community Annoyance (L_{dn}) - After 11 Days

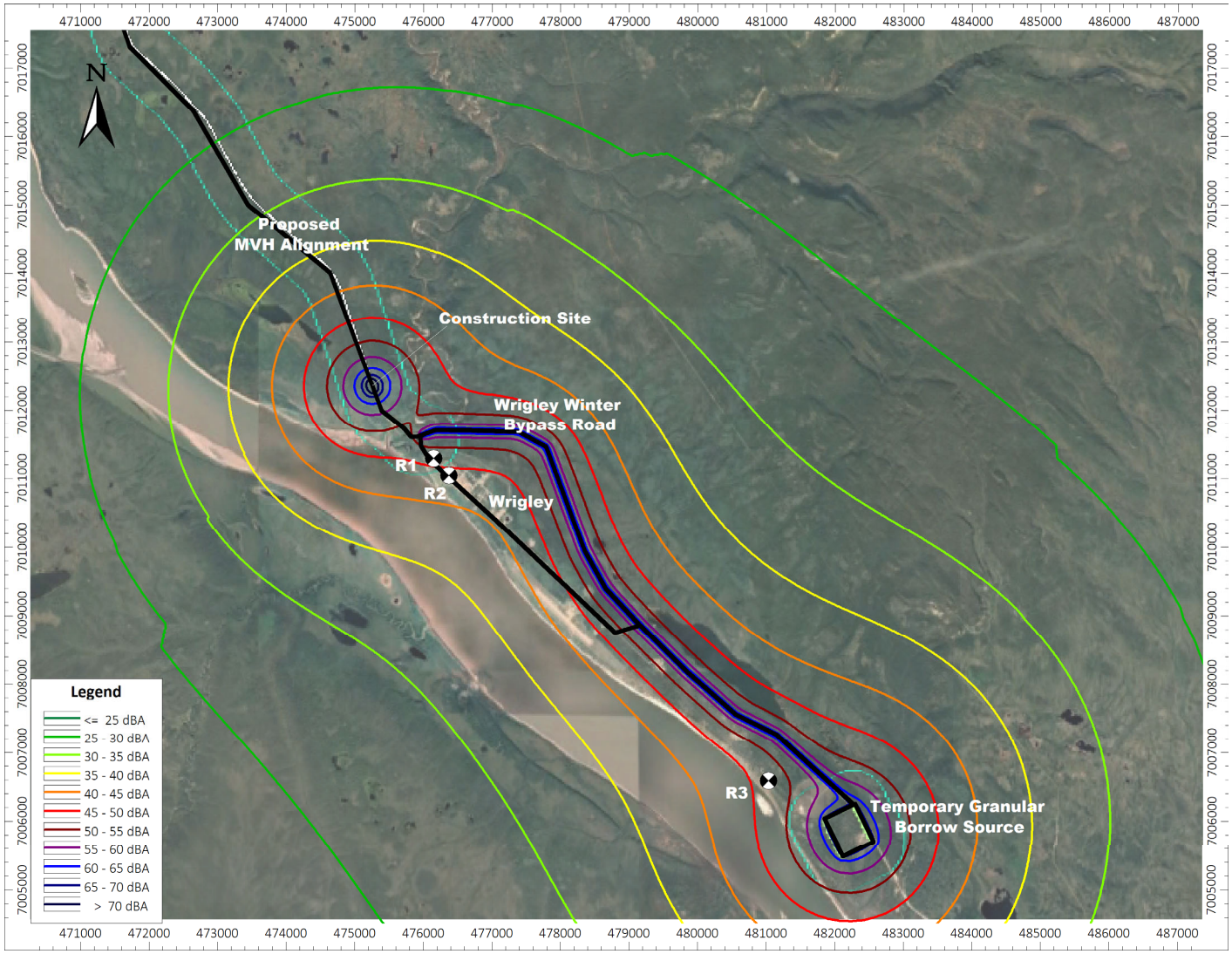
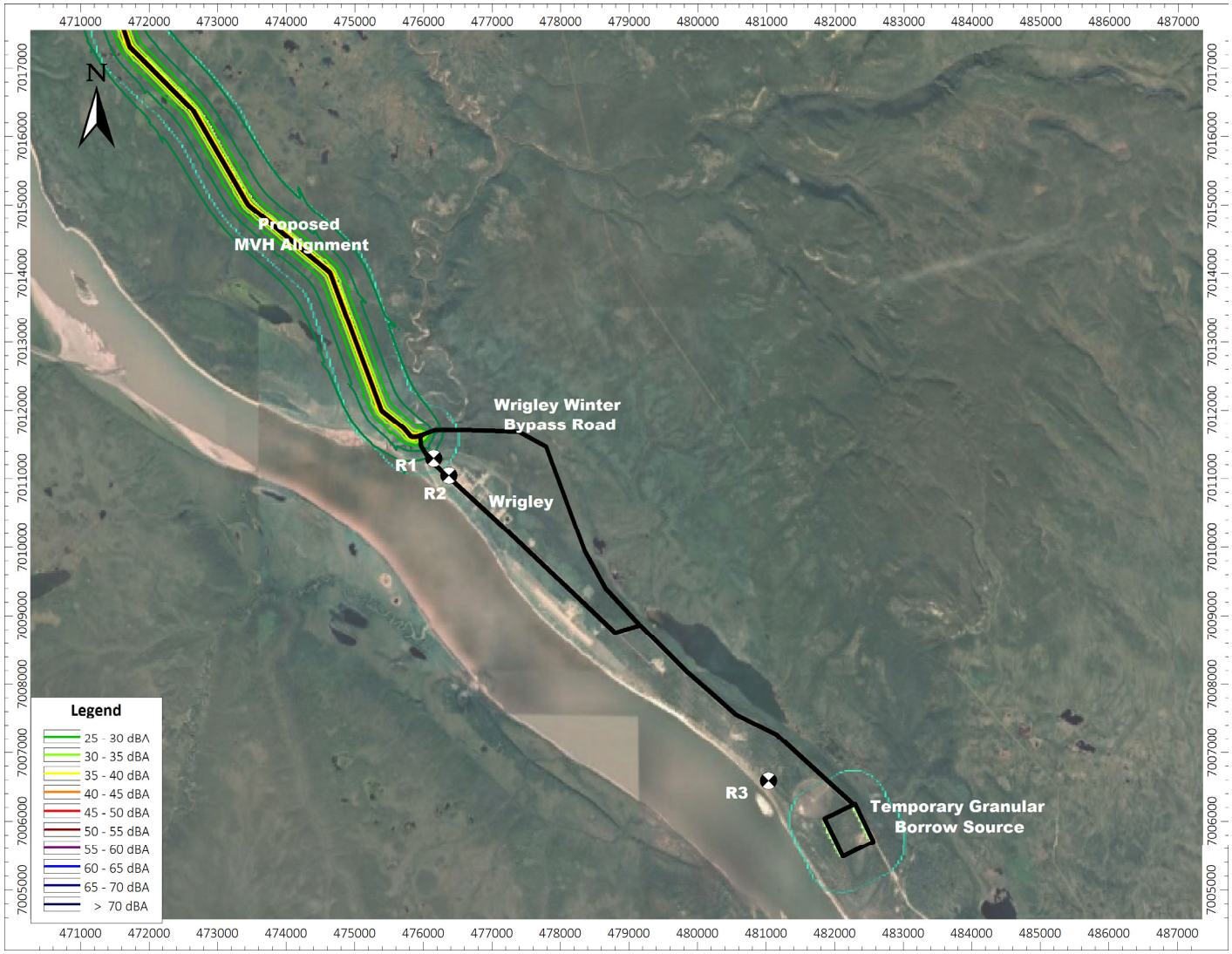


Figure 13B.4 Noise Map - Operations and Maintenance Phase - Traffic Noise ($L_{eq-24hr}$)



APPENDIX 14A

Terrain, Soils and Permafrost Technical Data Report

Mackenzie Valley Highway Project
Technical Data Report—Soils, Terrain and Permafrost

Prepared for:

Government of the Northwest Territories

Prepared by:

K'alo-Stantec Limited

March 2023

Project No.: 144903025

K'alo-Stantec

Limitations and Sign-off

This document entitled Mackenzie Valley Highway Project Technical Data Report—Soils, Terrain and Permafrost was prepared by K'alo-Stantec Limited ("K'alo-Stantec") for the account of Government of the Northwest Territories (the "Client") to support the regulatory review process for its Developer's Assessment Report (DAR) (the "Application") for the Mackenzie Valley Highway (the "Project"). In connection therewith, this document may be reviewed and used by the Government of the Northwest Territories Department of Infrastructure participating in the review process in the normal course of its duties. Except as set forth in the previous sentence, any reliance on this document by any other party or use of it for any other purpose is strictly prohibited. The material in it reflects K'alo-Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between K'alo-Stantec and the Client. The information and conclusions in the document are based on the conditions existing at the time the document was published and does not take into account any subsequent changes. In preparing the document, K'alo-Stantec did not verify information supplied to it by the Client or others, unless expressly stated otherwise in the document. Any use which another party makes of this document is the responsibility and risk of such party. Such party agrees that K'alo-Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other party as a result of decisions made or actions taken based on this document.

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Executive Summary

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Valley Highway (MVH) from Wrigley to Norman Wells, Northwest Territories (NT). The Project consists of a 321 km all-season highway that largely follows the route of the existing Mackenzie Valley Winter Road (MVWR) and includes temporary and permanent borrow and quarry sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Settlement Area (SSA) within the NT.

This technical data report (TDR) presents a summary of soils, terrain and permafrost data documenting baseline conditions within the Regional Study Area (RSA; a 10 km buffer centred on the MVH alignment, access roads and primary borrow sources) and Local Study Area (LSA; a 1 km buffer centred on the MVH alignment, access roads and primary borrow sources). A large volume of information about terrain and geotechnical subsurface conditions (including permafrost) within the Mackenzie Valley is publicly available. This data includes exploratory geotechnical investigations conducted to support highway studies in the 1970s, as well as more recent investigations and monitoring conducted within the last two decades. Studies conducted to support existing or proposed pipeline projects were also found to provide significant information to that document baseline conditions within the soils LSA and RSA.

Existing regional scale mapping was used to summarize bedrock geology within the LSA and RSA. The dominant geological units consist of sedimentary bedrock, predominantly sandstone, shale, limestone and dolostone. Exposed rocks and bedrock-controlled terrain are generally limited to the easternmost section of the RSA (i.e., towards Franklin Mountains), with most of the LSA overlaid by a thick mantle of surficial material. There are a few exceptions, including shallow bedrock at river crossings and shallow or exposed bedrock alongside Mount Gaudet and Bear Rock. Published surficial geology mapping identifies glaciolacustrine materials, till (moraine), colluvium, alluvial materials, glaciofluvial materials, eolian materials, bedrock, and organic materials within the RSA. Two soil orders, Cryosols and Brunisols, were identified in the LSA and RSA. Cryosols are mineral or organic materials that have perennially frozen material (permafrost) within 1 m of the surface or within 2 m of the surface if the soil is strongly cryoturbated. Brunisols are soils with a B horizon have undergone only minor alterations from the parent material and are mainly associated with coarse-textured and/or well-drained surficial materials absent of permafrost. Based on available regional permafrost mapping, the Project spans the extensive discontinuous permafrost (predominantly near Norman Wells), intermediate discontinuous permafrost (e.g., Mackenzie Plain area), and sporadic discontinuous permafrost (area surrounding Wrigley) zones. Climate is the predominant element controlling the broad distribution of permafrost in the RSA, followed by other factors such as topography, soils characteristics, vegetation cover, snow cover, and surface water. Permafrost may be absent or found at greater depth beneath large bodies of water (including rivers and lakes).

The availability of imagery and LiDAR allowed for a more precise characterization of terrain within the LSA. Geomorphological processes are identified and described, many of which are directly related to the presence of permafrost (e.g., seepage and mass movement processes). The surficial geology and terrain conditions in the LSA are summarized in a 1:10,000 scale map atlas. This mapping was used to refine the understanding of surficial materials, geomorphic processes, and terrain hazards present in the LSA.

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APPENDIX A RSA FIGURES

APPENDIX B LSA TERRAIN MAPPING

Abbreviations

%	percent
°C	degrees Celsius
AAFC	Agriculture and Agri-Food Canada
CIRNAC	Crown-Indigenous Relations and Northern Affairs Canada
cm	centimetre
CSA	Canadian Standards Association
DAR	Developers Assessment Report
DEM	digital elevation model
DIAND	Department of Indian and Northern Development
DOT	Department of Transportation
DSM	digital surface model
GIS	geographic information system
GNWT	Government of the Northwest Territories
GSC	Geological Survey of Canada
ha	hectare
INF	Department of Infrastructure
ka BP	thousands of radiocarbon years before present
km	kilometre
LiDAR	light detection and ranging
LSA	Local Study Area
m	metre
m^3	cubic metre
MGAR	Mount Gaudet Access Road
MGP	Mackenzie Gas Project
mm	millimetre
MVAP	Mackenzie Valley Airphoto Project
MVEIRB	Mackenzie Valley Environmental Impact Review Board
MVH	Mackenzie Valley Highway

MVWR	Mackenzie Valley Winter Road
NT	Northwest Territories
NTGS	Northwest Territories Geological Survey
PCAR	Prohibition Creek Access Road
PDR	Project Description Report
PIN	Permafrost Information Network
RSA	Regional Study Area
SCWG	Soil Classification Working Group
SSA	Sahtu Settlement Area
TDR	technical data report
the Project	Mackenzie Valley Highway Project
TK	traditional knowledge
TOR	terms of reference
TLRU	traditional land and resource use

1 Introduction

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway (MVH) Project (the Project) that will extend the Mackenzie Valley Highway (MVH) from Wrigley to Norman Wells, Northwest Territories (NT). The Project consists of a 321 kilometre (km) all-season highway that largely follows the route of the existing Mackenzie Valley Winter Road (MVWR), and the construction and operation of temporary and permanent borrow and quarry sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Settlement Area (SSA) within the NT (Figure 1.1).

The Project is subject to an environmental assessment and the requirements of Part 5 of the *Mackenzie Valley Resource Management Act*. This technical data report (TDR) presents the existing (baseline) conditions for the Soils, Terrain and Permafrost Valued Component (VC) to support development of the Developer's Assessment Report (DAR), as required by the Terms of Reference (TOR, MVEIRB, 2015).

The required elements specified in the TOR with respect to soils, terrain (including bedrock) and permafrost include the description, location, and geographic extent of the following features:

- topography and geology, including key terrain features such as rivers, lakes and wetlands and other important processes and features
- bedrock type and depth
- unconsolidated surficial materials and terrain types, including thickness of landforms
- soil types, including group, series and type, as applicable
- a description of proposed borrow sources, including information on locations, expected ice content, size of borrow areas, expected volumes to be removed, quality of materials at each location, existence and extent of ice rich permafrost areas that may be excavated and land ownership

The TOR also requires

- a description of permafrost and ice-rich soils in the study area, including their expected distribution (thickness and lateral extent)
- identification and description of permafrost processes, features and landforms and their stability
- description of subsurface ground ice conditions, temperature and ground thermal regime

Finally, the TOR specifies that the description of existing conditions for soils, terrain and permafrost should demonstrate an understanding of regional climate warming and documented warming of ground temperatures in the region; including a description of how warming ground temperatures and deepening active layers could affect the stability of the project highway and how mitigation measures will remain effective in various climate warming scenarios.

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Territorial Boundary

0 40 80 Kilometres

(At original document size of 8.5x11)
1:4,500,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/9/2023
TR by AJ on 3/9/2023

Client/Project
144903025-0056 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
1.1

Title
MVH Project Area

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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2 Study Area

The MVH Project is located in the Mackenzie Valley region of the Northwest Territories (NT) between the current terminus of the existing all-weather highway in Wrigley (Highway #1, km 690) and Norman Wells (KM 1011 of the MVWR). The project highway alignment roughly parallels the Mackenzie River to its east and passes through the community of Tulita (KM 938 of the MVWR).

The Local Study Area (LSA) and Regional Study Area (RSA) presented in this TDR are the areas (Figure 2.1) where data was compiled to characterize the existing environmental conditions for soils, terrain and permafrost in support of the Project-specific effects assessment and the cumulative effects assessment in the DAR.

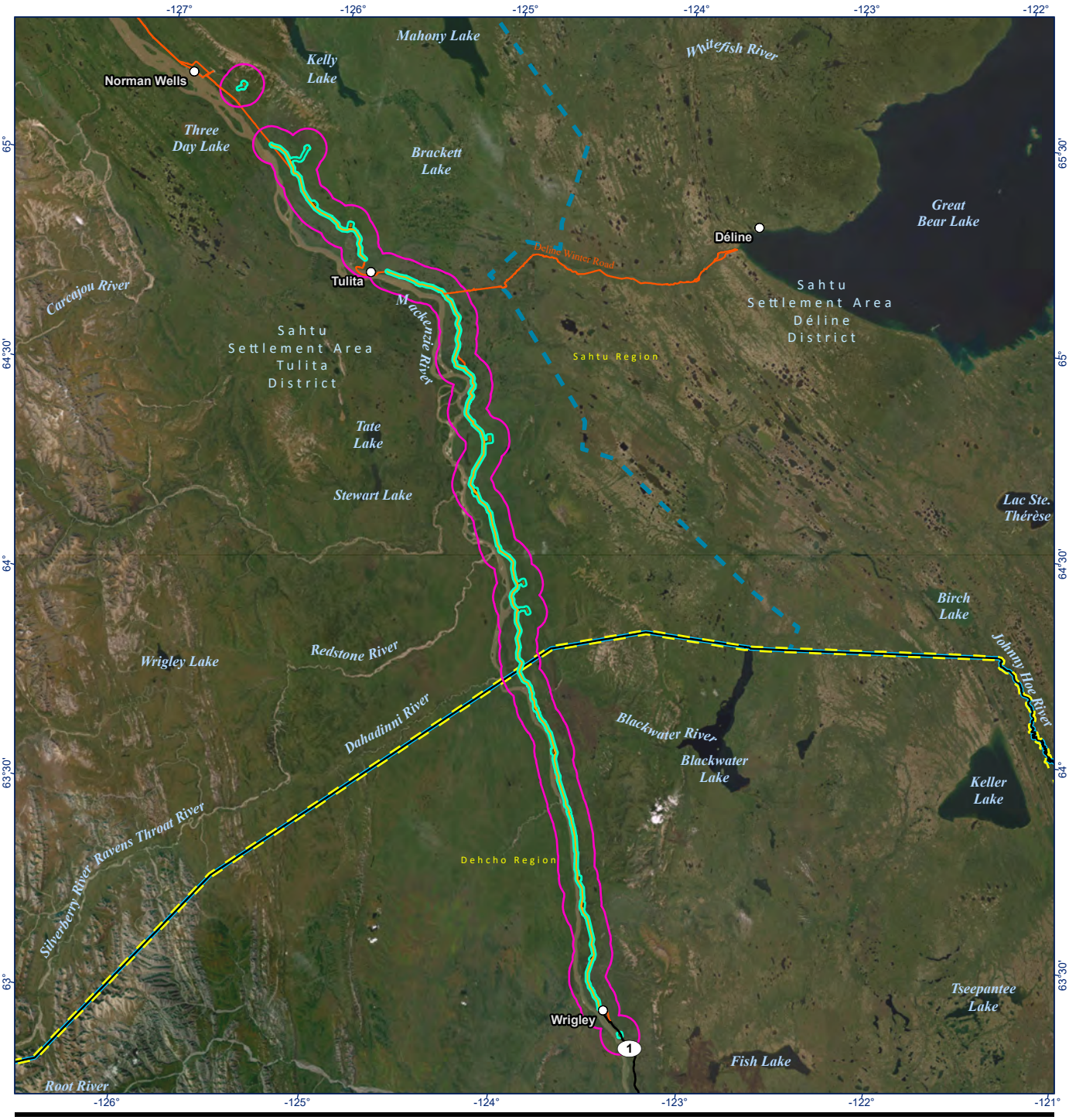
Because the MVH alignment has not been finalized yet, the existing MVWR route and corresponding kilometre markers have been used as the reference alignment.

2.1 Local Study Area

The LSA for soils, terrain and permafrost is defined as a 1 km buffer centred on the MVWR route. This LSA size was selected because measurable Project-related effects (direct or indirect) are expected to be limited to this area.

2.2 Regional Study Area

The RSA is defined as a 10 km buffer centred on the MVWR route. The 10 km buffer was selected to provide context for determining significance of Project-specific effects and potential cumulative effects.



- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area

- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/9/2023
TR by AJ on 3/9/2023

Client/Project
144903025-0057 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
2.1

Title
Local and Regional Study Areas - Soils, Terrain and Permafrost

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

3 Methods

The approach developed to gather information and present baseline conditions within the LSA and RSA consisted of three main tasks:

1. a review of existing traditional knowledge (TK) and traditional land and resource use (TLRU) (Section 3.1)
2. a review of literature and background data relevant to soils, terrain and permafrost (Section 3.2)
3. terrain mapping (Section 3.3)

Details regarding the methods associated with each of these tasks is presented below.

3.1 Traditional Knowledge and Traditional Use

Publicly available TK studies, along with information on current and historical TLRU, are important information sources to acknowledge when evaluating the potential effects of a project on local and regional soils, terrain and permafrost conditions. Knowledge about permafrost in the Sahtu area has been collected largely through oil and gas exploration and road construction projects (mainly bridges).

3.1.1 Data Sources

A preliminary compilation and review of relevant TLRU information has been completed as part of the Cultural and Traditional Land Use TDR (K'alo-Stantec, 2022a). The Cultural and Traditional Land Use TDR was compiled primarily using publicly available sources and will be considered complete once additional knowledge information is obtained through the engagement program for the Project. Information has been collected through the Project-specific TLRU study developed by the Tulita Renewable Resources Council (TRRC, 2022). Additional information is available from a compilation of TK relevant to permafrost, surface water, and groundwater for the Central Mackenzie Valley region (Golder, 2015).

3.1.2 Preliminary Results

A summary of existing conditions and potential project effects relevant to soils, terrain and permafrost identified by Indigenous groups in available source documents includes the following:

- interviews and conversations with Elders and land users in the Tulita region (Golder, 2015): there is "general consensus that permafrost is found in most areas except where there are natural underground springs and wet muskeg".
- warmer temperatures, melting permafrost and other environmental changes create concerns related to the environment (EBA, 2011)
- Increased temperatures and precipitation, effects on snow and vegetation conditions, effects on lake/river ice and boat access (Dehcho First Nations, 2011)

- forest fires and effects on boreal caribou habitat (Dehcho First Nations, 2011). It was reported that “wherever a forest fire has burned, all the permafrost will be disturbed for about 10 to 15 years until the moss is able to grow back. Without the moss, the permafrost is not well insulated.” (Golder, 2015)
- “Each spring, elders have noticed that melt water is draining into the soil too fast and thawing out the permafrost below. Locations such as cleared lands for seismic operations have been identified as places losing permafrost exceptionally fast” (Golder, 2015).
- public consultation for bridge projects supporting the MVWR north of Norman Wells reported community members stating that “when permafrost gets disturbed, it can cause a lot of trouble for any type of development” (GNWT, 2003)
- more erosion resulting from road construction and operation in the LSA along the MVWR (K’alo-Stantec, 2022b)
- more permafrost than before, therefore more boggy, sloughy areas in the LSA that have affect undertaking TLRU (K’alo-Stantec, 2022b)
- wood chips (collected from tree removal) should be used to insulate the road once constucted (K’alo-Stantec, 2022b)

3.2 Literature Review - Geosciences

A literature review was used to establish baseline conditions for soils, terrain and permafrost. Several different data sources were consulted, including documents and reports, open-source database as well as existing mapping data. Details on key data sources are provided in the following subsections. A complete list of references consulted to prepare this TDR is presented in Section 8.

3.2.1 Information Sources

3.2.1.1 MVH Project Description Reports

Among the first documents reviewed were the Project Description Reports (PDRs) produced in support of the scoping and development of the TOR, including:

- PDR for Construction of the Mackenzie Valley Highway through the Tulita District in the Sahtu Settlement Area (EBA, 2011)
- PDR for Construction of the Mackenzie Valley Highway through the Pehdzeh Ki Ndeh – Dehcho Region (Dessau, 2012)
- updated PDR submitted to the Mackenzie Valley Environmental Impact Review Board (MVEIRB) for the purpose of re-scoping the Environmental Assessment of the proposed MVH development (GNWT-DOT, 2014; now GNWT-INF)

These PDRs include summaries of information related to physiography, bedrock geology, and overall terrain conditions along the project highway alignment, including lists of proposed borrow sources. Relevant information has been incorporated into Section 4 of this TDR.

3.2.1.2 Historical Geotechnical Investigation Reports

The idea of building an all-weather highway through the Mackenzie Valley originated in the 1960s. During the early 1970s, the Federal Government (through Public Works Canada) conducted significant exploration work along a proposed highway corridor, including several geotechnical field investigation programs.

Historical documents consulted to develop the soils, terrain and permafrost TDR are listed in Section 8. These reports are associated with the following three main initiatives:

- geotechnical investigations conducted along the 1970s roadway alignment
- historical granular material inventory reports completed for the local communities and surrounding lands
- historical geotechnical pipeline route investigations completed for private industry

3.2.1.3 Borehole Databases

Data captured as part of historical geotechnical investigations have been compiled and released as parts of several different databases. The first compilation of publicly available geotechnical borehole data associated with the historical geotechnical investigations listed above was compiled by Proudfoot and Lawrence (1976) and Lawrence and Proudfoot (1976). This initial database was built on and improved over time, resulting in the release of a geographic information systems (GIS) compatible version containing over 13,000 boreholes extending from the Western Arctic coast to northwestern Alberta (Smith et al., 2005). Although most of this information was obtained from pipeline- and highway-related field drilling programs conducted between 1970 and 1975, the database also includes more recent boreholes, including about 1,400 boreholes compiled in the early 1990s in relation with the Enbridge's Line 21 "Norman Wells Pipeline" project, as well as other boreholes conducted/compiled as part of separate Geological Survey of Canada (GSC) projects (e.g., Chartrand et al., 2002).

In 2017-18, the GSC and Transport Canada initiated a collaborative project to develop a Permafrost Information Network (PIN) aiming to increase the public accessibility of permafrost information (Smith et al., 2017). Adapted from the existing web architecture developed for the Groundwater Information Network the PIN web application[1] allows viewing and download of borehole geotechnical data. Included in this database are data previously release by Chartrand et al. (2002), Smith et al. (2005), EBA (1989), Smith et al. (2009a), and Wolfe et al. (2010).

The information contained within these databases was downloaded and then imported into Esri's ArcGIS program to inform mappers about site-specific conditions while conducting detailed terrain mapping for the LSA.

[1] https://pin.geosciences.ca/en/

3.2.1.4 Seismic Shothole Data

Extensive seismic surveys have been conducted by the petroleum industry within the Mackenzie Valley and Delta regions over the last few decades. Seismic shothole log records are recorded by drill operators during geotechnical seismic operations when they auger/air-rotary drill holes in order to set explosive charges. The use of these driller's logs in support of surficial geology mapping activities in the Mackenzie Delta region and parts of northern British Columbia over the past five years have demonstrated them to be a reliable, albeit simplified, lithostratigraphic archive (Levson et al., 2004; Smith et al., 2007; Smith and Lesk-Winfield, 2012; Smith, 2011).

Because shothole data provides general parent material textures based on exploration drilling (e.g., some shotholes may be described as "sand and gravel", others as "gravel" and others as "clay, sand, shale"), it was used to inform on subsurface conditions as part of the LSA terrain mapping (see Chapter 5). Historical information contained in the seismic shothole database also contains information on ground ice and permafrost (Smith and Lesk-Winfield, 2012), but the results from recent site-specific geotechnical investigations conducted along the MVWR (e.g., TetraTech, 2000a, 2000b, 2000c, 2000d) are considered the most reliable source of geotechnical data for the Project.

3.2.1.5 Recent Geotechnical Evaluations

In 2020, Tetra Tech Canada Inc. (Tetra Tech) was retained by the GNWT to conduct geotechnical, geophysical and thermal evaluations to support the design and engineering of the Project and associated infrastructure (Tetra Tech, 2000a, 2000b, 2000c, 2000d). Areas of interest include the existing section of the Mount Gaudet Access Road (MGAR) near Wrigley and Prohibition Creek Access Road (PCAR) near Norman Wells.

Data from these studies were used in the descriptions of soils, terrain and permafrost baseline conditions.

3.2.1.6 Bedrock, Soils, Terrain and Permafrost Data

Bedrock

Regional bedrock geology information is available from a geological map compilation developed by the Northwest Territories Geological Survey (NTGS) (Okulitch and Irwin, 2014). The data consist of existing digital geological data that was assembled at a scale of 1:250,000 to present bedrock geology within most of the NT. Other relevant maps and papers include (but are not limited to) publications from Aitken and Cook (1976), Fallas et al. (2013), Fallas and McNaughton (2013).

Quaternary History, Surficial Geology and Landforms

Information relevant to the Quaternary history and surficial geology of the Mackenzie Valley region is available through numerous sources, including (but not limited to):

- surficial geology mapping by Hanley (1973), Hanley et al. (1975), Duk-Rodkin (2002), Duk-Rodkin and Couch (2004), Duk-Rodkin and Huntley (2009), Côté et al. (2013), as well as more recent compilation mapping by the GSC (2019a, 2019b)
- publications included in GSC Memoir 547 regarding the physical environment of the Mackenzie Valley
- historical work conducted as part of the Environmental-Social Program, Northern Pipelines (Tarnocai, 1973)
- publicly available reports associated to the Enbridge's Norman Wells Pipeline as well as the Mackenzie Gas Project (MGP), including Imperial Oil Resources Ventures Limited (2004), Burgess and Tarnokai (1997), Burgess and Lawrence (2000)

Some of the above-listed data sources include digital surficial geology (or terrain) mapping data (see additional details in Section 3.2.1.7 below).

Soils

A desktop review of existing information was completed to determine the general distribution of soil types within the MVH Project Area. The following key information sources were consulted:

- Soil Landscapes of Canada dataset and spatial maps were accessed from Agriculture and Agri-Food Canada's National Soil Database (AAFC, 1996). The spatial information was overlain on the MVH highway alignment to evaluate the distribution of soils in the LSA and RSA.
- The Canadian System of Soil Classification – Third Edition (AAFC, 1998) by the Soil Classification Working Group to classify soils in the Project area.
- Cryosolic soils of Canada: genesis, distribution, and classification by Tarnocai and Bockheim (2011) to provide general information about Cryosolic soils.

Landslides

Information on terrain stability was obtained from publications from Aylsworth et al. (2000a, 2000b), Aylsworth and Traynor (2001), Couture and Riopel (2008a, 2008b) and Huntley (2008).

Permafrost

A large volume of information regarding permafrost along the Mackenzie Valley is publicly available, including subsurface conditions, ground-thermal regime, and active-layer thickness. This information is useful for establishing baseline conditions, helping with land-use planning and the engineering design of infrastructure, and for understanding the effects of climate change on permafrost environments.

In addition to the permafrost-related papers included in GSC Memoir 547 (e.g., Heginbottom, 2000; Burgess and Smith, 2000; Wright et al., 2000; Burgess and Lawrence, 2000), key permafrost-related publications consulted in support of the TDR include work by Heginbottom et al. (1995), Smith and Burgess (2002), Smith et al. (2004, 2005), Smith and Duchesne (2017), Duchesne et al. (2020), and O'Neill et al. (2020). The list of available documents and reports discussing permafrost in the Mackenzie Valley is longer, including dozens of peer-reviewed publications and other scientific literature.

3.2.1.7 Review of Existing Mapping Data

The availability of ArcGIS shapefile mapping data, including high resolution orthophoto, LiDAR data and Digital Elevation Model (DEM) (see details in Table 3.1) allowed for the review of existing mapping datasets, including the following:

- surficial geology mapping produced by the GSC at 1:250,000 or 1:125,000 scales, including: Hanley (1973), Hanley et al. (1975), Côté et al. (2013), as well as more recent compilation mapping including portion of Map 371 and Map 375 (respectively GSC, 2019a, 2019b)
- terrain mapping conducted to support other projects led by GNWT in the region, including mapping for the PCAR and MGAR projects (G.V.M., 2016, 2019)
- terrain mapping conducted for the Mackenzie Valley Pipeline (Imperial Oil Resources Ventures Limited, 2006). Note that only the pdf version of these alignment sheets was reviewed.

Table 3.1 Aerial Photographs, Orthophoto and LiDAR and DEM Data Available for the Project

Data type	Source	Description
Aerial photography and orthophoto	Mackenzie Valley Airphoto Project (MVAP), 2004/2005	Aerial photography and ortho-imagery acquired for the Mackenzie Gas Project route. 15 km-wide corridor; covers the entire soils, terrain and permafrost RSA
	Hard copy aerial photographs	A collection of hard copy aerial photographs covering different areas of interest along the Project at various scales and acquisition dates
LiDAR and DEM data	LiDAR, 2010	Airborne LiDAR acquired in 2010 by LiDAR Services International Inc. of a 1 km-wide corridor centred on the MVWR; includes contour data, hillshade images and high resolution ortho-imagery
	Arctic DEM	Open-source 2 metre (m) spatial resolution Digital Surface Model (DSM) derived from optical imaging satellites covers the entire soils, terrain and permafrost RSA

The existing bedrock geology, surficial geology and soils data was used to describe baseline conditions within the RSA. Thematic map atlases and statistical summaries were generated from this data.

3.3 Local Study Area Terrain Mapping

Detailed terrain mapping was completed for the LSA (i.e., a 1 km-wide corridor. Mapping was conducted in an ArcGIS platform, using available aerial photography, ortho-imagery and LiDAR-derived data available for the Project (see Table 3.1).

Because the NT does not currently have specific standards for terrain mapping, widely accepted standards and guidelines developed by and for the Province of British Columbia were applied. They consist of:

- Guidelines and Standards to Terrain Mapping in British Columbia (Resource Inventory Committee, 1996)
- Terrain Classification System for British Columbia, Second Edition Ministry of Environment Manual 10 (Howes and Kenk, 1997)

As part of the mapping, relatively homogeneous terrain units (or polygons) were delineated on the basis of surficial materials (e.g., till, glaciolacustrine), surface expression (e.g., hummocky, fan), depth to bedrock (e.g., veneer, blanket) or stratigraphic composition (i.e., identifying the expected subsurface material), slopes, and geomorphological processes (e.g., groundwater seepage, mass wasting). Due to the detail of the mapping, some terrain map units (polygons) were classified using a composite label accounting for two main material types (e.g., fluvial and colluvial). For those terrain polygons, the two materials types are separated by a delimiter. These symbols (/ = 60/40, // = 80/20) indicate the relative amount (percentage) of each surficial material type.

In general, the delineation of individual terrain polygons was conducted at scales ranging from 1:2,500 to 1:7,500, with final map presentation at a scale of 1:10,000 (see Appendix B). As a general rule, surficial materials occupying less than 20% of a polygon were not indicated in the terrain unit label. Attempts were made to adhere to a minimum polygon size of 2 hectares (ha); however, in some areas, smaller polygon sizes were delineated when it was important from a terrain or ecosystem perspective (e.g., small wetlands, water bodies or geomorphic processes (geological hazards) occurring on, or immediately adjacent to the MVWR route).

A detailed map legend presented in Appendix B describes the terrain classification system (including map symbols) used for the LSA terrain mapping.

A senior terrain mapper reviewed the mapping, including both linework and terrain classification, to confirm that the mapping adhered to the standards listed above. Discrepancies in linework and classification, including comparisons with the existing terrain and surficial geology mapping datasets, were discussed with the mappers and revisions made as necessary.

4 Review of Existing Data

The following sections summarize the existing information compiled for the following key subjects:

- Bedrock Geology (see Section 4.1)
- Glacial and Post-Glacial History (see Section 4.2)
- Materials and Landforms (see Section 4.3)
- Soils (see Section 4.4)
- Permafrost (see Section 4.5)
- Geomorphological processes and Geological hazards (see Section 4.6)

4.1 Bedrock Geology

The bedrock along the MVWR route and within the RSA comprises a complex series of geologic units. These geologic units are composed of clastic sedimentary rocks (primarily shales and sandstones) and chemical sedimentary rocks (dominantly limestones and dolostones [dolomite]). Along most of the MVWR route, the bedrock is covered by a thick mantle of surficial material, primarily glaciolacustrine sediments and till (see Section 4.3). There are limited areas along the MVWR route mapped as shallow veneers of till, where bedrock is likely close to the surface. There may also be a few isolated areas where bedrock is exposed at the surface, for example, the dominating dolostone ridge of Bear Rock immediately west of the confluence of the Mackenzie River and the Great Bear River.

Table 4.1 tabulates the geologic units intersected along the MVWR route by map code, geologic unit (formation), geologic epoch, major lithology, and presence along (underlying) the MVWR route by kilometer stations (km). This data is derived from a geodatabase (shapefile) authored by Okulitch and Irwin (2014). These tabulations are organized in order of the first appearance of a geologic unit beginning at the south end of the alignment and moving north to the north end of the alignment. Some of the geologic units contain one or more minor bedrock lithologies, these rock types are enclosed in brackets in Table 4.1. These geologic units are identified by map codes on the bedrock geology figures accompanying this report (see Appendix A, Figures A.1 to A.7).

Table 4.1 Bedrock Geology Intersected by the MVWR Route

Map Code	Geologic Unit	Epoch	Major Lithologies	Kilometer Posts (approximate)
uDv-FS	Fort Simpson Formation	Middle to Upper Devonian	shale, siltstone, limestone	694-712; 712.5-717.5
mDv-N	Nahanni Formation	Middle Devonian	limestone	712-712.5
uDv-s	Upper Devonian sandstone unit	Upper Devonian	sandstone, mudstone, shale, (minor limestone)	717.5- 781
uCt-SR	Slater River Formation	Slater River Formation	sandstone, siltstone, shale, bentonite	781-793.5; 850.6-857.9; 873.5-874.6
uCt-SR	Slater River Formation	Slater River Formation	sandstone, siltstone, shale	793.5-820
uCm-SR	Saline River Formation	Furongian (Upper Cambrian)	shale, siltstone, sandstone, salt, anhydrite, gypsum, dolostone	820-820.8; 821.3-822; 827.5-832.8; 836.2-846.1; 863-868.2, 870.8-871.6; 960.1-960.5
mCm-MC	Mount Cap Formation	Lower to Middle Cambrian	shale, limestone, dolostone, sandstone, siltstone	820.8-821.3; 822-827.5; 846.1-850.6; 857.8-863; 868.2-870.8
uCm-FM	Franklin Mountain Formation (lower "cyclic" member)	Furongian	dolostone, conglomerate, shale	832.8-833.1; 960.5-961
CmOd-FM-m	Franklin Mountain Formation (middle "rhythmic" member)	Furongian to Lower Ordovician	dolostone	833.1-836.2; 961-961.5
CmOd-FM-m-c	Franklin Mountain Formation limestone facies	Furongian to Lower Ordovician	limestone, (minor conglomerate)	871.6-873.5
uCt-LB	Little Bear Formation	Upper Cretaceous	shale, sandstone	874.6-889.5
uCt-EF	East Fork Formation	Upper Cretaceous	shale, siltstone	889.5-911.3; 921-924.2; 959.5-960.1
CtpPg-SC	Summit Creek Formation	Upper Cretaceous to Paleocene	conglomerate, sandstone	911.3-921; 924.2-959.5
lmDv-BR	Bear Rock Formation	Lower Devonian to Middle Devonian	dolostone, dolostone solution-breccia, anhydrite, gypsum	961.5-962.8
mDv-Hu	Hume Formation	Middle Devonian	marlstone, limestone, shale	962.8-963.6
mDv-HI	Hare Indian Formation	Middle Devonian	shale	963.6-964
mDv-Ra	Ramparts Formation	Middle Devonian	limestone, (minor shale)	964-964.5
muDv-Ca	Canol Formation	Middle Devonian	shale; (minor limestone, ironstone, sandstone and conglomerate)	964.5-967.3
uDv-I	Imperial Formation	Upper Devonian	shale, sandstone (minor limestone)	967.3-1015.6

Source: Modified from Okulitch and Irwin (2014)

4.2 Glacial and Post-Glacial History

The following two sections describe the glacial history and the character and distribution of surficial materials within the RSA, LSA, and the MVWR route. The entire MVH Project Area is contained within the southern portion of the physiographic region known as the Mackenzie Plain.

The Mackenzie Valley, including the entire RSA, was covered by the by the Laurentide Ice Sheet during the Late Wisconsinan glaciation. The Laurentide Ice Sheet moving west and northwest from the Canadian Shield reached its maximum about 30 ka BP (thousands of radiocarbon years before present); extending north to the Beaufort Sea and pushing west onto the eastern slopes of the Mackenzie Mountains, extending up and blocking pre-existing east-draining valleys (Duk-Rodkin and Lemmen, 2000).

By 12 ka BP to 11.5 ka BP the Laurentide ice front in the Mackenzie Valley had retreated south to a position a short distance north of Norman Wells, while the eastern slopes of the Mackenzie Mountains were ice-free. About this time, Glacial Lake Mackenzie begun to form near Fort Good Hope; by 11 ka BP the lake had extended south southeast to a point a short distance south of Wrigley, and by about 10.5 ka BP reached a maximum southerly extent just south of Fort Simpson. During the same period, the Laurentide ice retreated to a roughly concave front extending north from south of Fort Simpson and east of Great Bear Lake to the to the Beaufort Sea. By about 10 ka BP, Glacial Lake Mackenzie had fully drained, leaving behind extensive deposits of glaciolacustrine silts and clays that extend along the Mackenzie Valley in a broad, occasionally discontinuous band, that ranges from five to ten km wide within the RSA.

The Mackenzie River and tributary rivers and streams have, subsequently, down-cut though the glacial deposits of the Laurentide Ice Sheet and the silts and clays of Glacial Lake Mackenzie to form extensive areas of alluvial sediments along their channels. Concurrently, mass wasting processes have generated colluvial deposits of various types found along the steep escarpments that now confine many of these streams and on steeper mountain sides and hillslopes. Organic deposits have accumulated gradually since the Laurentide Ice Sheet left, forming fens and bogs that now occupy many levels, and depressional areas on the uplands that bound the Mackenzie River.

4.3 Materials and Landforms

Published surficial geology mapping covering the RSA identifies glaciolacustrine materials, till (moraine), colluvium, alluvial materials, glaciofluvial materials, eolian materials, bedrock, and organic materials. The following descriptions of the character of these materials and their landforms are based in part on information gathered from publications and maps released by the GSC (Duk-Rodkin, 2002; Duk-Rodkin and Couch, 2004; Duk-Rodkin and Huntley, 2009; Côté et al., 2013; GSC, 2019a, 2019b).

Figures presenting existing surficial geology mapping for the RSA are located in Appendix A, Figure A.8 to A.23.

Glaciolacustrine materials are sediments deposited in and along the margins of glacial lakes and can include materials released by the melting of floating ice. Within the southern and central portion of the RSA, glaciolacustrine materials are dominantly composed of silt and fine sand, but locally can contain gravel and/or clay. In the northern part of the RSA, clay-textured glaciolacustrine materials are more common.

Within the RSA, glaciolacustrine deposits occur primarily as plains and blankets; but, to a lesser degree, as shallow veneers and as hummocky and ridged terrain. These materials generally overlay till and can range from less than 1 m to up to 50 m thick. In the Mackenzie Plain, in the area separating Big Smith Creek to the Great Bear River, glacio-deltaic sands overlay silty clay that had accumulated in the former glacial lake basin. Savigny (1989), in his investigation of the engineering geology of the Great Bear River area, describes how this sequence sits overtop Late Wisconsinan aged till. Glaciolacustrine beaches are rare. They are mapped locally as glaciolacustrine ridges and may also occur around the margins of Glacial Lake Mackenzie.

Till deposited directly by glacial ice likely occupies limited areas at higher and mid-elevations on local hills and ridges but, till will occur more frequently on lower elevation slopes and valley floors. Tills in the area are composed of clay, silt, minor sand and a small percentage of pebbles, cobbles, and boulders. These tills can be strongly calcareous, and the deposits range from thick plains to blankets and veneers overlying bedrock. Minor areas of hummocky and steeply sloping till occur locally. Depending on their surface morphology, these deposits range from a less than 1 m to up to 30 m thick.

Investigations of till in the Mackenzie Plain south of the Great Bear River (Savigny, 1989) suggest that the till is compact, matrix-supported and characterized by rare pockets and lenses of stratified material. The till matrix consists of a near-equal sand-silt-clay mixture, while clasts are subrounded and consist mainly of granite (40% to 50%) and carbonate (40%) with random sandstone, quartzite, syenite, and local siltstone and shale. The average clast size is 10 millimetres (mm), with only a few rare cobbles and boulders.

Colluvium is surficial material that has reached its present position as a direct result of gravity-induced movement, either by slow mass movement (soil creep, rock creep, periglacial processes such as solifluction) and by both slow-moving landslides and rapid landslides (e.g., rock avalanches, debris avalanches, debris flows, and thaw flows). Within the RSA, colluvial materials can be derived both from bedrock and from pre-existing deposits of other surficial materials. Consequently, they are generally rapidly to moderately-well drained and occasionally poorly drained. These deposits can range in depth from veneers less than a metre thick to landslide deposits tens of metres thick.

Within the RSA, colluvium derived from sandstone, or mixed sandstone and limestone or limestone, can take the form of a rubbly sandy deposit. These materials are predominant along the base of moderately steep to steep slopes marking the western side of the Franklin Mountains, as well as Mount Gaudet and Bear Rock. Colluvium derived from shale tends to be composed of small angular rubble in fine matrix, dominated by silts and clays. Colluvium derived from pre-existing surficial deposits will have textures reflective of the source material; for example, sandy or gravely from glaciofluvial deposits, fine sands, silts and clay when derived from glaciolacustrine deposits, or a diamicton when derived from till.

Colluvium mapped in the RSA on level to gently sloping surfaces are materials that could be more appropriately identified as weathered bedrock. Weathered bedrock will often form shallow to very shallow, often discontinuous veneers overlying bedrock and may be interspersed locally with bedrock outcrops. Weathered bedrock comprises bedrock decomposed or disintegrated in situ by mechanical and/or chemical weathering. Rock debris produced by mechanical weathering typically consists of angular fragments and, in the case of chemical weathering, may contain a high portion of residual silts and clays.

Colluvial deposits coded as “Cz” on the RSA surficial geology maps identify areas considered by the original mappers to be landslide deposits; however, our review suggests that some additional areas symbolled as “C” may also be subject to landslides and contain landslide debris. Due to the regional scale of most existing mapping, there are areas of colluvium and past landslide activity that are not mapped or identified as such (e.g., along the escarpments adjacent to fluvial plains or on steeper slopes along incised tributary rivers and smaller streams). A more precise inventory of colluvial and landslide deposits is presented in the LSA terrain mapping (see Section 5).

Alluvial (fluvial) materials are those that have been transported by streams and rivers and typically occupy valley floors. Alluvial materials are mostly imperfectly drained and moderately to rapidly permeable. Textures range from clayey silty sand to very gravelly sand. Alluvial soils often experience periodic flooding and sediment deposition; therefore, have either weak or no (pedogenic) soil development. These deposits typically occur as plains (floodplains) and terraces. In a few isolated upland locations, there are small areas mapped as alluvial fans and alluvial veneers. There is a reasonable chance that the steeper fans (i.e., slope gradients greater than or equal to 5%) are colluvial fans built up by periodic debris flow and/or debris flood events rather than by stream action. Subsequent re-working of these colluvial deposits by stream action does occur.

Glaciofluvial materials have been deposited by glacial meltwater streams, often close to glacial ice, are typically well to moderately-well drained, and rapidly permeable. These materials are composed of gravel, sand and silt in varying amounts. Within the RSA, these materials are generally found as plains and terraces, with lesser areas mapped as veneers, fans, ridges and hummocky terrain. These deposits can range from less than 1 m deep to depths in excess of 30 m.

Organic materials are deposits mainly composed of organic materials resulting from the accumulation of vegetative matter, typically in poorly to very poorly drained, level and depressional areas. These areas are generally level to very gently sloping, and bogs can have scattered mounds of organic material. Within the RSA, organic deposits occur both as fens and as bogs. The fens range in thickness from 2 m to 3 m and the bogs from 1.5 m to 7 m. Surface water may be present in fens in the summer months and be unfrozen to depths of 3 m or more.

Eolian materials are eroded, transported and deposited by wind action. These materials generally consist of fine to medium sand and silt and are not compacted. Individual grains may be rounded and frosted. These materials will tend to be well to moderately well drained. Eolian deposits, as identified within the RSA, occur as forested, parallel to sub-parallel linear dunes and can be up to 20 m thick. Eolian materials can also occur as shallow veneers overlying other surficial materials; but are not mapped as such

Anthropogenic disturbances to soils, terrain and permafrost occur in both the LSA and RSA. They include, but are not limited to:

- developed portions of local communities
- transportation infrastructure such as all-weather roads and winter road, bridges and trails
- Enbridge Norman Wells Pipeline and associated infrastructure (e.g., valve sites, pump stations)
- the Mackenzie Valley Fibre Line
- well sites and cut lines
- limited-use trails
- existing borrow sources and quarries

4.4 Soils

4.4.1 Land Types

Landcover types within the RSA include broadleaf forest, coniferous forest, mixedwood forest, wetlands, shrubland, herbaceous and un-vegetated areas (K'alo-Stantec, 2020c). The project highway alignment overlaps and parallels existing disturbances including roads, industrial developments, and settlements. As noted above, most of the MVH highway alignment parallels an existing winter road (MVWR). The Project also overlaps existing disturbed land through the Hamlet of Tulita.

4.4.2 Soil Development Process

Pedogenic soil development is the result of complex interactions between earth material (bedrock and surficial materials), the topography, the climate, vegetation, living organisms, and time. The soil layer is distinct from the underlying rocks or surficial material because its composition has been subjected to physical, chemical, biological, and anthropogenic factors changes. An important process occurring in cold-climate soils are the annual freeze/thaw cycles. Weak pedogenic soil development on the RSA can be attributed to low temperatures, which have limited chemical and biological activity, and the presence of permafrost, which limits the movement of water and nutrients through the soil profile and contributes to profile disruption (Zoltai and Pettapiece, 1973).

Soil temperature in subarctic environments is controlled by:

- vegetation cover—dense vegetation cover shades the ground from incoming solar radiation and limit heat transfer and encourage lower soil temperatures
- thickness of the surface organic layer—the surface moss layer and surface vegetation function as insulators and do not facilitate heat transfer from the environment, causing lower soil temperatures in organic soils compared with mineral soils (Tarnocai, 1973; Tarnocai and Zoltai, 1978)
- moisture content and topographic location (Tarnocai, 1973)—higher moisture content and depression topography tend to result in lower soil temperatures

Low soil temperatures can trigger cryogenic processes, which affect soil development. Cryoturbation disturbs a soil profile, resulting in mixed, broken, displaced and disrupted horizons (AAFC, 1998). Pressures generated in the active layer during annual freezing can cause displacement of material in the soil profile (Zoltai et al., 1978).

Soils lacking permafrost occur in areas with warmer temperatures and higher precipitation. These soils have a greater degree of soil profile development (i.e., increased weathering and soils biological activity).

4.4.3 Soil Classification

Soils in the LSA and RSA were classified according to the Canadian System of Soil Classification (AAFC, 1998). The broadest element of soil classification is the soil order. Soil order is determined from the nature of the soil environment and the effects of dominant, soil-forming processes. Soil orders are then subdivided in great groups, which are identified based on properties that reflect differences in the strengths of the dominant soil forming processes. Soil subgroups are further divisions of the great group based on diagnostic soil horizons.

Two soil orders, Cryosols and Brunisols, were identified in the LSA, RSA and along the MVH alignment. A summary description of these two soil orders is presented in Table 4.2. Soils are further described to the great group or subgroup level depending on the information available. The distribution of soils within the LSA, RSA, and along the MVH alignment are presented on the soil figures presented in Appendix A (Figures A.24 and A.25), with summary metrics presented in Table 4.3 and Table 4.4.

Cryosols are the dominant soil order in the LSA, RSA, and along the MVH alignment because of the presence of extensive discontinuous permafrost. Cryosolic soils have formed on a wide variety of parent materials and have permafrost within 1 m to 2 m of the ground surface (Turnocai and Bockheim, 2011; AAFC, 1998). All three great groups of the Cryosolic Order: Turbic Cryosols, Organic Cryosols and Static Cryosols, are present in the RSA.

Static Cryosols are the dominant great group, occupying 34.1% of the length of the MVH route. Static Cryosols typically develop on coarse-textured mineral material and lack evidence of cryoturbation. Static Cryosols in the LSA and RSA are Gleysolic Static Cryosols and are present on level to gentle slopes (0 to 9%) and are poorly to imperfectly drained.

Organic Cryosols, which develop from organic material, occupying 28.4 % of the length of the route. Organic Cryosols within the LSA and RSA are present on level to gentle slopes, ranging from 0 to 9%, and are poorly drained.

Turbic Cryosols show evidence of cryoturbation, and permafrost present within 2 m of the surface. Turbic Cryosols occupy approximately 12.8% of the length of the MVH alignment. Turbic Crysols are mostly Gleysolic Turbic Cryosols, which occur in poorly to imperfectly drained areas on gentle slopes (4 to 9%). An additional subgroup, Brunisolic Turbic Cryosol are found within the RSA. These soils are moderately well drained and occur on moderate slopes (10 to 15%).

Brunisols, developed on alluvial and glaciolacustrine deposits are present within the LSA and RSA. Brunisolic soils show some evidence of soil forming processes and lack permafrost within 1 m of the ground surface. Brunisolic soils within the RSA were described to the great group level as Eutric Brunisols, which develop on parent materials with high base status (AAFC, 1998). Eutric Brunisols in the LSA and RSA are moderately well drained, occur on gentle slopes (4% to 9%) and contribute to 18% of the MVH alignment.

Table 4.2 Description of Soils in the RSA

Soil Order	Description of Soil Order	Description of Soil Great Groups	Description of Soil Subgroups
Cryosol	Soils formed on both mineral and organic parent materials and have permafrost present within 1m of the ground surface or within 2 m if strong cryoturbation is present. Mean annual temperature is <0°C.	• Turbic Cryosols are mineral soils that have evidence of cryoturbation and often form patterned ground • Static Cryosols are mineral soils where cryoturbation is absent. • Organic Cryosols have developed from organic material and are classified into subgroups based on the type of peat materials on which they were formed	• Gleysolic Turbic and Static Cryosols develop in poorly drained areas under reducing conditions and show evidence of gleying such as mottling or low chromas • Brunisolic Turbic Cryosols have a Bm horizon that is at least 10 cm thick • Organic Cryosols in the RSA are not classified to the subgroup level, however, soils in the RSA form predominantly on bog peat materials with some occurrences of fen peat materials
Brunisol	Soils with a level of development that distinguishes them from other soil orders. They are considered an intergrade between undeveloped soils (Regosols) and developed soils of the other orders.	• Eutric Brunisols develop on parent material with high base status	• N/A - Brunisolic soils in the RSA were identified at the great group level

Table 4.3 Distribution of Soils in the LSA and RSA

Soil Great Group or Subgroup	Area of LSA (ha)	% of LSA	Area of RSA (ha)	% of RSA
Eutric Brunisol	5,518	17.4	63,742	19.8
Gleysolic Static Cryosol	12,021	37.9	83,664	25.9
Brunisolic Turbic Cryosol	--	--	7,139	2.2
Gleysolic Turbic Cryosol	4,464	14.1	28,651	8.9
Organic Cryosol	8,054	25.4	105,968	32.9
Orthic Turbic Cryosol	162	0.5	17,022	5.3
Non-classified	1,532	4.8	16,288	5.1
Total	**31,752**	**100**	**322,475**	**100**

Table 4.4 Distribution of Soils Along the MVH

Soil Great Group or Subgroup	Length (km)	% of Area
Eutric Brunisol	55.0	18.0
Gleysolic Static Cryosol	104.5	34.1
Brunisolic Turbic Cryosol	--	--
Gleysolic Turbic Cryosol	39.2	12.8
Organic Cryosol	86.9	28.4
Orthic Turbic Cryosol	9.7	3.2
Non-classified	10.8	3.5
Total	**306.2**	**100**

4.5 Permafrost

The following sections summarize permafrost-related information available for the Project. This includes a summary of climate normals originally presented in the TDR for air quality, greenhouse gases (GHG), and climate (K'alo-Stantec, 2022d). Refer to that TDR for additional climate data, including tabulated summaries.

4.5.1 Climate

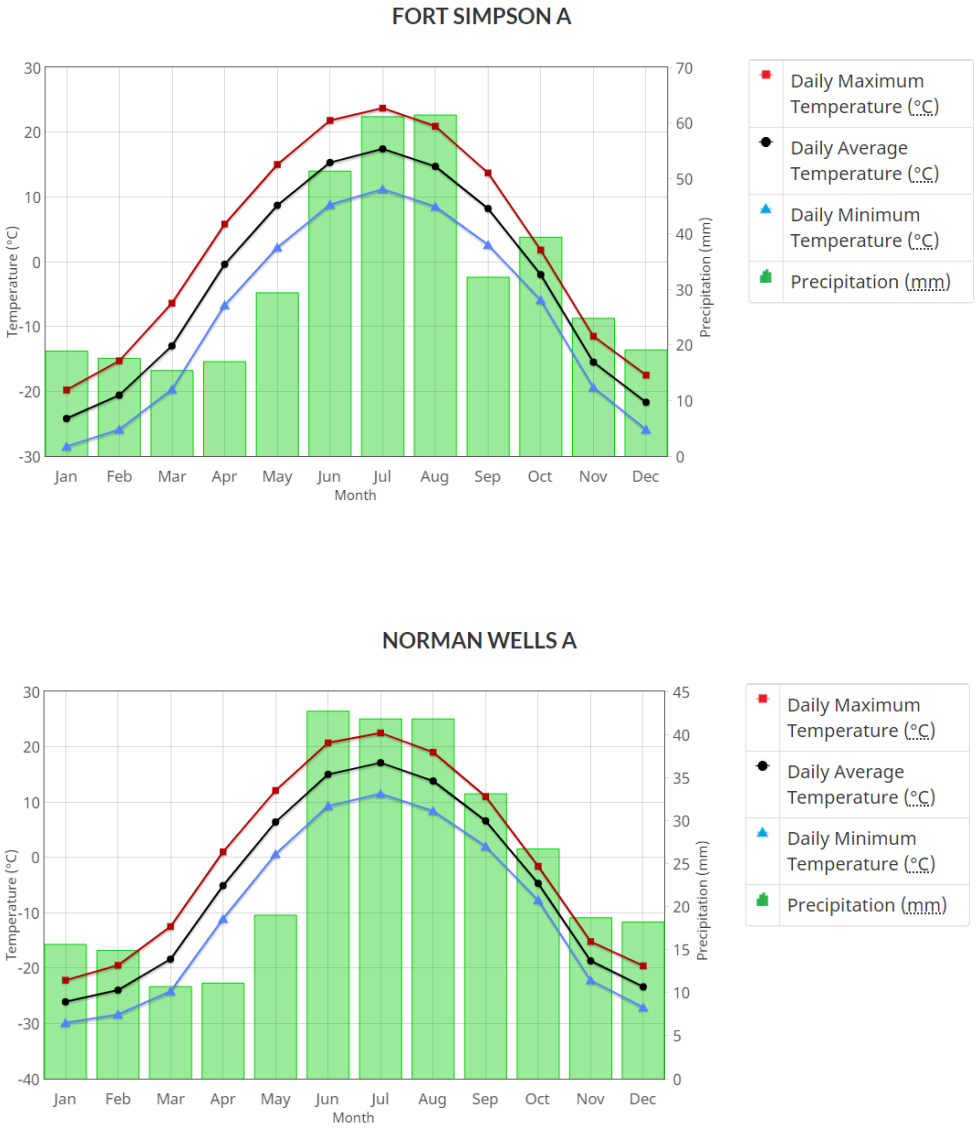
In general, the climate in NT can be described as subarctic, which usually involves short, warm summers and long, cold winters (Phillips, 1990). Environment Canada operates meteorological stations in Norman Wells and Fort Simpson, approximately 200 km south of Wrigley. Daily average temperatures are below 0 degrees Celsius (°C) for 7 months at Norman Wells and Fort Simpson stations with the coldest month being January, where daily average temperatures reach as low as -24.2°C at Fort Simpson and -26.1°C at Norman Wells. Summer months (June, July, and August) average daily temperatures reach the high teens, with the warmest month being July with average temperatures of 17.1°C and 17.4°C, respectively in Fort Simpson and Norman Wells. Extreme temperature ranges from -54.4°C to +35.0°C at Norman Wells and -53.3°C to +36.6°C at Fort Simpson. In general, the temperature data indicates that the climate near Fort Simpson is warmer than at Norman Wells (annual daily average temperature of -2.8°C in Fort Simpson versus -5.1°C in Norman Wells).

Precipitation includes rain and snowfall, with rain occurring mostly from May to September and snow from October to April for both stations. Most of the annual rain occurs during the three summer months (June, July, and August). At both climate stations, roughly 70% of the annual rainfall occurs during these months. For snowfall, the peak snow months for both climate stations are October to December, roughly 50% of the total annual snowfalls occurs during these months. However, for those peak months (October to December) the total amount of precipitation (rain and snow) is relatively low, when compared to the Canadian precipitation climatology (Government of Canada, 2020).

Annual total rainfall at Fort Simpson is slightly higher than at Norman Wells (238.6 mm versus 171.7 mm). Annual total snowfall for the two stations consists of 187 centimetres (cm) in Fort Simpson and 161.5 cm in Norman Wells. Recorded extreme daily rainfall amounts range from 49.3 mm at Norman Wells in August to 85.8 mm at Fort Simpson in July. Extreme daily snowfall values are 28.4 cm at Norman Wells and 33.8 cm at Fort Simpson, both were recorded in the month of April.

Figure 4.1 presents temperature and precipitation graphs as presented by the Government of Canada (2020) using climate normals data covering the 1981 to 2010 period.

Figure 4.1 Canadian Climate Normals - Fort Simpson and Norman Wells (1981-2010 Data)



4.5.2 Permafrost Distribution

Permafrost refers to a condition when the ground, either loose material or bedrock, remains at or below a temperature of 0°C for a minimum period of two years (Permafrost Subcommittee, 1988).

Based on regional permafrost mapping by Heginbottom et al. (1995) and Heginbottom (2000), the RSA between Norman Wells and Wrigley spans the following permafrost zones (see Figure 4.2):

- extensive discontinuous permafrost—permafrost underlying 65% to 90% of the area of exposed land surface. This zone predominantly occurs in the northern portion of the highway corridor near Norman Wells.
- intermediate discontinuous permafrost—permafrost underlying 35% to 65% of the area of exposed land surface. This zone is more likely to occur in the Mackenzie Plain on the western side of the Franklin Mountains.
- sporadic discontinuous permafrost—permafrost underlying less than 35% of the area of exposed land. This zone occurs predominantly in the southern portion of the highway corridor near Wrigley.

Regional scale permafrost distribution maps may not fully reflect current site conditions, especially when accounting that these maps were produced over two decades ago and may not account for recent impacts of climate change. The findings of recent geotechnical field investigations (Tetra Tech, 2020a, 2020b, 2020c, 2020d) and the LSA terrain mapping are considered the most useful dataset to inform on the overall distribution of permafrost along the project.

The climate is the predominant element controlling the broad distribution of permafrost. Other contributing factors influencing its distribution and local properties include the topography, soils characteristics, vegetation cover, snow cover, and surface water.

General comments on how these factors can impact permafrost distribution are provided below.

The topography and local relief (e.g., river valley, ridges or hills) influence the distribution of permafrost, primarily as a result of variation in solar radiation received at the ground surface. Differences in solar radiation could result in thinner or thicker active layer (i.e., the surface that freezes and thaws each year), or absence of permafrost, depending on the orientation of slopes. In discontinuous permafrost, frozen ground is more likely to occur on north-facing slopes and in low-lying plains where solar radiation is limited.

Soil texture affects the capacity of the material to retain water. Information on soil texture within the LSA and RSA is available from historical publications, reports and databases as well as from recent geotechnical investigations conducted for the MGAR and PCAR projects (Tetra Tech, 2020a, 2020b, 2020c, 2020d). These data, along with terrain mapping conducted for the LSA, reveals the distribution of fine- versus coarse-grained soils and, incidentally, on the distribution of soils that are frost-susceptible.

Frost susceptibility is a concept widely used in cold region to quantify the capacity of a soil in generating frost heave (i.e., upwards swelling of soil during freezing conditions caused by an increasing presence of ice) and frost damage (Sheng, 2021). Acknowledging that soil texture and material type are the most important factors affecting frost heave, special attention was given to conduct detailed terrain mapping along the MVH alignment so that this information can be used to support highway design.

Organic soils possess thermal properties effective in protecting the ground from atmospheric and solar heat. During the summer, when the surface layers are dry, the thermal conductivity may decrease and slow seasonal summer thaw. During autumn and winter, as peat becomes filled with ice, the thermal conductivity increases, thus leading to lower mean annual ground temperatures (French, 2007). Because organic matter has a high potential for water retention, high ice content permafrost is often found underneath organic soils.

Thick organic soils are often found in forest and shrub wetlands. These soils are predominant in areas associated with open water and adjacent to watercourses near the Mackenzie River. Permafrost is predominant in stands of low black spruce forest that have developed on thick organic soils. Localized peat plateaus, often elevated 1 m to 2 m above the surrounding terrain, are expected to be present in the elevated black spruce bogs.

Areas of thick organic accumulations often have ice-rich permafrost and, therefore, special attention was given to delineate wetlands (i.e., organic veneers (Ov) and organic blankets (Ob) as part of the LSA terrain mapping (see Chapter 5).

Soil drainage conditions can influence the presence of permafrost. A poorly and very poorly-drained soil may indicate that permafrost is present because the occurrence of permafrost may prevent water from draining, and thawing of the uppermost portion of permafrost may lead to accumulations of water at the ground surface.

The extent and dynamics of permafrost are tightly linked to the distribution and movement of water and, therefore, special attention was also given to observe drainage patterns as part of the LSA terrain mapping (see Chapter 5). Vegetation and snow cover both affect the thermal exchange between air and ground, influencing overall permafrost distribution. For example, the degree of canopy closure will influence how much solar radiation will reach the forest floor (i.e., the vegetation cover will shade the ground from direct solar radiation, limiting the amount of heat transferred to the ground). Similarly, a dense forest canopy can intercept more snowfall during winter than an open forest canopy. A soil with a thick organic horizon can insulate and retard heat transfer (upward and downward). Similarly, a thick snow blanket (either trapped by vegetation or by a topographic obstacle) can insulate underlying soils by retarding frost penetration in the fall, or by delaying thawing in the spring.

Vegetation types and cover help with the interpretation of terrain conditions, including potential permafrost dynamic, and special attention was given to observe vegetation patterns as part of the LSA terrain mapping (see Chapter 5),

Water bodies will influence the distribution of permafrost. Thermal exchange through bodies of water such as lakes and rivers can result in thinner, or absent permafrost. Taliks are bodies or layers of unfrozen ground in permafrost areas. Permafrost will be absent beneath large bodies of water such as the

Mackenzie River as well as large lakes (Burgess and Smith, 2000). Around lakes and tributary streams that do not freeze completely in the winter, the temperature of the water will influence the ground temperature regime, resulting in taliks that vary in size and shape.

Ares occupied by water bodies have been mapped within the LSA and RSA (see Chapter 5; these map units are good indicators of the presence of taliks.

4.5.3 Ground Ice

In permafrost soils, ground ice occurs in many forms, from ice fillings in the intergranular pores of soils to massive ice bodies several metres in thicknesses.

Segregated ice is expected to be the most common type of ground ice present within the LSA and RSA and consists of discrete ice lenses or layers that form by migration of unfrozen pore water towards a freezing front (O'Neill et al., 2019). Examples include ice structures that bond the enclosing sediments (intrusive ice), reticulate ice lenses, layers, and veins, ice crystals and icy coatings on soil particles. In the active layer, segregated ice pushes soil particles and stones to the surface and, on slopes, results in the slow, downslope movement of soil materials. The ice-content of the different overburden materials is expected to vary, from high (in peat and organic soils, fine-grained glaciolacustrine or clay-till) to low (in alluvial and glaciofluvial sand and gravels).

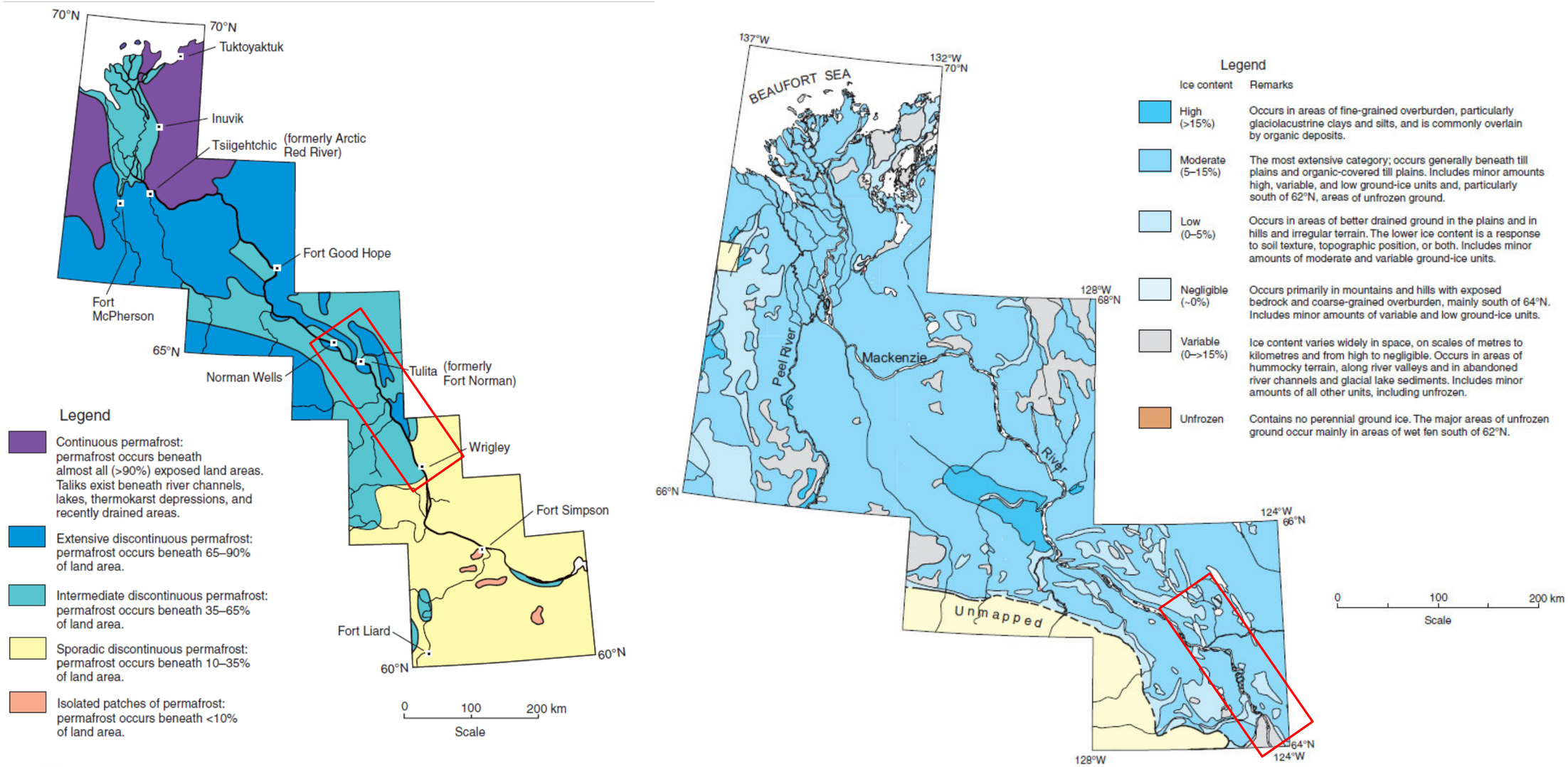
Geotechnical investigations conducted for the MGAR and PCAR projects (Tetra Tech, 2020a, 2020b, 2020c, 2020d) allowed for the classification of ground-ice encountered in different material types (see Section 4.5.5.2 MGAR and PCAR Permafrost Assessments).

Ice wedges are downward-tapering bodies of nearly pure ice that accumulate in near-surface permafrost (Lachenbruch, 1962; O'Neill et al., 2019). They form when cold winter temperatures cause the ground to contract under stress and crack. Meltwater later infills these cracks and refreezes. This repeated process results in the growth of an ice wedge over time, often leading to commonly recognizable pattern of ice wedge polygons in lowland terrain. The terrain along the LSA and RSA is expected to contain few areas characterized by the presence of ice wedges. This is supported by the review of LiDAR data available for the majority of the LSA (see results of LSA Terrain Mapping in Section 5).

Massive ice may occur as large bodies of preserved glacial ice or as thick ice beds developed in situ by segregation occurring between fine-grained materials (silts and clays) and coarser sands. These types of relic ice deposits have been described in several publications (e.g., Mackay, 1971; Mackay and Dallimore, 1992) and are expected to be limited to the Mackenzie Delta and Tuktoyaktuk Peninsula, well outside of the RSA.

Figure 4.2 presents maps showing permafrost distribution and the expected distribution of ground-ice within the Mackenzie Valley, based on mapping by Heginbottom (2000), with Figure 4.3 presenting maps showing permafrost distribution and expected ground-ice abundance based on modelling by O'Neill et al. (2019, 2020).

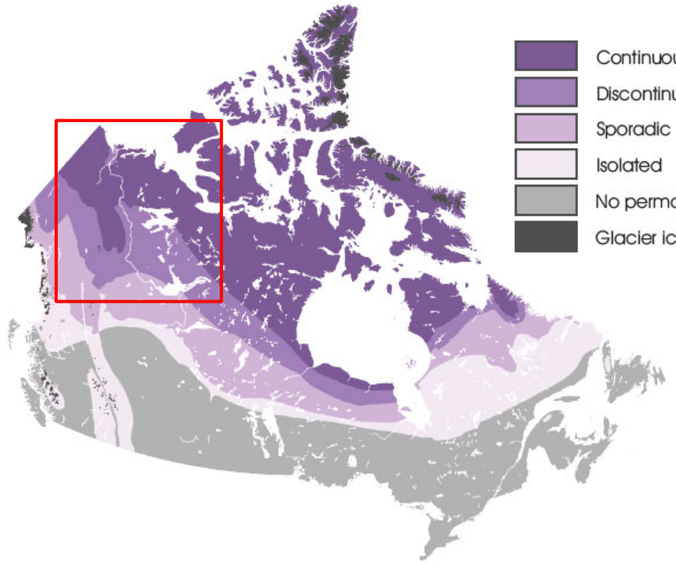
Figure 4.2 Permafrost Distribution (left) and Expected Ice Content (right) Along the Mackenzie Valley



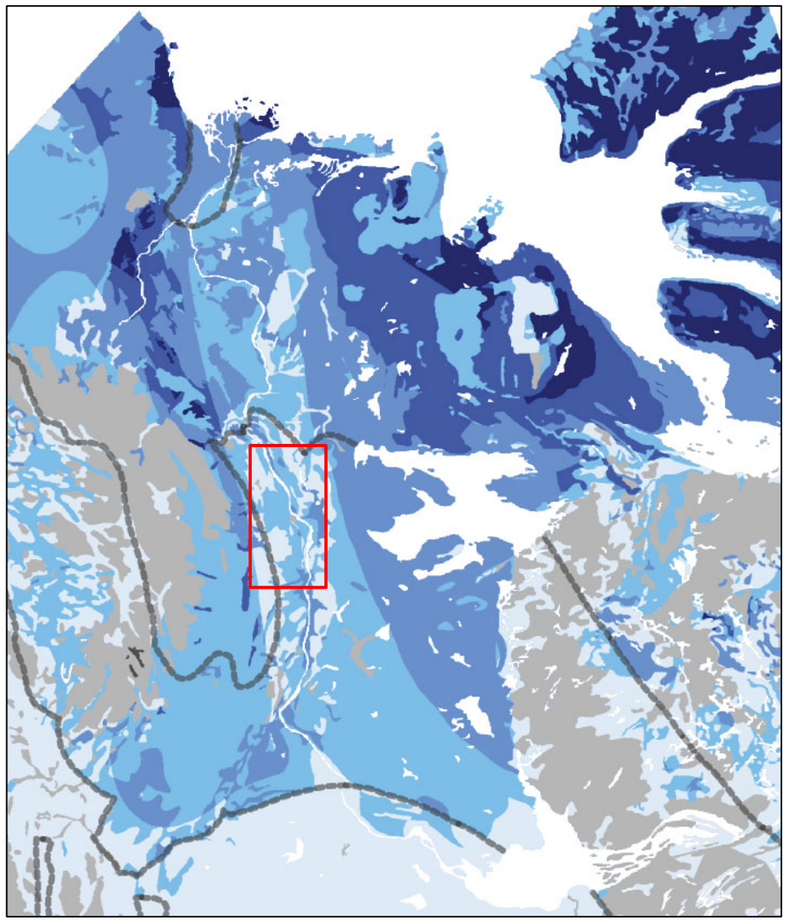
NOTE:
*The red polygon shows the approximate location of the Project

Source: from Heginbottom (2000)

Figure 4.3 Permafrost and Ground Ice Distribution Within the RSA



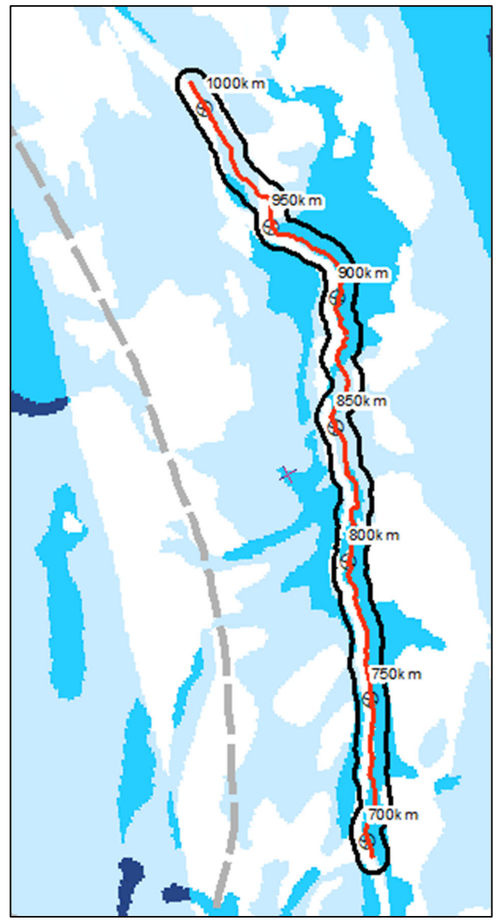
Permafrost distribution



Ground ice abundance
(Est. % excess ice volume in top 5 m of permafrost)

None	Negligible	Low	Medium	High	Very high
0	>0-5	>5-10	>10-20	>20-30	>30

--------- Permafrost zone boundary



Segregated ice distribution

None	Negligible	Low	Medium	High
0	>0-2	>2-5	>5-10	>10

10 km-wide RSA
MVWR route

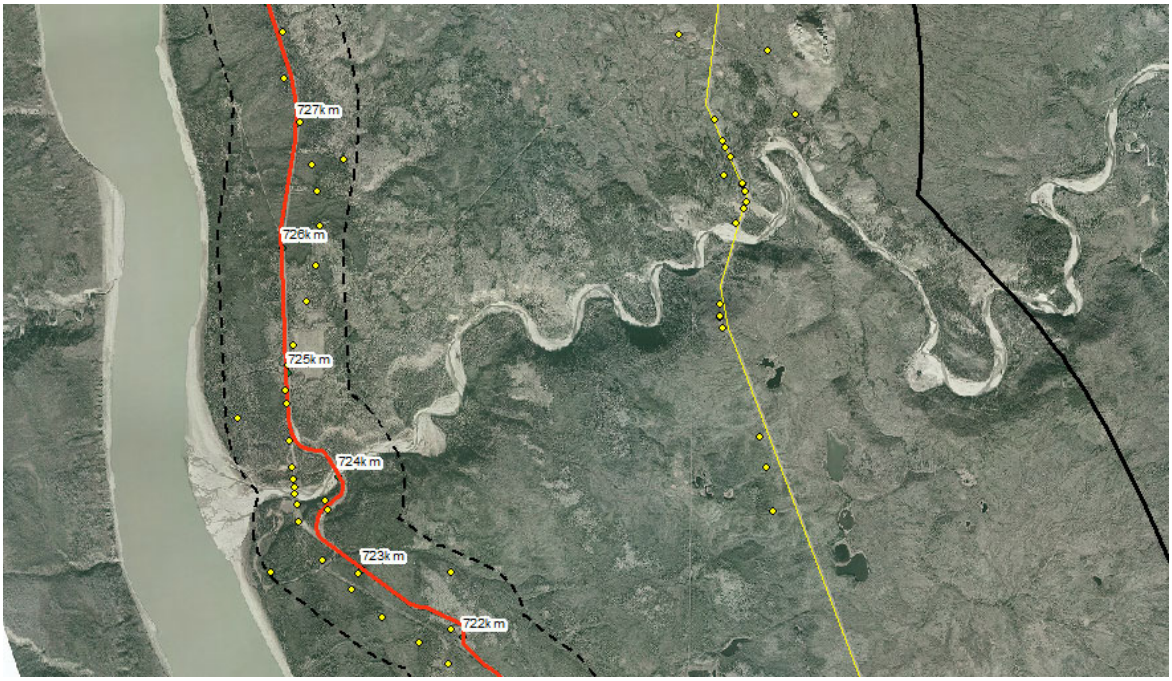
Source: Modified from O'Neill et al. (2019, 2020).

4.5.3.1 Existing Field Data Specific to Terrain and Permafrost

Field data indicative of the presence or absence of permafrost along the MVWR route include historical geotechnical boreholes conducted in support of pipelines and transportation projects within the Mackenzie Valley, most of which were incorporated in the borehole database compiled by Smith et al. (2005) and, subsequently, through the PIN web portal.

Filtering to boreholes located within the RSA resulted 2,994 borehole entries falling within a maximum 5 km from the MVWR route. Out of these boreholes, 1,786 fall within the LSA (i.e., within 0.5 km of the MVWR route). As an example, a screen capture showing the concentration of existing boreholes falling within both the current RSA and LSA in the area surrounding the Ochre River (MVWR KM 724) is presented in Figure 4.4.

Figure 4.4 Existing Geotechnical Boreholes in the Area Surrounding the Ochre River



Notes: MVWR (red line), Norman Wells Pipeline (yellow line), RSA (black polygon), LSA (dashed polygon). Yellow dots are borehole locations. SOURCE: data obtained through the PIN web portal.

As identified in the paper accompanying the release of the database, the quality of data recorded for any given borehole varies widely, likely because of the defined purpose of the geotechnical study for which the hole was originally drilled. Differences in formats, structure and/or units of measurements observed as part of the data consolidation might also be responsible for some of the original data not being included in the compilation database. For these reasons, the borehole data was mainly used to support the terrain mapping through the description of surface/subsurface material types and textures, without attempts to summarize permafrost distribution and ground ice conditions.

During the construction of the Normal Wells Pipeline by Interprovincial Pipeline Ltd. (now operated by Enbridge) in the early 1980s, a continuous ditchwall log was created during the excavation of the trench for pipeline burial (Nixon et al., 1991; Burgess and Lawrence, 2000). Information recorded included soil and ice description as well as geothermal (frozen/unfrozen) interpretations. Data collected during the construction of the pipeline allowed for the confirmation of the discontinuous character of the permafrost along its right-of-way. Findings indicated that frozen ground underlay 80% to 90% of previously undisturbed ground surface near Norman Wells, a proportion declining to around 40% in the area surrounding Wrigley. Nixon et al. (1991) notes that geophysics and borehole data available for the area generally supported the ditchwall log information, with the exception of a 50 km stretch north of Wrigley (pipeline KM 250-300). The geophysics and borehole data suggested a greater occurrence of permafrost (60% to 70% versus 40%).

Summarized permafrost occurrences per surficial geology as presented by Nixon et al. (1991) along the Norman Wells Pipeline is presented in Table 4.5. That route is within the RSA and parallels the MVWR (from 0.1 km to approximately 6 km between the segments).

Table 4.5 Frozen Terrain and Interfaces by Terrain Unit along Norman Wells Pipeline

IPL spread (km range)	LP (25.5%)	MG (19.4%)	OV-LP (13.9%)	LP-MG (10.5%)	OV-MG (6.3%)	GO (4.8%)	All (100%)
1 (0.0–149.5)							
% terrain occurrences	28.7	18.7	16.1	9.2	2.5	0.1	—
% frozen	91.0	92.3	90.2	81.9	91.9	100.0	89.6
Length (km)	42.89	28.0	24.13	13.76	3.68	0.11	149.5
No. of interfaces	56	16	39	25	6	0	191
No. of interfaces/km	1.31	0.57	1.62	1.82	1.63	0.0	1.28
2 (149.5–269.3)							
% terrain occurrences	41.3	1.5	9.5	22.0	0.0	9.0	—
% frozen	56.9	44.0	38.9	69.8	—	70.2	56.5
Length (km)	49.46	1.76	11.39	26.36	0.0	10.8	111.1
No. of interfaces	87	2	13	23	—	21	173
No. of interfaces/km	1.76	1.14	1.14	0.87	—	1.94	1.44
3 (269.3–380.4)							
% terrain occurrences	31.6	24.5	9.9	0.0	3.9	7.4	—
% frozen	55.6	81.0	53.3	—	80.3	49.9	63.4
Length (km)	35.1	27.2	10.99	0	4.32	8.18	119.8
No. of interfaces	70	21	34	—	3	12	179
No. of interfaces/km	1.99	0.77	3.09	—	0.69	1.47	1.61

Notes: IPL spread refers to sections of the Norman Wells Pipeline (Norman Wells corresponds to KM 0, and Wrigley to KM 336 (spread 3). Codes for terrain units are as follow: LP, lacustrine; MG, till; OV, organic; GO, outwash.

Source: from Nixon et al. (1991)

4.5.4 Active Layer

The active layer is defined as the layer of ground that is subject to annual thawing and freezing in areas underlain by permafrost (Permafrost Subcommittee, 1988). Generally, active layer thickness varies in response to air temperature, vegetation cover and type, snow cover, summer rainfall and local soil characteristics (texture, moisture and thickness of the surface organic layer).

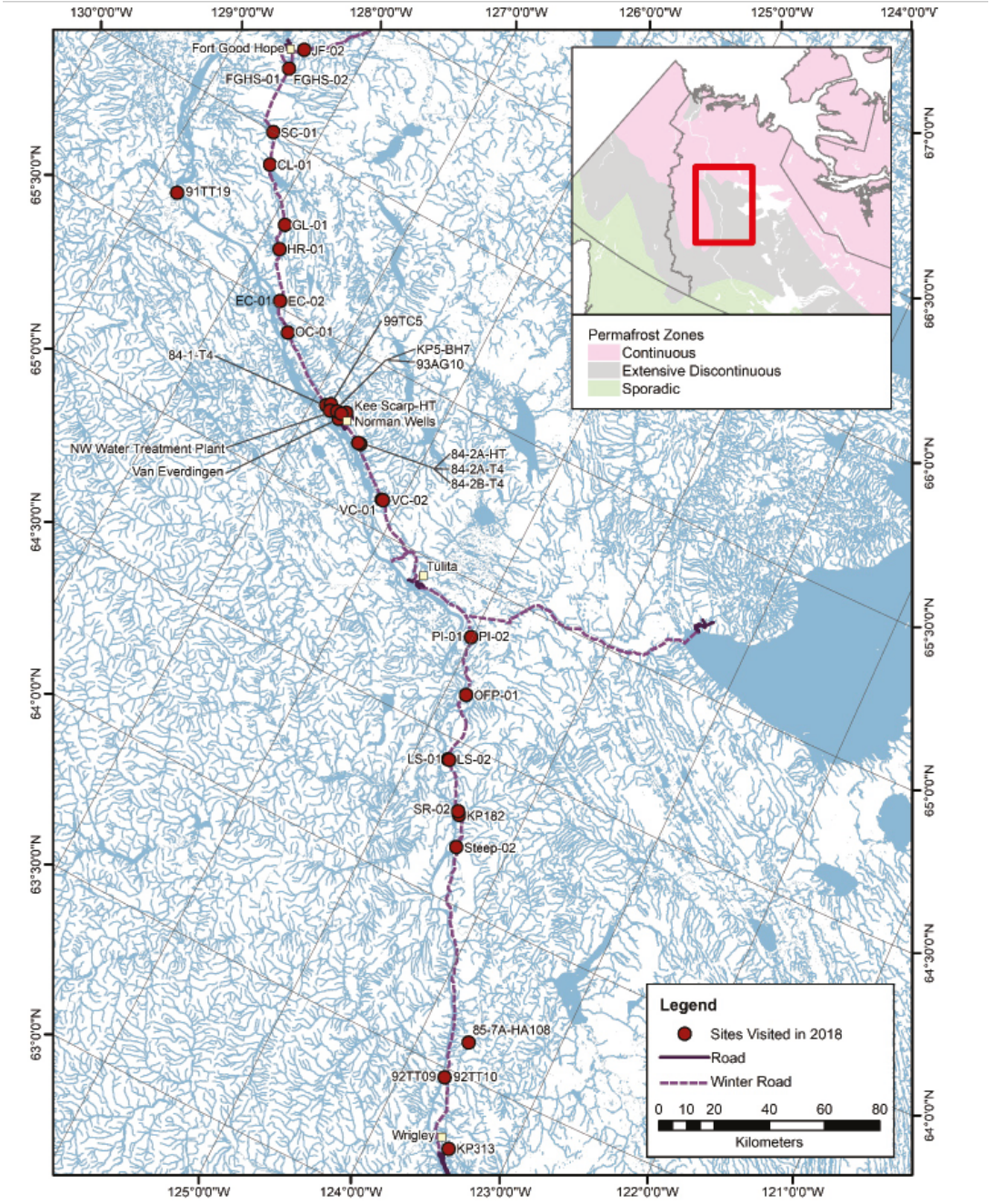
Key drivers of the variability of the active layer within Mackenzie Valley include climate, vegetation and soil condition factors. Published studies indicate that there is significant inter-annual variability, likely driven by variation in thawing degree days (i.e., the cumulative annual measure of degrees above 0°C), and inter-annual variations in soil moisture content. Higher variability occurs where moisture content and organic cover are high and spatially variable. The active layer of thick organic soils is generally less than the surrounding mineral soils.

The GSC maintains a series of active layer monitoring sites within the Mackenzie Valley, several of which have been in operation since the early 1990s and data available from these locations contributed to numerous publications (e.g., Nixon, 2000; Smith et al., 2009b; Duchesne et al., 2015, Duchesne et al., 2020). At GSC monitoring sites, air and ground temperatures are being monitored and thaw tubes are used to determine the maximum thaw penetration during the period of maximum thaw. Review of available data indicates that 17 monitoring sites are located within the RSA (Figure 4.5). There is a general southward increase in active-layer thickness with increasing thawing degree days and recent data (summer 2017) indicate thaw depths ranging from 0.46 m to 7.68 m (Table 4.6). The absence of active layer values at several sites suggests absence of permafrost, or a thaw depth deeper than the depth of recording.

Researchers cited above have been able to document trends in the active layer over time and data available for sites in Mackenzie Valley shows that there is significant inter-annual variability. For example, Duchesne et al. (2015) note that there has been an increase of the active layer between 1991 and 1998 (maximum in 1998), a thinning between 1999 and 2005, then an increase up to 2012. Although records are too short to make inferences about temporal trends related to climate[2], there is a consensus that the active layer has generally increased at sites along the Mackenzie Valley over the last few decades, which was most likely in response to warmer air temperatures. It is anticipated that the active layer will increase with climate change.

[2] https://www.enr.gov.nt.ca/en/state-environment/132-trends-active-layer-thickness-nwt#:~:text=In%20the%20NWT%2C%20there%20is,soil%20moisture%20and%20snow%20cover.

Figure 4.5 GSC Active Layer Monitoring Sites from Wrigley to Fort Good Hope



Source: from Duchesne et al. (2020)

Table 4.6 Summary of 2017 Thaw Depth at Monitoring Sites Located Within the RSA

Site ID	Lat/Long (°)	Approx. MVWR KM	Thaw Depth (m)	Landform	Vegetation
KM313	63.26 N 123.43 W	694	1.0 to 3.62	Lacustrine plain	Moss cover and peat, forested, mix of birch and spruce
92TT09	63.46 N 123.70 W	723	0.46 (probed)	-	-
92TT10	63.47 N 123.69 W	724	0.78 (probed)	Low fluvial terrace cut into glaciolacustrine plain	moss and typical boreal vascular plants
85-7A-HA108	63.61 N 123.64 W	738	N/A	Ground moraine	Lichen, moss, ericaceous shrubs with black spruce and alder
Steep-02	64.18 N 124.38 W	816	N/A	Alluvial and colluvial	Mixed, white spruce, jackmine, aspen, birch
KM182	64.28 N 124.47 W	832	N/A	Lacustrine plain	Forested (burned 1994) – Aspen, willow, birch, tamarack and moss and peat ground cover (unburned)
SR-02	64.29 N 124.49 W	833	7.09	Glaciofluvial veneer over lacustrine	Burnt black spruce forest
LS-01	64.43 N 124.74 W	853	N/A	Alluvial flood plain	Open mature black spruce forest – cleared between 2015 and 2016.
LS-02	64.43 N 124.73 W	854	7.68	Glaciofluvial outwash plain	Tamarack birch poplar, and pine forest transition to spruce
OFP-01	64.65 N 124.84 W	881	3.12	Lacustrine plain	Open mixed spruce, pine deciduous forest adjacent to open, low-lying fen
PI-01	64.83 N 125.01 W	906	5.11	Lacustrine plain	Recovering burn (burnt black spruce forest)
PI-02	64.83 N 125.01 W	906	N/A	Lacustrine plain	Unburnt, black spruce forest with moss and lichen ground cover
VC-01	65.10 N 126.14 W	987	2.75	Moraine plain	NW side of creek, on top of ridge in black spruce forest
VC-02	65.10 N 126.13 W	987	1.73	Moraine plain	SE side of creek on plateau in area of burnt black spruce
84-2A-HT	65.23 N 126.50 W	1011	3.32	Ground moraine	Lichen, moss, ericaceous shrubs with black spruce and tamarack
84-2A-T4	65.23 N 126.50 W	1011	3.39	Ground moraine	Lichen, moss, ericaceous shrubs with black spruce and tamarack
84-2B-T4	65.23N 126.52 W	1011	1.47	Ground moraine	Moss with white spruce

Source: Modified from Duchesne et al. (2020)

4.5.5 Ground Thermal Regime

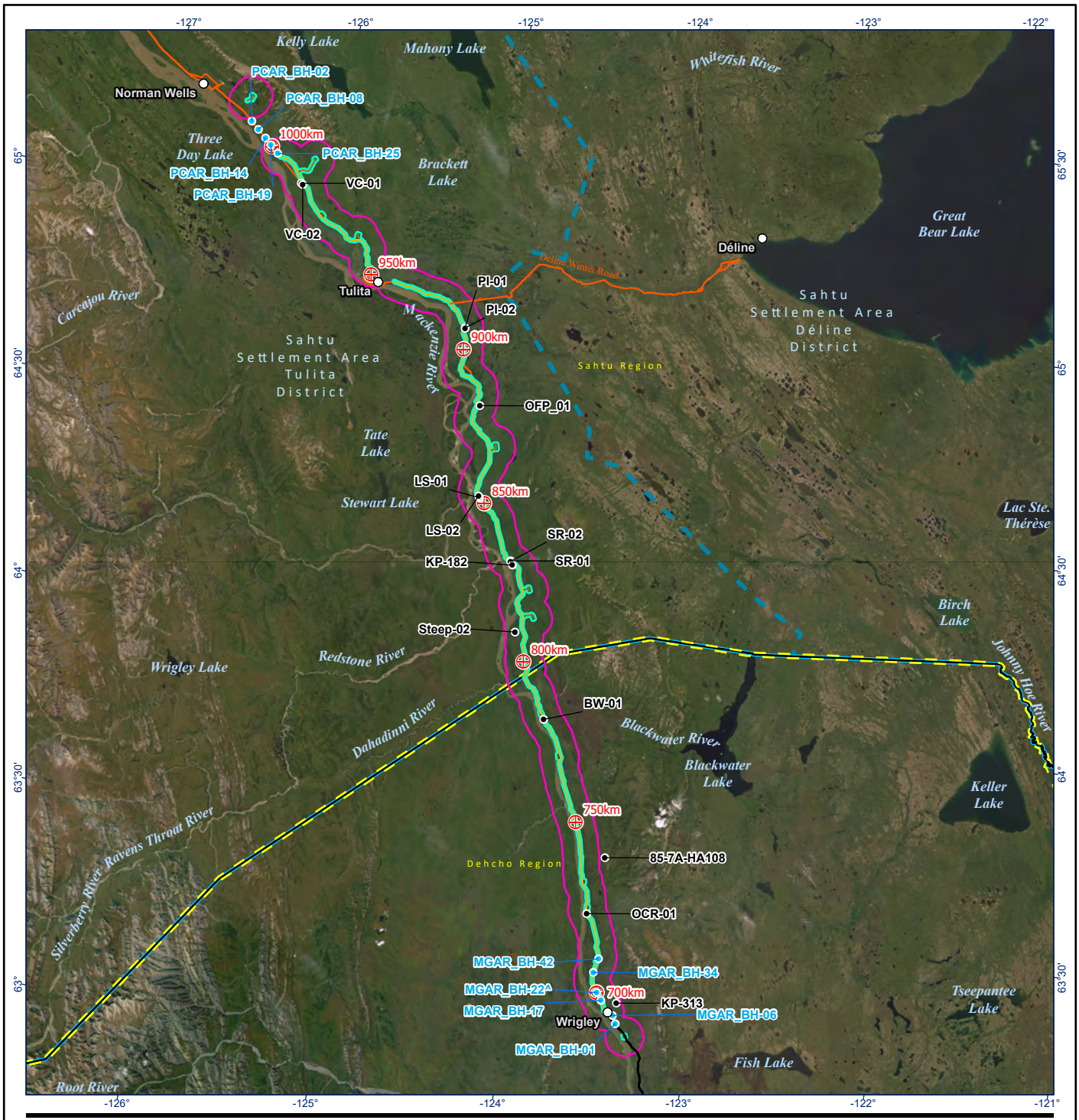
4.5.5.1 Monitoring by the Geological Survey of Canada

Historical information on ground thermal regime of the Mackenzie Valley is available from Judge (1973). Since the mid-1980s, the GSC has developed and maintained a permafrost monitoring network in the Mackenzie Valley, resulting in a suite of publications detailing permafrost conditions in the region (including but not limited to Smith and Burgess, 2000; Smith et al., 2004; Duchesne et al., 2014). A recent compilation of air temperature, ground-thermal and active-layer data acquired from these sites was released, including a summary of ground temperature records for the 2007–2018 period (Duchesne et al., 2020). That publication has tabulated summaries and thermal profiles at monitoring sites (trumpet curves).

Ground temperature monitoring sites within the RSA are presented in Figure 4.6. Recent data (summer 2017–2018) shows the annual mean ground temperatures at depth of zero annual amplitude (or deepest available measurements) range from above zero (i.e., absence of permafrost) to approximately -2°C. Ground temperature records for the 2007–2018 period indicated that permafrost is generally warming throughout the Mackenzie Valley and, for a majority of sites, permafrost is currently warmer than the baseline established during the International Polar Year (2007–2009) (Duchesne et al., 2020).

4.5.5.2 MGAR and PCAR Permafrost Assessments

A summary of key results obtained from the geotechnical, geophysical and thermal evaluations conducted by Tetra Tech along the PCAR and MGAR (Tetra Tech, 2020a, 2020b, 2020c, 2020d) are presented below.



- GSC ground temperature monitoring
- PCAR/MGAR ground temperature monitoring
- Mackenzie Valley Highway Kilometre Post
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access

- Local Study Area
- Regional Study Area
- Community
- All-Season Road (Hwy 1)
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/9/2023
TR by AJ on 3/9/2023

Client/Project
144903025-0073 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
4.6

Title
RSA Ground Temperature Monitoring Sites

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

MGAR

- The MGAR project begins in Wrigley (MVWR KM 690) and extends to Mount Gaudet at (MVWR KM 709).
- A total of 42 boreholes at approximately 500 m spacing were drilled along the MGAR alignment. Drill depths ranged from 0.9 m to 8.1 m.
- Both unfrozen and frozen soils, including visible ground ice, were encountered in the boreholes, with a total 37 out of the 42 boreholes showing frozen soils.
- The southern portion of the MGAR (Wrigley to MVWR KM 692.5) consisted of frozen coarse-grained glaciofluvial sand and gravel to the depth of the borehole (based on 12 boreholes completed in this section, which depth ranged from 0.9 to 6.6 m).
- The middle portion of the MGAR (MVWR KM 692.5 to KM 703) consisted of lacustrine silty clay that was frozen with excess visible ground ice throughout the depth of borehole.
- The northern portion of the MGAR (MVWR KM 703 to KM 707.3) consisted of both unfrozen and frozen lacustrine silty clay.
- The seasonally frozen (interpreted as the active layer in Tetra Tech report)layer was estimated to range from 0.5 m to 2.0 m thick, based on five ground temperature monitoring locations along the MGAR.

In August 2020, multi-bead ground temperature cables were installed in six boreholes, all in fine-grained till deposits. Their locations are presented in Figure 4.6.

Summary data as presented by Tetra Tech is presented in Table 4.7. Refer to the original reports for tabulated summaries and graphs depicting temperature profiles.

Table 4.7 MGAR Ground Temperature Data Summary

Borehole Number	BH-01	BH-06	BH-17	BH-34	BH-42
MVWR Milepost (km)	686.4	688.8	694.8	703.3	707.3
Permafrost Encountered	No	No	Yes	Yes	No
Estimated Depth of Active Layer*	0.5 m	0.6 m	2.0 m	1.4 m	1.5 m
Minimum Temperature below Active Layer (November 2020)	1.3°C @ 1.0 m	0.1°C @ 8.0 m	-0.4°C @ 7.7 m	-0.2°C @ 7.7 m	1.9°C @ 6.0 m
Maximum Temperature below Active Layer (November 2020)	3.7°C @ 4.0 m	0.7°C @ 3.0 m	0.0°C @ 2.7 m	0.1°C @ 1.7 m	2.6°C @ 2.0 m

** Active layer is defined as the top layer of ground subject to annual thawing and freezing in areas underlain by permafrost.*

MGAR Section	MVWR Milepost (km)		Permafrost Conditions	GTCs within Section	Boreholes within Section
	From	To			
South (Wrigley to MVWR km 692.5)	686.4	692.5	Unfrozen Frozen, No Excess Ice	2 (BH-01, BH-06)	12 (BH-01 to BH-12)
Middle (MVWR km 692.5 to 703.0)	692.5	703.0	Frozen, Ice-Poor Frozen, Ice-Rich	1 (BH-17)	21 (BH-13 to BH-33)
North (MVWR km 703.0 to Mount Gaudet)	703.0	707.3	Unfrozen Frozen, Ice-Poor	2 (BH-34, BH-42)	9 (BH-34 to BH-42)

Source: Tetra Tech (2020a, 2020b)

PCAR

- The PCAR project begins at Canyon Creek (MVWR KM 1009) and extends to Prohibition Creek (MVWR KM 995).
- A total of 25 boreholes drilled to depth ranging from 5.5 m to 8.1 m showed both unfrozen and frozen soils.
- The alignment from KM 997 to KM 1009 consisted primarily of clay till with layers or pockets of silt, sand and gravel. KM 997 to KM 999.5 encountered highly weathered shale bedrock underlying the mineral soil.
- Permafrost was encountered in most of the boreholes, with ice contents generally ranging from no visible ice to around 20% visible ice.
- Active layer was observed in all 25 boreholes, at depths ranging from 0.6 m to 1.5 m.
- Ground ice contents were observed to be higher closer to the surface and decreasing with depth.
- No areas of massive ground ice were encountered.

In August 2020, multi-bead ground temperature cables were installed in five of the previously drilled boreholes, all in fine-grained till deposits (see location on Figure 4.6). A first complete set of readings were collected in October 2020. Summary data as presented by Tetra Tech are in Table 4.8.

Table 4.8 PCAR Ground Temperature Data Summary

Borehole Number	BH-02	BH-08*	BH-14	BH-19	BH-25
MVWR Milepost (km)	1008.2	1005.0	1001.8	999.2	996.0
Depth of Active Layer	0.8 m	-	0.6 m	1.2 m	1.5 m
Minimum Temperature below Active Layer (October 2020)	-1.0°C @ 7.8 m	4.4°C @ 8.0 m	-0.3°C @ 1.2 m	-1.9°C @ 7.3 m	-1.0°C @ 7.2 m
Maximum Temperature below Active Layer (October 2020)	-0.4°C @ 1.3 m	8.6°C @ 2.0 m	0.2°C @ 3.7 m	-0.3°C @ 1.3 m	-0.2°C @ 1.7 m

** Ground temperature readings incorrectly high in Borehole BH-08, likely due to Amphenol connector issue with GTC.*

PCAR Section	MVWR Milepost (km)		Permafrost Conditions	GTCs within Section	Boreholes within Section
	From	To			
South (Prohibition Creek to MVWR km 999)	995.3	999.2	Frozen, Ice-Poor Unfrozen	1 (BH-25)	6 (BH-20 to BH-25)
Middle (MVWR km 999 to Christina Creek)	999.2	1001.1	Frozen, Ice-Poor Frozen, Ice-Rich	1 (BH-19)	5 (BH-15 to BH-19)
North (Christina Creek to Canyon Creek)	1001.1	1009.3	Unfrozen Frozen, Ice-poor	3 (BH-02, BH-08, BH-14)	14 (BH-01 to BH-14)

Source: Tetra Tech (2020c, 2020d)

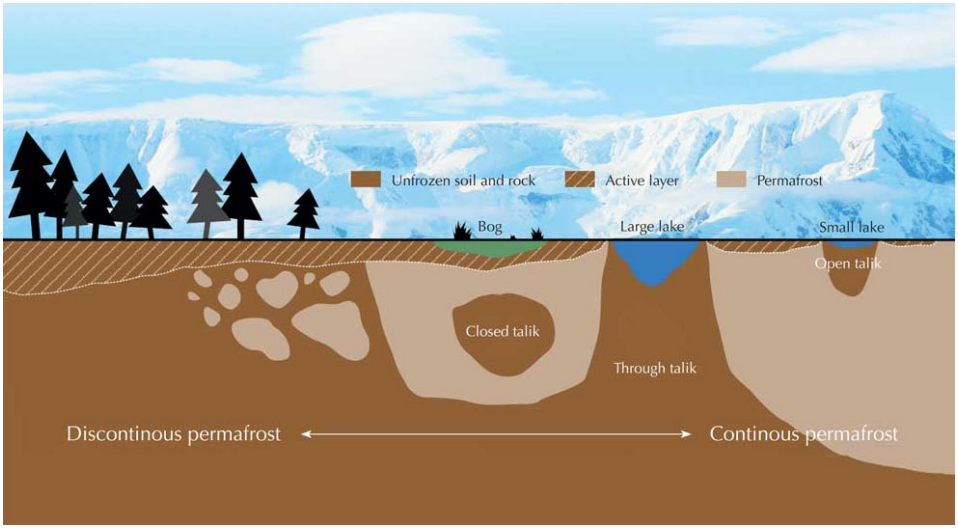
4.5.6 Permafrost, Surface Water and Groundwater Interactions

At the watershed scale, surface and subsurface runoff transports snowmelt and rainfall from hillslopes to numerous lakes and stream systems. In the Taiga Plains, drainage conditions are characterized by runoff peaks during spring snowmelt and are influenced by high surface water storage in waterlogged soils, wetlands, and ponds. A large portion of the RSA is characterized by the presence of wetlands (40% of the RSA in the Sahtu Region and approximately 30% in the Dehcho Region) (K'alo-Stantec, 2022c), with waterlogged soils influenced by the distribution of permafrost.

Water discharges in streams, mainly through river valleys that have developed along the main tributaries to the Mackenzie River. Within the LSA, the MVWR route often crosses these streams in areas of wide floodplains, opening onto even larger fans. Streams and water bodies are underlain by taliks, some contained within permafrost, others are interconnected through discontinuous permafrost (through taliks; Figure 4.7). In undulating terrain, surface drainage is often condensed into channels, some of the larger ones associated to post-glacial erosion. On moderately-steep to steep hillslopes and escarpments, surface runoff is directed into gullies, which often show signs of mass movement. Along low-angle hillslopes, areas affected by increased seepage and surface runoff often host distinct vegetation communities that facilitate their identification on air photos and satellite imagery.

Drainage patterns are seasonally controlled by the depth to the frost table and the presence of ephemeral drainage channels. In continuous permafrost terrain, the presence of frozen ground limits groundwater flow, and surface runoff and seepage occur through the active layer. In discontinuous permafrost or areas characterized by interconnected taliks, near-surface drainage can interact with a deeper aquifer. Local groundwater quantity and flow patterns are influenced by the presence of permafrost.

Figure 4.7 Simplified Schematic Representation of Continuous/Discontinuous Permafrost and Taliks (from PhysicalGeography.net)



Poor drainage conditions along a road in permafrost terrain may cause surface water ponding, thermal erosion, thermokarst and/or the formation of icings (see Section 4.6.4). To facilitate the identification of potential drainage flow intersecting the MVH alignment, apparent drainage flow paths were delineated as part of the LSA terrain mapping (Section 5).

4.6 Geomorphological Processes and Geological Hazards

Geomorphological processes are natural mechanisms of weathering, erosion, transport and deposition that result in the modification of the surficial materials and landforms at the Earth's surface (Howes and Kenk, 1997. The terrain within the RSA is influenced by several geomorphological processes, many of which are directly related to the presence of permafrost.

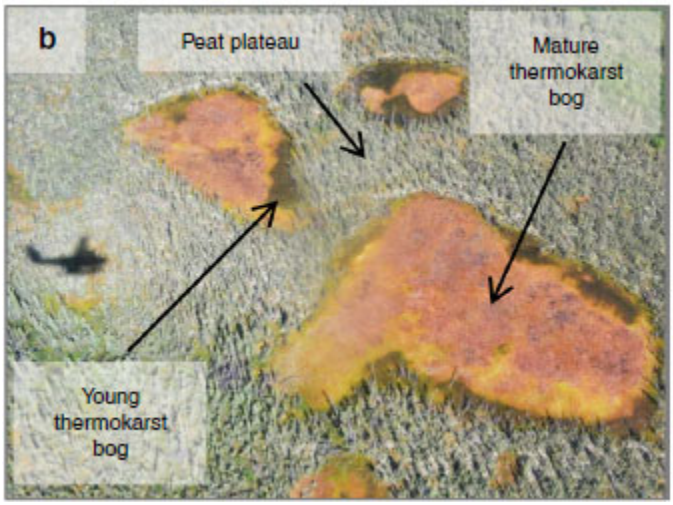
4.6.1 Thermokarst

Thermokarst features ("Xt" in the LSA terrain mapping) are topographic depressions created in a variety of shapes and sizes as a result of thawing ground ice. These features occur in terrain where the near-surface thermal regime has changed, allowing for the active layer to increase and ground ice to thaw. Processes triggered by thermokarst include the transformation of frozen peatlands to collapsed wetlands, lake expansion and localized flooding, and the initiation or reactivation of shallow landslides.

Within the RSA, visual indicators of thermokarst are prevalent in low-lying terrain associated with thick organic soils, especially in peat plateaus where the distinct signature of collapse scars or "thermokarst bogs" are often visible on the ground surface. These features generally initiate as small, water-saturated depressions that progressively expand as circular features, often coalescing with each other by lateral expansion. In their young stage, the depressions or collapse portions of the plateaus present distinctive drainage patterns when compared to the generally dry surface of the peat plateaus (Figure 4.8). Soils will be saturated and surface water may accumulate. Affected areas initially dominated by black spruce and Labrador tea will transition to vegetation cover initially dominated by sphagnum and sedges, then progressively by shrubs. Forest fires affecting peat plateaus are known to increase the rate of formation and magnitude of thermokarst.

On hillslopes, the increased input of water from melting ground ice can alter the water quality of lakes and streams with implications for aquatic ecosystems (Kokelj and Jorgenson, 2013). This increased water input can also lead to mass movements (e.g., active layer detachments).

Figure 4.8 Example of a Peatland Impacted by Thermokarst (from Gibson et al., 2018)



4.6.2 Landslides

Landslides within the RSA are of a variety of forms and types. The landslide types listed below are documented in landslide inventory databases produced by Couture and Riopel (2008a, 2008b) and Aylsworth and Traynor (2001). These inventories took place in the Mackenzie Valley and adjacent areas; they include the mapped locations of numerous landslides with baseline characteristics tabulated in databases. The portion of the RSA covered by these landslide inventories includes the MVH alignment sections from Wrigley (KM 696) to KM 790 (Aylsworth and Traynor, 2001), and from KM 910 to Norman Wells (KM 1010).

The information below describes the various landslide types previously identified in the RSA and briefly characterizes the terrain as observed in the RSA. The authors of these studies describe relative landslide ages as recent, intermediate, and ancient. In general, with this type of study, the older the mapped landslide feature the less reliable the data. Many of the mapped landslides appear well vegetated or forested on the orthophoto imagery reviewed, making identification and classification by type more difficult. It is important to note that the RSA and LSA are susceptible to both permafrost and non-permafrost related landslides: active layer detachments and retrogressive thaw slumps are associated with permafrost however, debris flows or debris slides are not.

Active layer detachments (thaw flows, “Xf” in the LSA terrain mapping) are shallow landslides involving the detachment and downslope movement of the active layer sediment (peat, mixed fine, and coarse debris) and vegetation. They are initiated by the detachment of a thin veneer of vegetation and active layer materials and their subsequent movement occurs along an inclined surface matching the permafrost table (McRoberts and Morgenstern, 1974). They occur in soils characterized by moderate to high water content, with movement generally triggered by an event or condition that allowed for a progressive or sudden thickening of the active layer.

Active layer detachments are included in the mapping by Aylsworth et al. (2000b) along the right bank escarpments of the Mackenzie River, but also along the escarpments that define the channels of tributary streams and rivers. They are also mapped as occurring along gullied escarpments on some upland hillsides. When occurring on low-angled slopes above an escarpment, these landslides can be precursors to retrogressive thaw slumps (i.e., when ground ice is exposed in the headwall). Not all occurrences of active layer detachments are included in existing landslide databases; therefore, special attention was given to delineate landslides as part of the LSA terrain mapping.

Debris flows ("Rd" in the LSA terrain mapping) are very rapid to extremely rapid flows of saturated non-plastic sediment and debris in moderately-steep to steep gradient channels. Debris flows commonly travel down zero- and first-order incised channels (gullies) but can occur in second-order channels. However, the term, as used in the landslide inventory by Couture and Riopel (2008a, 2008b), may or may not infer containment within a channel. Debris flow deposits often take the form of lobate features on moderately-steeply sloping colluvial cones or gently-to-moderately sloping colluvial fans, but debris flows can also deposit in some confined, but wide, low-gradient stream channels (gullies) or rivers. There is typically limited or no particle-sorting within the deposition zone, but subsequent stream action may sort, transport, and re-deposit limited amounts of sediment and organic debris within and below the original deposition zone.

Debris flows that do not flow in channels are typically called debris avalanches, and they are defined as very rapid to extremely rapid, shallow flows of partially or fully saturated debris, usually on a moderate to steep sloping hillside, without confinement. Several such features, mapped as debris flows, occur along the steep escarpments of tributary streams and one or two occur along the right bank escarpments of the Mackenzie River. These would more appropriately be mapped as and termed debris avalanches.

Debris slides (or debris avalanche, "Rs" in the LSA terrain mapping) are shallow planar slides of deformed material (Huntley, 2008), likely involving siding of an intact, unfrozen mass on an underlying, frozen or unfrozen surface, without confinement. Where present within the RSA, these tend to be small features. Several features tabulated as debris slides in the landslide inventory by Couture and Riopel (2008a, 2008b) are located along the escarpments of the Mackenzie River and on the escarpments of tributary rivers (e.g., the Great Bear River) and tributary streams.

Retrogressive thaw flows (or rotational slump, "Ru" in the LSA terrain mapping) are landslides that occur in ice-rich terrain. These landslides have a somewhat circular or bowl-like shape, with a steep, near-vertical headscarp and a low-angle flow lobe. The landslide fails retrogressively with the headscarp retreating upslope as ground ice and/or ice within the soil thaws. The unfrozen, saturated surficial material flows downslope and typically has a high to very high water content (Aylsworth et al., 2000; Huntley, 2008). In the case of shallow translational lobate flow of surface earth materials, the thawed layer moves along a planar contact with the underlying permafrost or competent material. Retrogressive thaw flows are indicative of an ice-rich terrain. The features remain active as long as ice continues to be exposed, hence making potential mitigation difficult.

Retrogressive thaw flows are mapped along the escarpments of the Mackenzie River and the Great Bear River and along the escarpments and gully walls of incised tributary streams. There is also a small cluster of these features mapped on the level-to-gently sloping organic mantled-upland west of KM 910. In this

case, several appear to have become debris flows, which ran into a small, incised stream tributary to the Mackenzie River. Several retrogressive thaw flows are also mapped (Aylsworth and Traynor, 2001) along the Mackenzie River escarpment between Wrigley and Blackwater River.

Rockfall (”Rb” in the LSA terrain mapping) is the detachment of individual rock fragments from a steep rock slope and their gravitational downhill transport by falling, bouncing, and rolling. Evidence for ongoing or periodic rockfall includes the presence of colluvial accumulations (talus or scree) or individual fragments of rock below a steep rock slope.

There are a few areas of rockfall mapped along the escarpments of small, incised tributaries to the Mackenzie River in locations where those streams intersect and cut through low, rounded bedrock (shale) ridges. Rockfall is also mapped in upland locations were major joints or small faults cut though bedrock ridges: this occurs, for example, along the southeast side of Bear Rock and along the low limestone and dolostone ridge that trends north-northwest from Bear Rock. At some of these locations, there is also evidence of debris flow and, possibly, debris avalanche activity.

Figure 4.9 Examples of Landslides along the LSA

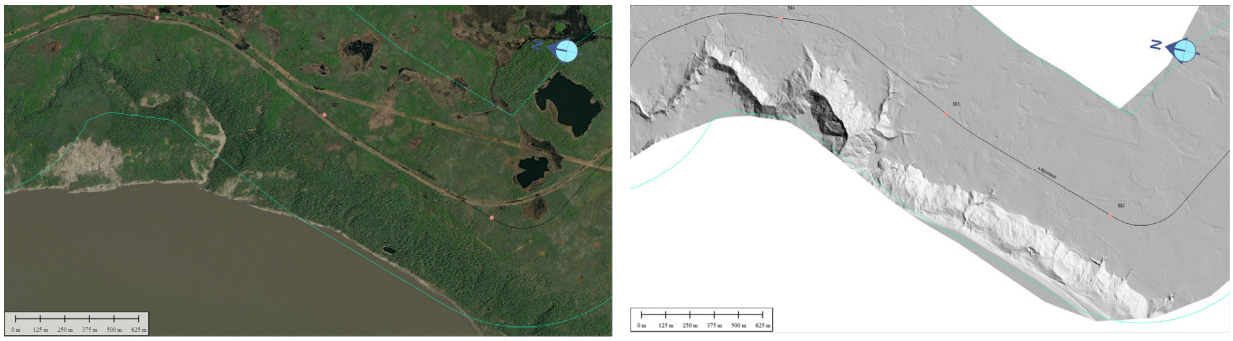
Retrogressive landslide along the Mackenzie River south of Tulita

Post-fire debris flow along Prohibition Creek, a few kilometers upstream from the MVH.

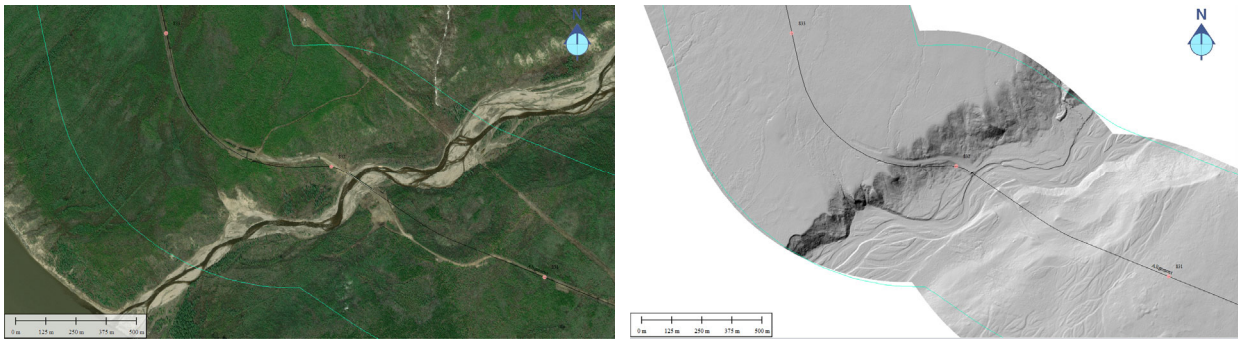
Rockfall along a bedrock ridge near Bear Rock

Rockslide along a colluvial apron (southeast of Bear Rock)

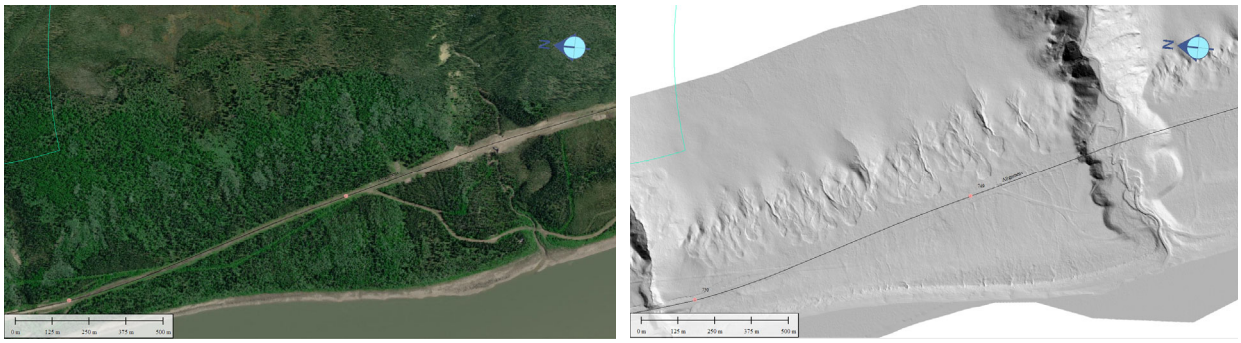
Figure 4.10 LiDAR Hillshade View of Some Areas Impacted by Landslides



Gullying and retrogressive landslides between MVH KM 882 and KM 885



Landslides along the north bank of the Saline River (MVH KM 832)



Landslides upslope from the MVH alignment near Vermillion Creek South (MVH KM 752 to KM 754)

4.6.3 Forest Fire

Large portions of the LSA and RSA have burned in the past. Dyke (2004), in his investigation of frozen and thawing slopes along the Norman Wells pipeline, indicated that forest fire had probably reached every point in forested areas of the Mackenzie Valley at least once in the last 200 years. The frequency of forest fires and the proportion of area burned were determined by decade (1960 to 2019) as part of the Vegetation and Wetlands TDR (K'alo-Stantec, 2020c). Along both the LSA and RSA, a higher frequency of forest fires was observed in the Dehcho Region (MVWR KM 690 to KM 796), where portions of the LSA has burned each decade between 1960 and 2019. Fires are not as common in Sahtu Region portion of the LSA (MVWR KM 796 to KM 1011) where a maximum of 2 fires per decade have been recorded (1990-1999).

The implications of forest fires on terrain and permafrost stability are considerable and the importance of forest fires as a driver of permafrost thaw has been researched by several authors (e.g., Jafarov et al., 2013; Zhang et al., 2015; Gibson et al., 2018). The presence of an often thick, organic soil cover is an important factor controlling soil temperature and permafrost stability, especially in the discontinuous permafrost region. Permafrost, at the same time, preserves the carbon in a frozen state and, as a result, protects it from decomposition. The primary effect of the forest fire is to reduce or eliminate the insulative quality of surface vegetation, causing great influences on the dynamic of the active layer and near-surface permafrost. The impact of forest fire on the thermal regime will generally depend on the thickness of organic soils remaining after the fire: the greater the residual organic layer, the better it may still protect the underlying permafrost from thaw.

Comparison of thermal conditions before and after forest fire at sites located along the Norman Wells Pipeline showed annual mean surface temperatures at burned sites that were generally 1 °C to 2 °C warmer than at the unburnt site (Smith et al., 2015; Smith and Bonaventure, 2016). Ground warming at burned sites was accompanied by an increase in active layer thickness. Although a decrease in ground temperature can occur following regrowth, recovering forest fire sites located in mineral soils generally host degrading permafrost.

Permafrost degradation and landslides are known to be initiated following forest fire in the Mackenzie Valley (e.g., Harry and MacInnes, 1988; Savigny et al., 1989; Burn, 1998; Dyke, 2004). In 1986, the occurrence of a forest fire about 250 km north of Norman Wells resulted in the development of extensive active layer detachments within one year from the forest fire event (Harry and MacInnes, 1988). The mass movements were predominant in silt-rich soils rich in ground ice. Small thaw slides were also observed to have evolved into retrogressive thaw flows (Dyke, 2004). Forest fires that occurred south of Norman Wells during the summers of 1994 and 1995 appear to have affected terrain stability along the Norman Wells Pipeline. These situations included observations of shallow active layer detachments on burned areas immediately adjacent to the pipeline right-of-way (Hanna et al., 1998). Investigations along the pipeline indicated that these landslides had mainly formed within weak colluvial deposits found along most valley walls and were generally absent from areas underlain by more competent clay till. Intentional clearing of vegetation for a fire line could have an impact on permafrost stability in the long run, potentially contributing to the initiation of landslides.

4.6.4 Other Potential Geohazards or Constraints

Karst landforms and associated groundwater systems refer to features created by bedrock dissolution. Karst forms in carbonate rocks such as limestone, dolomite or other highly soluble evaporite rocks such as gypsum and anhydrite; all are lithologies that are present in bedrock formations found in the Norman Wells region. The weathering and dissolution processes can result in distinctive features ranging from irregular topography, sinkholes and vertical shafts, dry valleys, and gorges, disappearing and reappearing streams, and caves.

The occurrence of karst in the central portion of the Mackenzie Valley is well documented (e.g., Ford, 1982, 1987, 2004; Hamilton, 1995; Hamilton and Ford, 2002; Ford, 2008), including karst landforms located within the LSA and RSA. Couture and Riopel (2008a) have identified a series of karst depressions approximately 5 km east of the MVWR KM 983 as part of the landslide inventory described above. This includes the 120 m x 60 m x 40 m deep “Bear Rock sinkhole” (see Figure 4.11) which is thought to be the largest simple cylindrical collapse landform known anywhere in Canada (Ford, 2008). The sinkhole is located approximately 325 m east from the Prohibition Creek quarry (reference number 7.083).

Figure 4.11 Bear Rock Sinkhole Near Prohibition Creek (4 km northeast from MVH KM 977)

Further south, just before the confluence of Great Bear River with Mackenzie River at Tulita, the prominent Bear Rock is reported as "*an outstanding example of glaciokarstic landform development that includes many sinkholes and larger closed depressions, some with permanent lakes that are drained underground at their overflow points, plus some striking pinnacle clusters, and a major group of perennial springs that display big ice build-up (icings) in winter*" (Ford, 2008). A portion of the RSA at the northern limit of Bear Rock near MVWR KM 961. No distinct karst features are visible within the RSA at that location. With the exception of Mount Gaudet, a few locations along the base of the western side of the Franklin Mountains, and Bear Rock, most of the MVWR is located in terrain where a thick cover of surficial materials is present. Karst features may be present in bedrock-controlled terrain found in the southern portion of the alignment; however, if present, these features are often too small to be visible on the imagery and LiDAR reviewed as part pf the assessment.

Gully erosion refers to the modification of surficial materials and bedrock by processes such as running water, mass movement (e.g., debris flows) and snow avalanching. These processes result in the formation of parallel and sub-parallel, long, V- and U-shaped channels (modified from Howes and Kenk, 1997).

Extensive areas of gully erosion (gullies) are present along many of the escarpments that bound the Mackenzie River and the escarpments along tributary rivers and streams that are incised into the uplands of the Mackenzie Plain. Many of the gullied areas will experience periodic landslide events over time. For example, there are debris avalanches on gully sidewalls and debris flows that travel down the gully channels and runout, depositing on the terrain (often fans) at the base of the gullies.

Gullies were delineated as part of the LSA terrain mapping. Their identification is based on distinctive morphology visible on the LiDAR hillshade data.

Inundation refers to terrain seasonally under standing water. The term is commonly applied to ephemeral lakes and ponds and to surficial materials (e.g., organic terrain) with seasonally high-water tables that result in local flooding for a continuous and significant time period (Howes and Kenk, 1997). Within the RSA, inundation will most likely occur in terrain dominated by organic deposits.

Areas interpreted as susceptible to inundation or seasonal flooding were identified as part of the LSA terrain mapping.

Surface seepage is the movement of surface water discharge, where evidence of substantial seasonal seepage is provided by physical and vegetative indicators (Howes and Kenk, 1997). The process is often associated with low soil-infiltration rates and high water-storage capacity. In northern regions, the process is influenced by the presence of permafrost. The existing surficial geology mapping does not document the presence of surface seepage; however, examination of the orthophoto imagery provided for this assessment suggests that extensive areas of surface seepage may occur where long, gently sloping toe slopes are located below the escarpments along the Mackenzie River (for example, between KM 723 and KM 754). Surface seepage, if present, may be a constraint on constructability .

Terrain polygons interpreted to be subject to seasonal seepage were part of the LSA terrain mapping.

Icings are sheet-like masses of layered ice that form during the winter by freezing of successive flows of water on the ground surface, or on top of river or lake ice (ACGR, 1988). The feature generally forms when water in a stream channel becomes pressurized because of ice buildup, then flows onto existing ice cover or the ground surface. This winter hydrological phenomenon is influenced by severe continental climate, cold winters with low snow cover, the presence of groundwater springs or unfrozen, water bearing layers (taliks), and highly permeable materials such as deposits of sand or gravel, organic matter, or karst terrain (Romanovskii et al., 1996).

Icings have been reported to negatively impact the performance of seasonal and all-season roads, with adverse effects on bridges and culverts; therefore, they are a transportation risk in the Arctic (Carey, 1973).

No spatial data is currently available on the occurrence and distribution of icings along the MVWR route, LSA, or RSA.

Frost heave is the upward/outward movement of the ground surface caused by the formation of ice in the soil. Frost susceptibility is a concept widely used in cold-region geotechnical design to quantify the capacity of a soil in generating frost heave. Soil texture does affect the degree of seasonal frost heave (and subsequent thaw) of local soils. Clayey silty-sand materials are generally classified as frost susceptible because they contain fine particles allowing for the formation of ice lenses when exposed to moisture and freezing temperature. Other soils containing organic layers and peat that are exposed to a high level of moisture may also undergo frost heaving when freezing occurs. In comparison, granular materials are generally classified as low to non-frost susceptible.

4.7 Climate Change Considerations

Warming in the North has triggered changes that are affecting both infrastructure and the livelihood of communities. Terrain hazards, especially permafrost degradation, are anticipated to be exacerbated by the effects of climate change. Available records show long-term trends in temperature increase and precipitation increase across most northern regions, and climate models suggest that warming over much of the North will continue at a rate that may increase. Similarly, it is anticipated that active-layer thicknesses will increase with climate warming. The Canadian Standards Association (CSA) provides guidance for screening the sensitivity of permafrost and the consequence of its degradation due to climate change (CSA, 2019). This risk-based approach requires site-specific information to be collected (e.g., ground material, ice content, and an estimate of the ground temperature), which is then used to determine the level of risk of the permafrost to a specific project. More specifically, the following three main factors are considered to assess permafrost sensitivity:

- likelihood of thaw settlement due to the active layer deepening
- potential for a reduction in bearing strength and creep resistance due to warming of the frozen ground
- potential for accentuated frost heaving

As stated previously, Tetra Tech (2020a, 2020b, 2020c, 2020d) completed geotechnical, geophysical and thermal assessments to support the design and engineering of the MGAR and PCAR, which are subsets of the MVH (i.e., it is expected that these two road sections will be upgraded to highway standard and integrated to the MVH alignment). Key findings of these assessments indicated that 1) local materials were predominantly silts and clays (i.e., clay-till near Norman Wells and glaciolacustrine silts and clays near Wrigley and Mount Gaudet), 2) permafrost was generally present but discontinuous (37 of 42 boreholes along the MGAR and 23 of 25 for the PCAR), and 3) where recorded, permafrost is warm with a mean annual ground temperature above -2°C. Accounting for these conditions, the permafrost sensitivity of the MGAR /PCAR was characterized as high (see Table 5.3 in CSA, 2019). However, the sensitivity of permafrost is expected to vary when evaluated along the remaining sections of the MVH alignment, especially in coarse-grained materials such as colluvial, glaciofluvial or alluvial deposits. The reduced presence of permafrost and ice-rich soils in these materials is expected to result in a medium-to-low permafrost sensitivity.

Considering ground conditions encountered as part of recent geotechnical investigations along the MGAR and PCAR sections, it is expected that climate warming will increase ground temperatures and cause a deepening of the active layer. Thawing permafrost may also generate changes in soil moisture, resulting in ground subsidence where ice-rich soils are located.

Permafrost degradation is expected to result in a loss of soil strength over time (e.g., as the heat is absorbed by the road surface and ground temperature rises), This may then result in ground surface deformation on flat terrain (i.e., as ground ice melts and the soil consolidates), to progressive deformation (creep), and the occurrence of landslides on sloping ground.

Climate change also has the potential to accentuate frost heave where the deepening of the active layer and greater availability of groundwater may lead to greater frost heave potential (CSA, 2019). During the winter months, the moisture in the ground freezes and expends. In the spring, the active layer melts and the subgrade condition may provide limited support. The repeated freeze-thaw cycles may destabilize frost-susceptible soils, causing heaving and deformation of the roadway surface.

4.7.1 Forest Fires

A predicted increase in forest fires frequency and severity with climate change will most likely accelerate the degradation of permafrost in burned areas. Empirical models of forest fires frequency and severity in Alaska and Canada suggest that the average area burned per decade will double by 2041–2050 and will increase on the order of 3.5 to 5.5 times by 2100 (Balshi et al., 2009). Soil types and near-surface ice content are expected to influence the distribution of landslides in permafrost terrain, where the sudden thickening of the active layer can cause the melting of excess ice, triggering the downslope movement of water-saturated soils.

The destabilization of slopes showing previous signs of landslides, particularly through the occurrence of active layer detachments, could occur following forest fires. This includes sections of the escarpment marking the edge of the main fluvial terrace on the southern portion of the route (MVWR KM 725 to KM 788). In this area, dozens of shallow landslides (mainly thaw flow and debris flows) are located within a few hundred metres from the MVWR, hidden under a well grown forest cover.

5 LSA Terrain Mapping

The following sections provide a summary and description of findings from terrain mapping. The goal of terrain mapping was to compile a map-based inventory of terrain conditions in the LSA. Of interest is the recorded occurrence of terrain constraints and geomorphological processes and other landscape hazards that are important to consider in the design and operations of the Project.

5.1 Surficial Material Distribution

The following section describes the spatial and, to some extent, the topographical distribution of the surficial materials, by dominance, in the RSA and LSA (see Table 5.1, Table 5.2 and Table 5.3). The spatial distribution of surficial materials using the MVWR route as the basis for the study areas. When interpreting spatial extent and tabulated statistical summaries of percent cover, it is important to acknowledge that these statistics and descriptions are based on two separate scales of mapping (greater than 1:100,000 for the RSA and 1:10,000 for the LSA); also, the LSA terrain mapping has not been ground-truthed by K'alo-Stantec.

Table 5.1 Distribution of Surficial Materials Within the RSA

Dominant Surficial Geology	Area (ha)	Percent of Area (%)
Glaciolacustrine (GL)	117,165	38.3
Till (T)	57,948	18.9
Alluvial (A)	41,739	13.6
Colluvium (C)	25,468	8.3
Glaciofluvial (FG)	16,174	5.3
Organic (Ob) - bog	4,072	1.3
Organic (Of) - fen	1,748	0.6
Bedrock (R)	7,461	2.4
Eolian (E)	497	0.2
Waterbody (W)	33,936	11.1
Total	**306,208**	**100**

Table 5.2 Distribution of Dominant Surficial Materials Within the LSA

Dominant Surficial Geology	Area (ha)	Percent of Area (%)
Morainal Material (M)	7,406	23.3
Glaciolacustrine Material (LG)	6,535	20.6
Organic Material (O)	4,855	15.3
Glaciofluvial Material (FG)	4,469	14.1
Colluvium (C)	3,485	11.0
Eolian (E)	1,952	6.1
Fluvial Materia (F)	1,559	4.9
Bedrock (R)	177	0.6
Anthropogenic Material (A)	58	0.2
Not Classified (N)	1,068	3.4
Total	**31,752**	**100**

Table 5.3 Distribution of Dominant Surficial Materials Along the MVH

Dominant Surficial Geology	Length (km)	Percent Length (%)
Glaciolacustrine Material (LG)	79.1	25.8
Morainal Material (M)	65.1	21.3
Glaciofluvial Material (FG)	59.6	19.5
Organic Material (O)	39.0	12.7
Eolian (E)	23.3	7.6
Fluvial Materia (F)	19.6	6.4
Colluvium (C)	17.8	5.8
Anthropogenic Material (A)	2.1	0.7
Not Classified (N)	0.6	0.2
Grand Total	**306.2**	**100.0**

The surficial geology mapping used to characterize the RSA includes regional work initiated in the 1970s and often presented at a scale of 1:100,000 or smaller. The interpretation would have been carried out using an optical stereoscope and stereo air photos, without the aid of LiDAR data. It is likely that on these regional maps, smaller deposits of some surficial materials would be under-represented; for example, small bogs and fens, bedrock outcrops, and eolian deposits of limited extent would not have been mapped. Similarly, many of the surficial material map units include more than one surficial material type; but in this summary, only the dominant surficial material in each map unit is considered. Two small areas of the RSA recently mapped at scales of 1:20,000 and 1:30,000 near the north and south ends of the RSA (i.e., MGAR and PCAR) have been inserted to replace the original regional mapping in those areas.

Detailed mapping conducted for the LSA allowed for more precise characterization of terrain conditions. Glaciolacustrine materials are dominant in the LSA, followed by till, alluvial, colluvial and glaciofluvial materials. Organic deposits (fens, bogs) and bedrock exposures are all mapped as minor components of the landscape. Eolian deposits are rare.

Available borehole data shows the depth to bedrock to vary greatly; however, it does suggest that most of the MVH alignment is covered by thick mantle of unconsolidated materials (generally over 5 m). Bedrock is absent in a significant portion of the boreholes compiled as part of historical database (e.g., Smith et al., 2005). Shallow (less than 2 m from ground surface) or exposed bedrock is present locally, but overall, is expected to be present along only limited sections of the MVH.

Glaciolacustrine materials are present as extensive deposits covering flat-to-gently undulating terrain throughout the LSA. Geotechnical investigation along the MGAR (Tetra Tech, 2020a, 2020b) confirmed the presence of lacustrine (glaciolacustrine) silty clay along the section of road between MVWR KM 692.5 to KM 707.3. The material extends farther north, that is part of the Mackenzie Plain.

Except for a few locations, till is absent in the southern portion of the LSA up to about the MVWR KM 800. It is present in the upland areas farther east into the RSA and occasionally interspersed with glaciolacustrine materials (exposed till likely occupies slightly higher elevations and is otherwise buried at depth under glaciolacustrine materials). Till is generally present on the uplands along the MVWR route until MVWR KM 867 with a break near Big Smith Creek. Till is generally present within the LSA from MVWR KM 952 and on the uplands east of the MVWR to near the base of the Discovery Ridge of the Norman Wells Range. In some areas, the till is overlain by glaciolacustrine materials. Geotechnical investigation along the PCAR (Tetra Tech, 2020c, 2020d) confirmed the presence of clay till with layers or pockets of sand, silt, and gravel along the section of road between MVWR KM 997 to KM 1,009. Permafrost was encountered in most boreholes, with ice content generally ranging from no visible ice to about 20% visible ice.

Alluvial materials are dominant along the sides of the Mackenzie River where the river is not confined by steep riverside escarpments. Alluvial materials are also mapped along the lower reaches of the tributary rivers and larger streams along the east side of the Mackenzie River, including large fans where some tributaries join the Mackenzie River. Along some incised tributary rivers and streams, the alluvial map units include portions of the steep colluvial escarpments that bound the river and stream channels. In some areas along the Mackenzie River, wide alluvial terraces are mapped along the river above steep, right bank escarpments.

Colluvial materials are common along the steep, often gullied escarpments that bound the Mackenzie River and along the gorge and gully walls that bound tributary rivers and streams that flow into the Mackenzie River. Colluvial materials also occur along steeper uplands slopes (hills and ridges and gullies on these features) to the east of the Mackenzie River, often in association with overlying bedrock slopes. Fine-grained colluvial materials derived from glaciolacustrine deposits are common on low-lying to moderately steep slopes.

Glaciofluvial materials occur as occasional large terraces along the Mackenzie River and at the confluences with some larger tributaries formed in part as deltas building into Glacial Lake Mackenzie (e.g., the Great Bear River). Geotechnical investigation along the MGAR (Tetra Tech, 2020c, 2020d) confirmed glaciofluvial sands and gravels reaching over 10 m in thickness between Wrigley and MVWR KM 692.5.

Organic veneers (less than 1 m thick) and blankets (greater than 1 m thick) are present throughout the low-lying landscape that marks the Mackenzie Valley. In the southern part of the LSA, wetlands have mostly formed on top of level or very gently sloping glaciolacustrine surfaces and farther north on both glaciolacustrine and till surfaces. Areas mapped as organic range from well-defined wetlands marked by distinct low-lying vegetation, and also more densely forested terrain where available field data indicates the presence of a significant accumulation of organic material (greater than 30 cm).

Eolian materials are restricted in extent, occurring primarily as low elongated ridges found above the glaciolacustrine plain extending from Big Smith Creek (MVWR KM 873) to the Great Bear River area (MVWR KM 950).

5.2 Terrain Constraints and Geomorphological Processes

As part of the LSA terrain mapping, special attention was given to the identification of potential terrain constraints or terrain hazards found close to the MVWR route. For the MVH Project, terrain constraints are interpreted as naturally occurring features having the potential to negatively affect the design, construction, and maintenance of the road infrastructure. Examples of this are steep slopes, poor drainage conditions, occurrence of thick organic soils, and ice-rich permafrost. Terrain hazards consist primarily of features or geomorphological processes having the potential to lead to localized or widespread damage to property and pose a threat to personal safety. Examples of this are landslides, gully erosion, and thermokarst.

Tabulated statistics performed on LSA terrain polygons intersected by the MVWR route indicated that surface seepage is the dominant geomorphological process occurring along the route (Table 5.4). The identification of areas where seepage is believed to be present is based on a combination of distinctive topography (e.g., gullies and rills) and vegetation communities. Seepage was mapped in areas of non-channelized flow where excess water is expected to concentrate. Seepage was also mapped in areas containing thick organic soils and in areas characterized by fine-grained till and glaciolacustrine silt and clay. The occurrence of a shallow permafrost table (i.e., upper limit of the permafrost) in several of these areas is likely, resulting in surface flow and shallow sub-surface seepage.

Table 5.4 Key Constraints and Geomorphological Processes Along the MVH

	Length (km)	Percent Length (%)
Seepage	43.5	14.2
Gullying	12.9	4.2
Landslides	4.5	4.5
Thermokarst	3.8	1.2

The overall location of the MVH along the east bank of the Mackenzie River means that its alignment will cross numerous tributaries rivers, drainage channels and gully systems routing surface water towards the river. Deep gullies have developed in a variety of materials; however, the most active and potentially unstable ones are likely to have developed along the east bank escarpments in glaciolacustrine materials and fine-grained till. Well-developed “V”-shaped gullies (e.g., MVWR KM 787 and KM 814) appear to grow by basal incision, headward erosion as well as by small landslides along the gully sidewalls. “U”-shaped gully cross-sections are often indicative of debris flow travel down the gullies. Landslides initiating in or entering these gullies may pose a hazard to roadway infrastructure constructed across, or downstream of, gully channels.

5.2.1 Landslide Hazard Summary

The largest and apparently most active landslides observed from the LiDAR and satellite imagery are a series of retrogressive thaw flows located along the Mackenzie River (MVWR KM 854 to KM 855, KM 874 to KM 878, KM 886 to KM 889). Most of these landslides occupy the western limit of LSA, downslope from the MVH alignment (i.e., 300 m west of the MVWR route). Although no recent landslides were observed to intersect the MVWR, the retrogression of some of these landslides remains a possibility in the future.

At large river crossings, the terrain mapping suggests that landslides are more prevalent on south-facing slopes than on north-facing slopes. The increase in landslide activity is sometimes identified by distinct topography and vegetation. As with the northern portion of the MVH Project Area, the southern section of the alignment intersects a moderate number of incised river and stream gorges. Landslides occur periodically along the steep, sometimes discontinuous escarpments that border these streams. There are also several locations along the southern portion of the alignment where the MVWR route runs along the base of an escarpment marked by old landslides. There was no clear evidence of recent forest fires resulting in permafrost degradation or landslide initiation in the imagery used for the LSA terrain.

A summary of the main locations where landslides were observed is presented in Table 5.5. Additional landslides are also present, as indicated in the LSA terrain mapping.

Table 5.5 Main Landslide Occurrence Along the MVWR

MVWR KM	Description
694	Shoreline erosion and landslides at Hodgson Creek
724	Shoreline erosion and landslides at Ochre Creek
725 to 748	Old landslides along terrace escarpment from Ochre River to Strawberry Creek
751	Old and recent landslides along terrace escarpment surrounding Vermillion Creek South
754	Recent erosion and landslides along escarpment north of Bob's Canyon Creek
765	Old and recent landslides along terrace escarpment near Dam Creek
788	Old and recent landslides along terrace escarpment north of Blackwater River
816	Old retrogressive landslide along terrace escarpment
833	Landslides along south facing slope at Saline River
845	Landslides along south facing slope at unnamed tributary
853	Landslides at Little Smith Creek
874	Retrogressive landslides along Big Smith Creek (right bank)
876-877, 883-887	Retrogressive landslides along Mackenzie River

Note:
Landslides described as “old” appear completely re-vegetated on available imagery. No indicators of recent movement were observed; however, could still be slow-moving or dormant. Other landslides were observed to be devoid of vegetation, partly re-vegetated or re-vegetated with pioneer species only or were displaying morphology indicative of recent movements. Depending on subsurface conditions old “stable” retrogressive thaw slumps may reactivate in the future (landslide should not be assumed to be stable forever, regardless of their vegetated status).

5.2.2 Permafrost Distribution

Landscape features can be indicative of the presence (or absence) of permafrost. Patterned ground and other periglacial landscape features are also indicative of the presence of permafrost. Ice wedge polygons are expected to be rare along the MVH. Only two general locations displaying the distinctive polygonal pattern were identified from the LiDAR data (i.e., MVWR KM 800 and KM 812). Ice wedges could be present locally even if not readily visible; however, their overall limited occurrence is not expected to cause major permafrost stability concerns. Other features indicative of permafrost include peat plateaus and palsas (i.e., peat mounds with permanently frozen peat and mineral soil cores), formed by the expansion of freezing peat as segregated ice lenses form to create an ice-rich permafrost. These features are generally elevated in comparison to the surrounding low-lying and poorly-drained ground. Although no distinct palsas were identified as part of the LSA terrain mapping, extensive areas of black spruce bogs where identified (including areas of peat plateaus). Several of these bogs show the distinctive morphology (e.g., pits and irregular depressions), drainage conditions (e.g., localized flooding and pooling of water), and vegetation characteristics (e.g., “drunk forest” and other areas of impacted vegetation) often associated with thermokarst.

The use of geomorphic site characteristics to assess the presence or absence of permafrost is helpful; however, site characteristics provide only limited evidence to characterize or map permafrost distribution within the LSA. Geotechnical investigations (including geophysical and thermal evaluations) like those carried out along the MGAR and PCAR sections of the MVH Project, conducted in conjunction with desktop terrain analysis, are the most appropriate method to obtain precise, site-specific information on permafrost.

6 Borrow Sources and Access Roads

An extensive number of desktop evaluations, field reconnaissance and geotechnical field investigations have been completed in relation to the availability of borrow sources along the Mackenzie Valley over the last 50 years. In the early 1970s, the Department of Indian and Northern Development (DIAND); now Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC)) first attempted to establish a comprehensive inventory of granular resources present within the Mackenzie Valley. These efforts were in anticipation of an increase in demands due to hydrocarbon exploration activity in the Mackenzie Delta, completion of the Mackenzie Highway, and competing proposals for large diameter gas transmission facilities.

During the 1980s and 1990s, additional investigations of potential borrow sources were conducted, which included a compilation of over 50 granular resource studies conducted in the Lower Mackenzie Valley by Hardy Associates (1986), as well as a similar compilation produced for the Upper Mackenzie Valley by EBA (1988). In the early 2000s and 2010s, lists of potential borrow sources were presented as part of environmental assessment studies and PDRs developed in support of the proposed routes developed for oil and gas pipelines (e.g., Mackenzie Gas Project) and for the MVH Project.

Using existing data listed above, K'alo-Stantec, supported by Tetra Tech, conducted a desktop and reconnaissance field evaluation of prospect granular and quarry sites between Wrigley and Norman Wells, NT (K'alo-Stantec, 2020e). Selection criteria used for initial borrow source screening focused predominantly on technical considerations (e.g., material quality and quantity, relative proximity to the Project, absence of major terrain-related constraints) although it also considered environmental, archeological/cultural and land use and land ownership factors.

Following the background data review and a field reconnaissance visit, a list of prospective borrow sources was identified (K'alo-Stantec, 2021). As part of the assessment, the sources were subdivided into "primary" versus "secondary", where the primary sources were considered as having the greatest potential for future development and should be prioritized during the field reconnaissance and follow-up geotechnical investigations. The secondary sources could be considered later if the primary sources are discarded based on technical, economic, social and/or environmental considerations.

The list of prospective borrow sources was refined over time, resulting in a shortlist of 15 primary sources to be part of the Project and assessed (7 borrow sources and 8 quarries, see Table 6.1). Nine (9) of the 15 Primary sources were identified for permanent use (including highway construction and long-term operations) and 6 were identified for temporary use (i.e., highway construction only). Another 10 alternate sources were identified in case additional sources were required (see Table 6.2).

Table 6.1 MVH Primary Borrow Sources and Quarries

Source ID[1]	Source Type	Planned Usage	MVWR KM	Access Road Length (km)	Borrow Pit/Quarry Description	Overburden Type and Thickness (m):	Development Considerations
10.043	Borrow Pit	Temporary	683		• Existing borrow source located approximately 6 km southeast of Wrigley, adjacent to the west side of Highway 1. • Deposit consists of a large glaciofluvial terrace (approximately 2.5 km in length and 0.75 km in width) and is adjacent and parallel to the east bank of the Mackenzie River.	• Coarse-grained material observed at ground surface throughout the site. • Organic silty topsoil layer in undisturbed terrain supporting dense growth of spruce with occasional clusters of birch poplar and pine. • Good overall drainage conditions with exception of localized areas of poorly drained soils.	• Existing borrow source • Existing access (HWY 1) • Wetland present south of existing borrow site (<1 m of organic expected). Respect of 300 m buffer around airport VOR Station (Crown Lands) and 65 m buffer for MVWR.
10.028	Quarry	Permanent	709		• Bedrock ridge (N-NE/S-SW orientation) associated with medium to thick bedded grey limestones of the Nahanni Formation and with dolomite and limestone of the Bear Rock Formation. • An existing pit is located approximately 3 km north from the current prospect area (MVWR KM 710).	• Thick colluvial and till along the base of the ridge, with discontinuous veneer of weathered bedrock and/or till on the ridge. • Good overall drainage conditions.	• Potential limitation associated to steep slopes. Reported thermal springs and rare plant in the area (9). Respect of 65 m buffer for MVWR.
10.020	Borrow Pit	Temporary	725	0.1	• Flat to gently undulating glaciofluvial terrace alongside the north bank of the Ochre River at its confluence with the Mackenzie River. • Large laydown clearing area served as a borrow source in the past.	• Thin layer of peat or organic topsoil and silt generally less than 0.5 m in thickness • Overall good drainage with localized fair drainage in low-lying areas. Poor drainage in the wetlands to the north.	• Deposit intersected by MVWR, development buffer needs to be respected. Respect 100 m buffer with watercourse and 65 m buffer with MVWR. Cleared area used as pullout for people travelling on the MVWR.
10.014A	Borrow Pit	Permanent	733	0.2	• Flat to gently undulating glaciofluvial terrace alongside north bank of Whitesand Creek at its confluence with the Mackenzie River.	• Shallow organic topsoil development (< 0.3 m). Potential for organic veneers in low-lying terrain north of the site. • Good drainage toward Whitesand Creek and Mackenzie River. • Fair to poor drainage to the west and north of the site.	• Respect 100 m buffer with watercourse and 65 m buffer with MVWR. • Potential for seasonal groundwater seepage along northwestern corner of prospect area.
10.007	Borrow Pit	Permanent	751		• Flat to gently undulating fluvial terrace alongside the east bank of the Mackenzie River, north from the confluence of Vermillion Creek South. The terrace is approximately 0.4 km wide and 2.5 km in length, with a flat to gently inclined surface sloping towards the Mackenzie River. • Some organic materials have accumulated over the terrace in some areas; for example, near the central portion of the terrace.	• Organic topsoil, peat and/or silt ranging in thickness from 0.3 m to a maximum of approximately 2 m. • Permafrost observed during site reconnaissance (active layer between 0.8 m and 1.85 m)	• The portion of the terrace located south from Vermillion Creek is not recommended for development due to environmental (watercourse) and infrastructure buffers. • Respect 100 m buffer with watercourse and respect 65 m buffer with MVWR
10.004	Borrow Pit	Temporary	770	0.2	• Located approximately 16 km south of the Blackwater River bridge. The site consists of a glaciofluvial terrace (approximately 1.0 km in length and 0.5 km in width) and is adjacent and parallel to the east bank of the Mackenzie River.	• Shallow organic topsoil layer (0 to 0.3 m deep) that supports dense growth of spruce and birch. An area with up to 1.4 m of silt was also observed overlying the gravel deposit (4). • Good overall drainage conditions, except for the wetlands observed to the north and east of the prime prospect area. • Small drainage channels observed both north and south of the target deposits	• Direct access from MVWR • Respect 100 m buffer with watercourse and 64 m buffer with MVWR

Source ID[1]	Source Type	Planned Usage	MVWR KM	Access Road Length (km)	Borrow Pit/Quarry Description	Overburden Type and Thickness (m):	Development Considerations
9.043	Borrow Pit	Permanent	783	0.1	• Glaciofluvial terrace located just south of the Blackwater River and Mackenzie River confluence. • Two distinct gravel pits observed at the site. Historical borrow source east of MVWR is generally open with scattered bushes and few young trees.	• Exposed material consisted of sand and gravel with variable cobble content. Existing pits were estimated to be 8 m to 10 m deep • Good drainage conditions. • Organic topsoil general under 0.3 m thick, which supports moderate to dense growths of spruce, birch, and poplar	• Existing access by the MVWR • Respect 100 m buffer with watercourse and 65 m buffer with MVWR
9.025B	Quarry	Temporary	813	2.4	• Located approximately 10 km southeast of the Steep Creek bridge. The site encompasses a bedrock ridge approximately 3.0 km in length and 0.5 km in width.	• Bedrock ridge is mostly exposed and includes only minor shallow glacial drift cover. A veneer of glacial drift and slope wash overlying undulating bedrock covers the area west of the ridge	• New access required • Area toward MVWR is heavily treed. Includes some low-lying wetland terrain
9.019	Quarry	Permanent	822	1.7	• Located approximately 5 km north of the Steep Creek bridge. The site encompasses a bedrock ridge (approximately 1.5 km in length and 0.7 km in width) that consists of Ordovician and Silurian dolomite with minor shale inclusion. • Steep slope on western ridge. Gently sloping to the east. • Dense tree coverage. Moderately dense surrounding bedrock exposure areas. Mostly mature spruce, pine, some areas with younger forest with birch.	• Shallow glacial drift cover and slope wash material with few exposures of weathered dolomite. • Drainage channels or creek to the north and south	• Seepage
9.002	Borrow Pit	Permanent	851	0.9	• Site consists of a large glaciofluvial terrace (approximately 2.4 km in length and 0.7 km in width) southeast of the Little Smith Creek, 2 km upstream from the east bank of the Mackenzie River. • Existing granular borrow source on site; 1 m to 2 m depth of excavation with material stockpiles.	• A thin topsoil layer (approximately 0.2 m thick) overlay the sand and gravel deposit and supports dense growths of spruce and birch.	• Potentially unstable moderate sloping colluvium ravine located on the northern end of the deposit. • Respect of 65 m buffer with MVWR and 300 m buffer with the Norman Wells to Zama Lake Pipeline.
8.039	Quarry	Permanent	867	1.3	• Bedrock hills comprised of dolomite of the Franklin Mountain Formation. Mix of exposed bedrock and undulating till veneer overlying shallow bedrock	• Variable. Some exposed bedrock. Thin layer of topsoil and discontinuous veneer of till and/or weathered bedrock. Blanket of till in topographic depressions. • Good drainage on the bedrock hill. Apparent fair to poor drainage along the lower access to the MVWR.	• New access required
7.109	Quarry	Permanent	962	0.5	• Exposed bedrock approximately 16 km northwest from Tulita. Bedrock surface is undulating with outcrop extending up to 500 m west at the northern portion of the prospect.	• Variable. Topsoil and discontinuous veneer of till and/or weathered bedrock. Blanket of till in topographic depressions. Some colluvial in areas characterized by steep bedrock escarpments.	• New access required. • Norman Wells to Zama Lake Pipeline crossing. • Respect of 100 m buffer with waterbody and 300 m buffer with the Norman Wells to Zama Lake Pipeline.
7.090	Quarry	Temporary	975	0.5	• Northwest/southeast oriented bedrock ridge. The ridge is approximately 3.5 km in length and 0.4 km in width. The southwest facing slope is covered with till (Mv to Mb), while the northwest-facing slope consists of a bedrock escarpment and colluvial deposit. Competent bedrock confirmed at shallow depth.	• Topsoil and clay till overlying bedrock. The thickness of the overburden decreases at the upper limit of the ridge (approximately 2 m thick within the middle section of the ridge, near the crest of the slope).	• Norman Wells to Zama Lake Pipeline crossing. • Respect of 100 m buffer with watercourse and waterbody and 300 m buffer with the Norman Wells to Zama Lake Pipeline
7.083 (Prohibition Creek Quarry)	Quarry	Permanent	990	6.6	• Area consists of an NW-SE oriented bedrock ridge overlain by till. Bedrock exposures of blocky and fractured limestone are noted in the area. • Existing bedrock quarry.	• Vegetation is cleared up to northeast extent of prospect	
Edie Lake Quarry	Quarry	Temporary	1013	2.2	• Active bedrock quarry. Area consists of an NW-SE oriented bedrock ridge.	• Topsoil and organic silt (generally under 0.6 m in thickness) overlying till veneer.	• Respect 100 m buffer with watercourse and waterbody.

Table 6.2 MVH Alternate Borrow Sources and Quarries

Source ID[1]	MVWR KM Access	Distance from Alignment (km)	Ownership	Material Type
10.041	683	Intersected by MVWR route	Crown/Territorial	Granular
10.037	709	0.1 km W	Territorial	Quarry
10.001	725	50 m E	Territorial	Granular
9.044B	733	0.1 km E	Territorial	Granular
9.037	751	50 m E	Territorial	Granular
9.010	770	50 m W	Territorial	Granular
9.002A	783	Intersected by MVWR route	Territorial	Granular
7.155A	813	2.6 km E	Private (Sahtu)	Quarry
Dhu1	822	1.6 km E	Territorial	Quarry
Dhu2	851	Intersected by MVWR route	Private (Sahtu)	Granular

7 Closure

This TDR was prepared for the sole benefit of GNWT to describe existing conditions related to soils, terrain and permafrost within the soils LSA and soils RSA. If you have any questions, please do not hesitate to contact the undersigned.

Respectfully submitted,

K'alo-Stantec Limited

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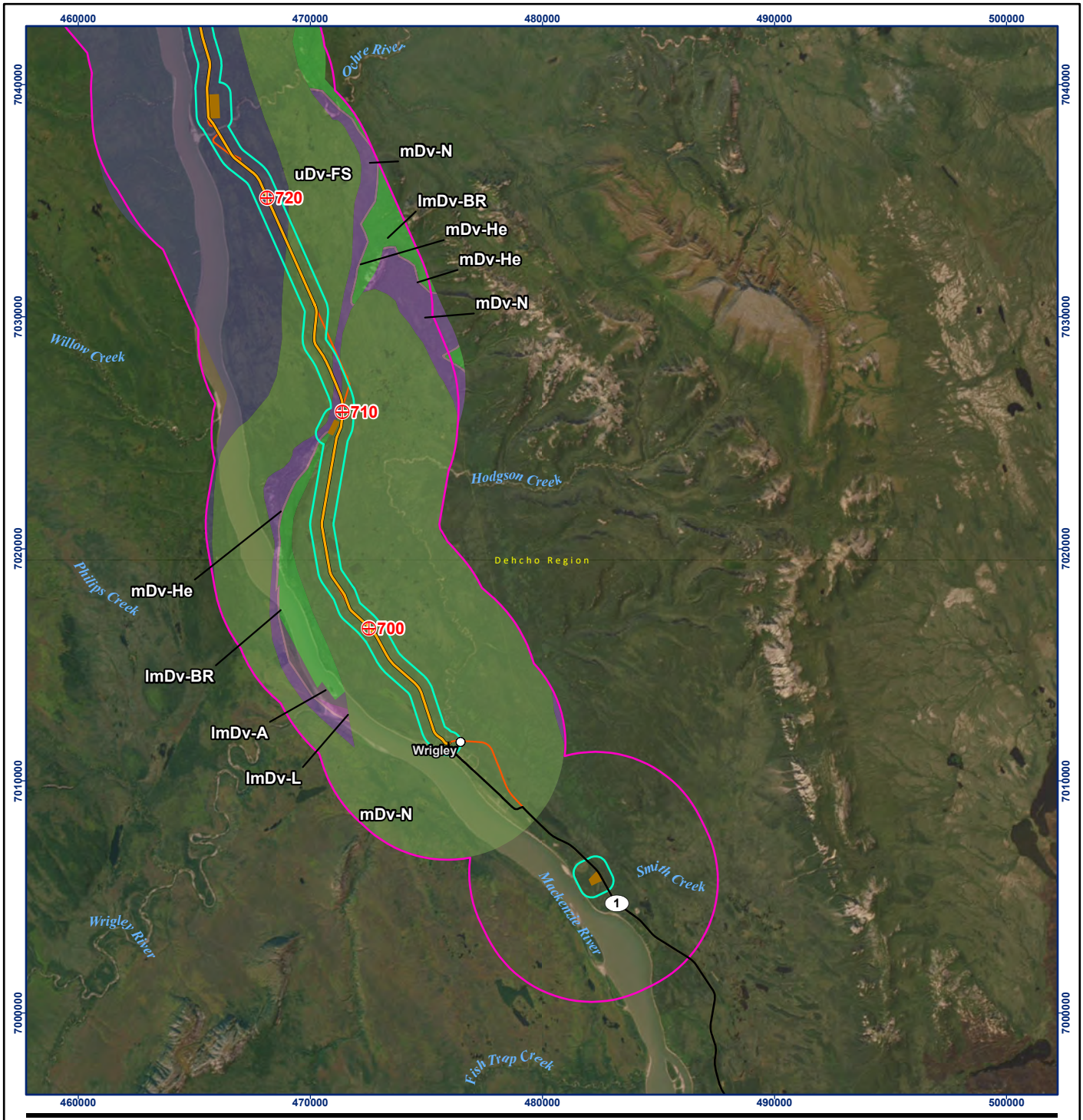
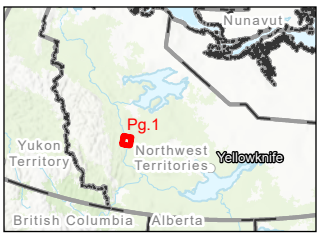
Appendix A RSA Figures

Bedrock Geology	Figures A.1 to A.7
Surficial Geology	Figures A.8 to A.23
Soils	Figures A.24 and A.25





Notes

1. Coordinate System: NAD 1983 UTM Zone 10N

2. Data Sources: Government of Canada. Bedrock Geology source: Okulitch, A. V. and Irwin, D., 2016. Geological Compilation of the Western Mainland and Arctic Islands of the Northwest Territories; Northwest Territories Geological Survey, NWT Open File 2016-09
Esri, FAO, NOAA, USGS, NRCan, Earthstar Geographics, Esri, USGS

Bedrock Geology

- lmDv-A,dolostone, fine-crystalline, thick bedded, grey, finely porous, vuggy and brecciated in part; limestone
- lmDv-BR,dolostone; dolostone solution-breccia; anhydrite; gypsum; locally may include unit SIDv-T at base; marine
- lmDv-L,limestone, dark grey, thick-bedded, cryptogranular
- mDv-He,shale, grey; limestone, argillaceous, silty, thin to medium-bedded, nodular, bioclastic; minor dolostone; limestone, fine to crypto-crystalline, thin-bedded
- mDv-N,limestone, fine to coarse-grained, dark grey, medium to thick-bedded, bioclastic
- uDv-FS,shale, green and grey; siltstone; limestone; may include HORN RIVER fm or HARE INDIAN fm at base
- uDv-s,sandstone, greenish-grey, fine-grained, calcareous; mudstone, silty; shale, grey and greenish-grey; minor limestone
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- Prohibition Creek Access Road
- Proposed Great Bear River Bridge Project
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/9/2023
TR by AJ on 3/9/2023

Client/Project
144903025-0003 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.1

Title
RSA Bedrock Geology

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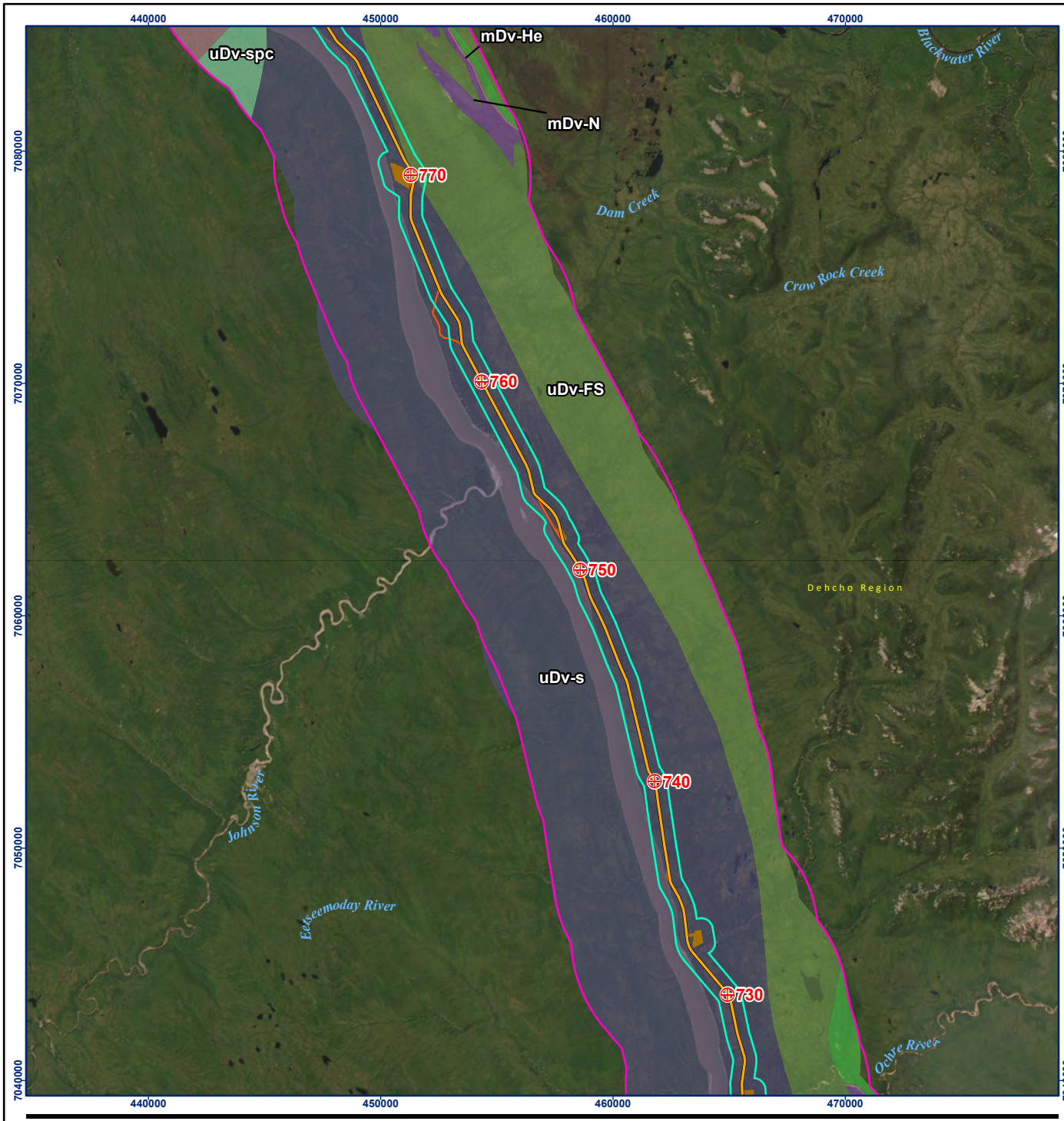

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Esri, FAO, NOAA, USGS, NRCan, Earthstar Geographics, Esri, USGS

Bedrock Geology

- lmDv-BR,dolostone; dolostone solution-breccia; anhydrite; gypsum; locally may include unit SIDv-T at base; marine
- mDv-He,shale, grey; limestone, argillaceous, silty, thin to medium-bedded, nodular, bioclastic; minor dolostone; limestone, fine to crypto-crystalline, thin-bedded
- mDv-N,limestone, fine to coarse-grained, dark grey, medium to thick-bedded, bioclastic
- uCt-SR,BASAL: sandstone. UPPER: siltstone; shale, black and grey; bentonite interbeds; minor siltstone; sandstone, fine-grained
- uDv-FS,shale, green and grey; siltstone; limestone; may include HORN RIVER fm or HARE INDIAN fm at base
- uDv-s,sandstone, greenish-grey, fine-grained, calcareous; mudstone, silty; shale, grey and greenish-grey; minor limestone
- uDv-spc,shale, green, grey and red; siltstone and sandstone, fine-grained, greenish-grey; limestone, fossiliferous

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- Winter Road
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- Region Boundary
- Settlement Area Boundary

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Figure No.
A.2

Title
RSA Bedrock Geology

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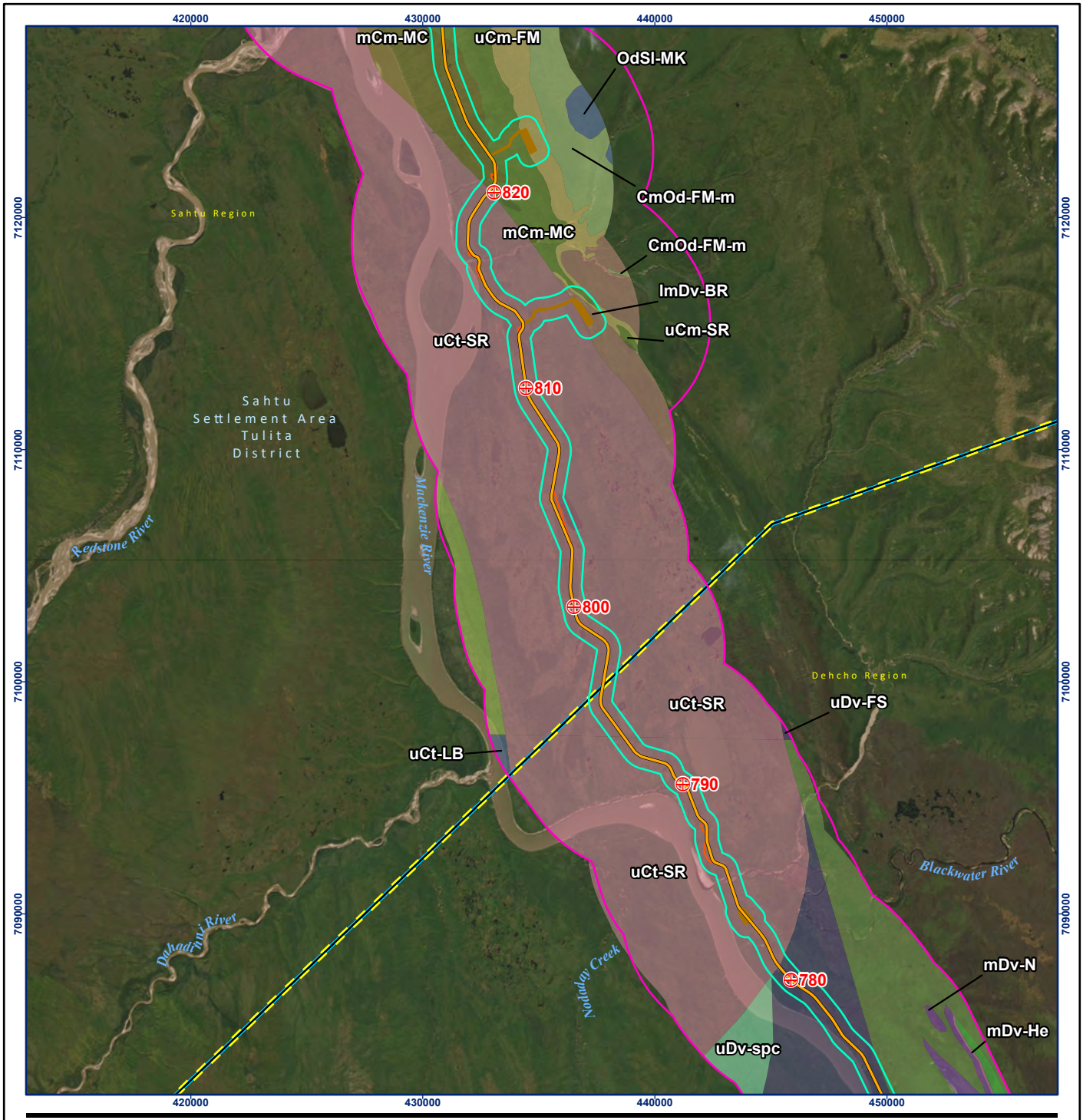

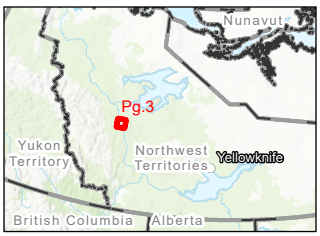

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Esri, FAO, NOAA, USGS, NRCan, Earthstar Geographics, Esri, USGS

Bedrock Geology

- CmOd-FM-m,dolostone, silty, very fine-crystalline alternating with dolostone, fine- to medium-crystalline, oolitic; locally quartzose; minor conglomerate, flat-pebble
- OdSl-MK,BASAL member: dolostone, argillaceous, silty, flaggy, nodular; shale, dolomitic; UPPER member: dolostone, cherty, medium to dark brownish-grey, fine- to medium crystalline, silicified corals, stromotoporoids, brachipods
- lmDv-BR,dolostone, dolostone solution-breccia, anhydrite, gypsum; locally may include unit SDT at base
- lmDv-BR,dolostone; dolostone solution-breccia; anhydrite; gypsum; locally may include unit SlDv-T at base; marine
- mCm-MC,shale, silty, black, red, green; limestone, pure, quartzose, glauconitic, thin-bedded; dolostone, grey, buff, brown, thin-bedded; sandstone, glauconitic, quartzose; siltstone

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Project Location
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Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.3

Title
RSA Bedrock Geology

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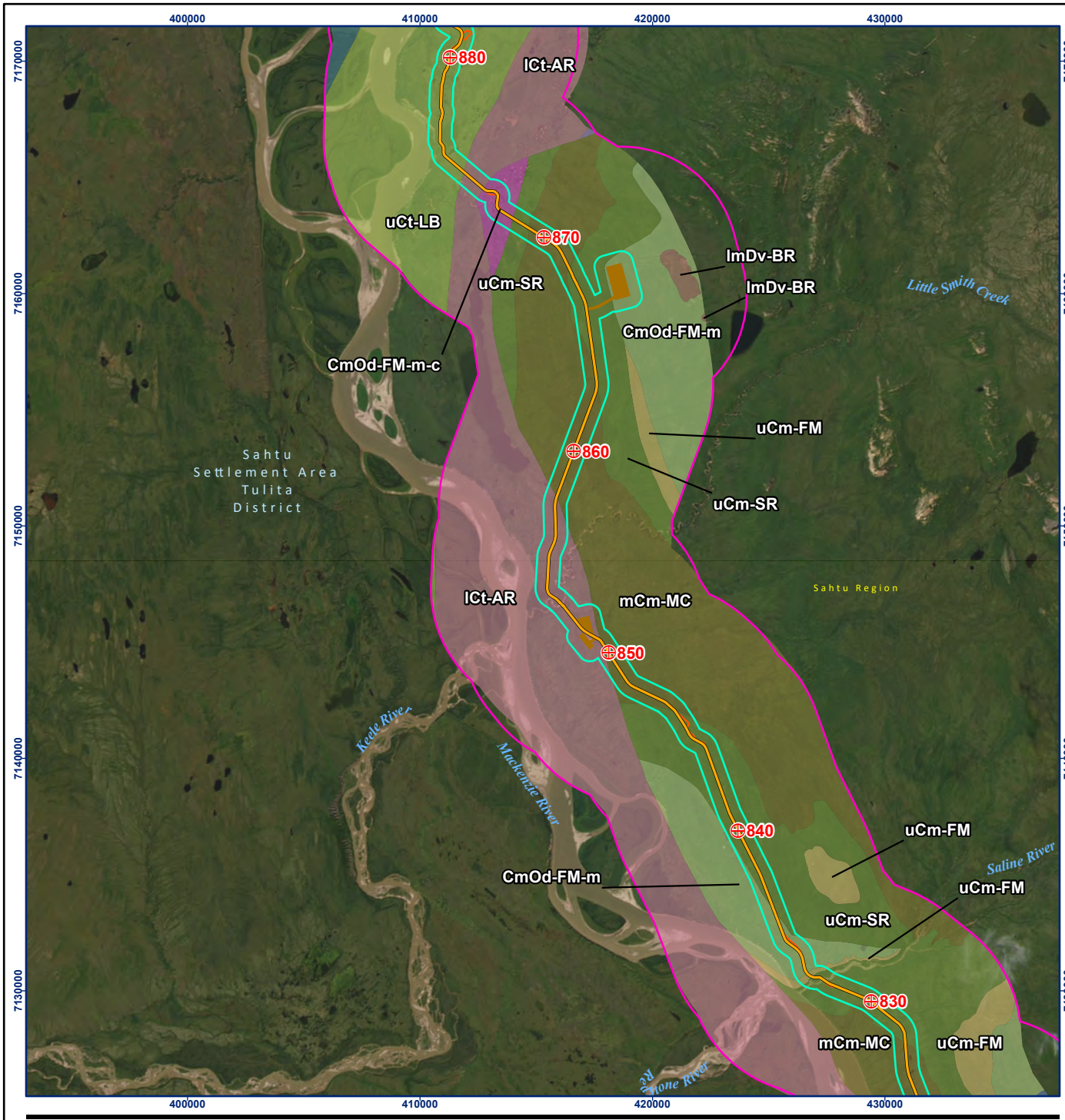

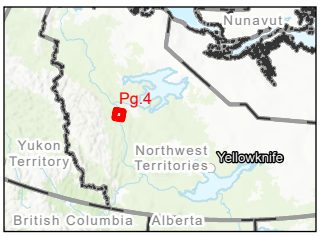

Bedrock Geology

- CmOd-FM-m,dolostone, silty, very fine-crystalline alternating with dolostone, fine- to medium-crystalline, oolitic; locally quartzose; minor conglomerate, flat-pebble
- CmOd-FM-m-c,limestone, silty, fine grained; minor conglomerate
- OdSl-MK,BASAL member: dolostone, argillaceous, silty, flaggy, nodular; shale, dolomitic; UPPER member: dolostone, cherty, medium to dark brownish-grey, fine- to medium crystalline, silicified corals, stromotoporoids, brachipods
- ICt-AR,shale, brownish-grey; minor radioactive shale
- lmDv-BR,dolostone, dolostone solution-breccia, anhydrite, gypsum; locally may include unit SDT at base
- mCm-MC,shale, silty, black, red, green; limestone, pure, quartzose, glauconitic, thin-bedded; dolostone, grey, buff, brown, thin-bedded; sandstone, glauconitic, quartzose; siltstone
- uCm-FM,dolostone, laminated, very thin-bedded, aphanocrystalline, oolitic; conglomerate, dolomitic, flat-pebble; dolostone, stromatolitic; shale, dolomitic, light green, maroon, thin-bedded
- uCm-SR,shale, red and green; siltstone, red, green; sandstone, red, green; salt; anhydrite; gypsum; dolostone
- uCt-EF,shale, siltstone; minor sandstone
- uCt-LB,LOWER shale, sandstone; UPPER sandstone, shale, coal
- uCt-SR,BASAL: sandstone. UPPER: siltstone; shale, black and grey; bentonite interbeds; minor siltstone; sandstone, fine-grained

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Project Location
Wrigley to Norman Wells, NWT

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Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.4

Title
RSA Bedrock Geology

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N

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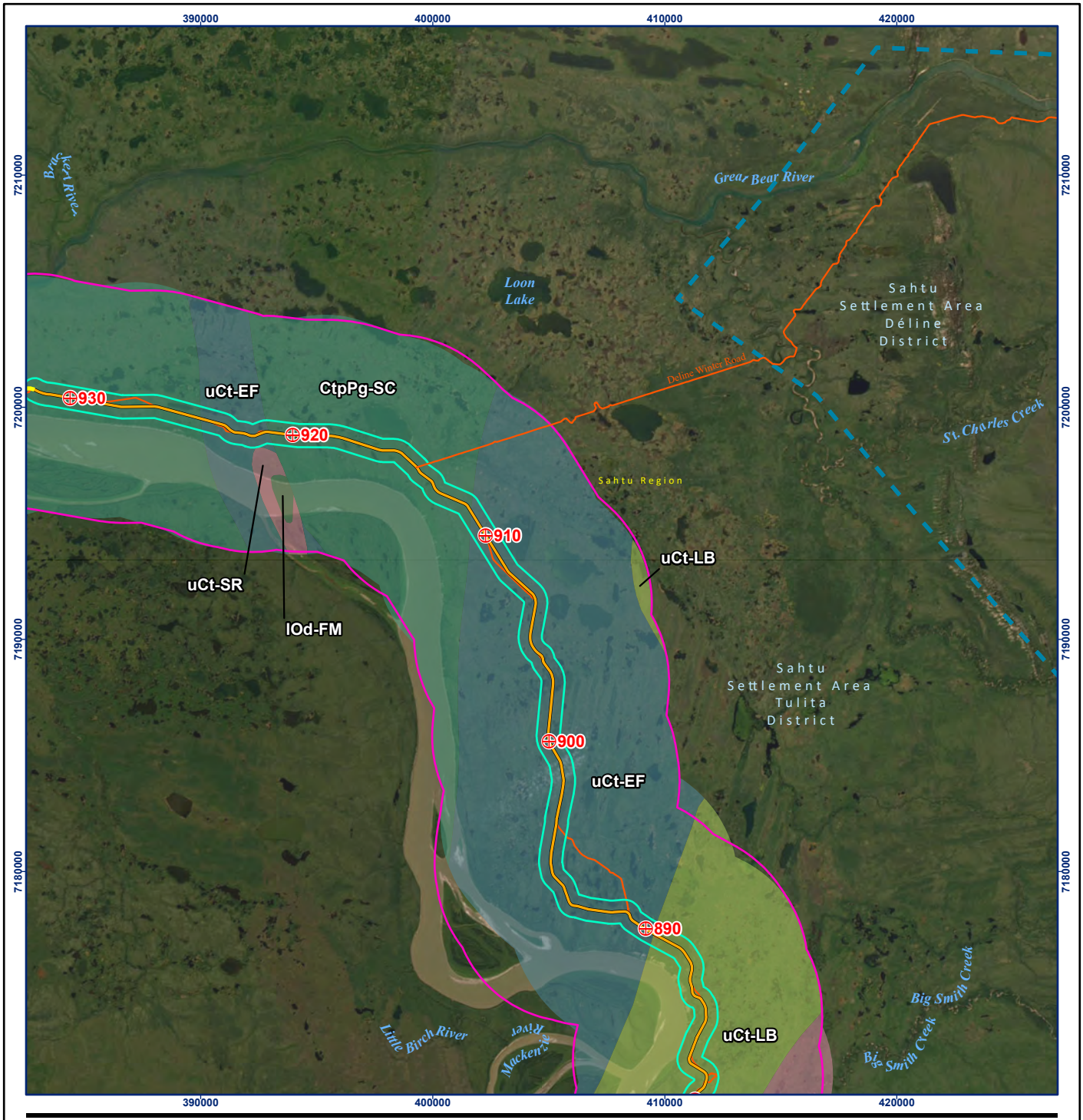

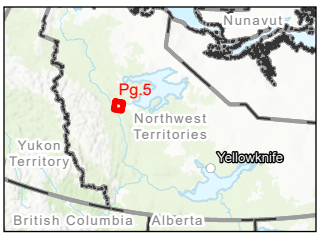

Notes

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2. Data Sources: Government of Canada. Bedrock Geology source: Okulitch, A. V. and Irwin, D., 2016. Geological Compilation of the Western Mainland and Arctic Islands of the Northwest Territories; Northwest Territories Geological Survey, NWT Open File 2016-09
Esri, FAO, NOAA, USGS, NRCan, Earthstar Geographics, Esri, USGS

Bedrock Geology

- CtpPg-SC,conglomerate, sandstone; coal, thin interbeds
- lOd-FM,dolostone, pale yellow-brown to pale grey, medium crystalline; chert, bedded, replacing stromatoporoids and oolites, white, yellowish-grey
- uCt-EF,shale, siltstone; minor sandstone
- uCt-LB,LOWER shale, sandstone; UPPER sandstone, shale, coal
- uCt-SR,BASAL: sandstone. UPPER: siltstone; shale, black and grey; bentonite interbeds; minor siltstone; sandstone, fine-grained
- Mackenzie Valley Highway Kilometre Post
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
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- Regional Study Area
- Community
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- Proposed Great Bear River Bridge Project
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 2.5 5 Kilometres
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N

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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/9/2023
TR by AJ on 3/9/2023

Client/Project
144903025-0003 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.5

Title
RSA Bedrock Geology

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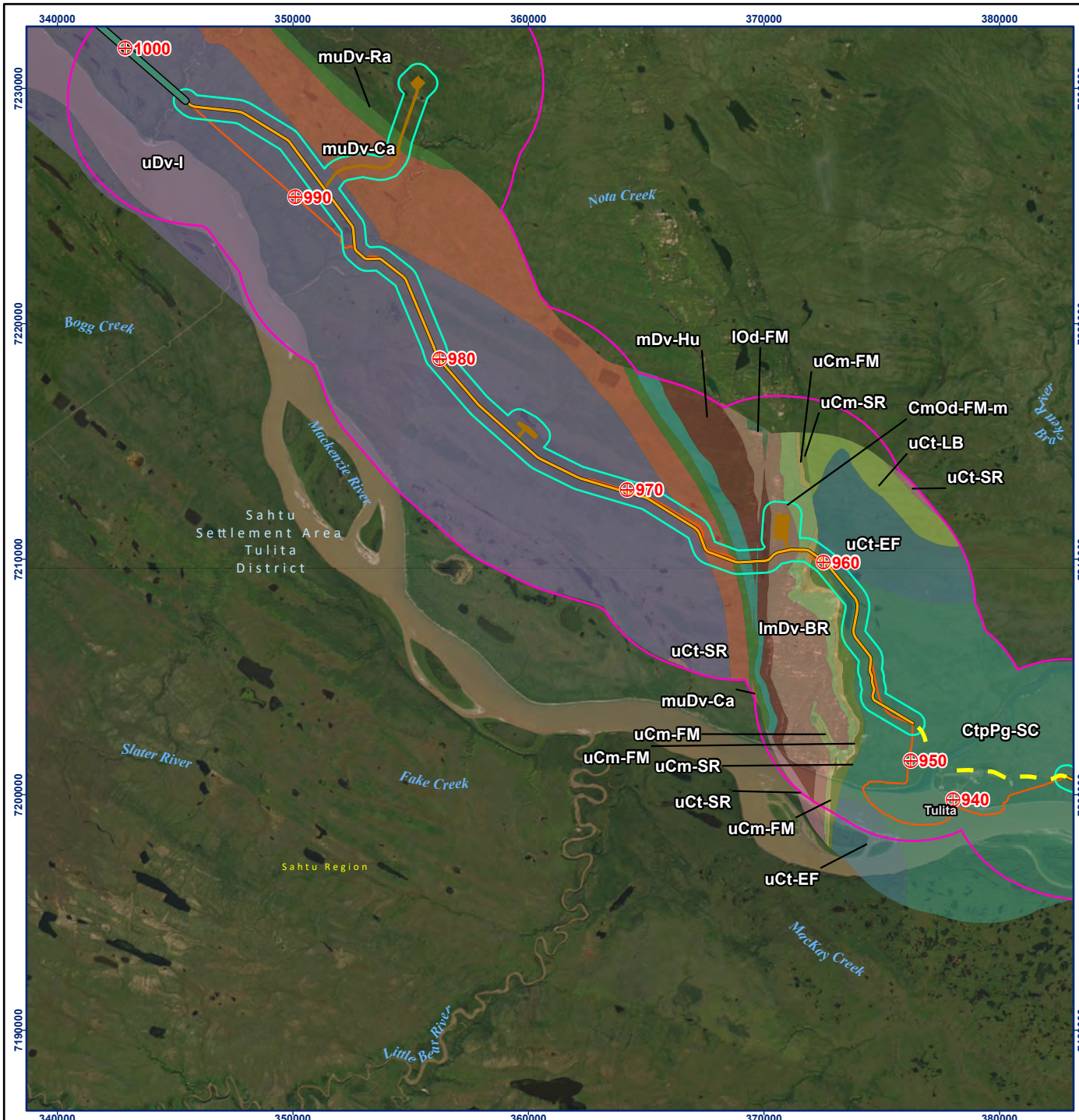

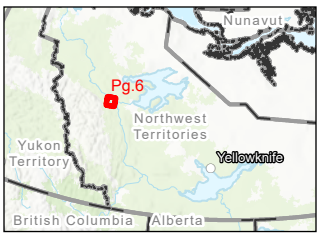

Bedrock Geology

- CmOd-FM-m,dolostone, silty, very fine-crystalline alternating with dolostone, fine- to medium-crystalline, oolitic; locally quartzose; minor conglomerate, flat-pebble
- CtpPg-SC,conglomerate, sandstone; coal, thin interbeds
- lOd-FM,dolostone, pale yellow-brown to pale grey, medium crystalline; chert, bedded, replacing stromatoporoids and oolites, white, yellowish-grey
- lmDv-BR,dolostone, dolostone solution-breccia, anhydrite, gypsum; locally may include unit SDT at base
- mDv-Hl,basal BLUEFISH Member: shale, bituminous, dark grey, spore-bearing. UPPER member: shale, calcareous, bluish-grey, thin bedded; minor limestone, thin interbeds
- mDv-Hu,LOWER member: interbedded marlstone, dark grey and limestone, dark greyish brown, micro- to fine-fragmental, fossiliferous; MIDDLE member: interbedded limestone, argillaceous; marlstone; shale, silty
- mDv-Ra,limestone, largely skeltal-fragmental, fossiliferous
- muDv-Ca,shale, black, siliceous, rarely calcareous, platy; minor limestone, ironstone and barite nodules; sandstone; conglomerate
- uCm-FM,dolostone, laminated, very thin-bedded, aphanocrystalline, oolitic; conglomerate, dolomitic, flat-pebble; dolostone, stromatolitic; shale, dolomitic, light green, maroon, thin-bedded
- uCm-SR,shale, red and green; siltstone, red, green; sandstone, red, green; salt; anhydrite; gypsum; dolostone
- uCt-EF,shale, siltstone; minor sandstone
- uCt-LB,LOWER shale, sandstone; UPPER sandstone, shale, coal
- uCt-SR,BASAL: sandstone. UPPER: siltstone; shale, black and grey; bentonite interbeds; minor siltstone; sandstone, fine-grained
- uDv-l,shale; sandstone

Mackenzie Valley Highway Kilometre Post
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Winter Road
District Boundary
Region Boundary
Settlement Area Boundary

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Kálo-Stantec

Project Location
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Prepared by AT on 3/9/2023
TR by AJ on 3/9/2023

Client/Project
144903025-0003 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.6

Title
RSA Bedrock Geology

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N

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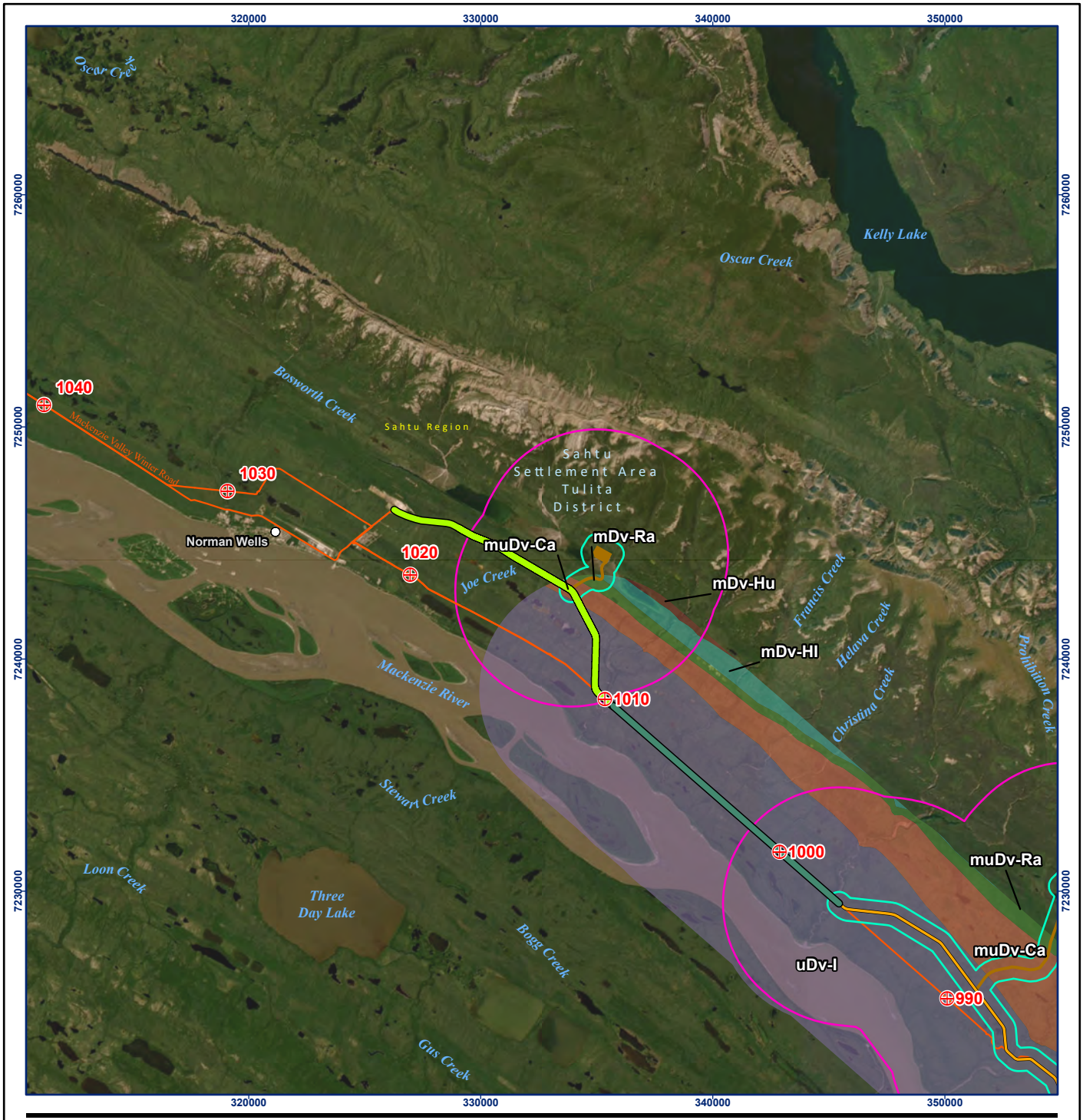

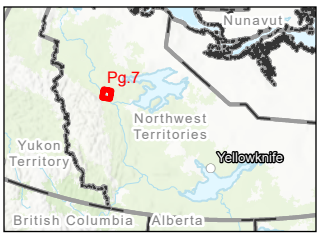

Notes

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Bedrock Geology

- mDv-Hl,basal BLUEFISH Member: shale, bituminous, dark grey, spore-bearing. UPPER member: shale, calcareous, bluish-grey, thin bedded; minor limestone, thin interbeds
- mDv-Hu,LOWER member: interbedded marlstone, dark grey and limestone, dark greyish brown, micro- to fine-fragmental, fossiliferous; MIDDLE member: interbedded limestone, argillaceous; marlstone; shale, silty
- mDv-Ra,limestone, largely skeltal-fragmental, fossiliferous
- muDv-Ca,shale, black, siliceous, rarely calcareous, platy; minor limestone, ironstone and barite nodules; sandstone; conglomerate
- uDv-l,shale; sandstone

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0 2.5 5 Kilometres
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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/9/2023
TR by AJ on 3/9/2023

Client/Project
144903025-0003 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.7

Title
RSA Bedrock Geology

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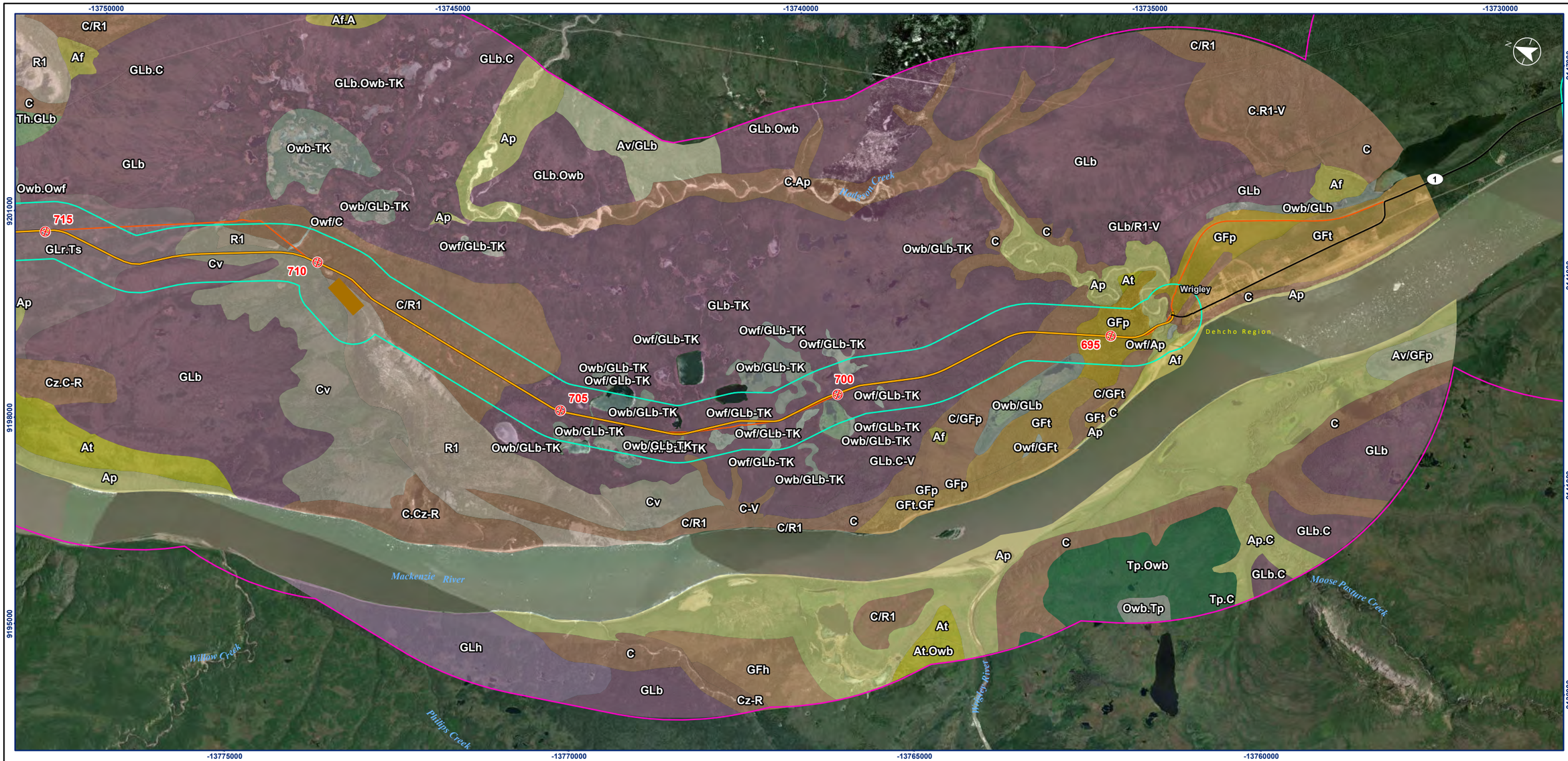

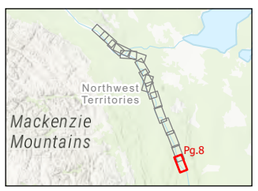

Surficial Geology

- Af: Alluvial fan
- Ap: Alluvial floodplain sediment
- At: Alluvial terraced sediment
- Av: Alluvial veneer
- C: Colluvial deposit, undifferentiated
- Cv: Colluvial veneer
- Cz: Landslide deposit
- E: Eolian deposit, undifferentiated
- GFf: Glaciofluvial outwash-fan sediment
- GFh: Glaciofluvial hummocky sediment
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- GLr: Glaciolacustrine beach sediment
- GLv: Glaciolacustrine veneer
- Owb: Bog deposit
- Owf: Fen deposit
- R1: Sedimentary bedrock
- Tb: Till blanket
- Th: Hummocky till
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- Settlement Area Boundary

Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

Stratigraphic relationship
Two map-unit designators separated by a slash (/) are used where the stratigraphic relationship is observed or confidently inferred (e.g. GLv/T indicates glaciolacustrine veneer overlying till.)

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
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3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
World Imagery: Earthstar Geographics
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4. Terrain mapping was compiled and modified based on a series of maps including OpenFile 7289 - middle east section from Côté et al. (2013), maps 371 and 375 from GSC (2019), and MGAR and Great bear prohibition mapping from G.V.M. Geological Consultant Ltd. (2016, 2019)

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Project Location
Wrigley to Norman Wells, NWT

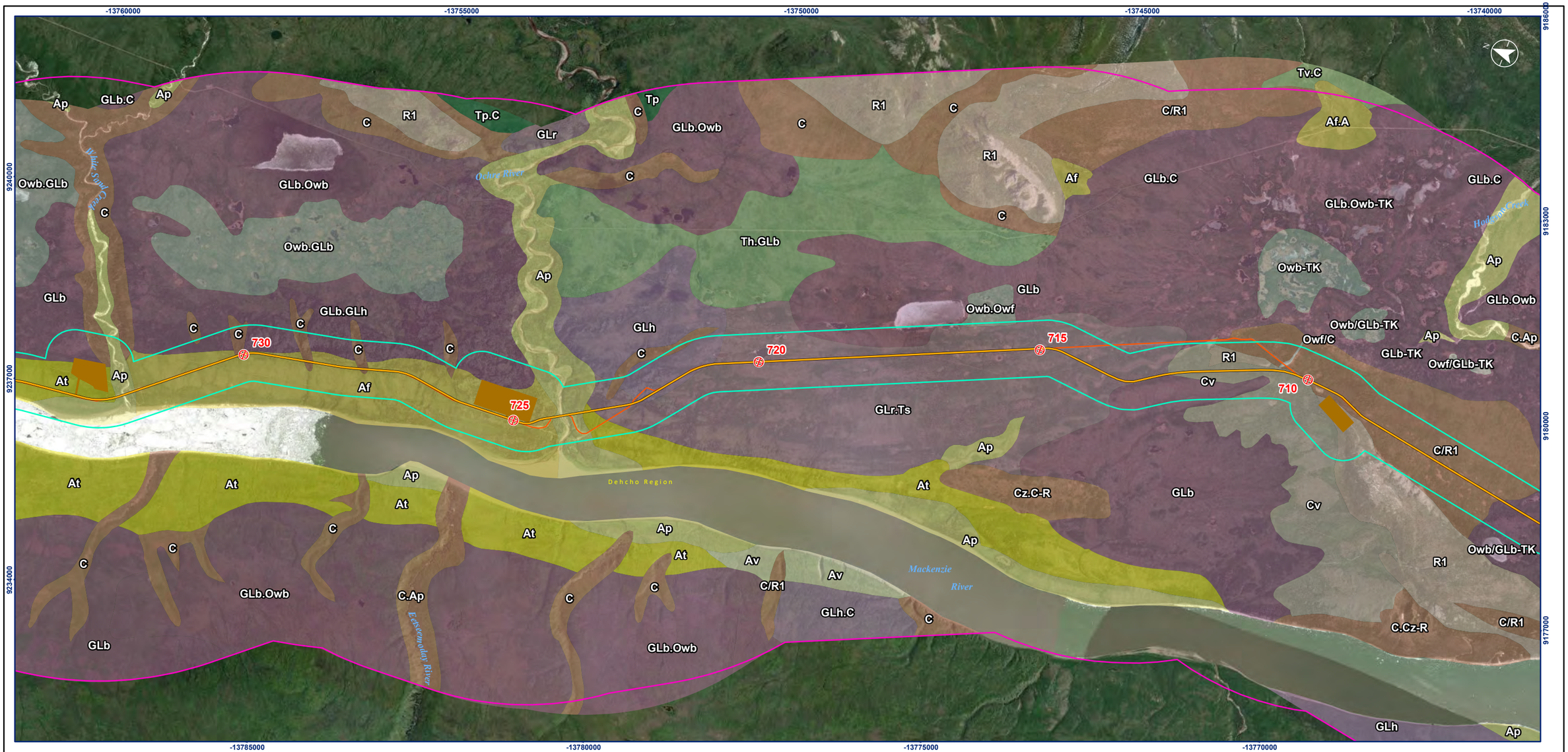
Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

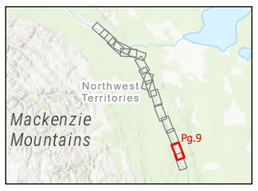
Client/Project
Government of Northwest Territories
Mackenzie Valley Highway Project

144903025-0020 REV8

Figure No.
A.8

Title
RSA Surficial Geology





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Geomorphological Process

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Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

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Two map-unit designators separated by a slash (/) are used where the stratigraphic relationship is observed or confidently inferred (e.g. GLv/T indicates glaciolacustrine veneer overlying till.)

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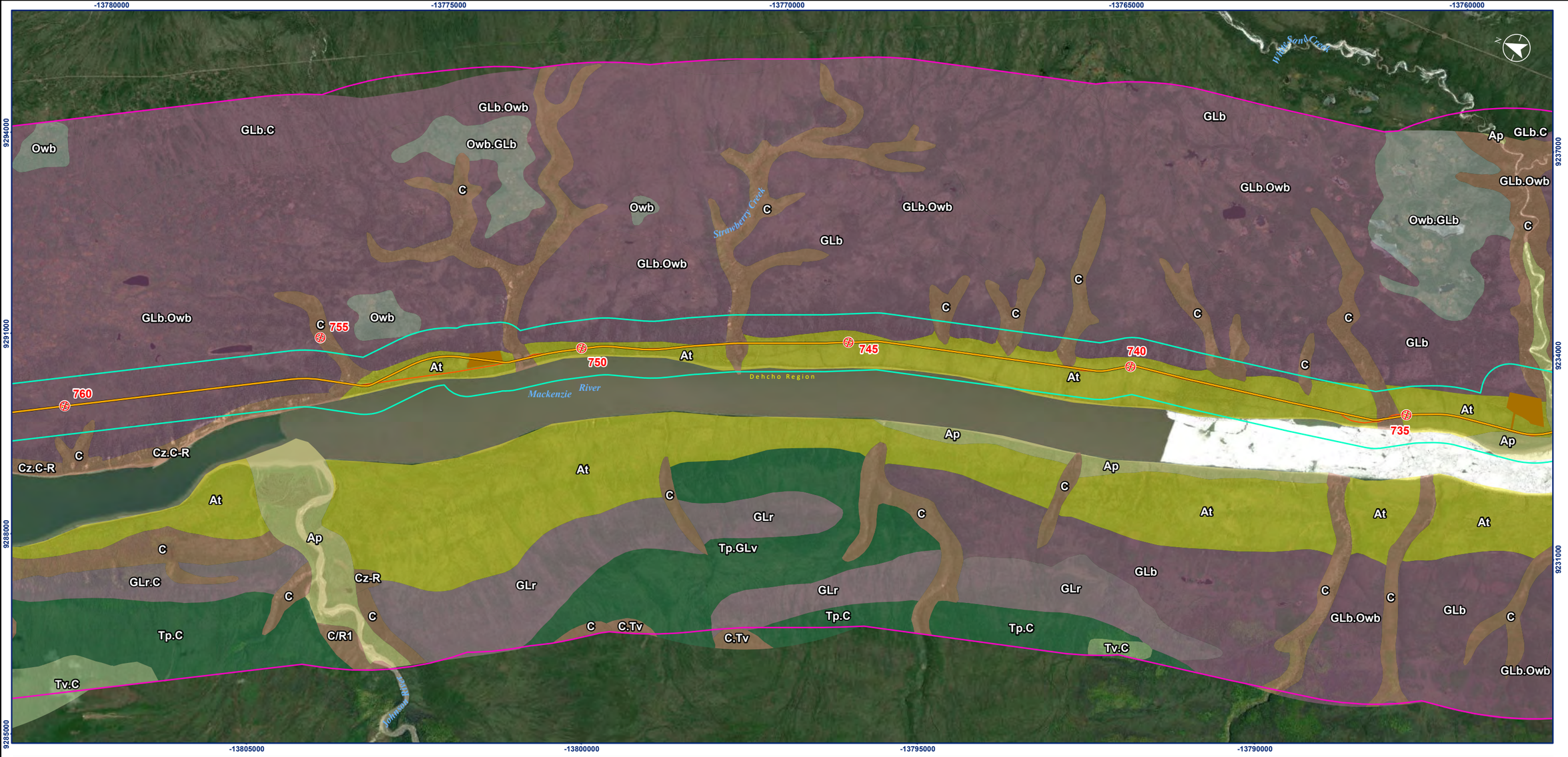
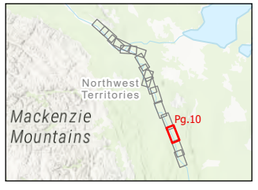
Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.9

Title
RSA Surficial Geology





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Geomorphological Process

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Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

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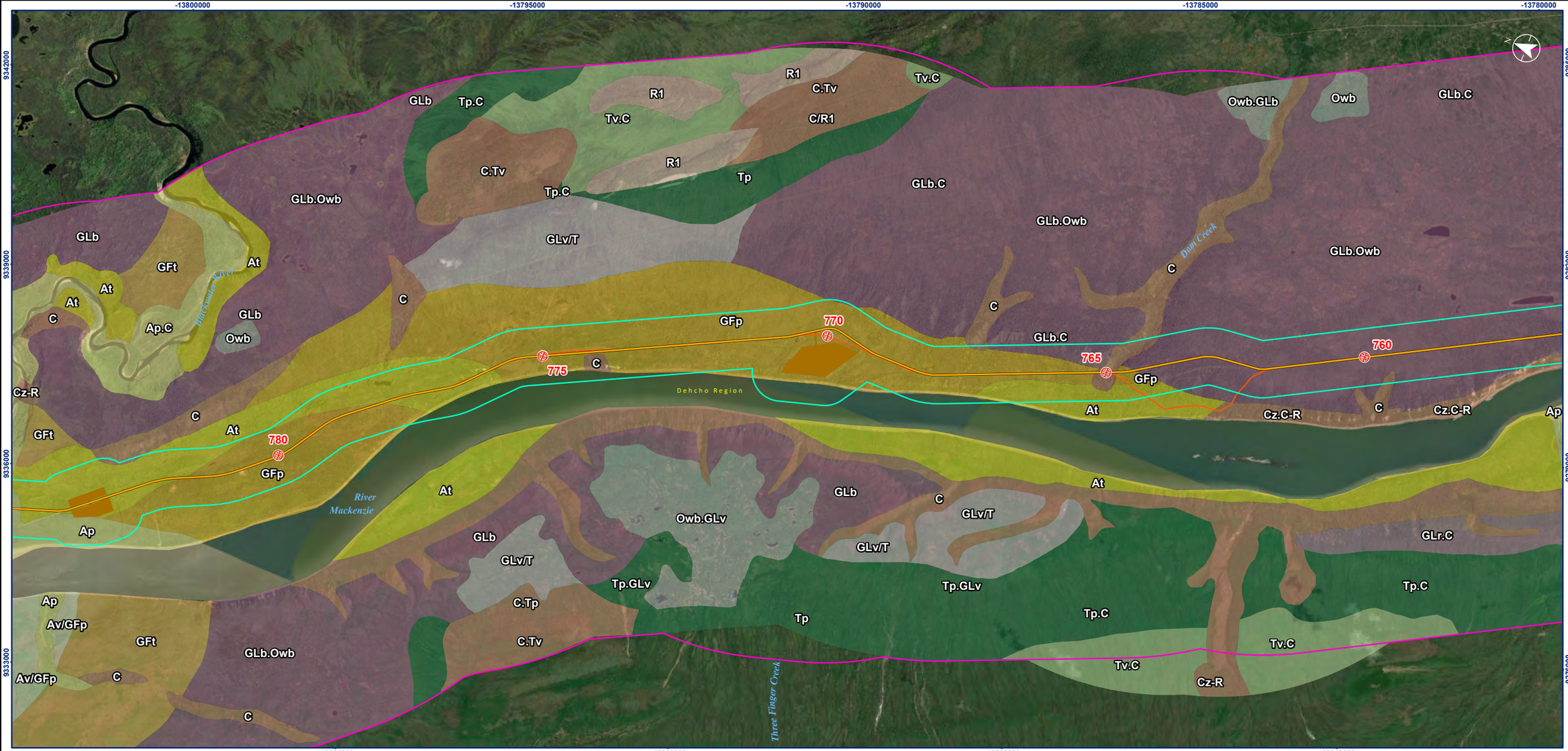
Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.10

Title
RSA Surficial Geology



Surficial Geology

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Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
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Stratigraphic relationship
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Project Location
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Client/Project

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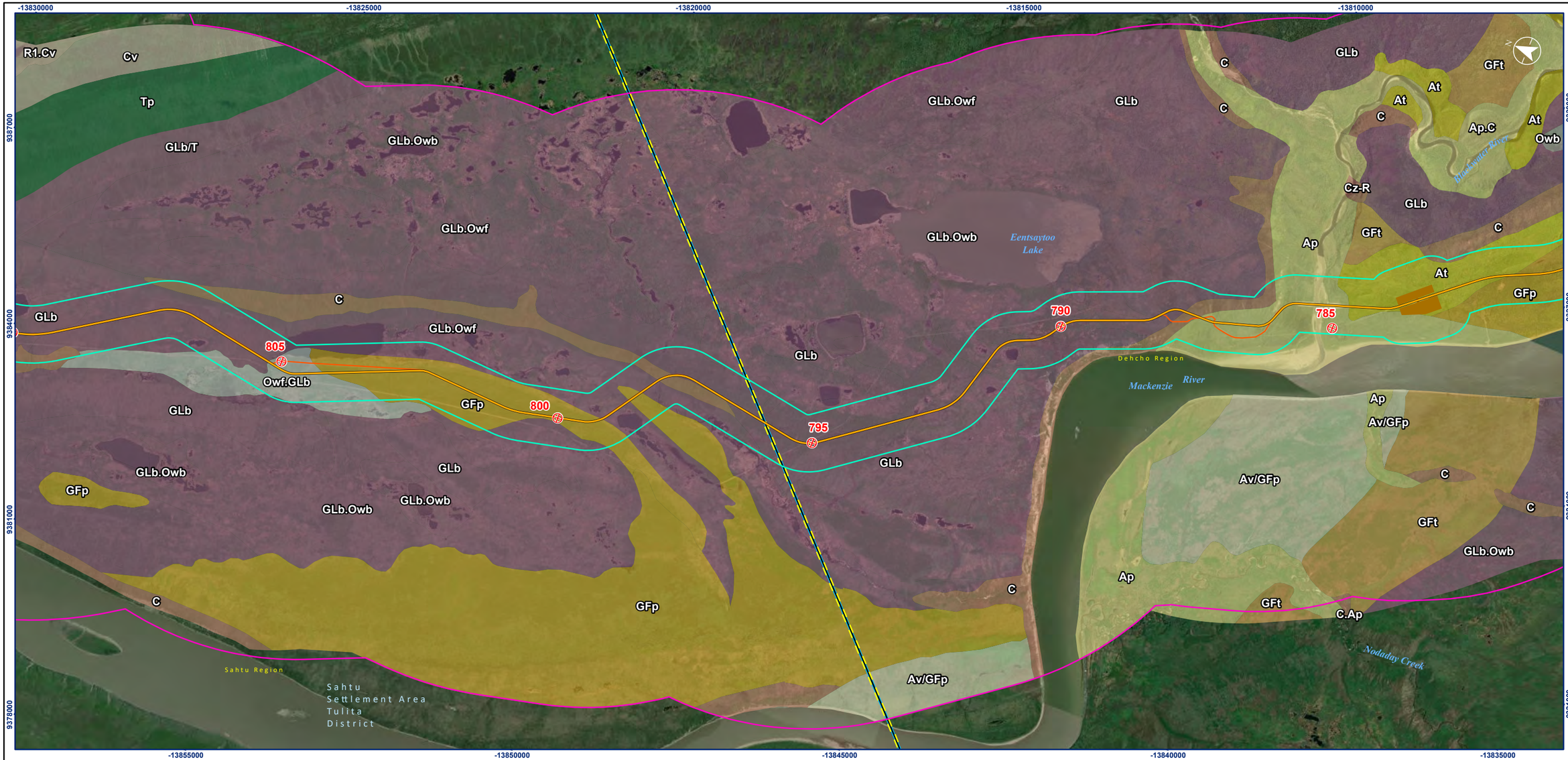
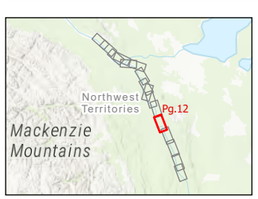
Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.11

Title
RSA Surficial Geology





Surficial Geology

- Af: Alluvial fan
- Ap: Alluvial floodplain sediment
- At: Alluvial terraced sediment
- Av: Alluvial veneer
- C: Colluvial deposit, undifferentiated
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- Region Boundary
- Settlement Area Boundary

Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

Stratigraphic relationship
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0 1 2 Kilometres
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Kalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway Project

144903025-0020 REV8

Figure No.
A.12

Title
RSA Surficial Geology

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Government of Canada
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
World Imagery: Earthstar Geographics
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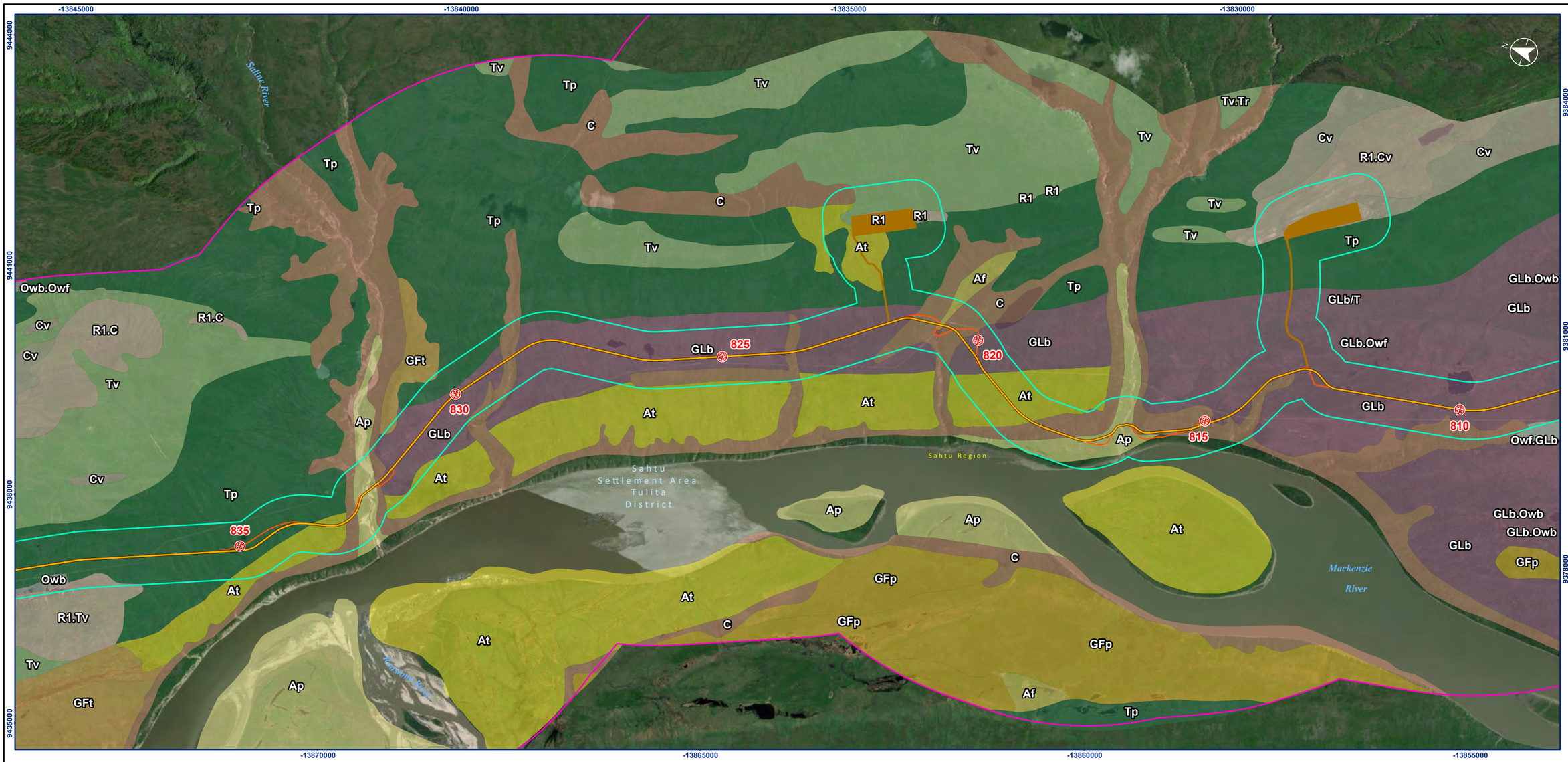

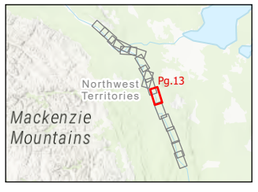

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Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
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Project Location
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Client/Project
144903025-0020 REV8

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.13

Title
RSA Surficial Geology

Notes

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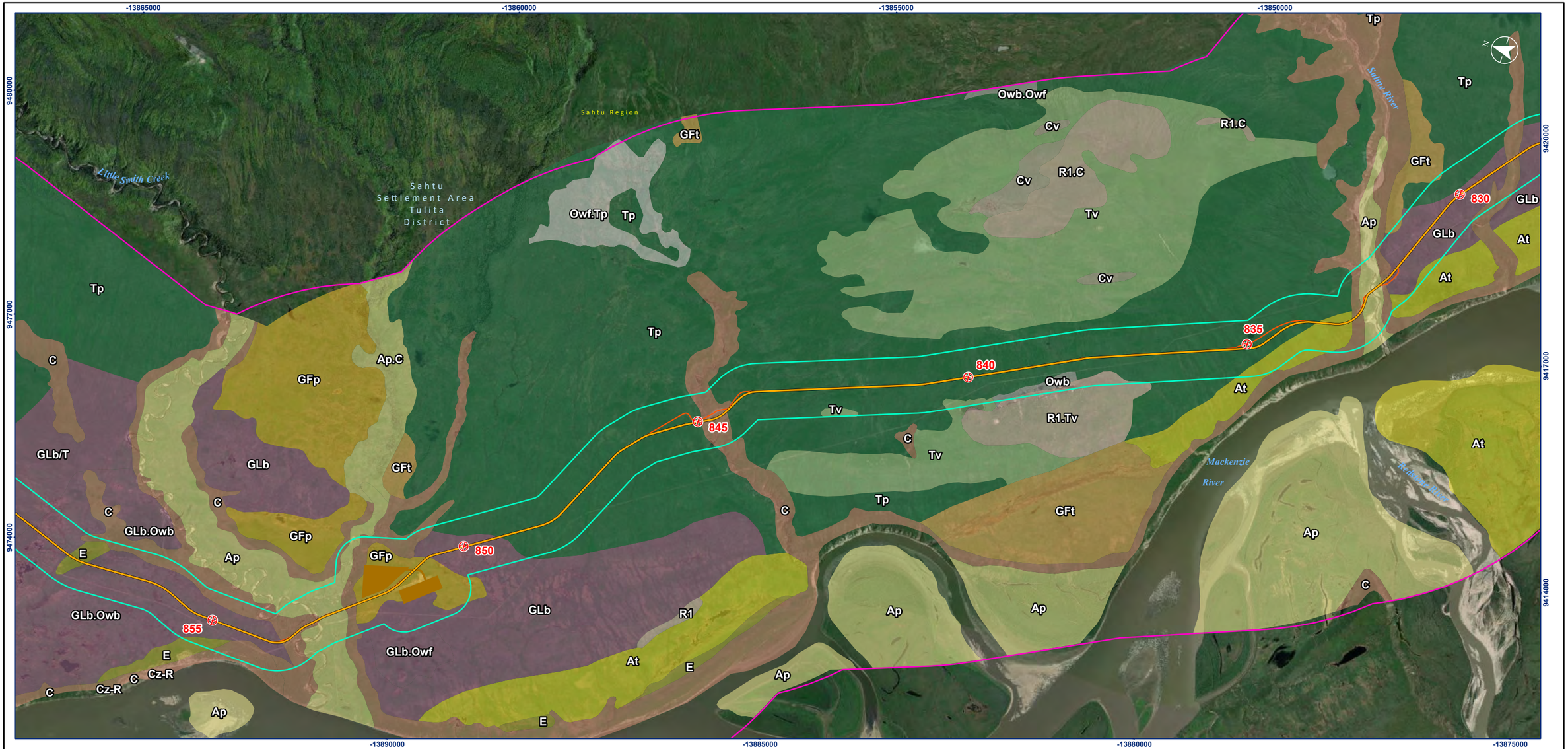

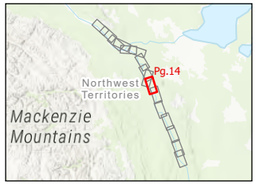

Surficial Geology

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Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

Stratigraphic relationship
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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

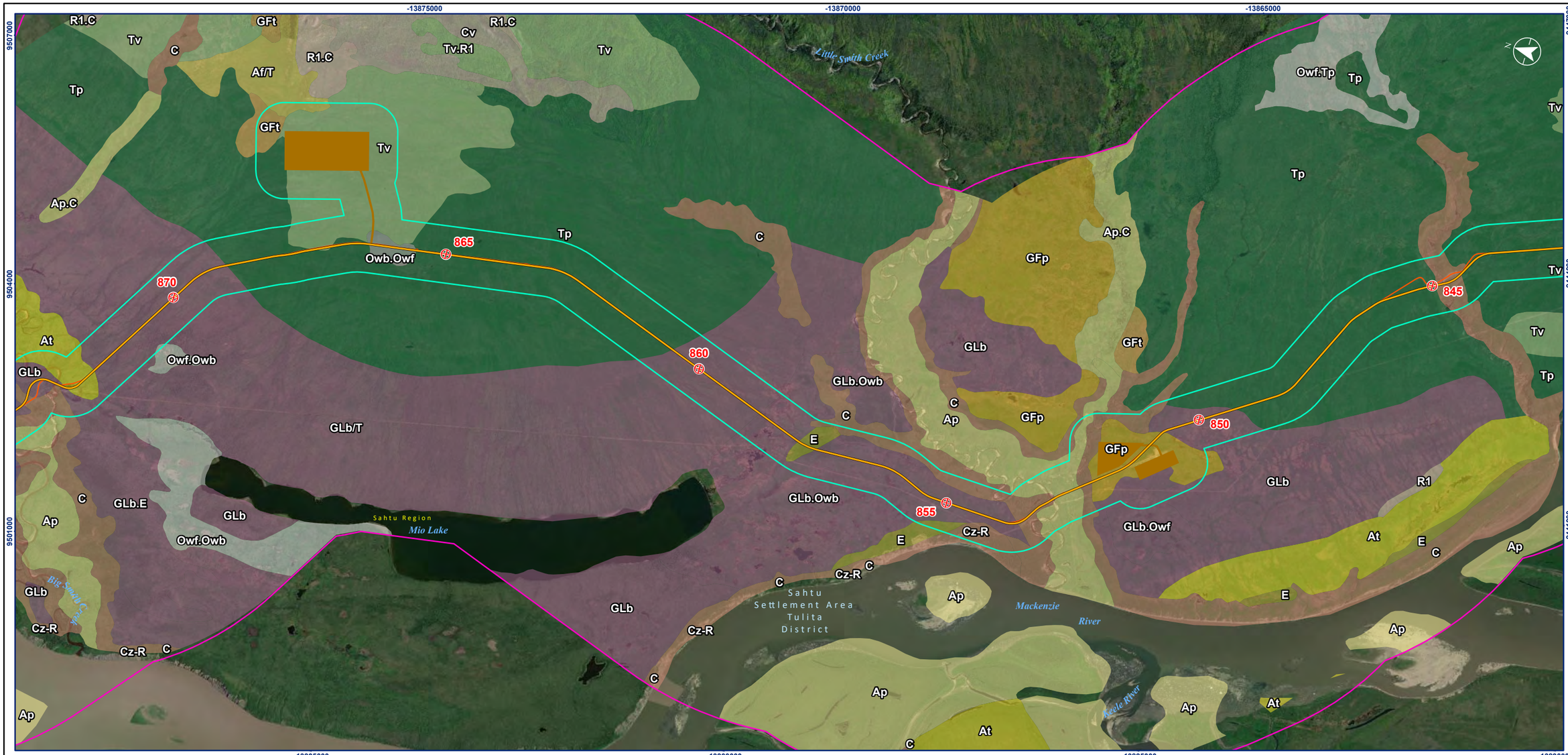
Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

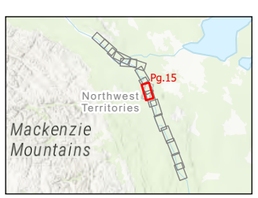
Client/Project
144903025-0020 REV8

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.14

Title
RSA Surficial Geology





Surficial Geology

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Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⇒ AF/Tp - TK ⇐ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
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Project Location
Wrigley to Norman Wells, NWT

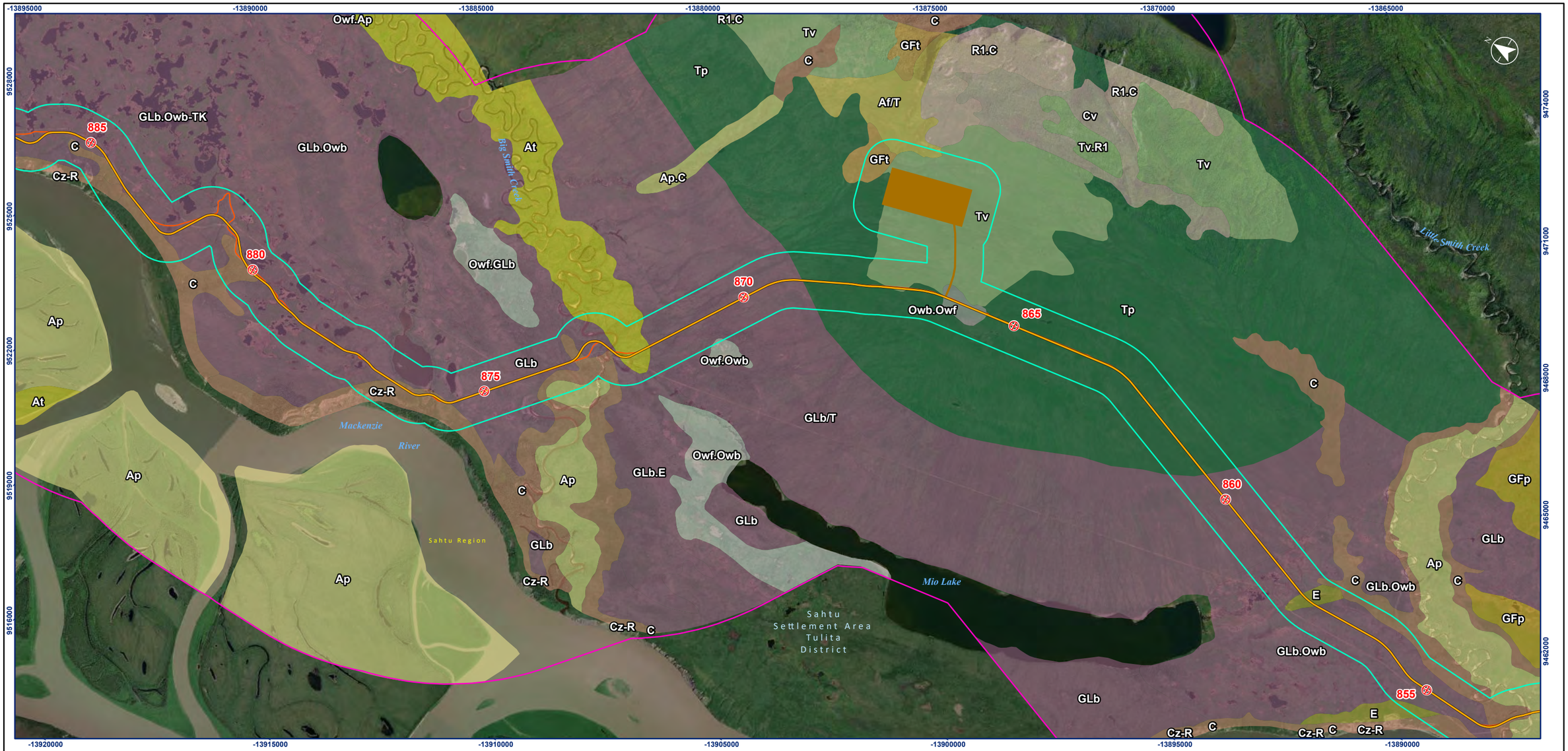
Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

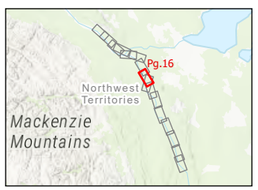
Client/Project
144903025-0020 REV8

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.15

Title
RSA Surficial Geology





Surficial Geology

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Geomorphological Process

R: Mass movement
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Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.16

Title
RSA Surficial Geology

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
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3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
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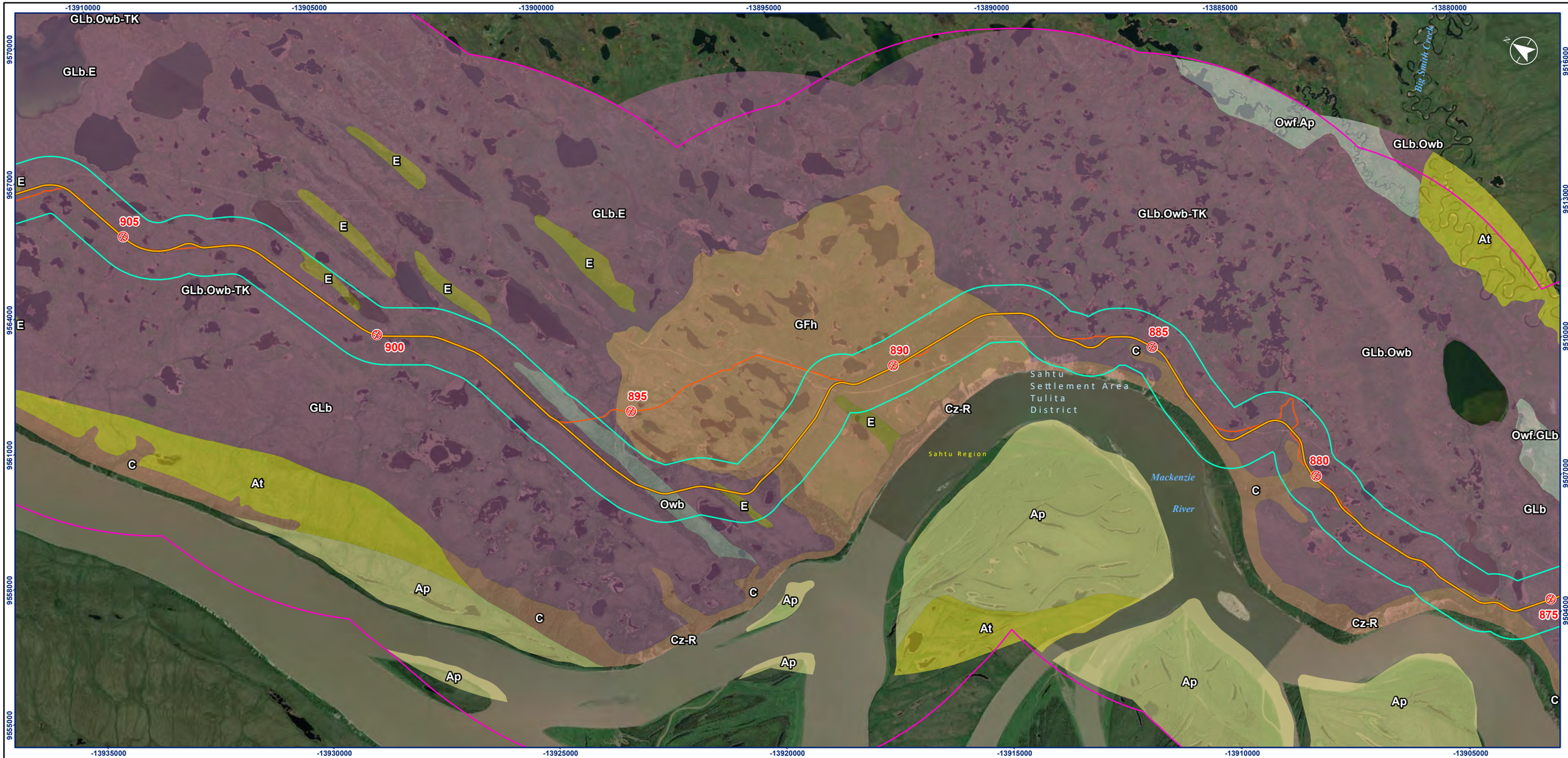

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Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

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Project Location
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Prepared by AT on 2023-03-20
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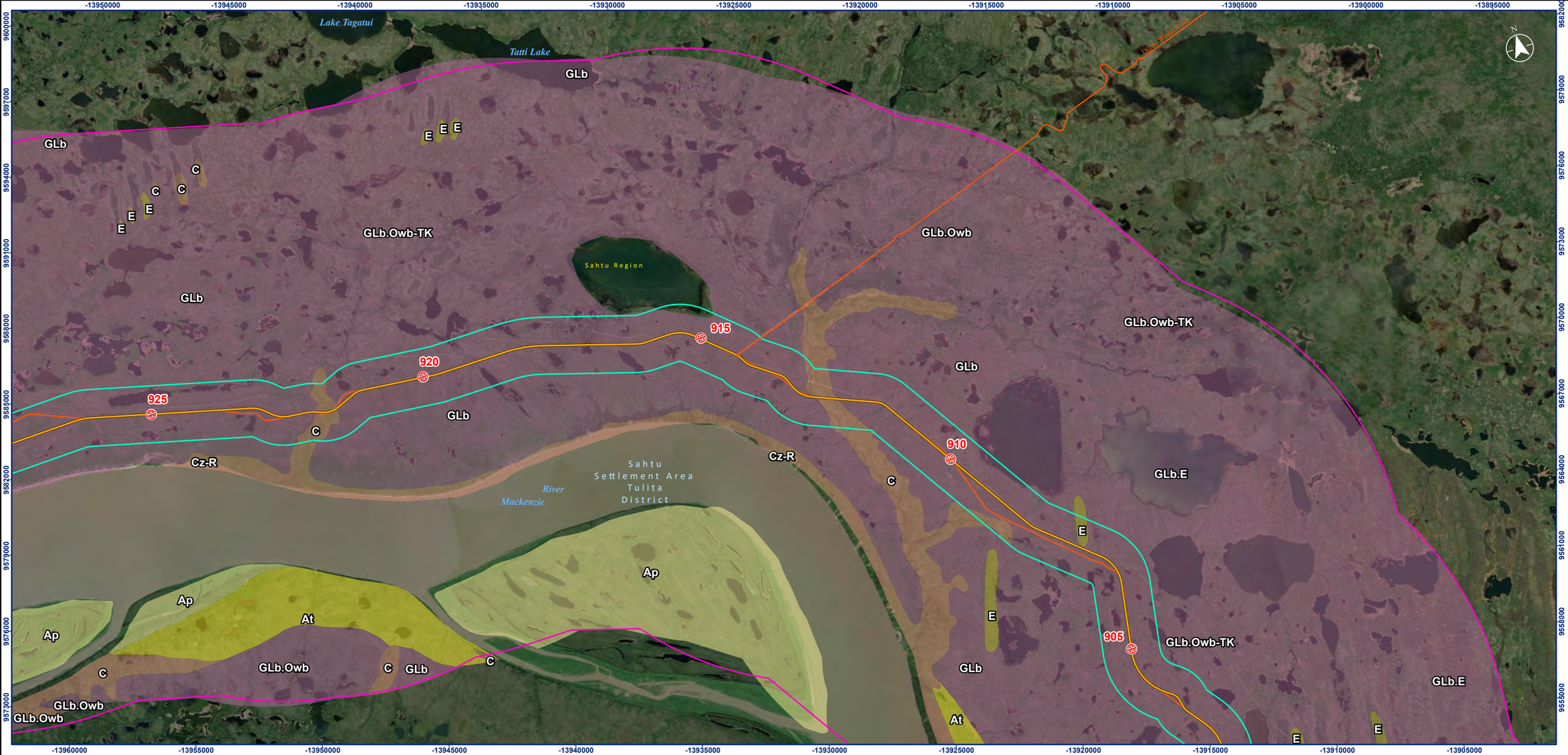
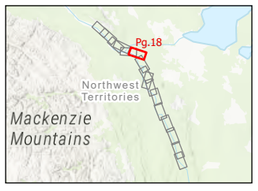
Client/Project
144903025-0020 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.17

Title
RSA Surficial Geology





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- Proposed Great Bear River Bridge Project
- Granular Borrow / Rock Quarry Site and Access
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

Stratigraphic relationship
Two map-unit designators separated by a slash (/) are used where the stratigraphic relationship is observed or confidently inferred (e.g. GLv/T indicates glaciolacustrine veneer overlying till.)

0 1 2 Kilometres
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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

Client/Project
14490302S-0020 REV8

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.18

Title
RSA Surficial Geology

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Government of Canada
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
4. Terrain mapping was compiled and modified based on a series of maps including OpenFile 7289 - middle east section from Côté et al. (2013), maps 371 and 375 from GSC (2019), and MGAR and Great bear prohibition mapping from G.V.M. Geological Consultant Ltd. (2016, 2019)

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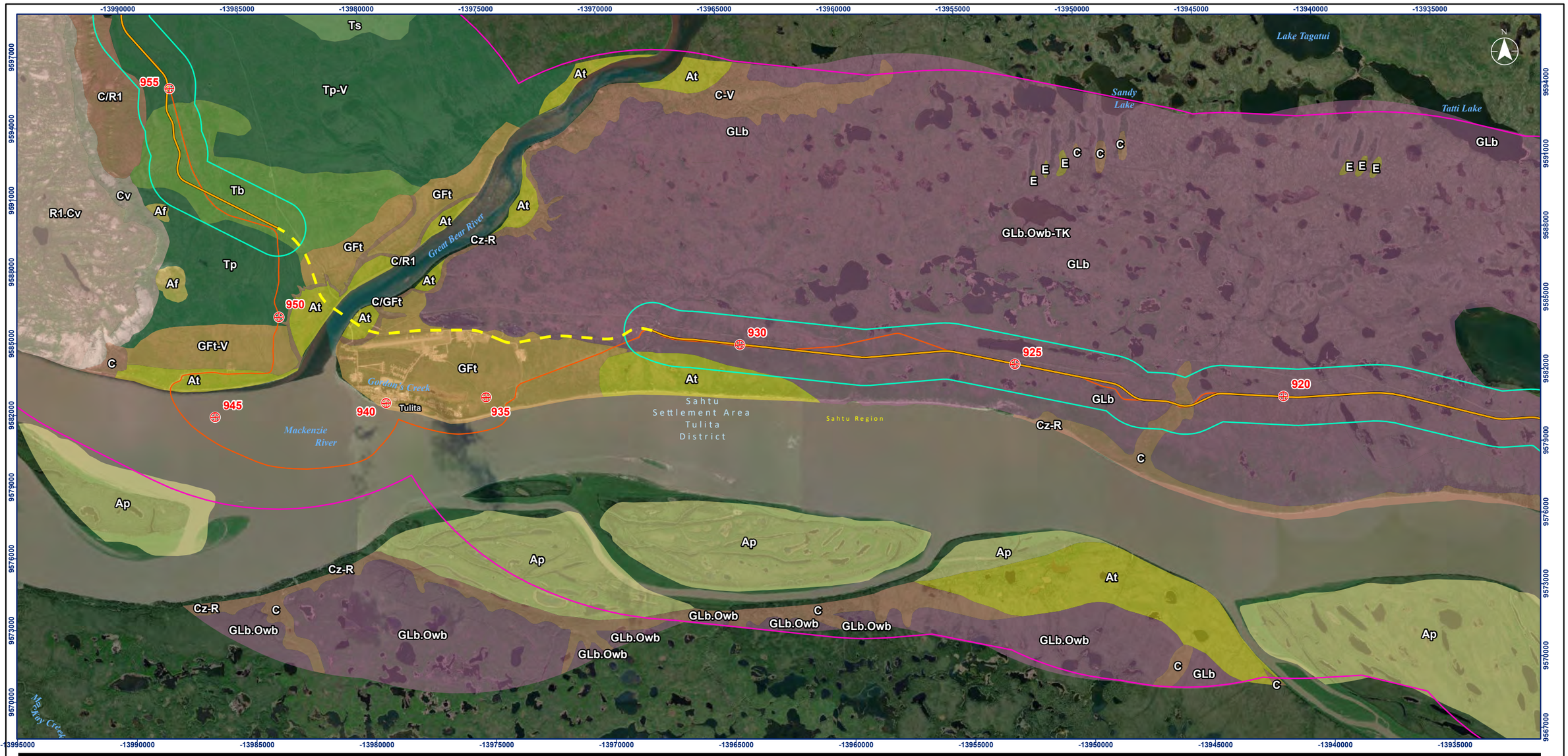

Surficial Geology

- Af: Alluvial fan
- Ap: Alluvial floodplain sediment
- At: Alluvial terraced sediment
- Av: Alluvial veneer
- C: Colluvial deposit, undifferentiated
- Cv: Colluvial veneer
- Cz: Landslide deposit
- E: Eolian deposit, undifferentiated
- GFf: Glaciofluvial outwash-fan sediment
- GFh: Glaciofluvial hummocky sediment
- GFp: Glaciofluvial outwash-plain sediment
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- GFv: Glaciofluvial veneer
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- GLv: Glaciolacustrine veneer
- Owb: Bog deposit
- Owf: Fen deposit
- R1: Sedimentary bedrock
- Tb: Till blanket
- Th: Hummocky till
- Tp: Till plain (all)
- Ts: Streamlined till
- Tv: Till veneer

- Mackenzie Valley Highway Kilometre Post
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Local Study Area
- Regional Study Area
- Canyon Creek All Season Access Road
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- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

Stratigraphic relationship
Two map-unit designators separated by a slash (/) are used where the stratigraphic relationship is observed or confidently inferred (e.g. GLv/T indicates glaciolacustrine veneer overlying till.)

Notes

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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

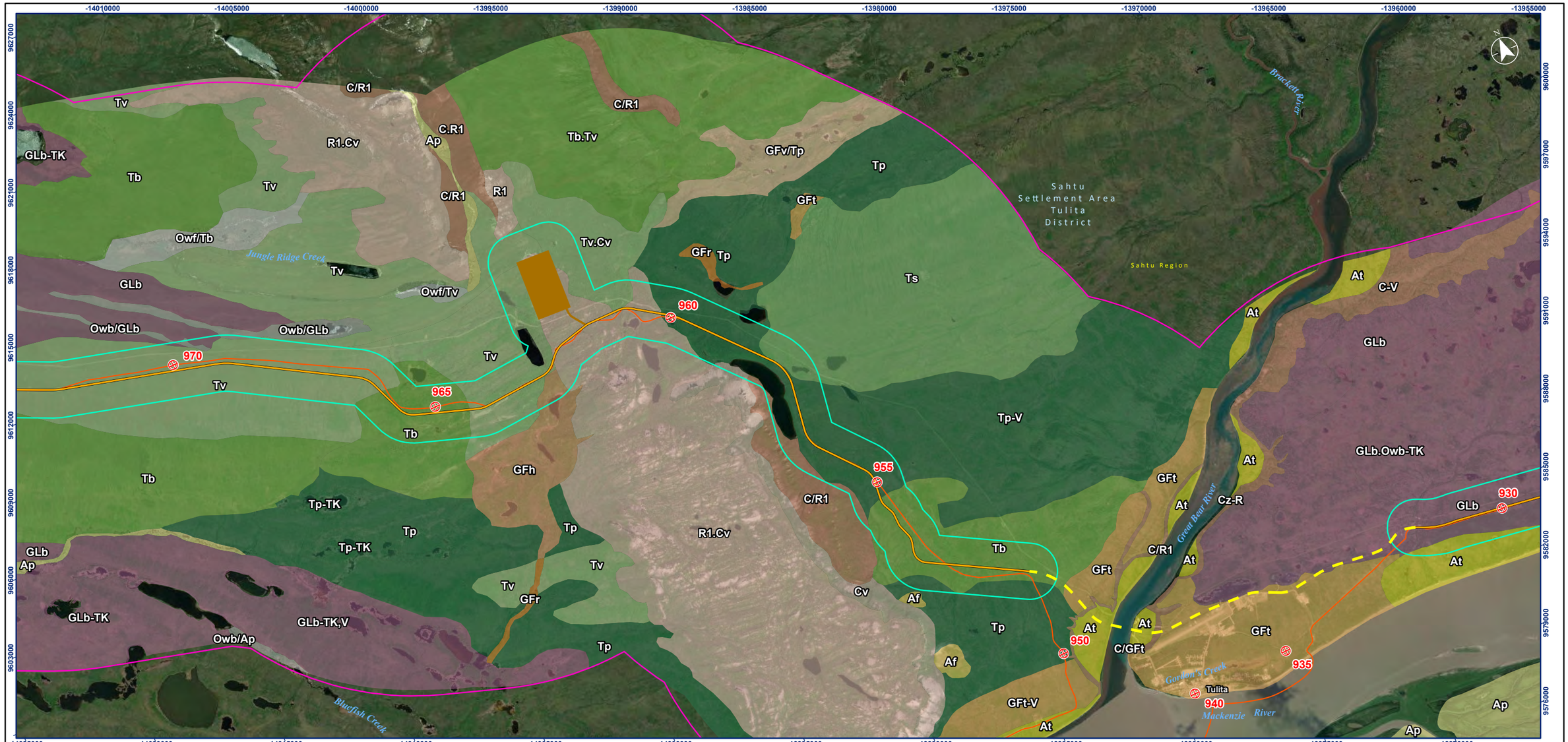
Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

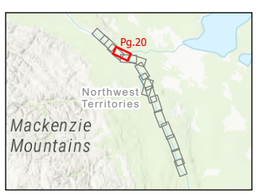
Client/Project
Government of Northwest Territories
Mackenzie Valley Highway Project

144903025-0020 REV8

Figure No.
A.19

Title
RSA Surficial Geology





Surficial Geology

- Af: Alluvial fan
- Ap: Alluvial floodplain sediment
- At: Alluvial terraced sediment
- Av: Alluvial veneer
- C: Colluvial deposit, undifferentiated
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- Tv: Till veneer
- Mackenzie Valley Highway Kilometre Post

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- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

Stratigraphic relationship
Two map-unit designators separated by a slash (/) are used where the stratigraphic relationship is observed or confidently inferred (e.g. GLv/T indicates glaciolacustrine veneer overlying till.)

Notes

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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

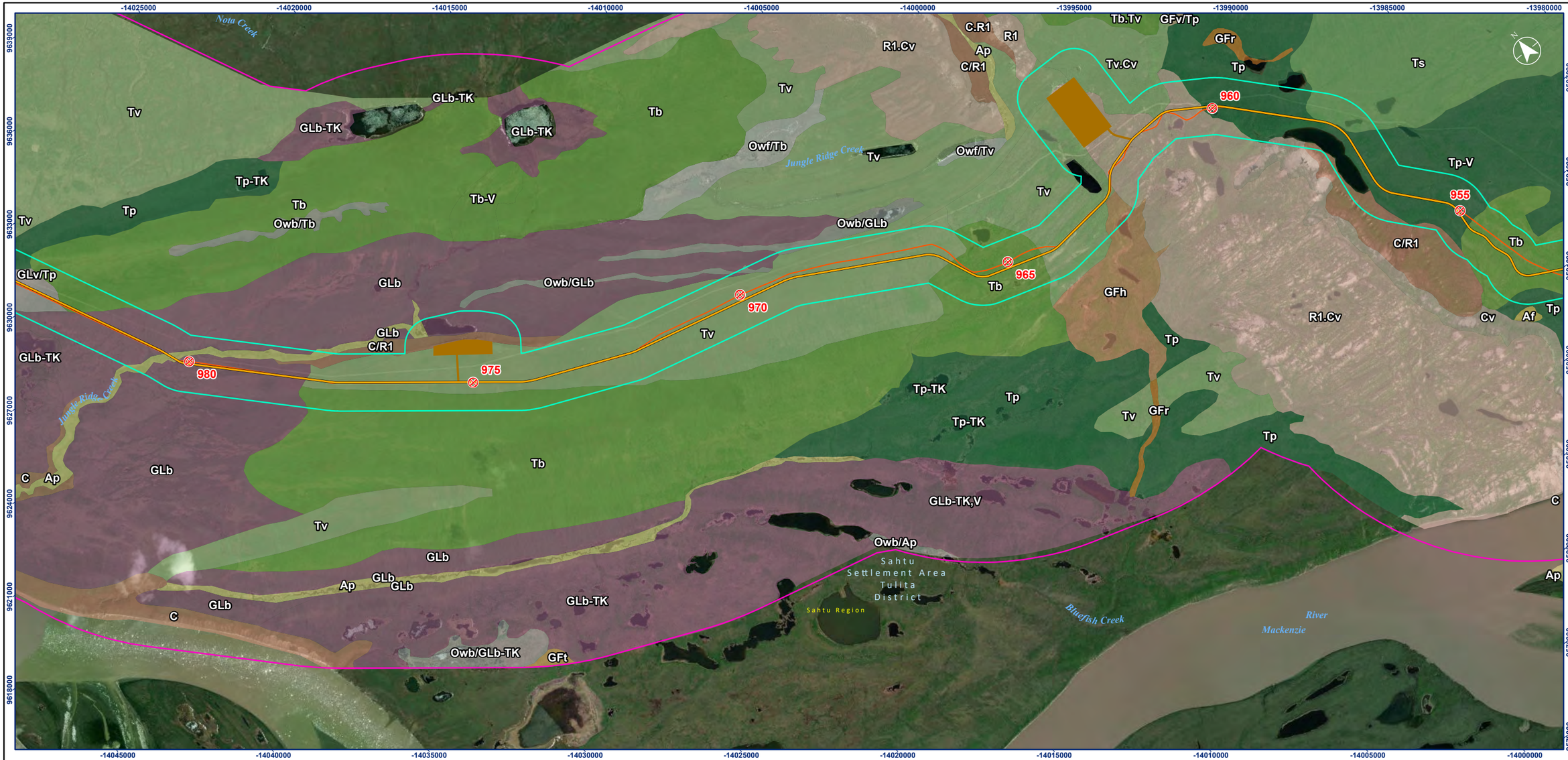
Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

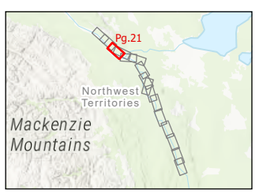
Client/Project
144903025-0020 REV8

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.20

Title
RSA Surficial Geology





Surficial Geology

- Af: Alluvial fan
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- Mackenzie Valley Highway Kilometre Post
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- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

Stratigraphic relationship
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Project Location
Wrigley to Norman Wells, NWT

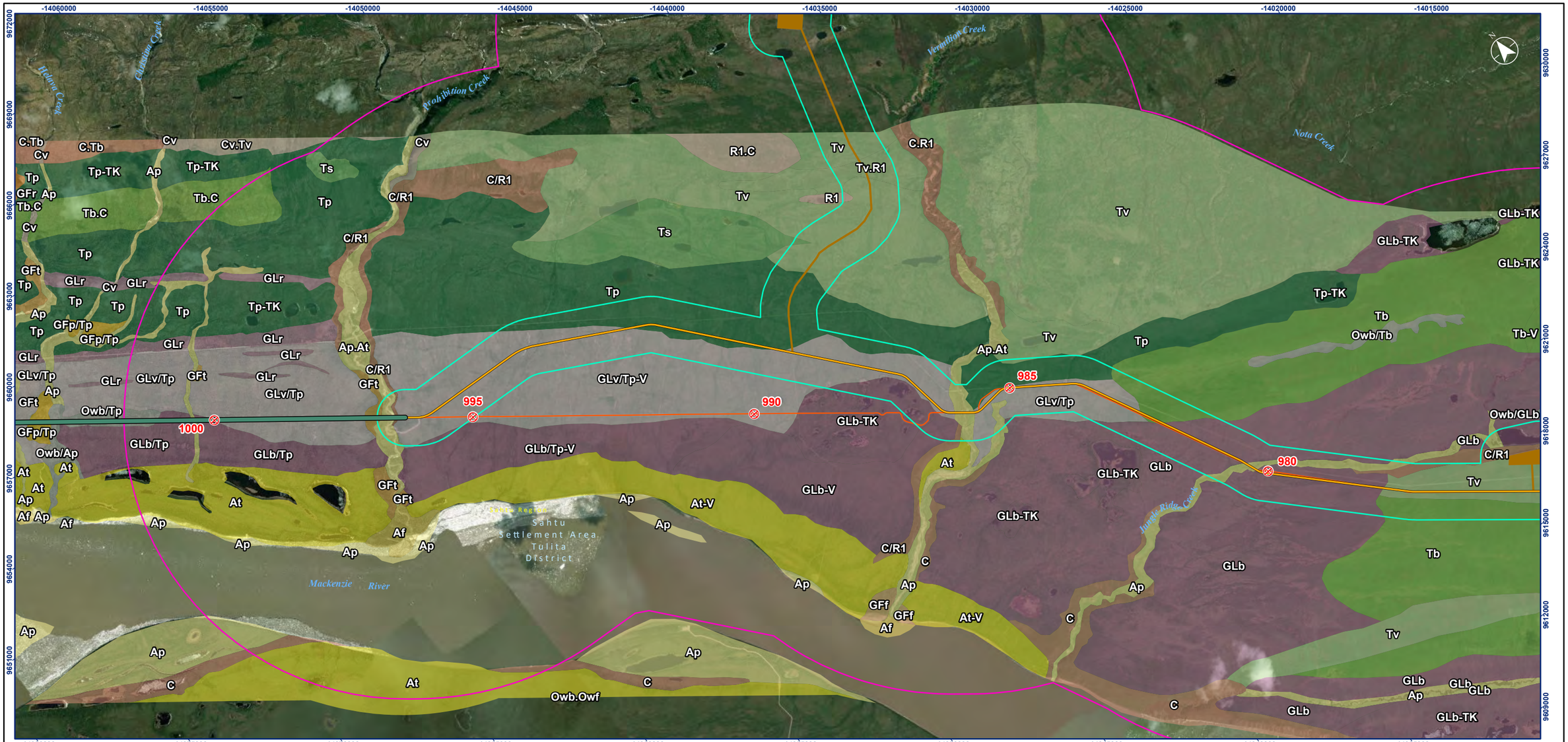
Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

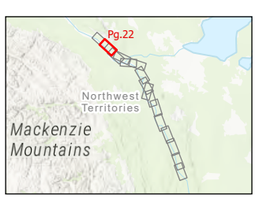
Client/Project
144903025-0020 REV8

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.21

Title
RSA Surficial Geology





Surficial Geology

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- Owb: Bog deposit
- Owf: Fen deposit
- R1: Sedimentary bedrock
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- Th: Hummocky till
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- Tv: Till veneer
- Mackenzie Valley Highway Kilometre Post

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- Prohibition Creek Access Road
- Proposed Great Bear River Bridge Project
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- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⇒ AF/Tp - TK ⇐ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

Stratigraphic relationship
Two map-unit designators separated by a slash (/) are used where the stratigraphic relationship is observed or confidently inferred (e.g. GLv/T indicates glaciolacustrine veneer overlying till.)

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Kalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

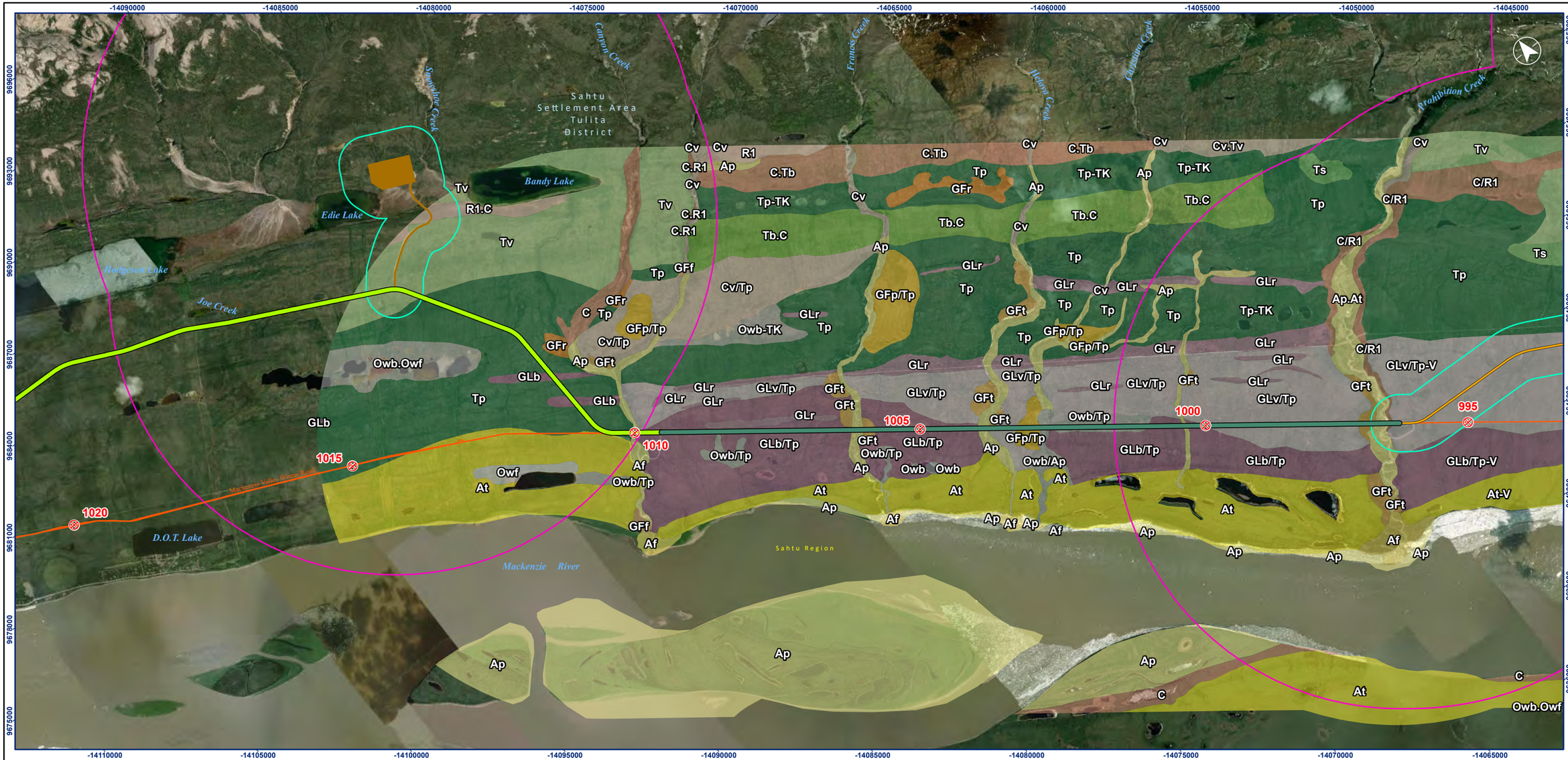
Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

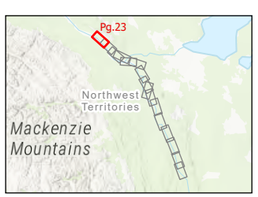
Client/Project
Government of Northwest Territories
Mackenzie Valley Highway Project

144903025-0020 REVB

Figure No.
A.22

Title
RSA Surficial Geology





Surficial Geology

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- Av: Alluvial veneer
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- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Local Study Area
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- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
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Stratigraphic relationship
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0 1 2 Kilometres
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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

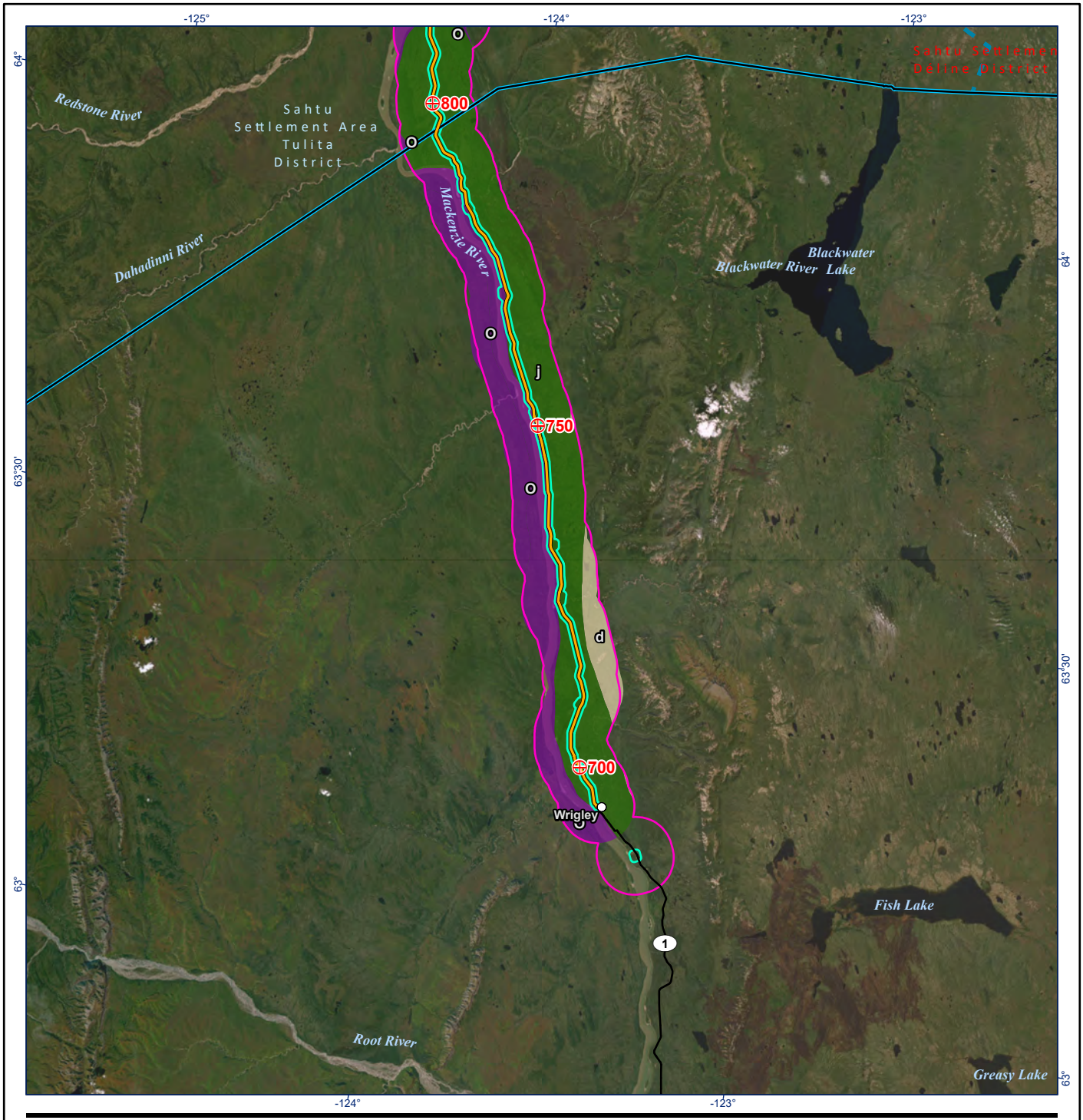
Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

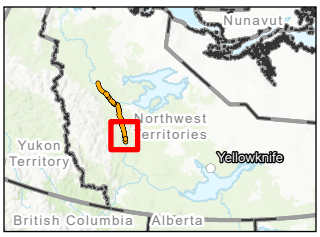
Client/Project
144903025-0020 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.23

Title
RSA Surficial Geology





Soil Classification

- d: Brunisolic Turbic Cryosol
- j: Gleysolic Static Cryosol
- O: Organic Cryosol
- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- District Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:800,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by ZN on 2020-10-25
TR by CS on 2020-12-01

Client/Project
144903025-0028 REVA

Government of Northwest Territories
Mackenzie Valley Highway

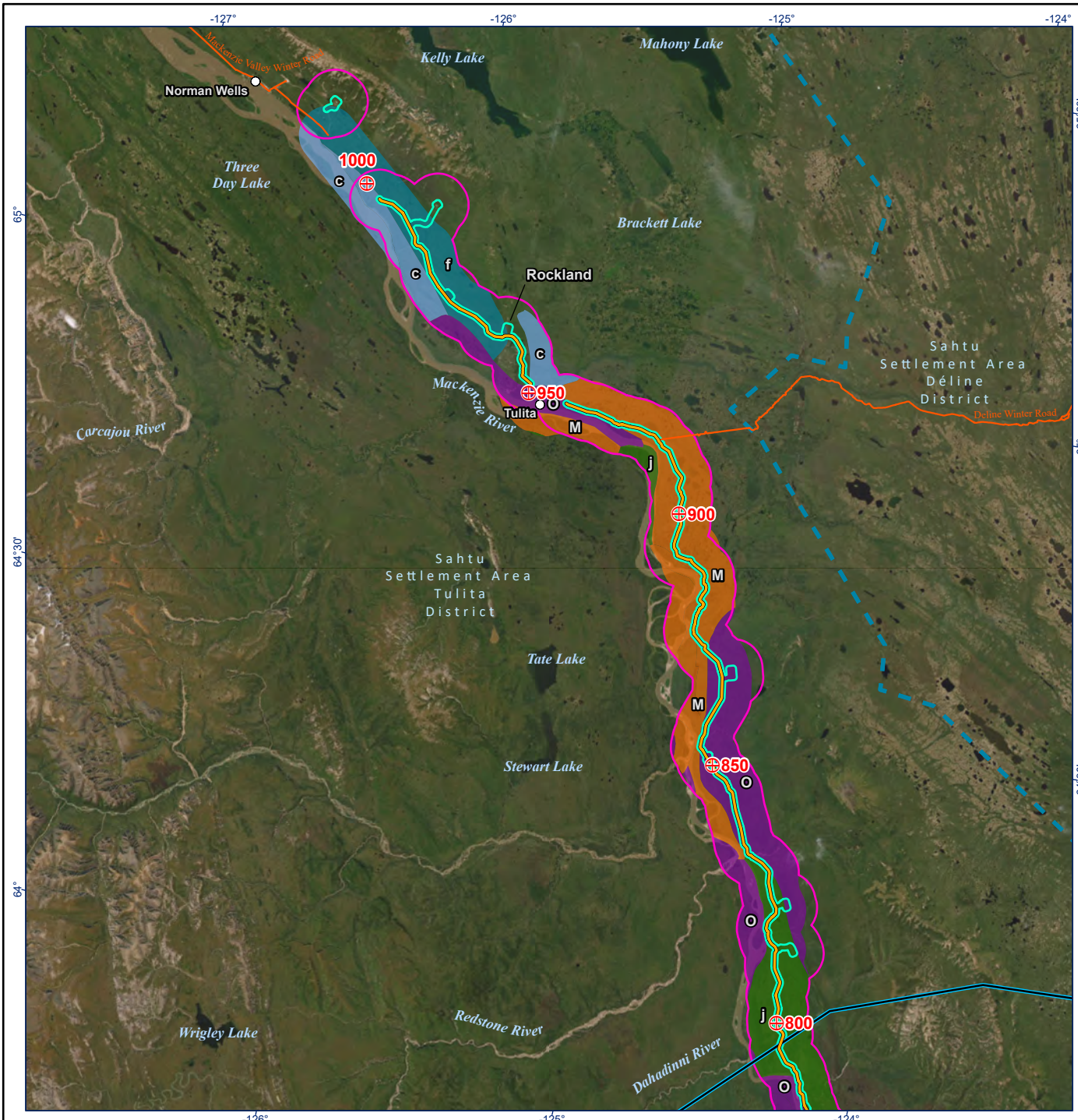
Figure No.
A.24

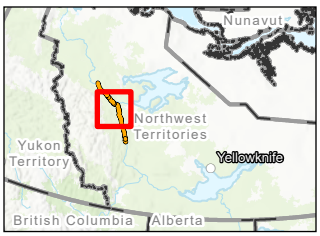
Title
RSA Soils

Notes

1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
4. Soil Mapping: National Soil DataBase, Agriculture and Agri-Food Canada (1996)

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.





Soil Classification

- M: Eutric Brunisol
- j: Gleysolic Static Cryosol
- f: Gleysolic Turbic Cryosol
- O: Organic Cryosol
- c: Orthic Turbic Cryosol
- Mackenzie Valley Highway Kilometre Post

- Mackenzie Valley Highway Extension Project
- Local Study Area
- Regional Study Area
- Community
- Winter Road
- District Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,000,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by ZN on 2020-10-25
TR by CS on 2021-03-31

Client/Project
144903025-0027 REVA

Government of Northwest Territories
Mackenzie Valley Highway

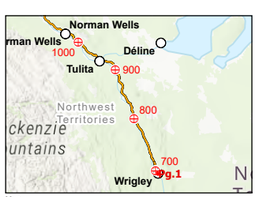
Figure No.
A.25

Title
RSA Soils

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
4. Soil Mapping: National Soil DataBase, Agriculture and Agri-Food Canada (1996)

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

Appendix B LSA Terrain Mapping



Notes
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World Hillshade: Esri, USGS and LiDAR-derived hillshade provided by GNWT
4. Terrain mapping conducted in 2D using available airphotos, ortho-imagery and LiDAR data. Refer to Soils, Terrain and Permafrost TDR for detailed methodology

- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material
- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/	The component in front of the symbol is more extensive than the one that follows
//	The component in front of the symbol is considerably more extensive than the component that follows
^	Geomorphological process initiation zone
A	Active

Geomorphological Process

Permafrost Process

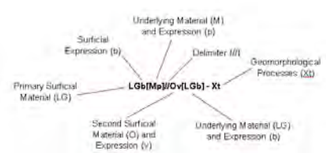
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

1 44903025-0065 REV.A

Figure No.
B.1

Title
LSA Terrain Mapping

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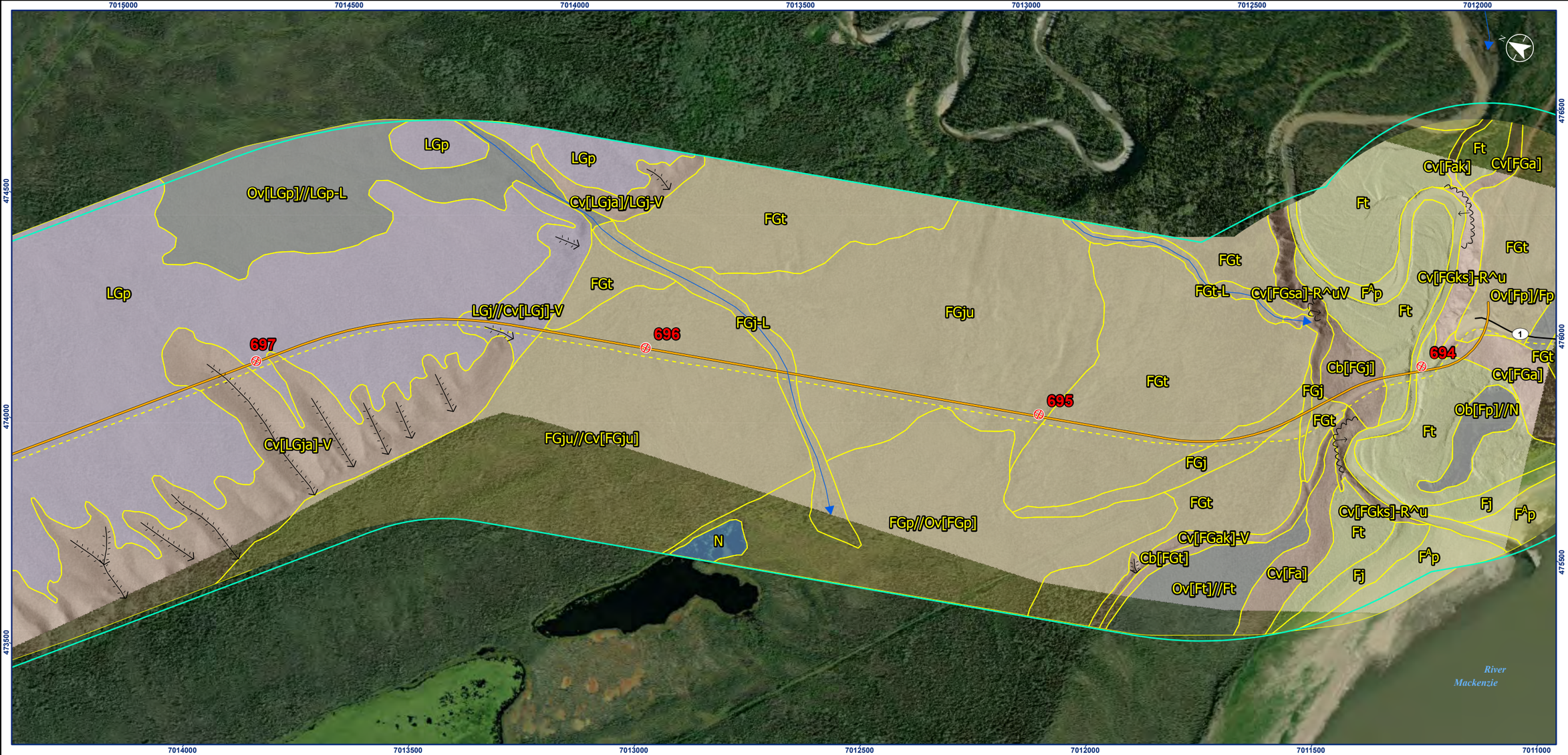

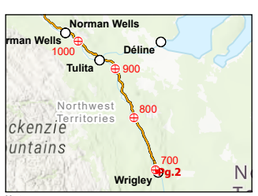

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
// The component in front of the symbol is considerably more extensive than the component that follows
^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

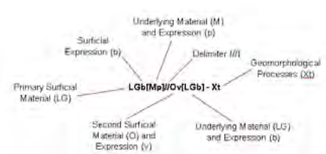
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.2

Title
LSA Terrain Mapping

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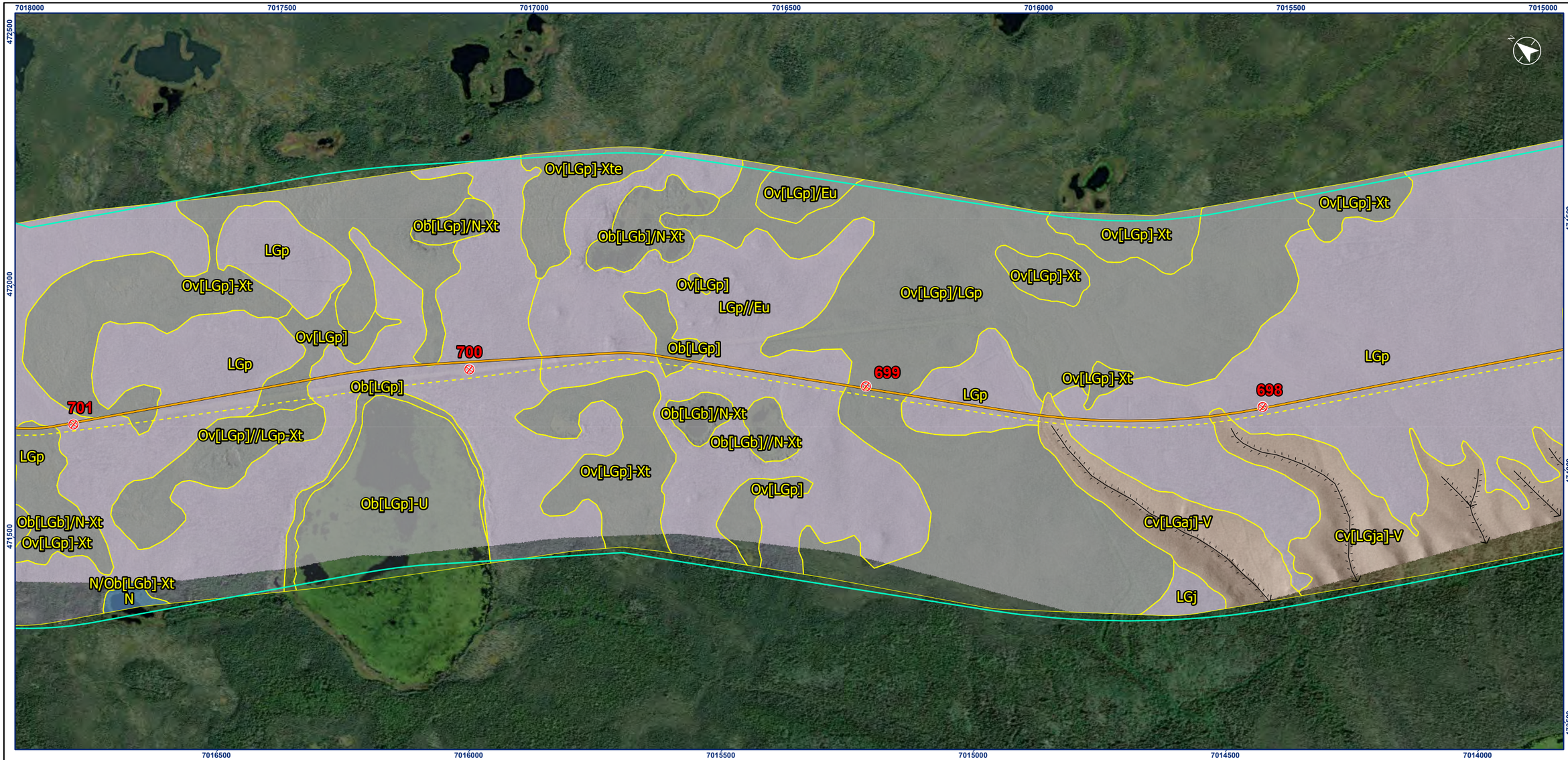

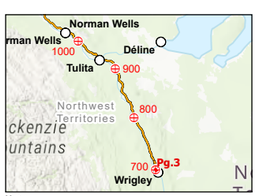

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Moraine Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
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^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

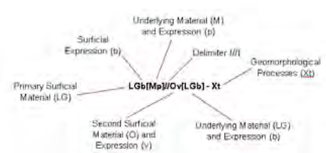
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.3

Title
LSA Terrain Mapping

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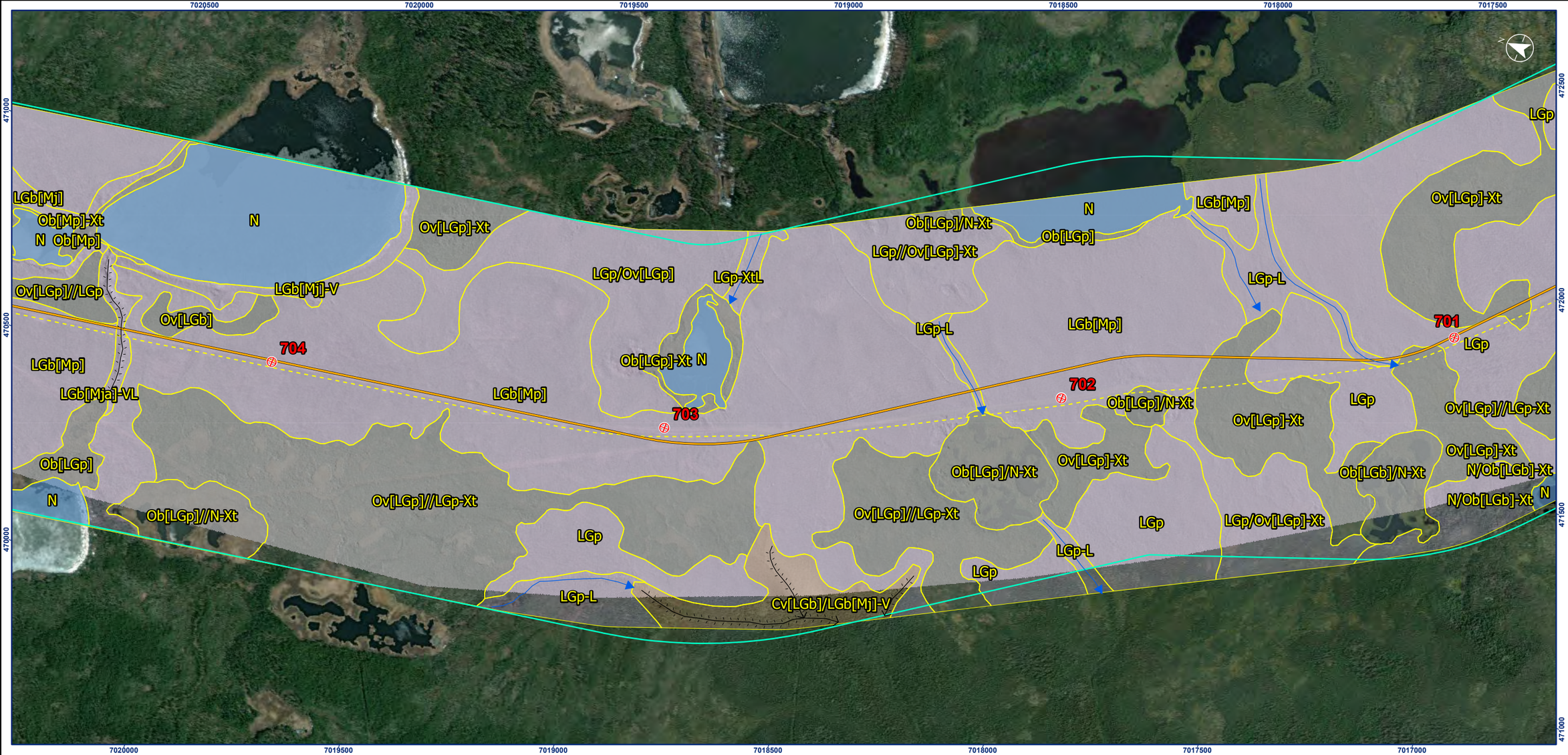

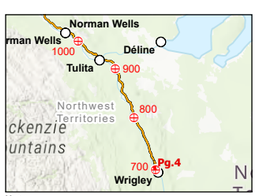

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
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^ Geomorphological process initiation zone
ᴬ Active

Geomorphological Process

Permafrost Process

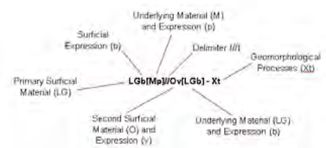
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.4

Title
LSA Terrain Mapping

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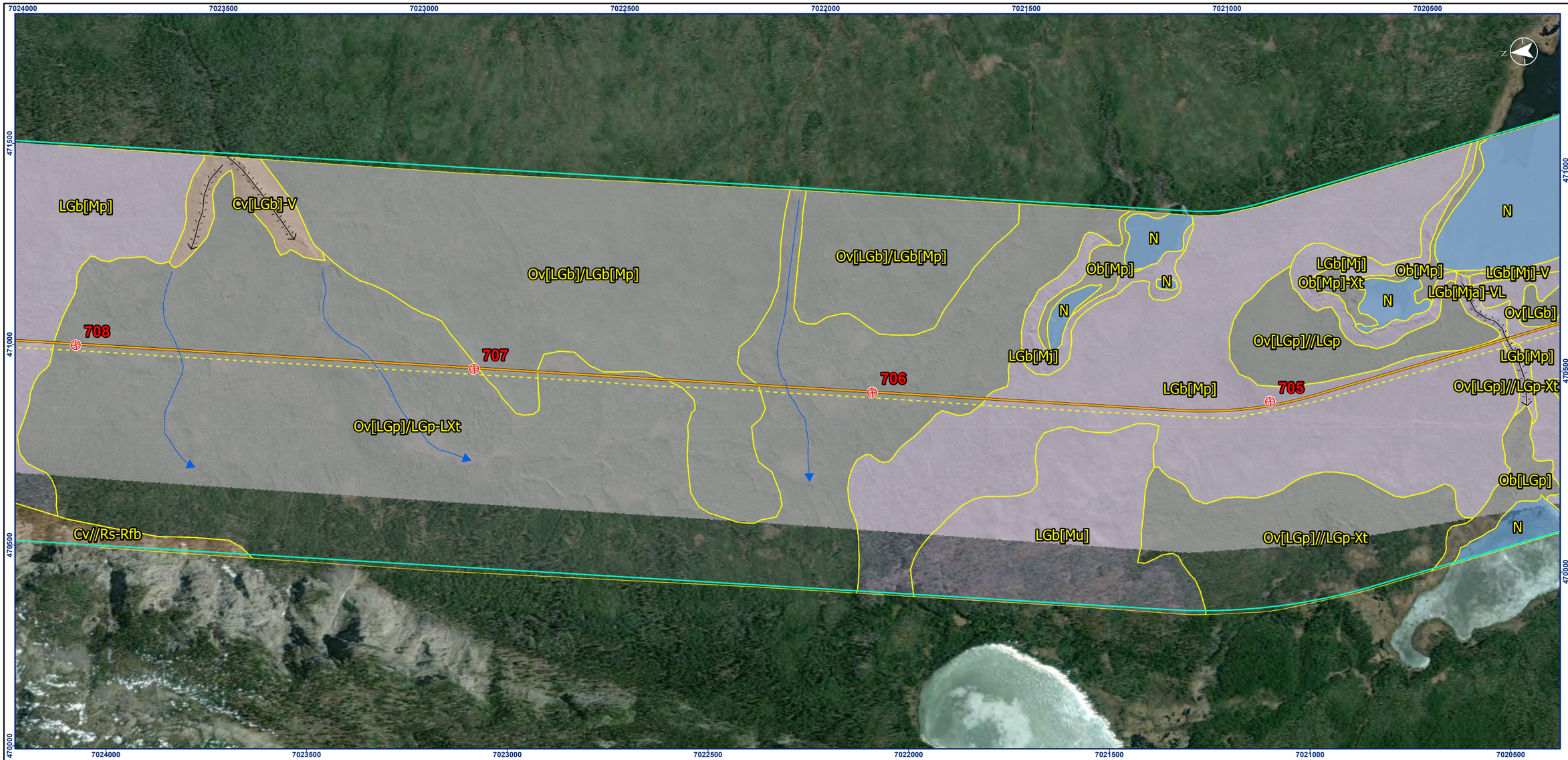

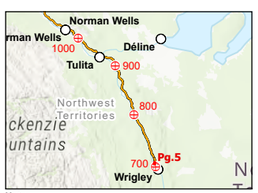

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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ᴬ Active

Geomorphological Process

Permafrost Process

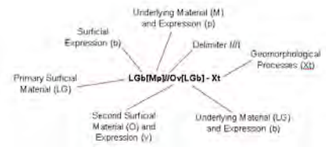
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.5

Title
LSA Terrain Mapping

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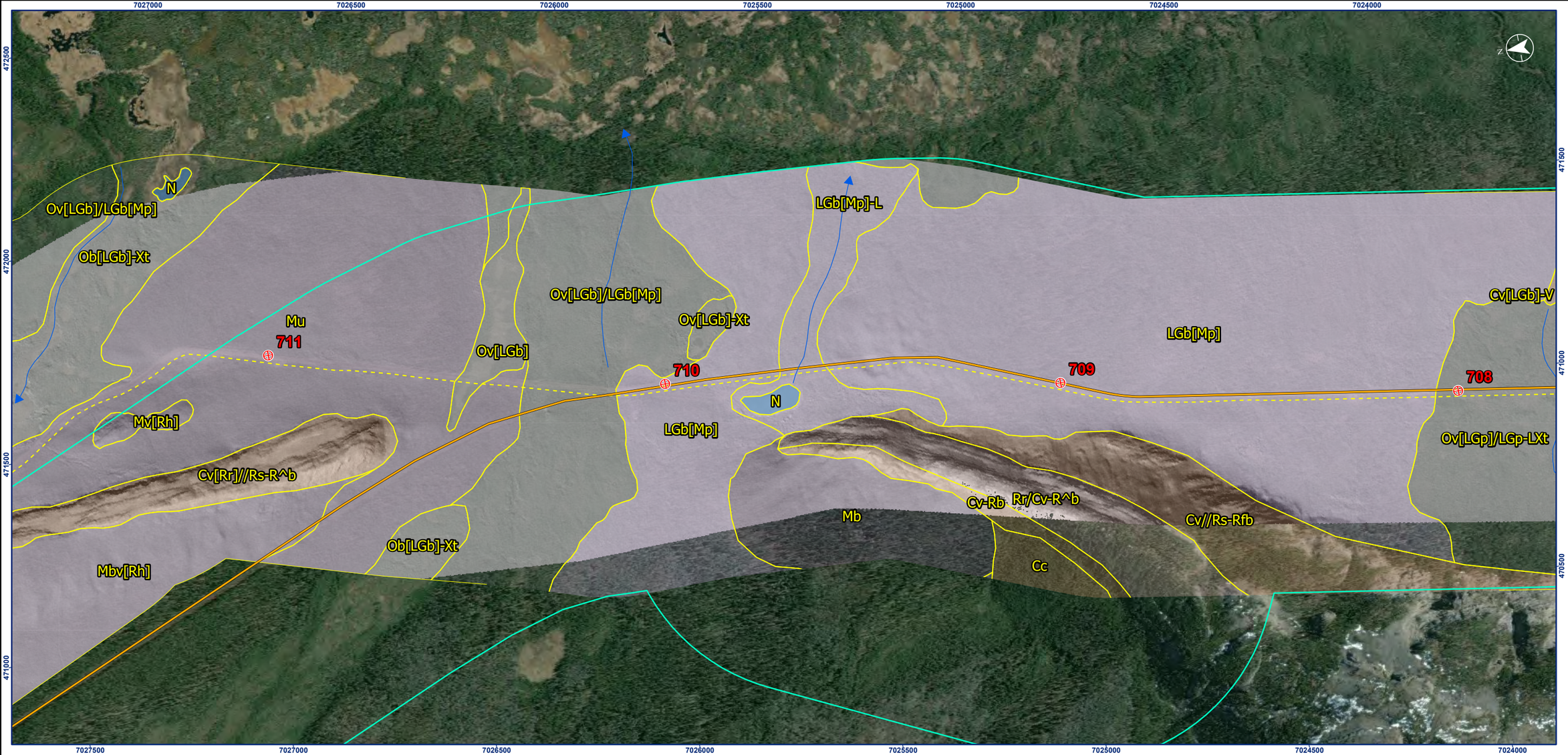

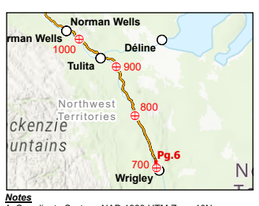

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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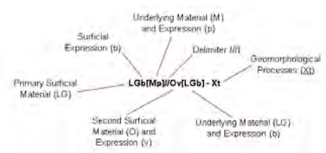
^	Geomorphological process initiation zone
^A	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.6

Title
LSA Terrain Mapping

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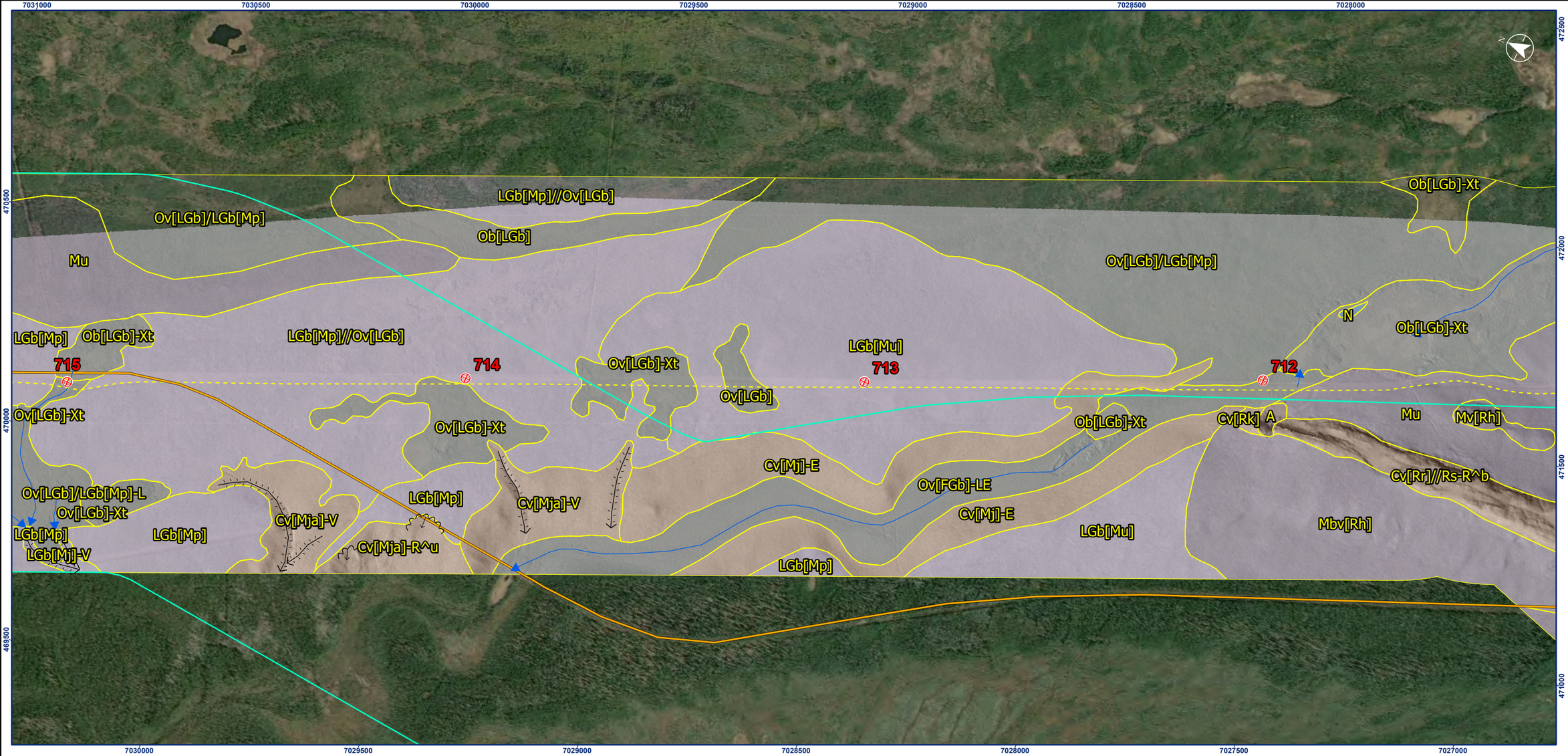

Notes
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World Hillshade: Esri, USGS and LiDAR-derived hillshade provided by GNWT
4. Terrain mapping conducted in 2D using available airphotos, ortho-imagery and LiDAR data. Refer to Soils, Terrain and Permafrost TDR for detailed methodology

- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material
- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

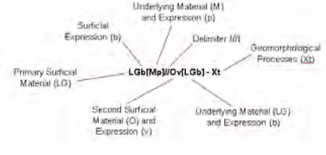
moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/	The component in front of the symbol is more extensive than the one that follows
//	The component in front of the symbol is considerably more extensive than the component that follows
^	Geomorphological process initiation zone
A	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.7

Title
LSA Terrain Mapping

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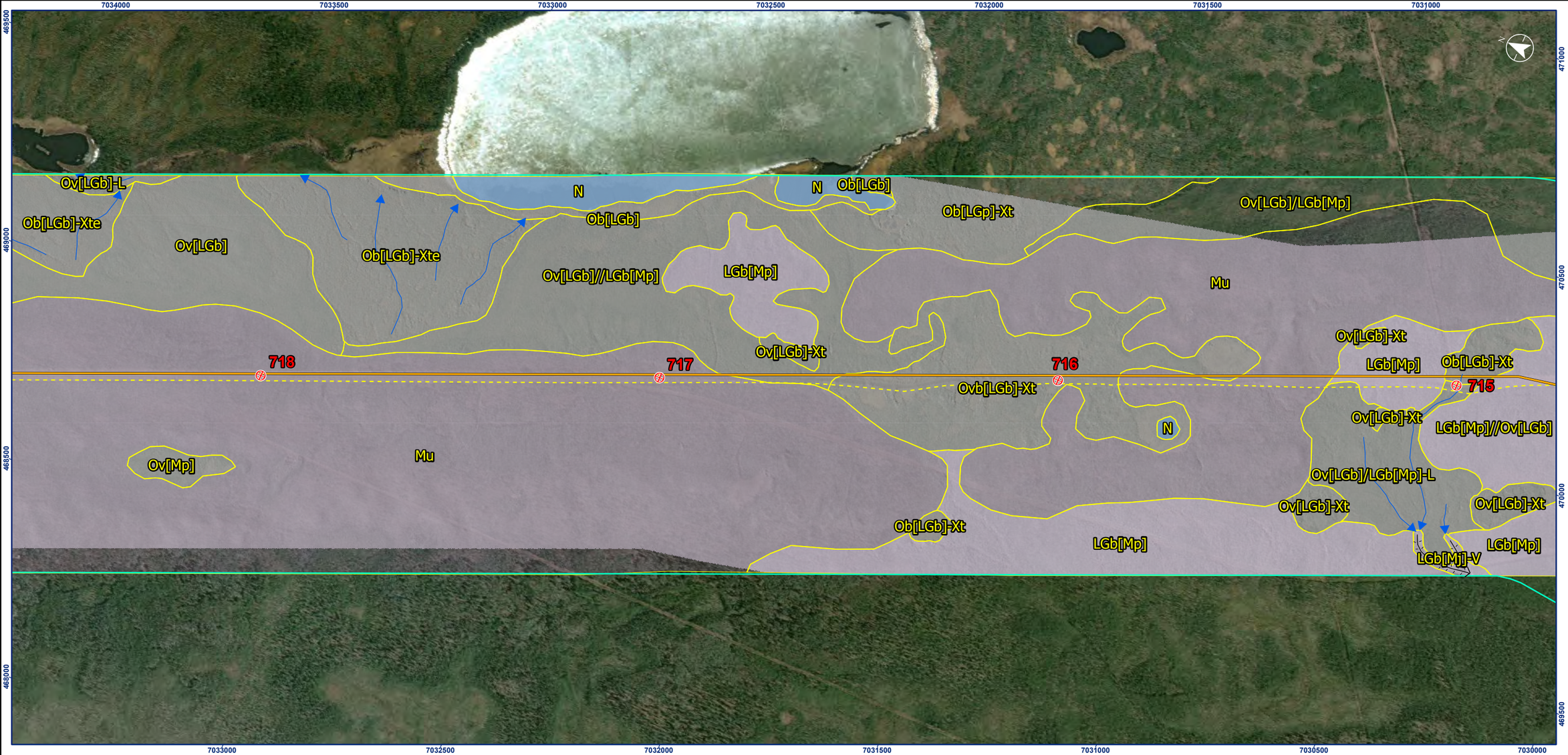

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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ᴬ Active

Geomorphological Process

Permafrost Process

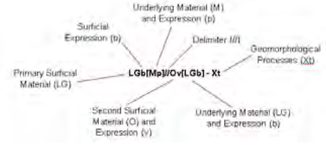
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.8

Title
LSA Terrain Mapping

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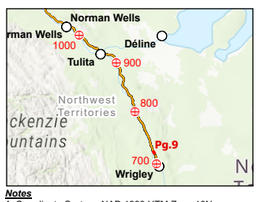

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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A Active

Geomorphological Process

Permafrost Process

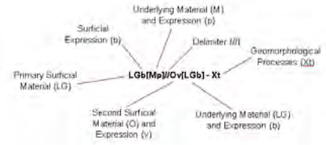
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.9

Title
LSA Terrain Mapping

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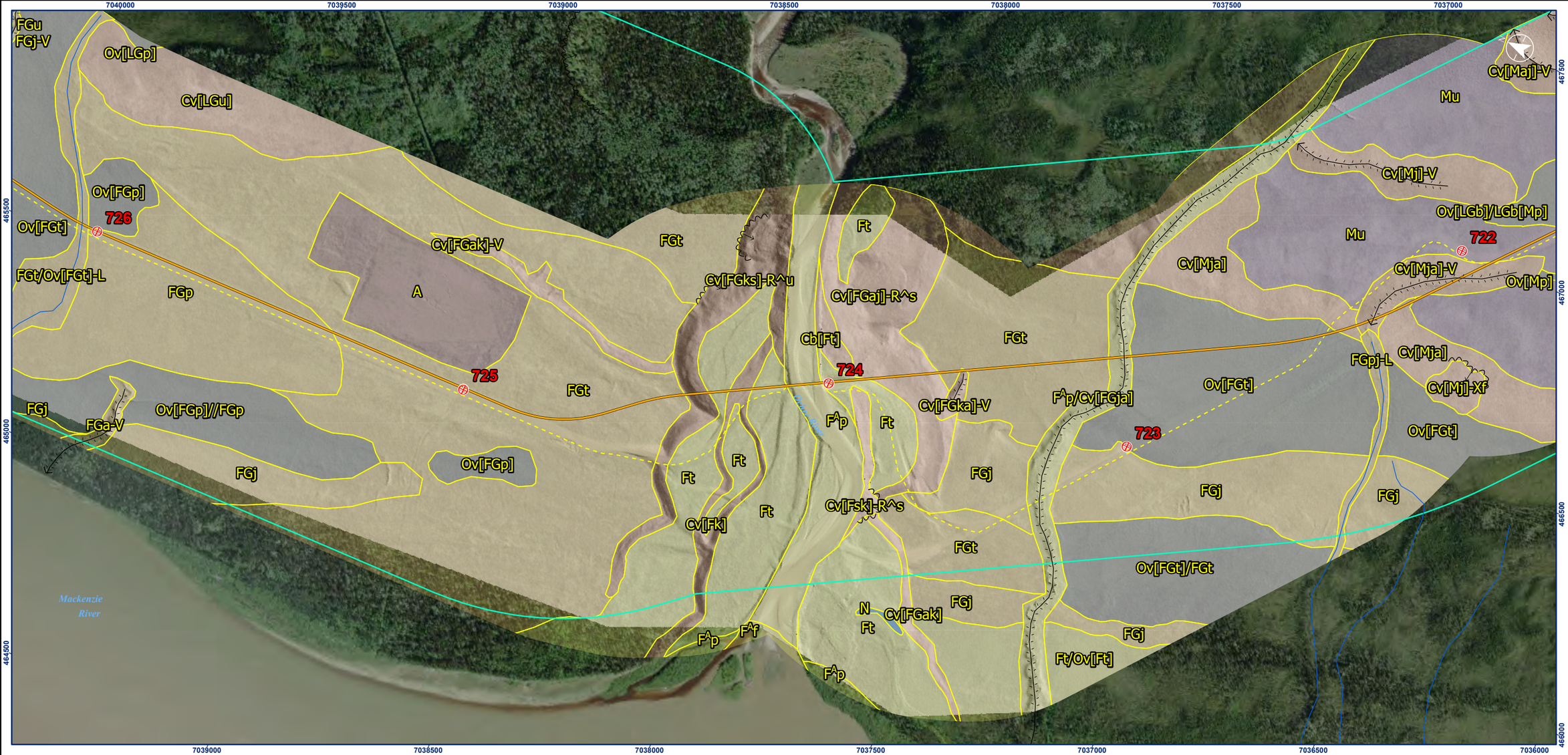

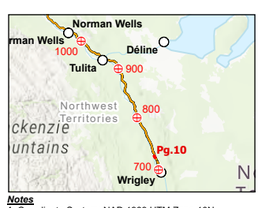

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
ᴬ Active

Geomorphological Process

Permafrost Process

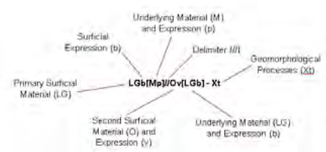
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
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Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.10

Title
LSA Terrain Mapping

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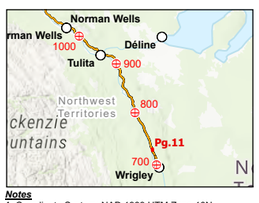

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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A Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V

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Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
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Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.11

Title
LSA Terrain Mapping

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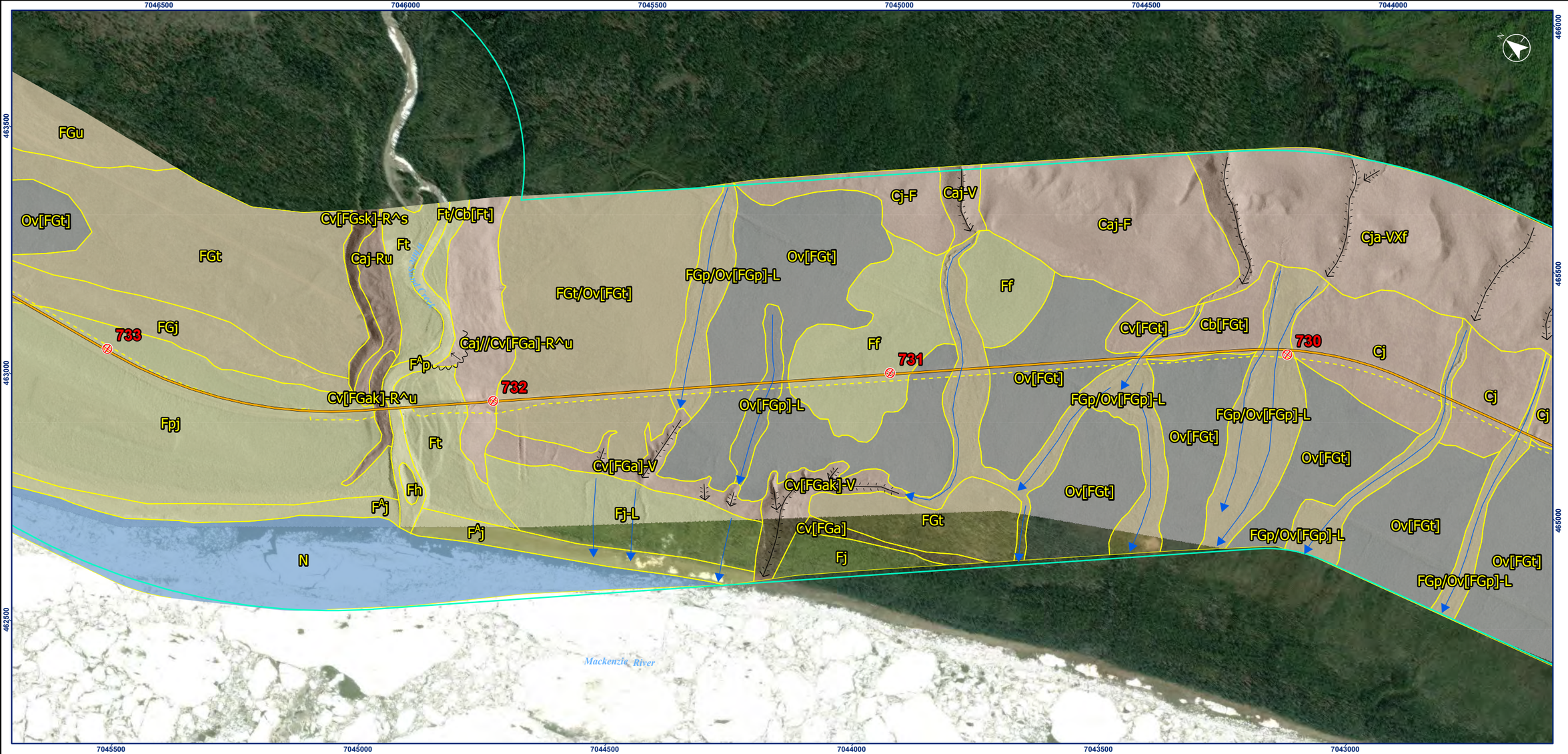

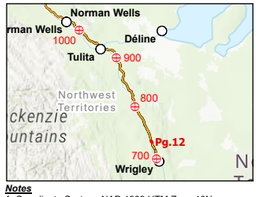

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
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rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

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Geomorphological Process

Permafrost Process

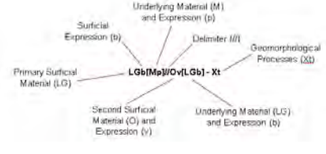
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location

Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project

144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.

B.12

Title

LSA Terrain Mapping

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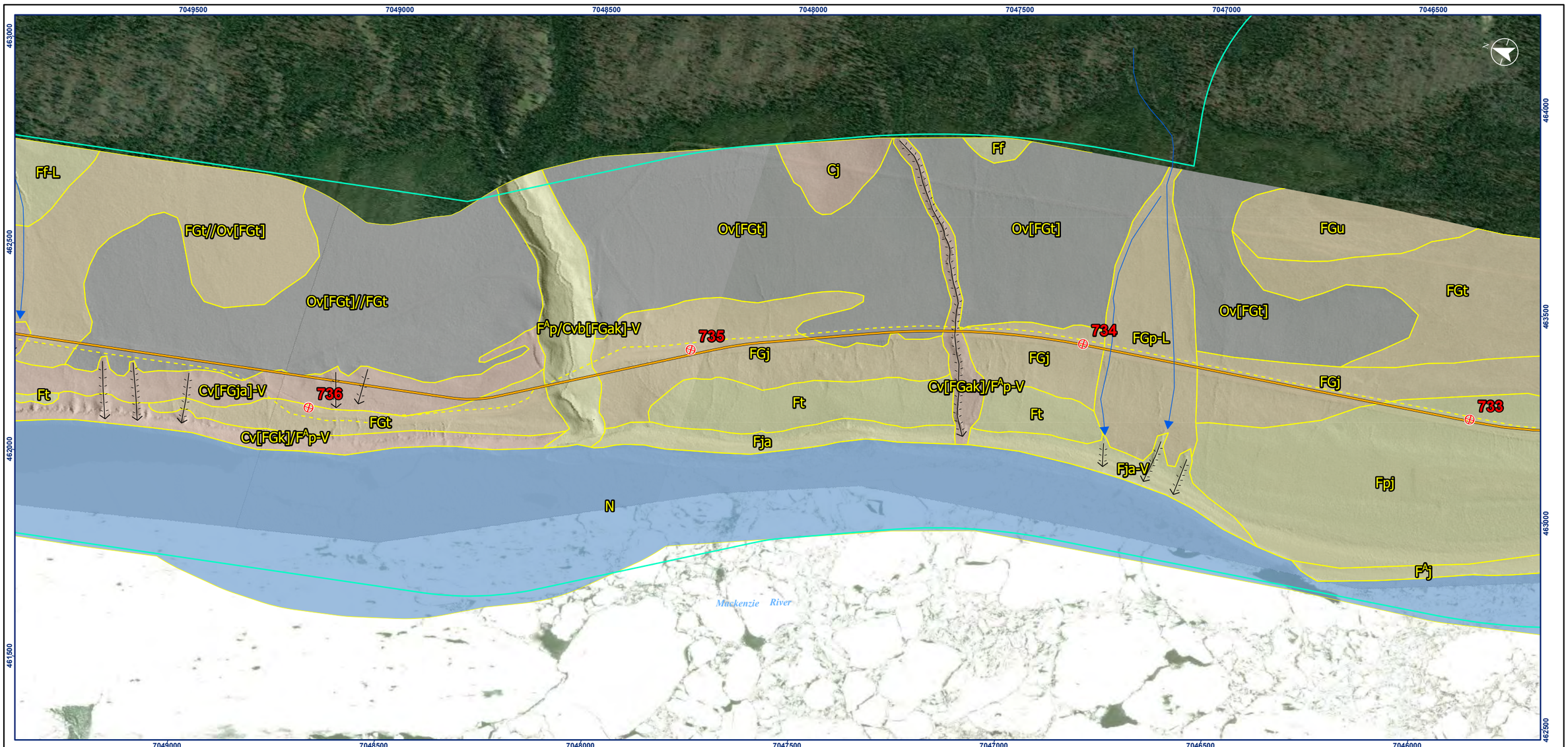

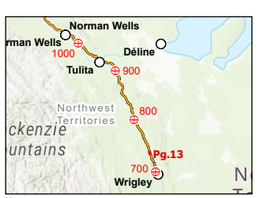

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
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Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

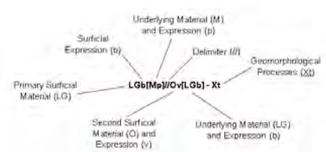
moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/	The component in front of the symbol is more extensive than the one that follows
//	The component in front of the symbol is considerably more extensive than the component that follows
^	Geomorphological process initiation zone
^A	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

1.44903025-0065 REV.A

Figure No.
B.13

Title
LSA Terrain Mapping

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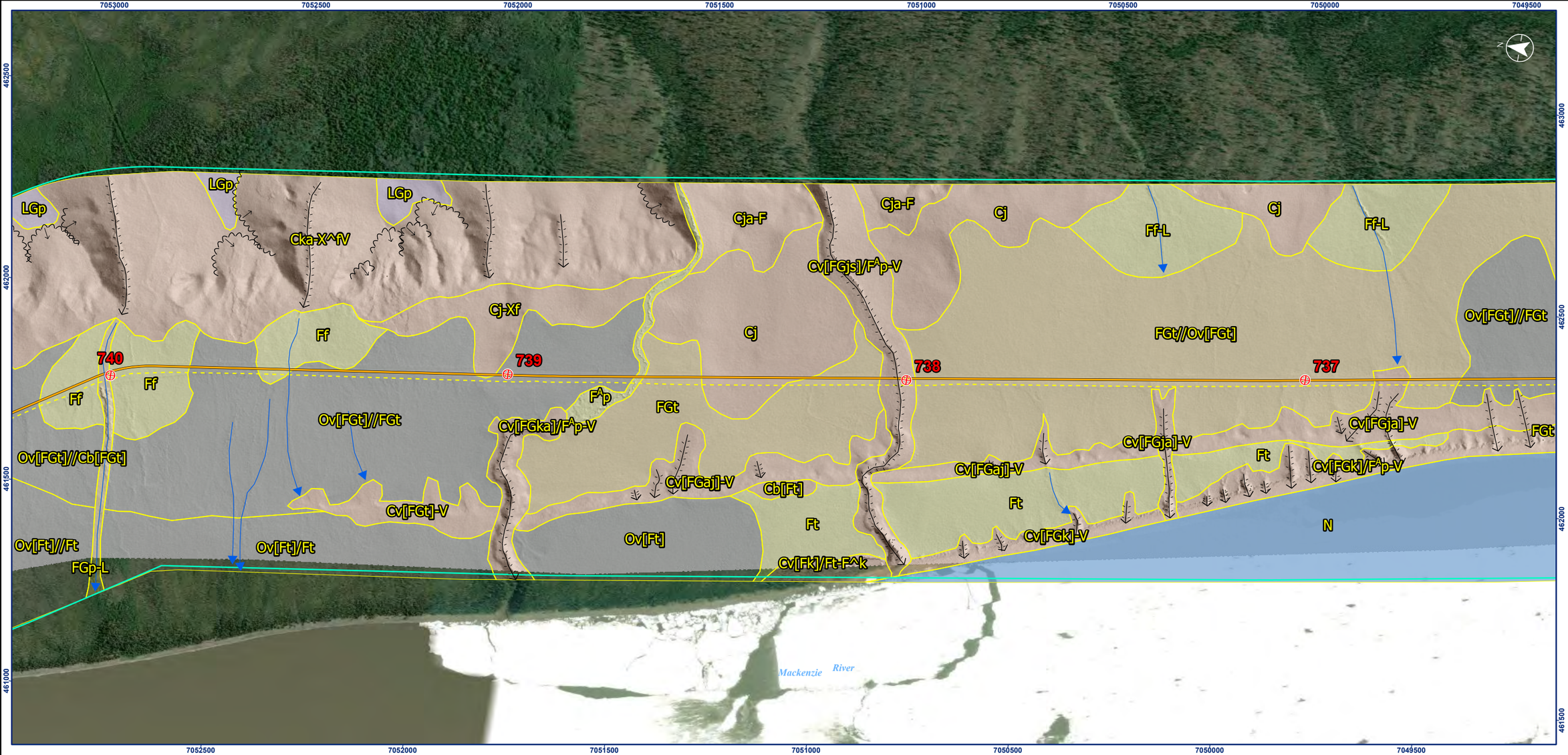

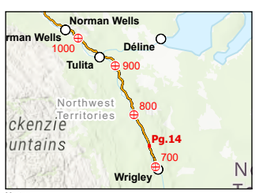

Notes

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4. Terrain mapping conducted in 2D using available airphotos, ortho-imagery and LiDAR data. Refer to Soils, Terrain and Permafrost TDR for detailed methodology

- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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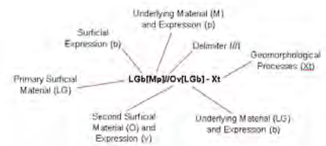
^	Geomorphological process initiation zone
A	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location

Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project

144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.

B.14

Title

LSA Terrain Mapping

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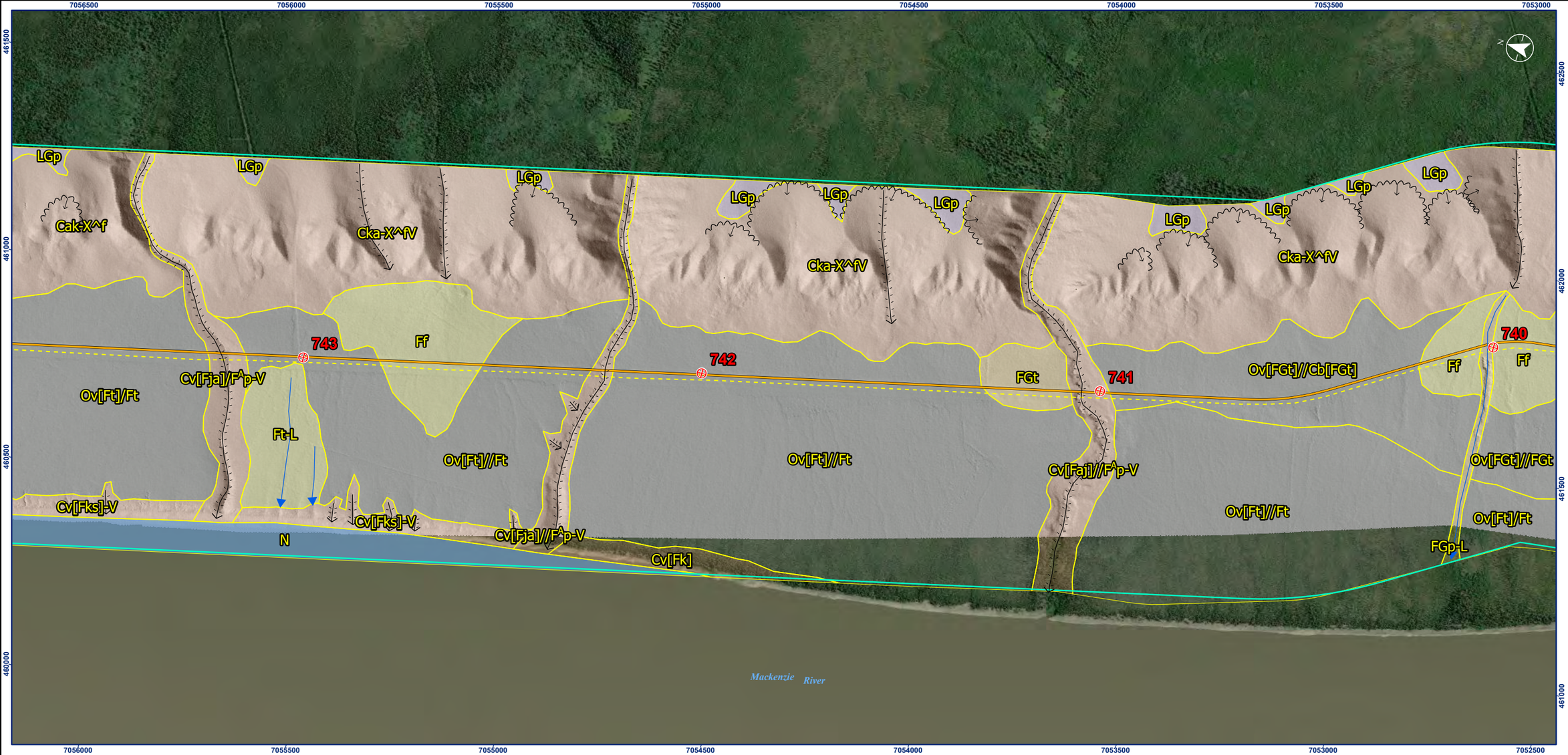

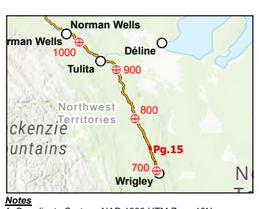

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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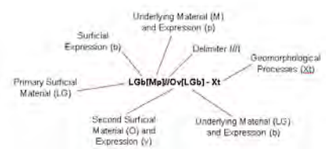
^	Geomorphological process initiation zone
^A	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location

Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project

Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.

B.15

Title

LSA Terrain Mapping

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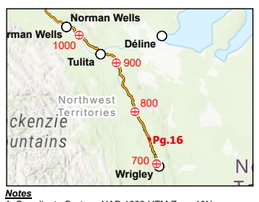

Notes
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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material
- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

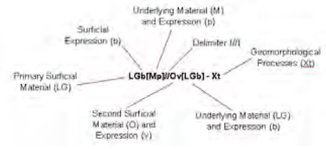
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REV.A

Figure No.
B.16

Title
LSA Terrain Mapping

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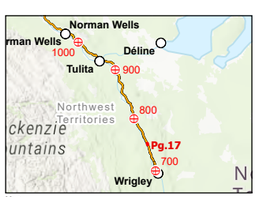

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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A Active

Geomorphological Process

Permafrost Process

Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V

0 0.15 0.3 Kilometres
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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

1449030025-0065 REV.A

Figure No.
B.17

Title
LSA Terrain Mapping

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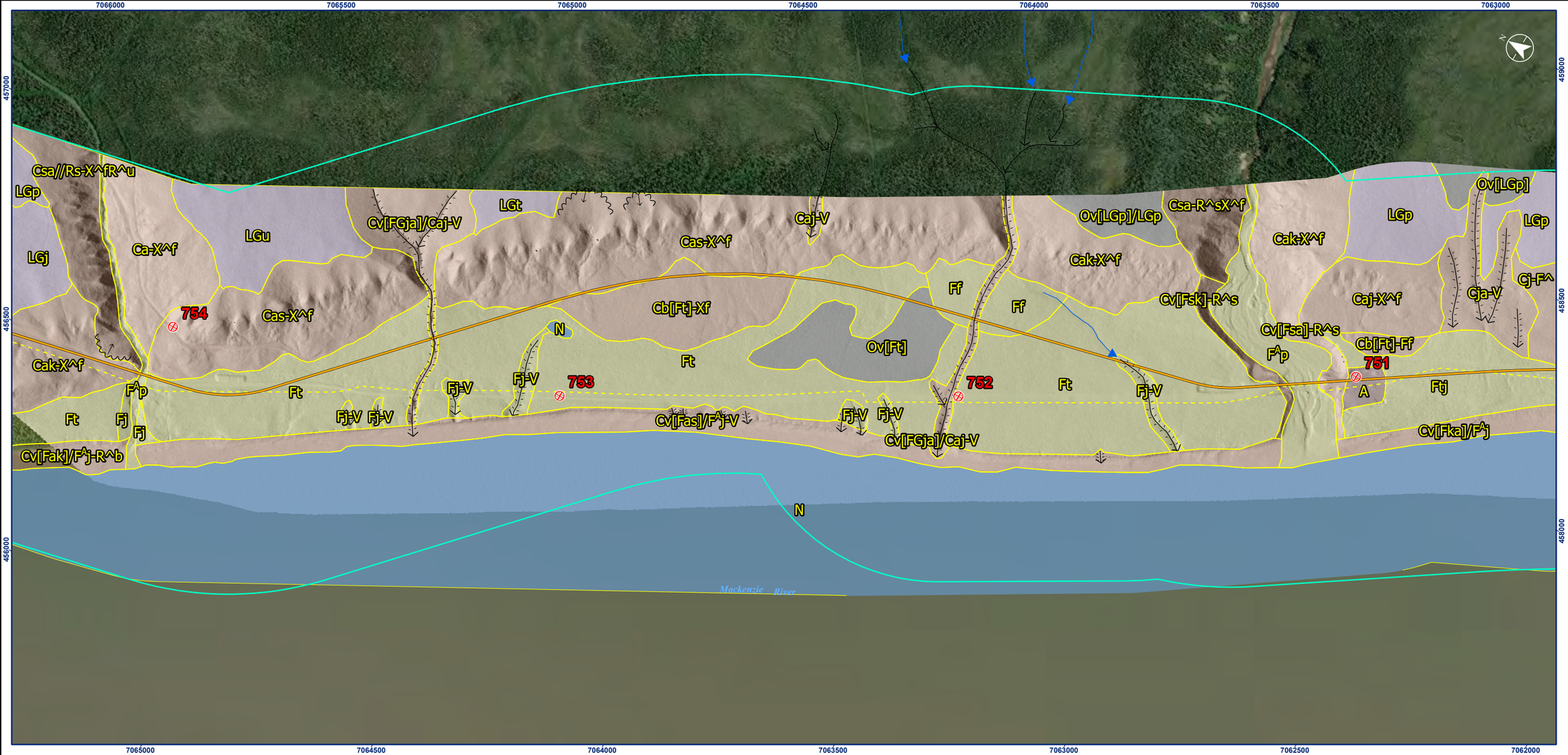

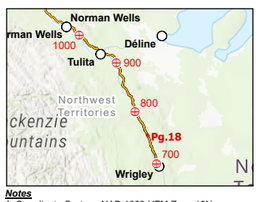

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- Seepage Flow Direction
- Gully
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Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
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- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
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Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
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depression	d
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hummocky	h
gentle slope (6-26%)	j
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rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

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A Active

Geomorphological Process

Permafrost Process

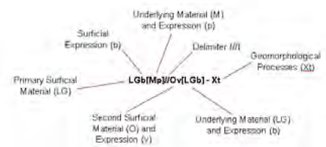
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.18

Title
LSA Terrain Mapping

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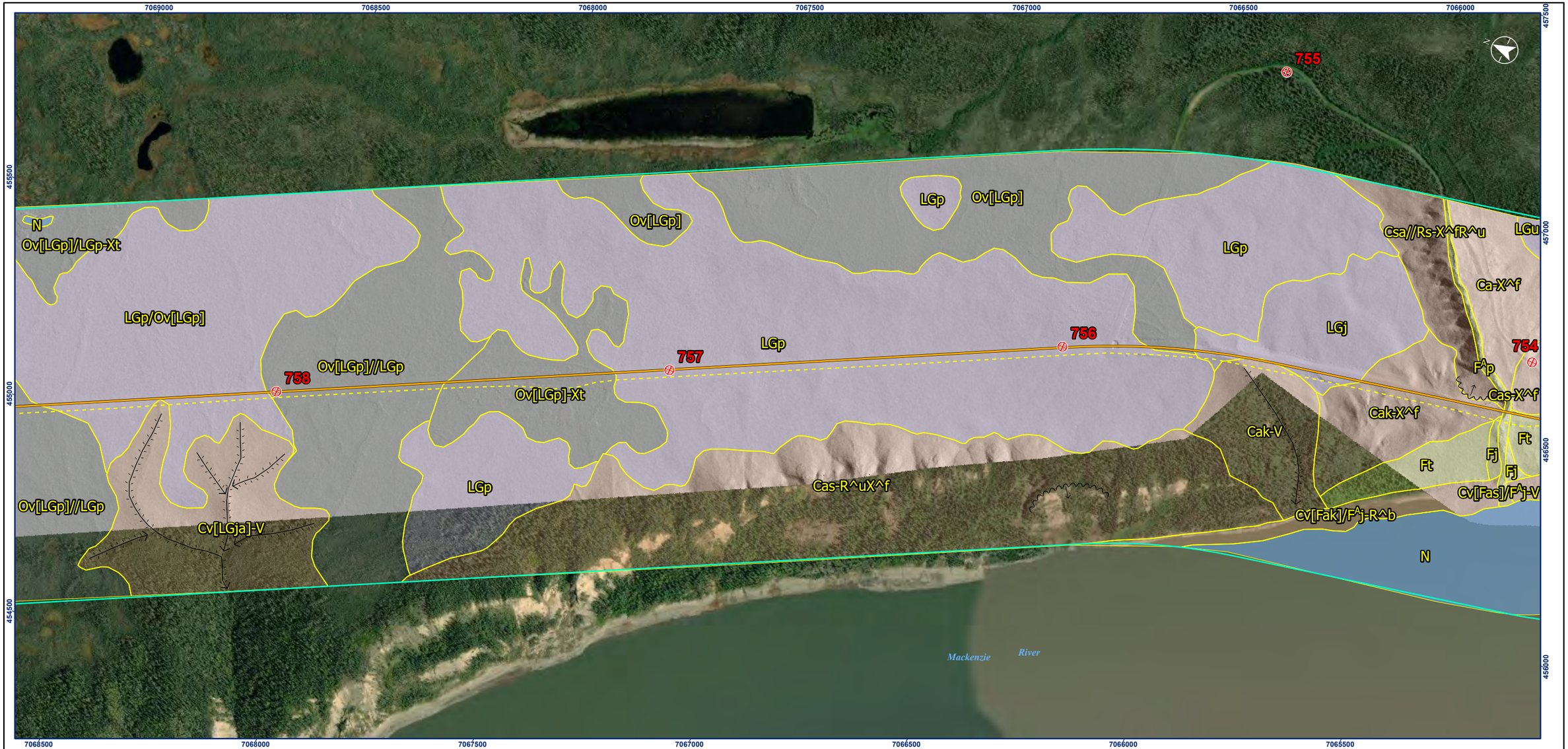

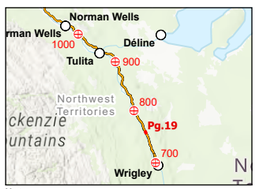

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
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rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

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A Active

Geomorphological Process

Permafrost Process

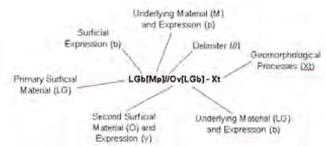
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

1449030025-0065 REVA

Figure No.
B.19

Title
LSA Terrain Mapping

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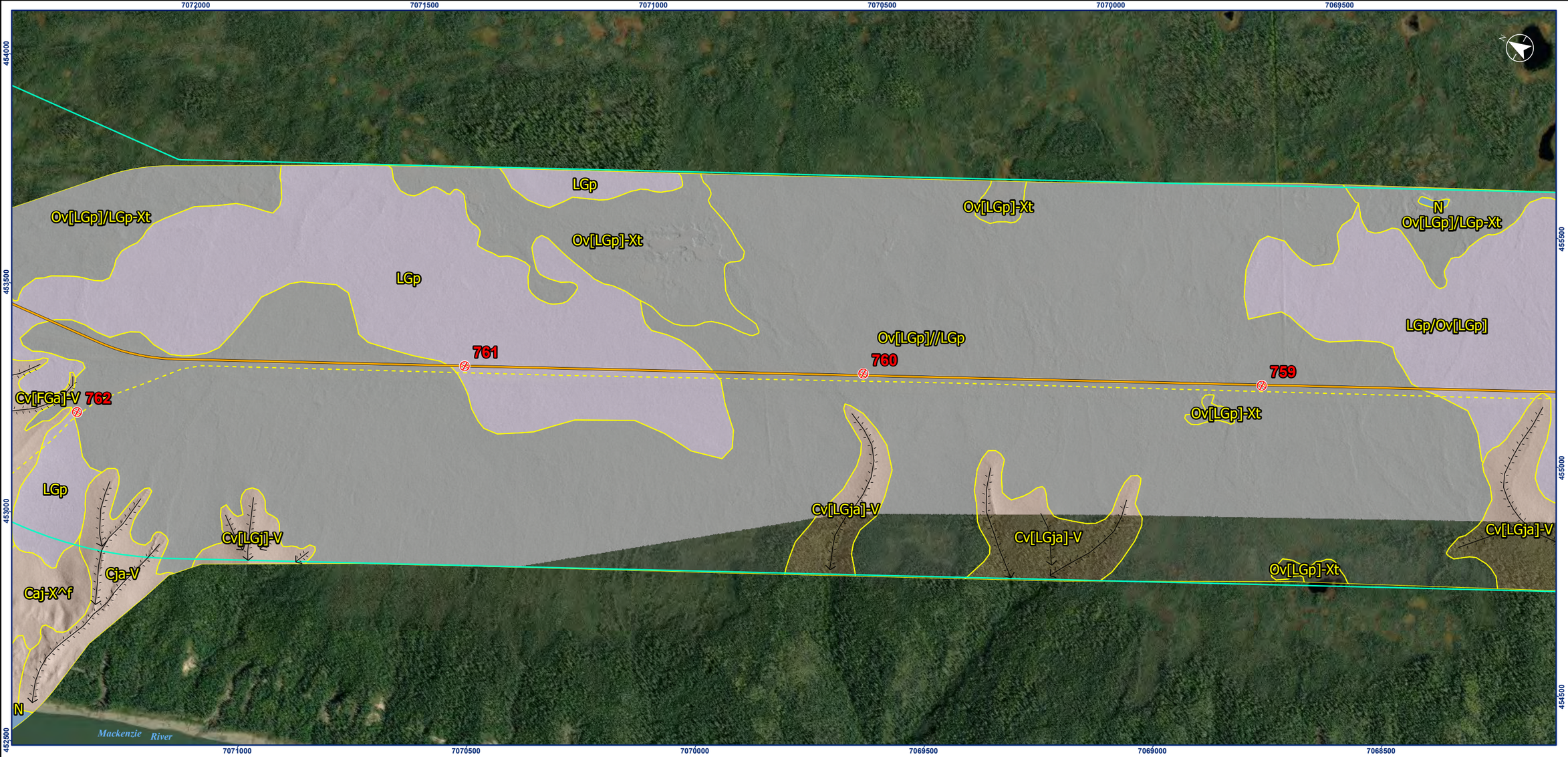

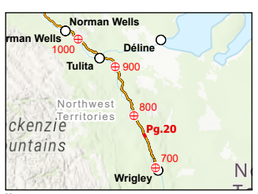

Notes

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3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
World Imagery: Maxar
World Hillshade: Esri, USGS and LiDAR-derived hillshade provided by GNWT
4. Terrain mapping conducted in 2D using available airphotos, ortho-imagery and LiDAR data. Refer to Soils, Terrain and Permafrost TDR for detailed methodology

- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

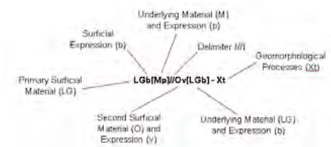
moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
// The component in front of the symbol is considerably more extensive than the component that follows
^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo·Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
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Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.20

Title
LSA Terrain Mapping

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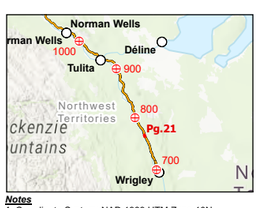

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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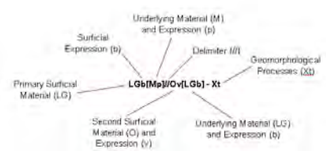
^A	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
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Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.21

Title
LSA Terrain Mapping

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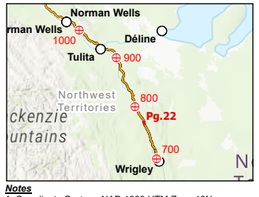

Notes

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4. Terrain mapping conducted in 2D using available airphotos, ortho-imagery and LiDAR data. Refer to Soils, Terrain and Permafrost TDR for detailed methodology

- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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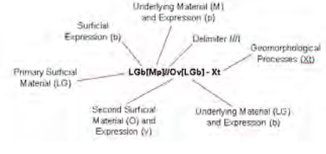
A	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location
Wrigley to Norman Wells, NWT

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Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.22

Title
LSA Terrain Mapping

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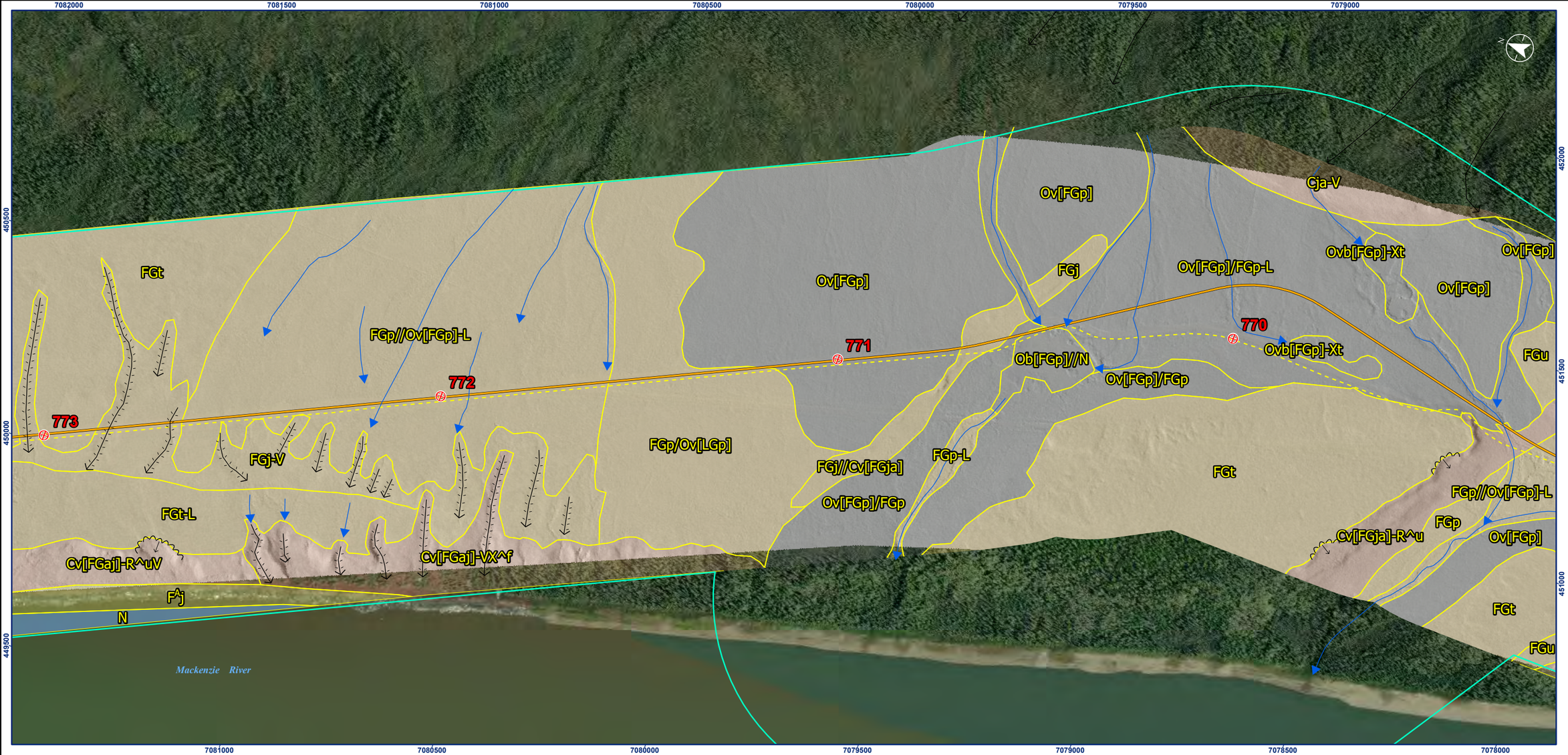

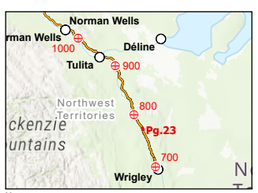

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V

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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

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Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.23

Title
LSA Terrain Mapping

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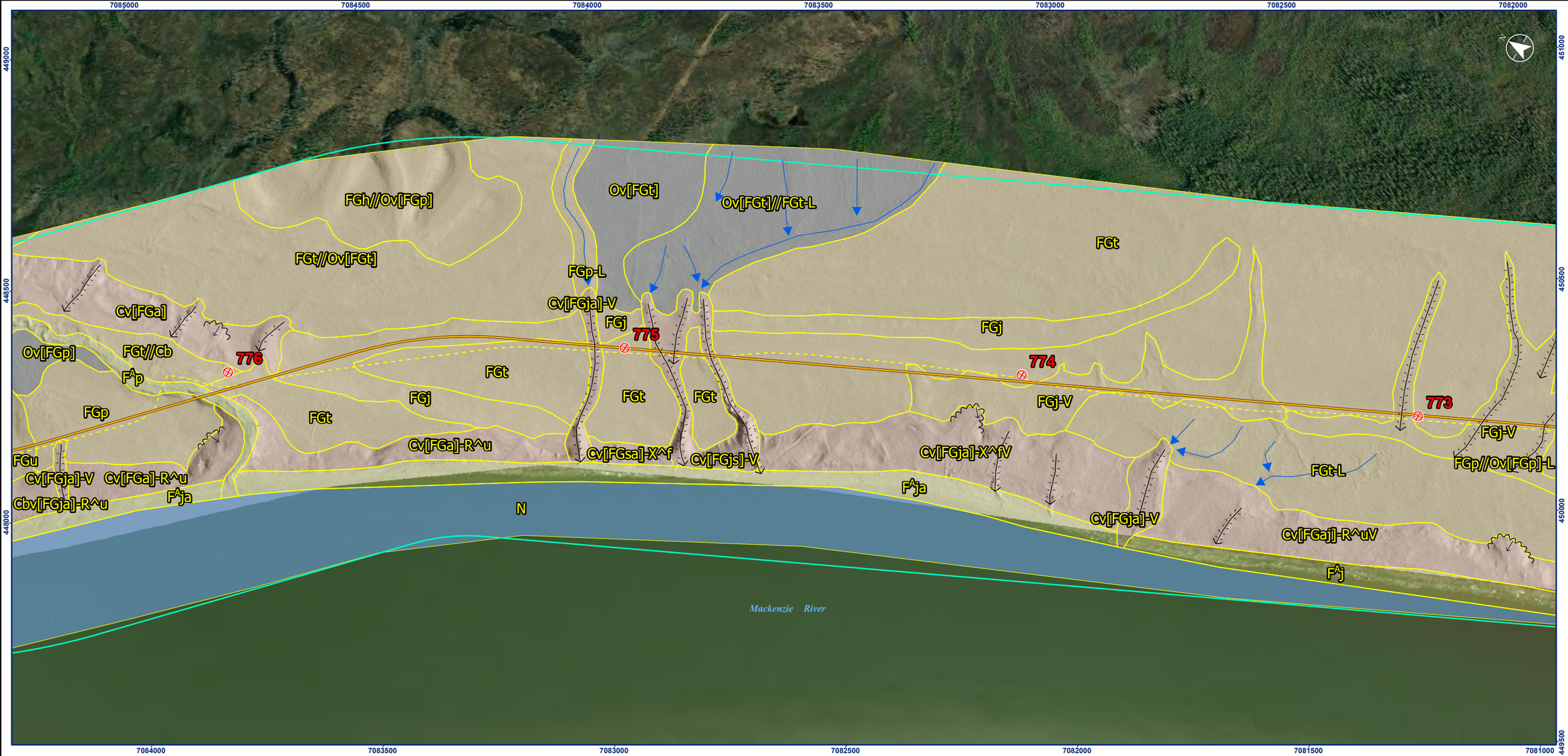

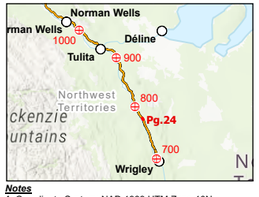

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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A	Active

Geomorphological Process

Permafrost Process

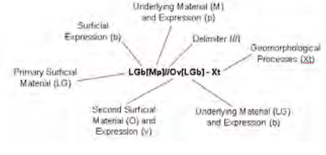
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.24

Title
LSA Terrain Mapping

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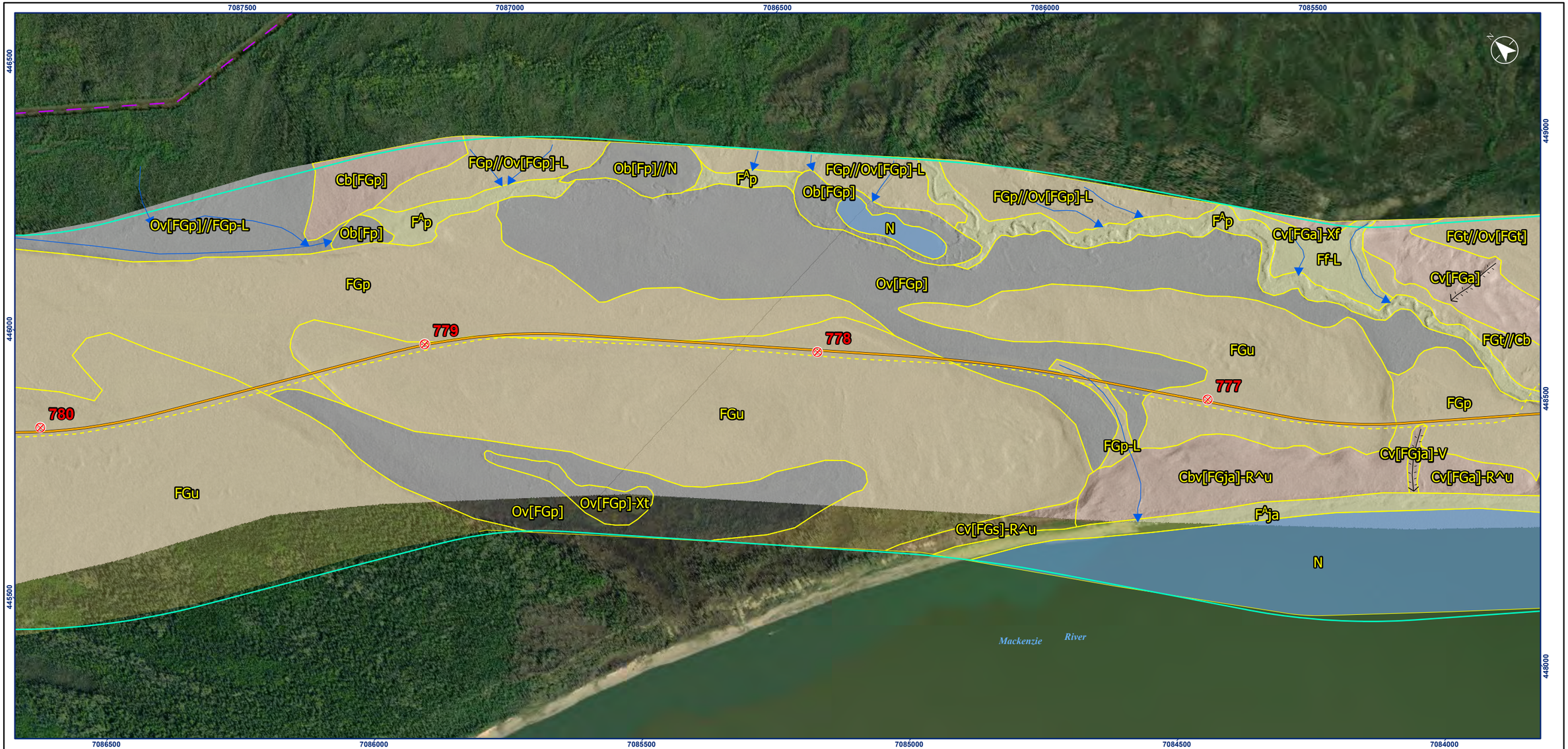

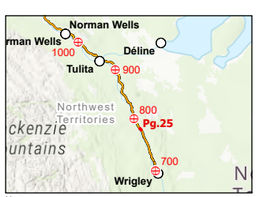

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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A Active

Geomorphological Process

Permafrost Process

Thermokarst	Xt
Thaw flow	Xf
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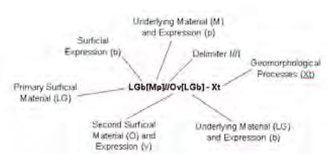
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.25

Title
LSA Terrain Mapping

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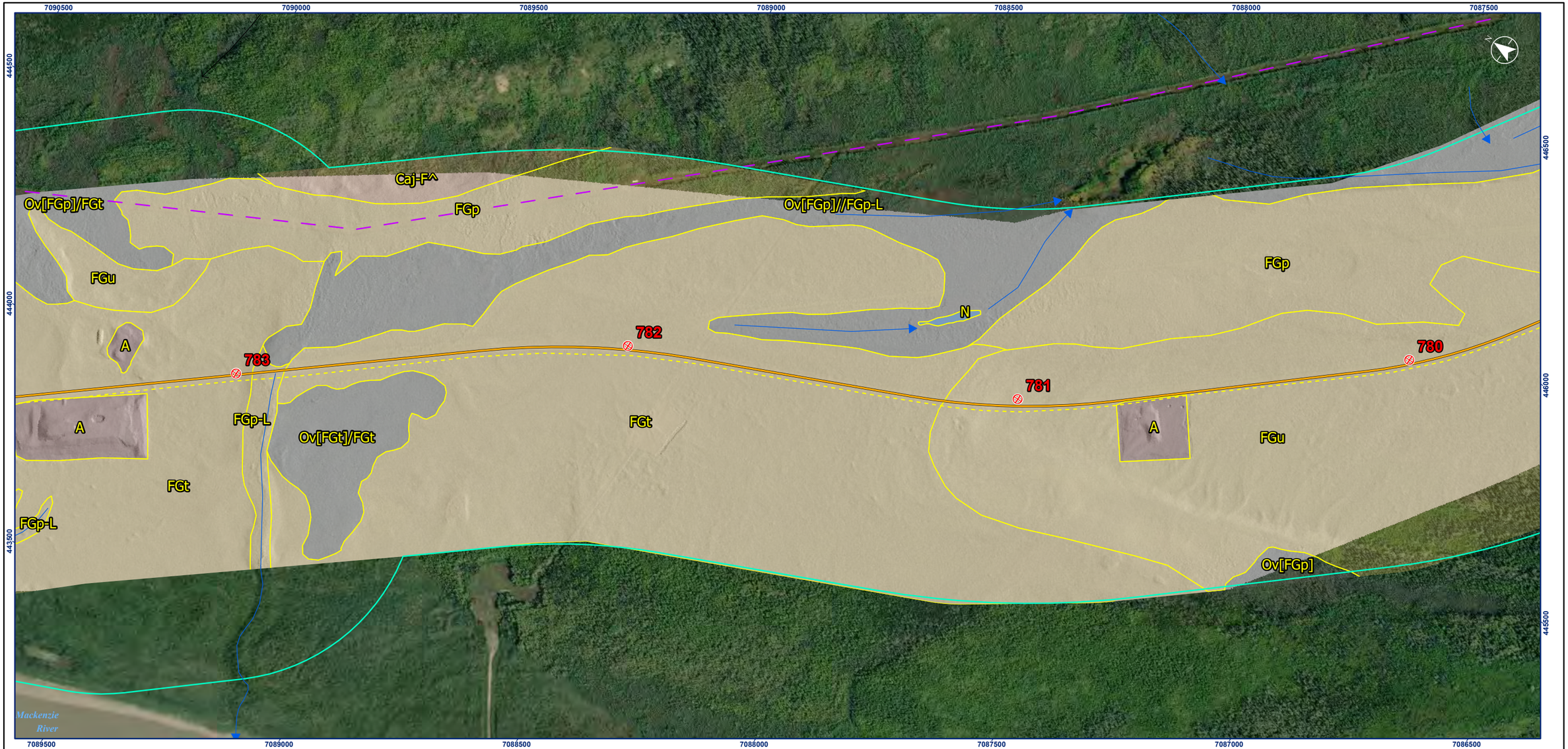

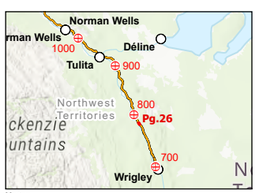

Notes

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World Hillshade: Esri, USGS and LiDAR-derived hillshade provided by GNWT
4. Terrain mapping conducted in 2D using available airphotos, ortho-imagery and LiDAR data. Refer to Soils, Terrain and Permafrost TDR for detailed methodology

- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
// The component in front of the symbol is considerably more extensive than the component that follows
^ Geomorphological process initiation zone
ᴬ Active

Geomorphological Process

Permafrost Process

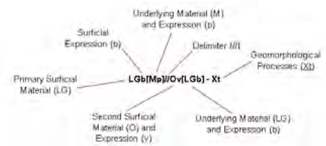
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.26

Title
LSA Terrain Mapping

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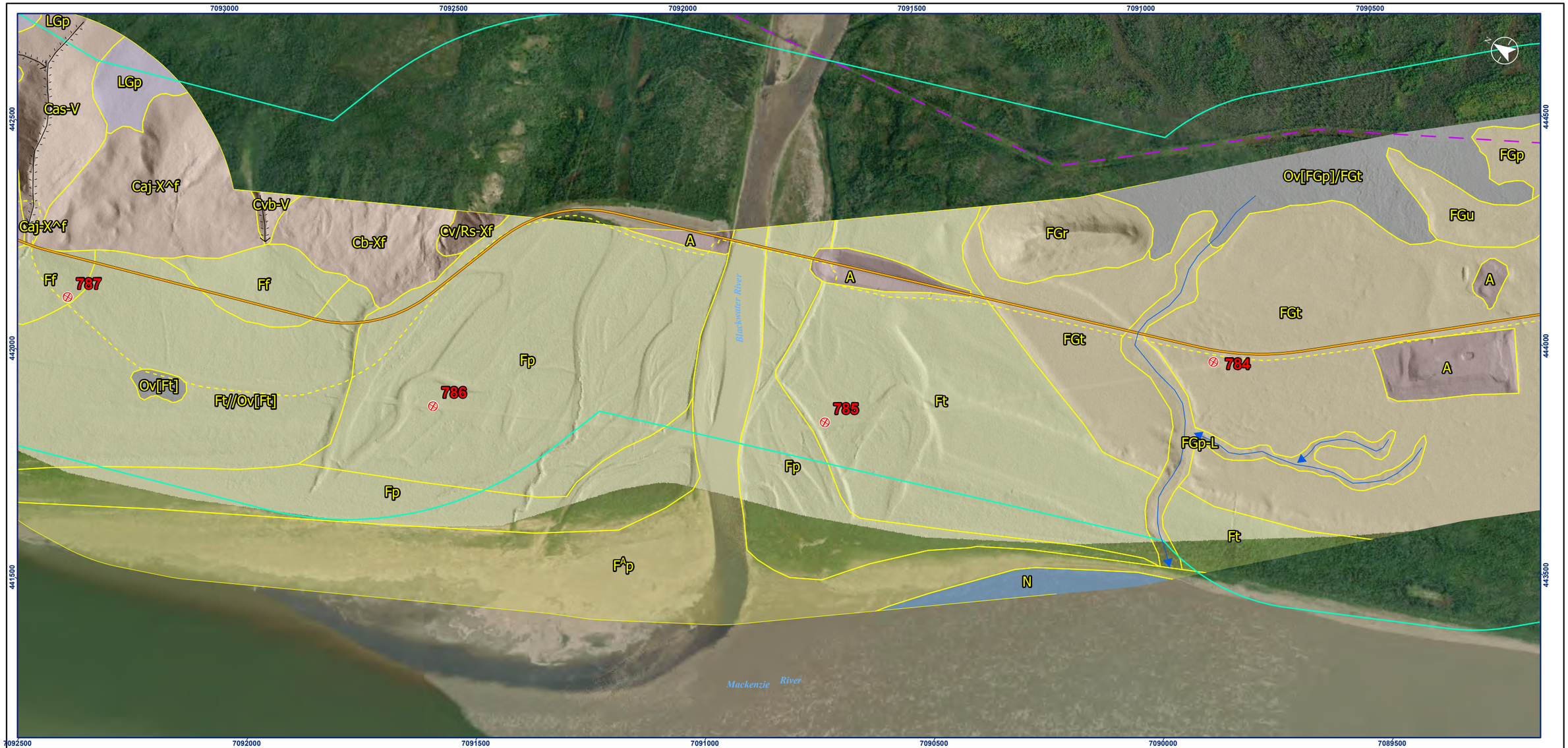

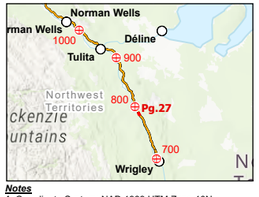

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Moraine Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
// The component in front of the symbol is considerably more extensive than the component that follows
^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

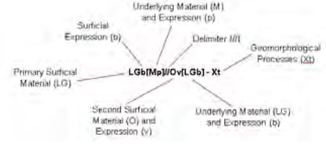
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.27

Title
LSA Terrain Mapping

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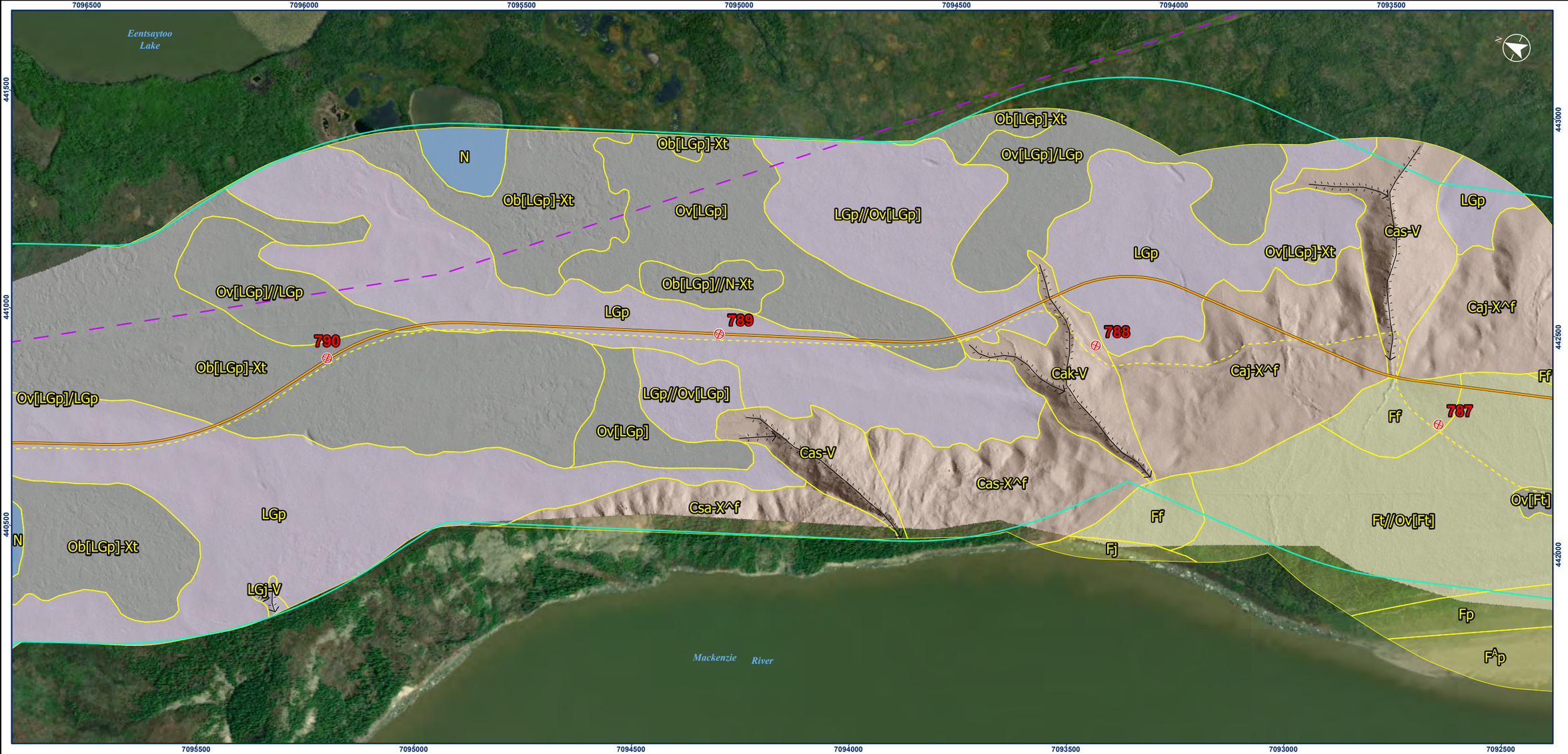

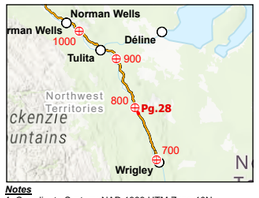

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/	The component in front of the symbol is more extensive than the one that follows
//	The component in front of the symbol is considerably more extensive than the component that follows
^	Geomorphological process initiation zone
A	Active

Geomorphological Process

Permafrost Process

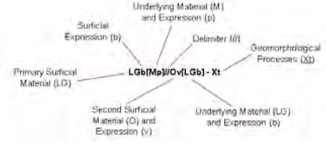
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location

Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project

144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.

B.28

Title

LSA Terrain Mapping

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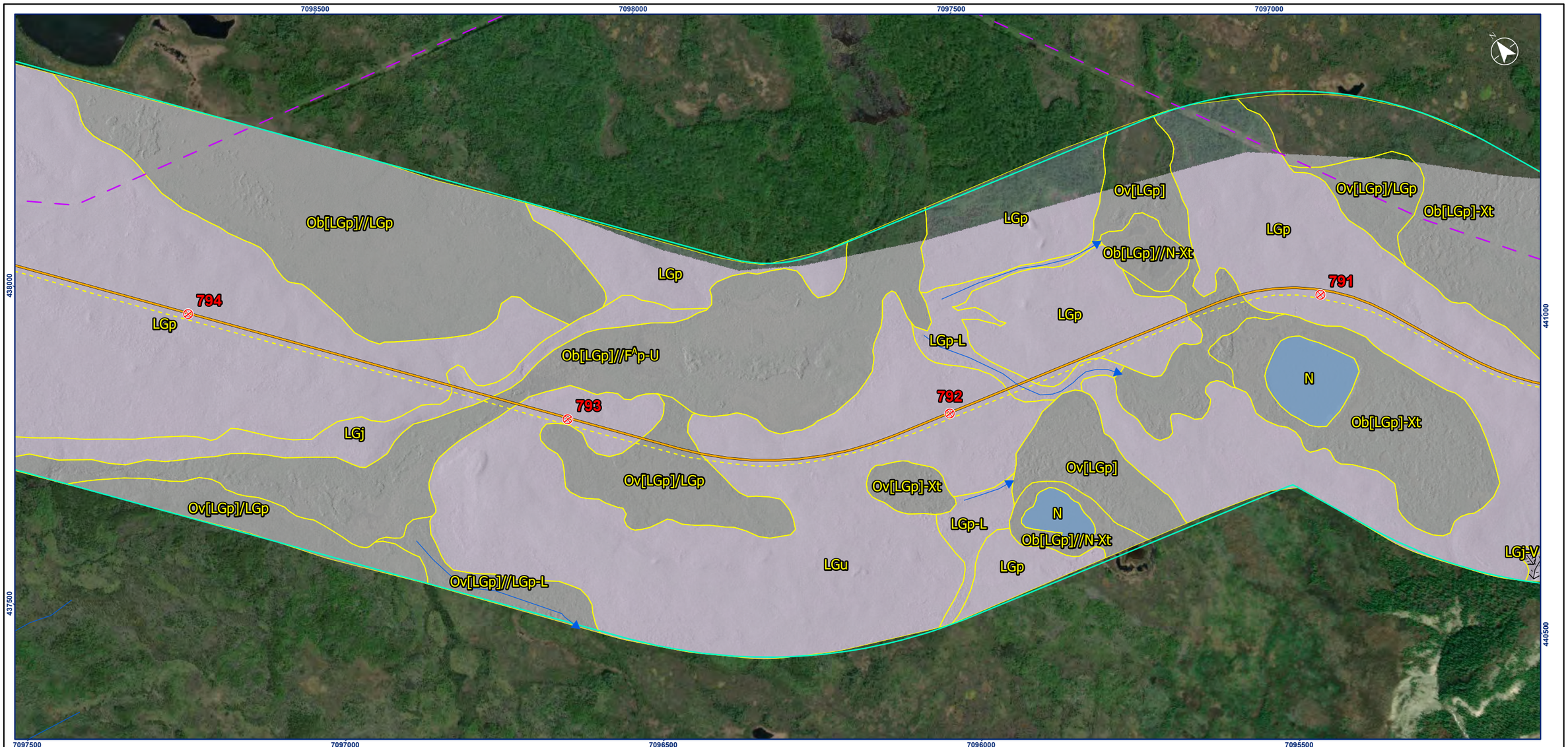

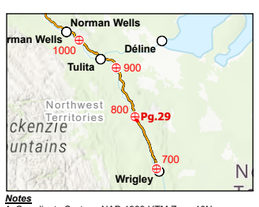

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
^A Active

Geomorphological Process

Permafrost Process

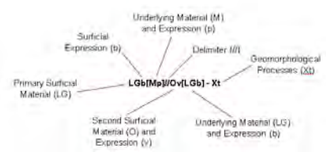
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.29

Title
LSA Terrain Mapping

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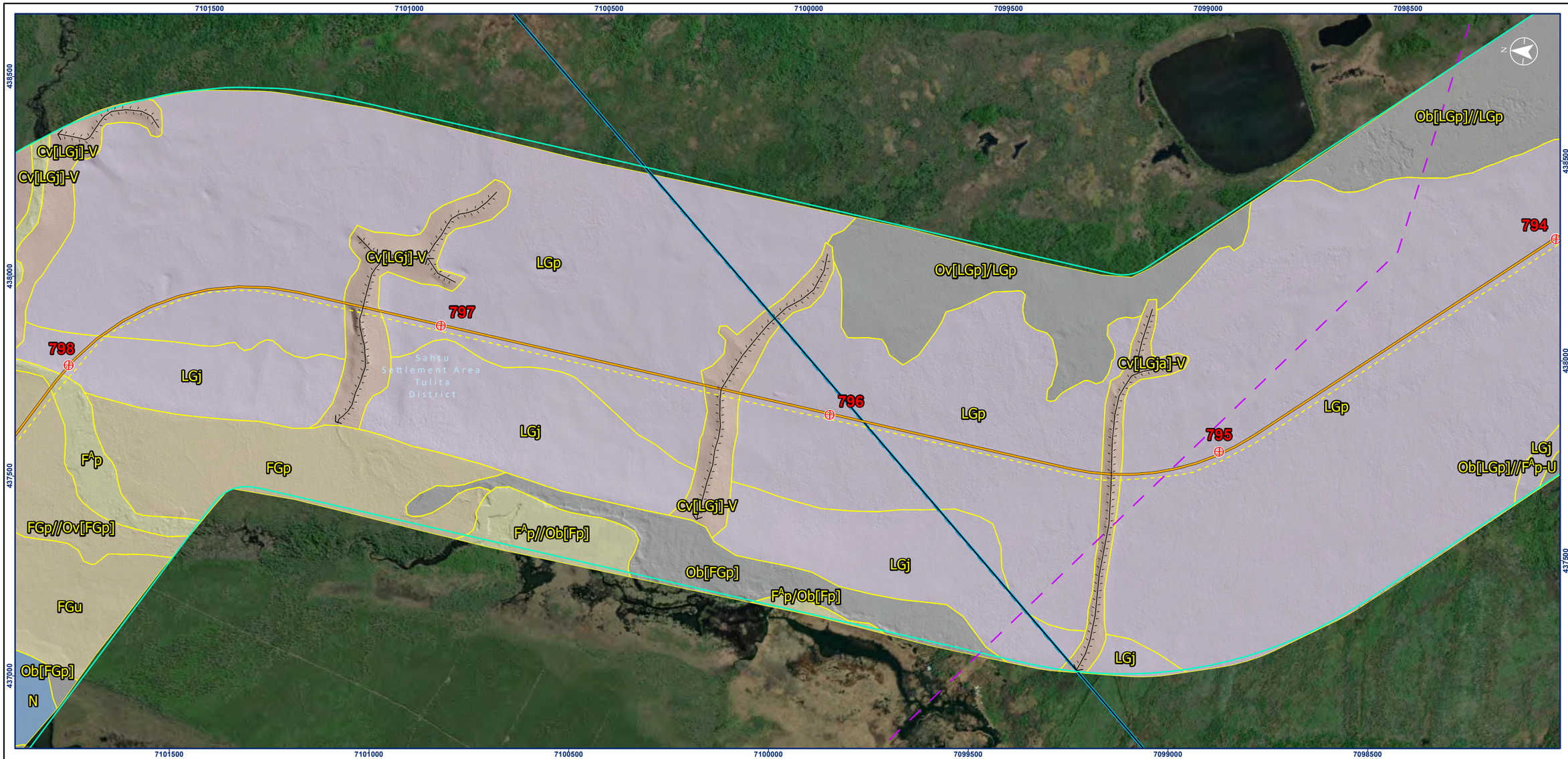

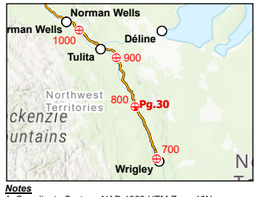

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

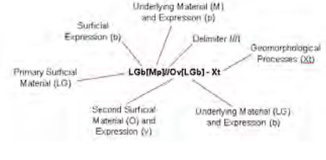
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location

Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project

144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.

B.30

Title

LSA Terrain Mapping

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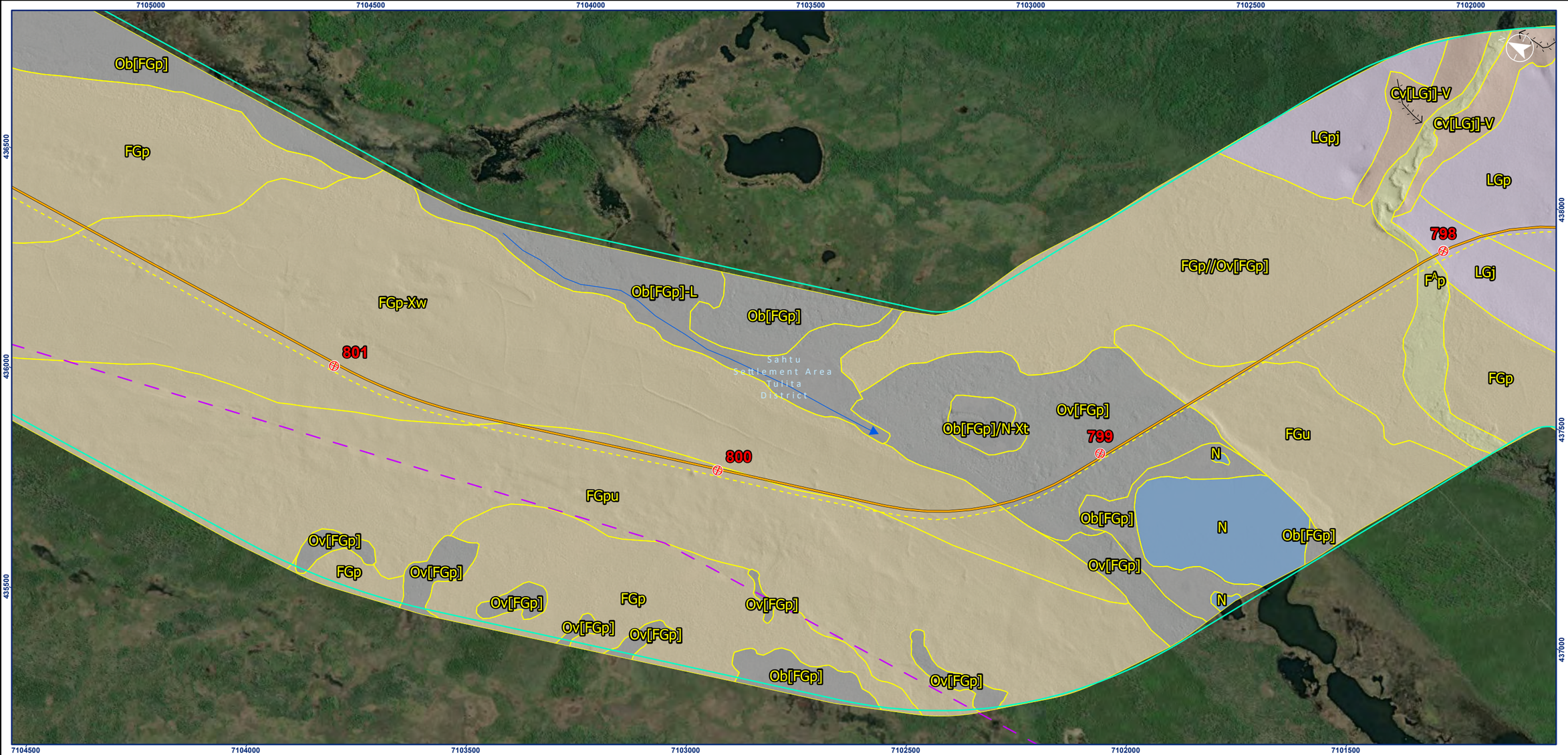

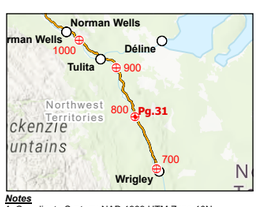

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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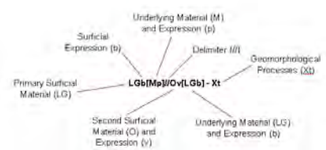
^ Geomorphological process initiation zone
ᴬ Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.31

Title
LSA Terrain Mapping

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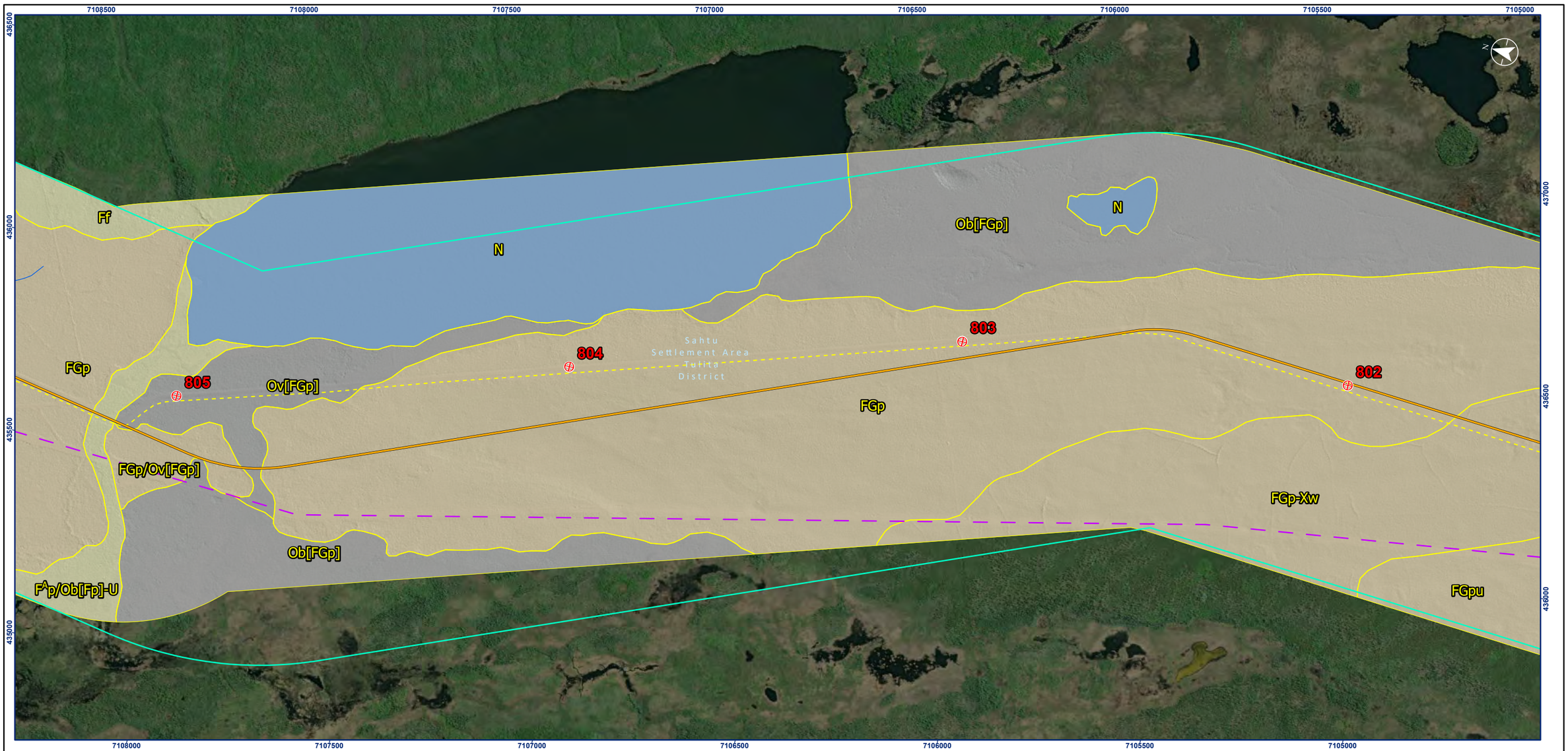

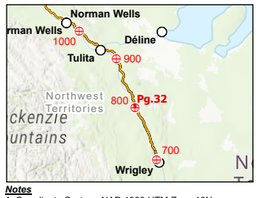

Notes
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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material
- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/	The component in front of the symbol is more extensive than the one that follows
//	The component in front of the symbol is considerably more extensive than the component that follows
^	Geomorphological process initiation zone
A	Active

Geomorphological Process

Permafrost Process

Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V

0 0.15 0.3 Kilometres
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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.32

Title
LSA Terrain Mapping

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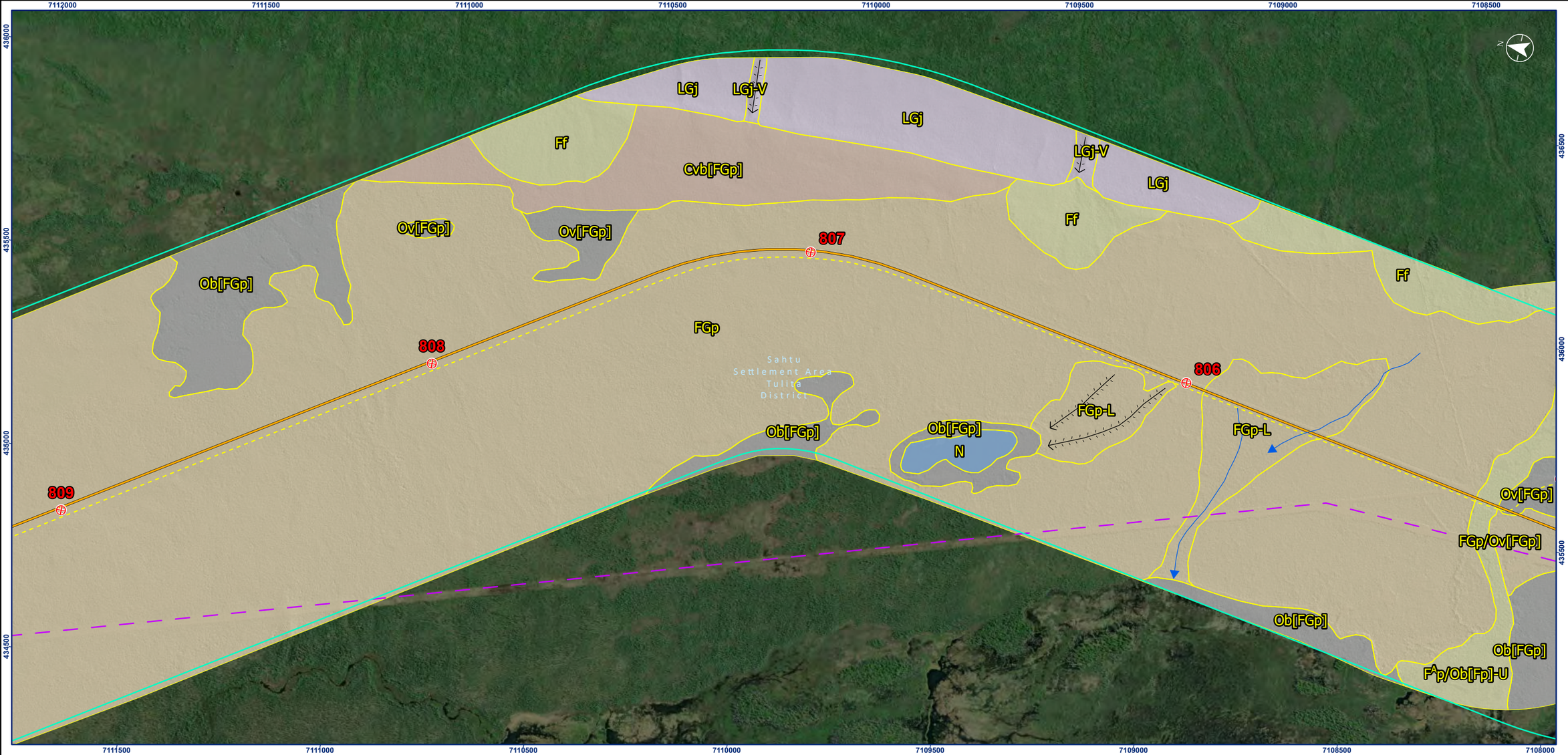

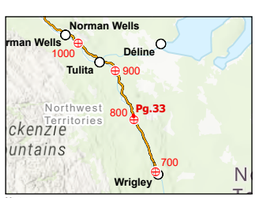

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- Seepage Flow Direction
- Gully
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Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
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Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
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Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
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fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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A Active

Geomorphological Process

Permafrost Process

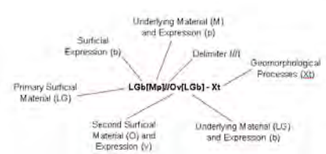
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.33

Title
LSA Terrain Mapping

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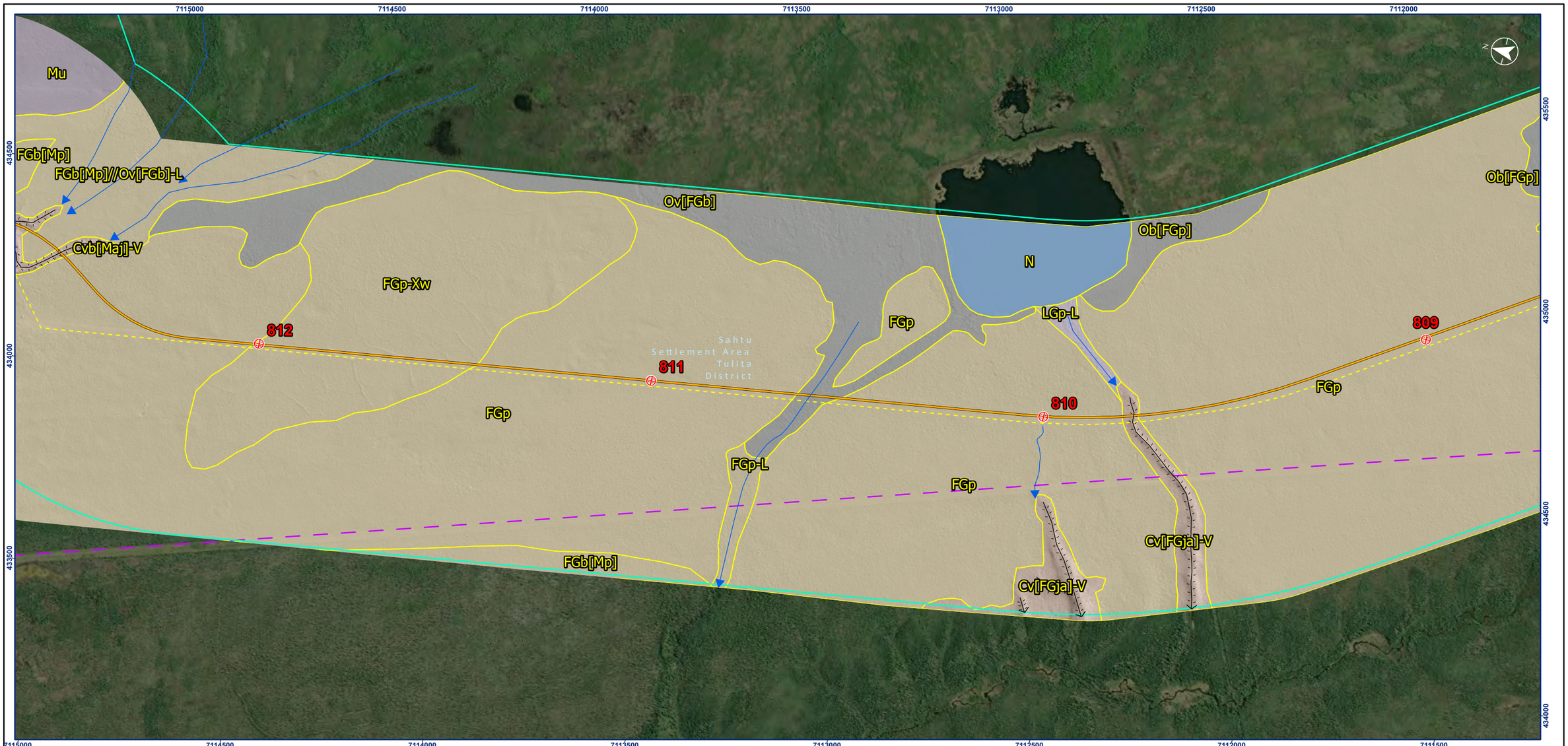

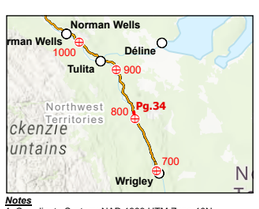

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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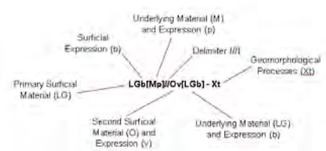
^	Geomorphological process initiation zone
^A	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.34

Title
LSA Terrain Mapping

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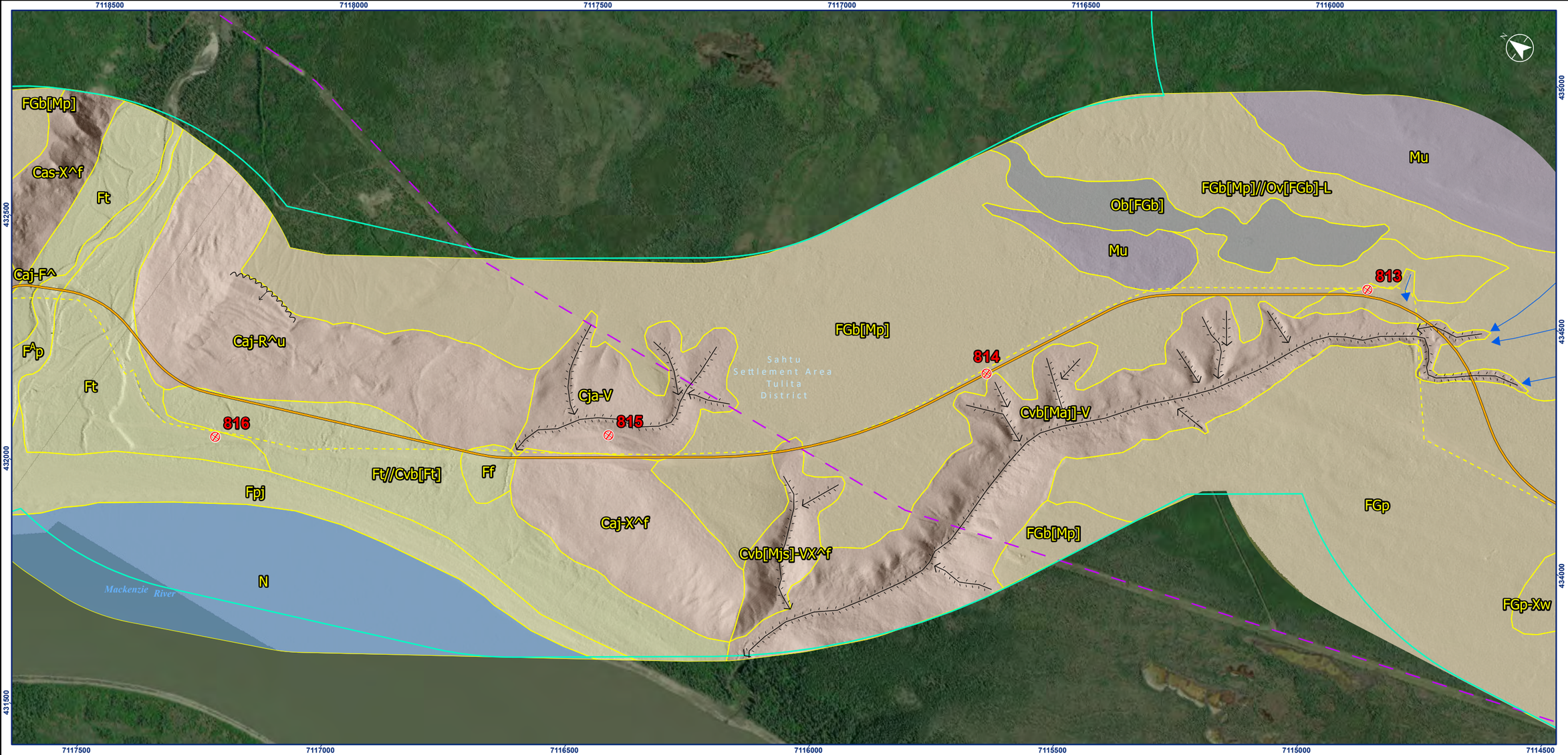

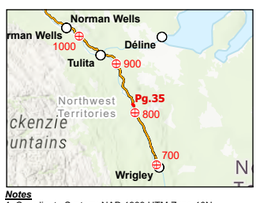

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material
- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

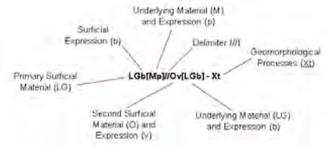
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.35

Title
LSA Terrain Mapping

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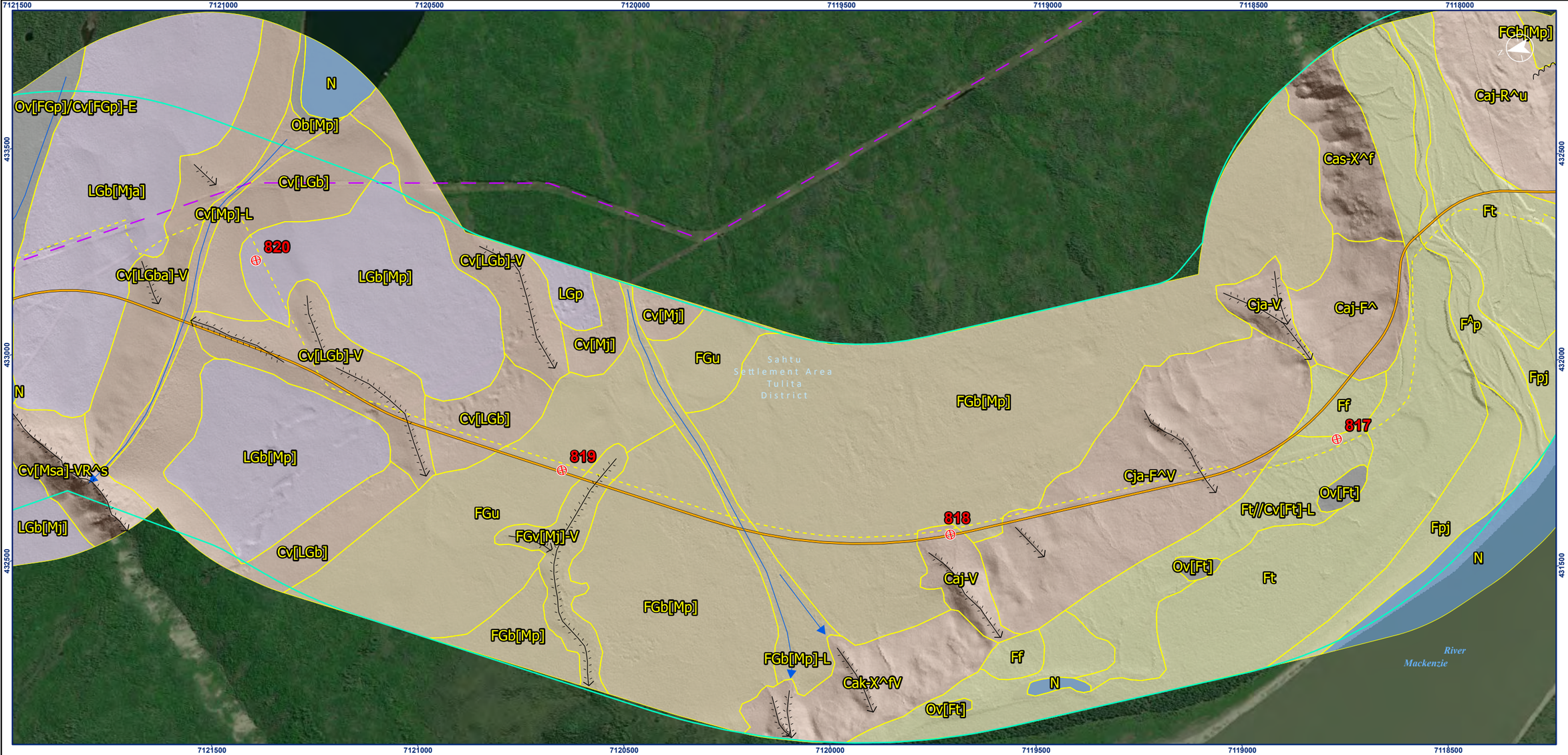

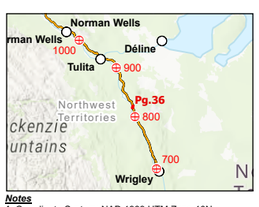

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
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rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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ᴬ Active

Geomorphological Process

Permafrost Process

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Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
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Rockfall	Rb
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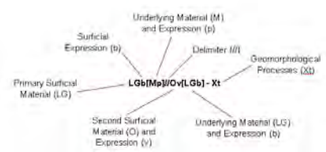
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

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Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.36

Title
LSA Terrain Mapping

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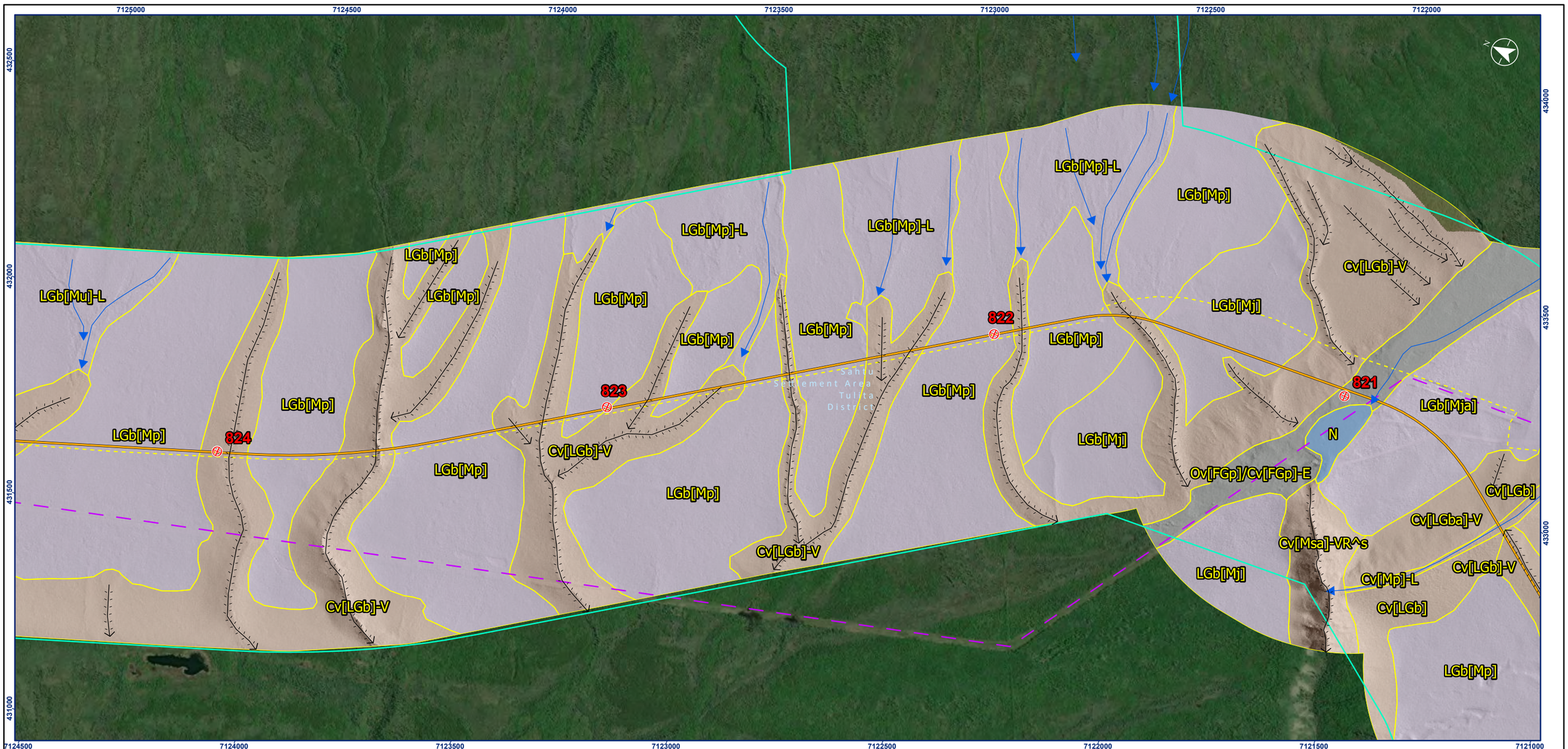

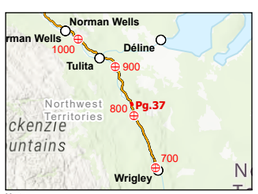

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Surficial Material

- Anthropogenic Material
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- Colluvium
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- Fluvial Material
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- Morainal Material (till)
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Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
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Morainal (till)	M
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Surface Expression

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plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

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^	Active

Geomorphological Process

Permafrost Process	
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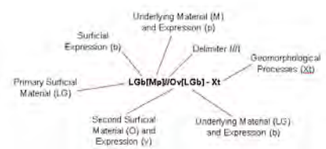
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

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Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.37

Title
LSA Terrain Mapping

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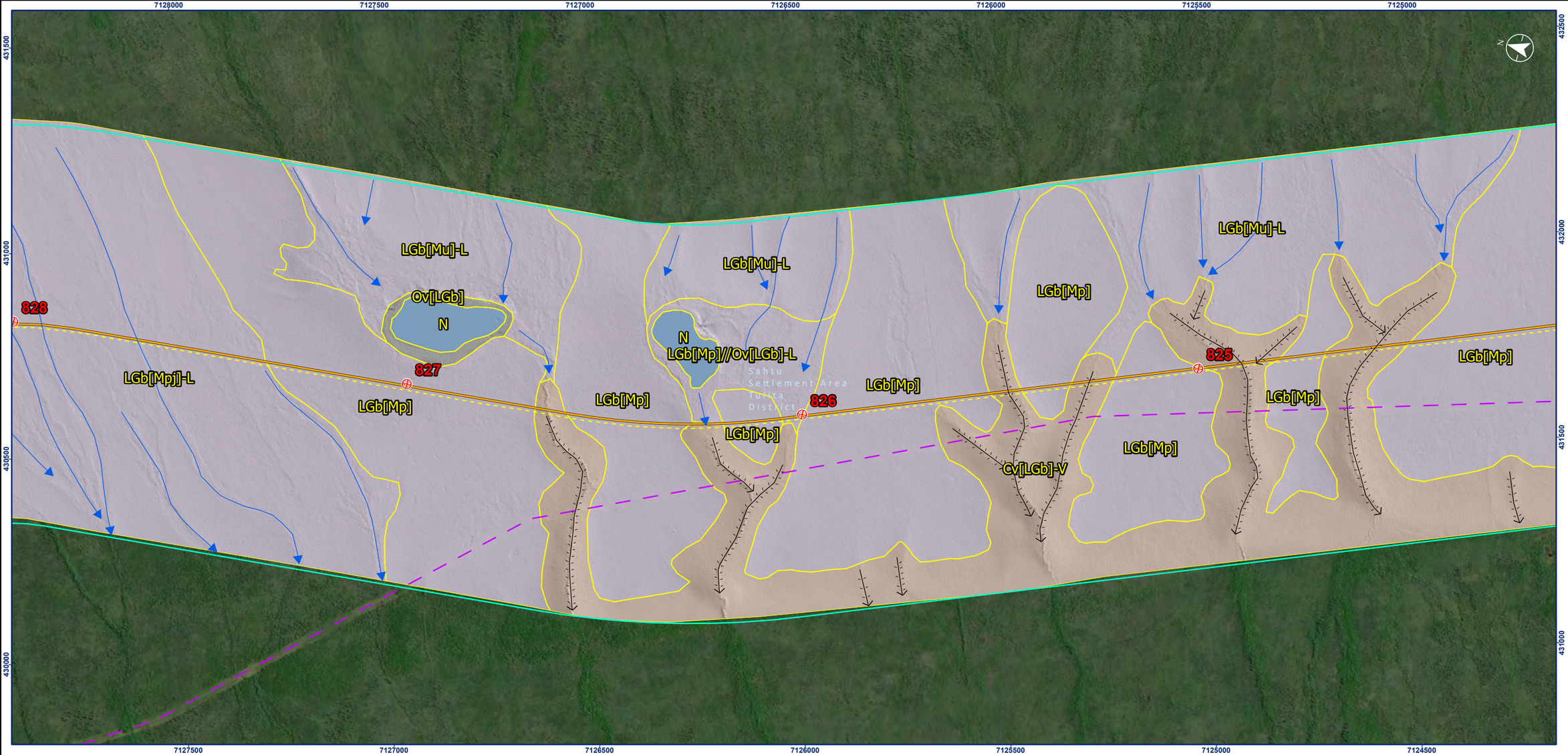

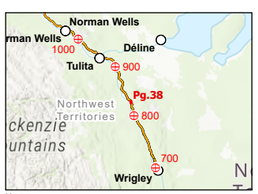

Notes

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2. Data Sources: Government of Northwest Territories
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
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4. Terrain mapping conducted in 2D using available airphotos, ortho-imagery and LiDAR data. Refer to Soils, Terrain and Permafrost TDR for detailed methodology

- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/	The component in front of the symbol is more extensive than the one that follows
//	The component in front of the symbol is considerably more extensive than the component that follows
^	Geomorphological process initiation zone
ᴬ	Active

Geomorphological Process

Permafrost Process

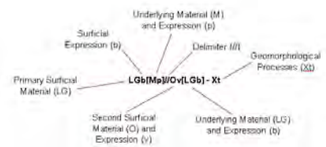
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.38

Title
LSA Terrain Mapping

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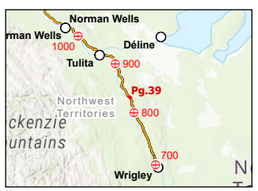
7131000 7130500 7130000 7129500 7129000

428500 431500 428000 431000

FGp
LGb[Mp]
Cv[Mas]-VR^s
Eu
Cb[Ma]-X^f
LGb[Mu]-L
830
829
LGb[Mp]
LGb[Mp]
LGb[Mu]
Sahtu Settlement Area Tulita District
FGv[Mp]
831
828
LGb[Mpj]-L
Cv[Mja]-V
Cv[Ma]-V
Cv[Mj]
FGb[Mp]

7129500 7129000 7128500 7128000 7127500



Notes
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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material
- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
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^ Geomorphological process initiation zone
ᴬ Active

Geomorphological Process

Permafrost Process

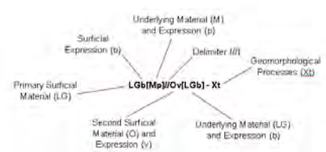
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.39

Title
LSA Terrain Mapping

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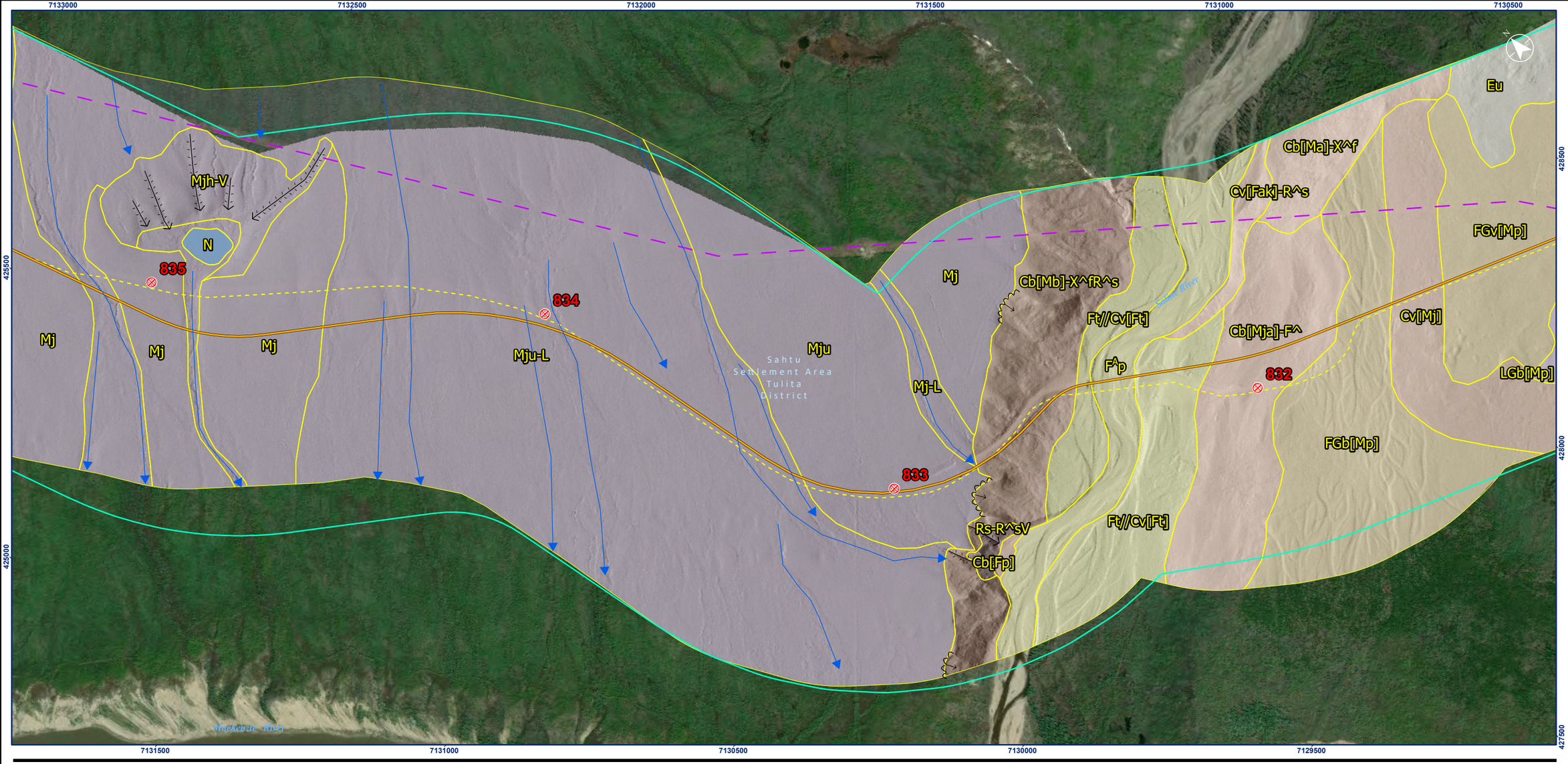

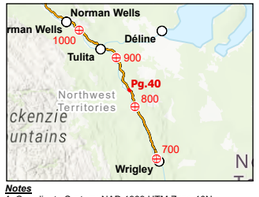

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Moraine Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

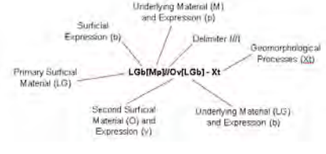
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

1 44903025-0065 REVA

Figure No.
B.40

Title
LSA Terrain Mapping

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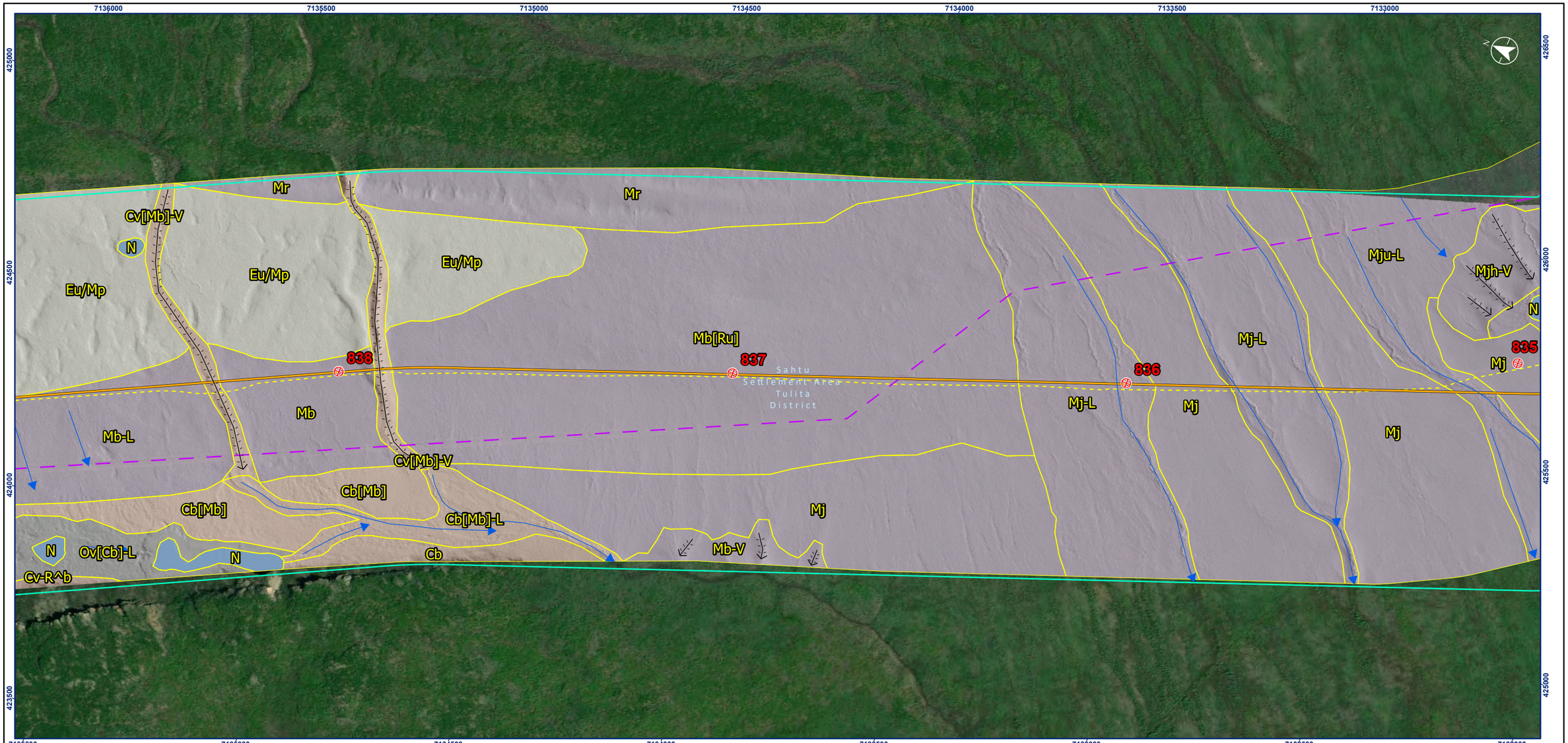

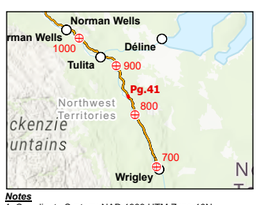

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V

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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
144903025-0065 REVA
Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.41

Title
LSA Terrain Mapping

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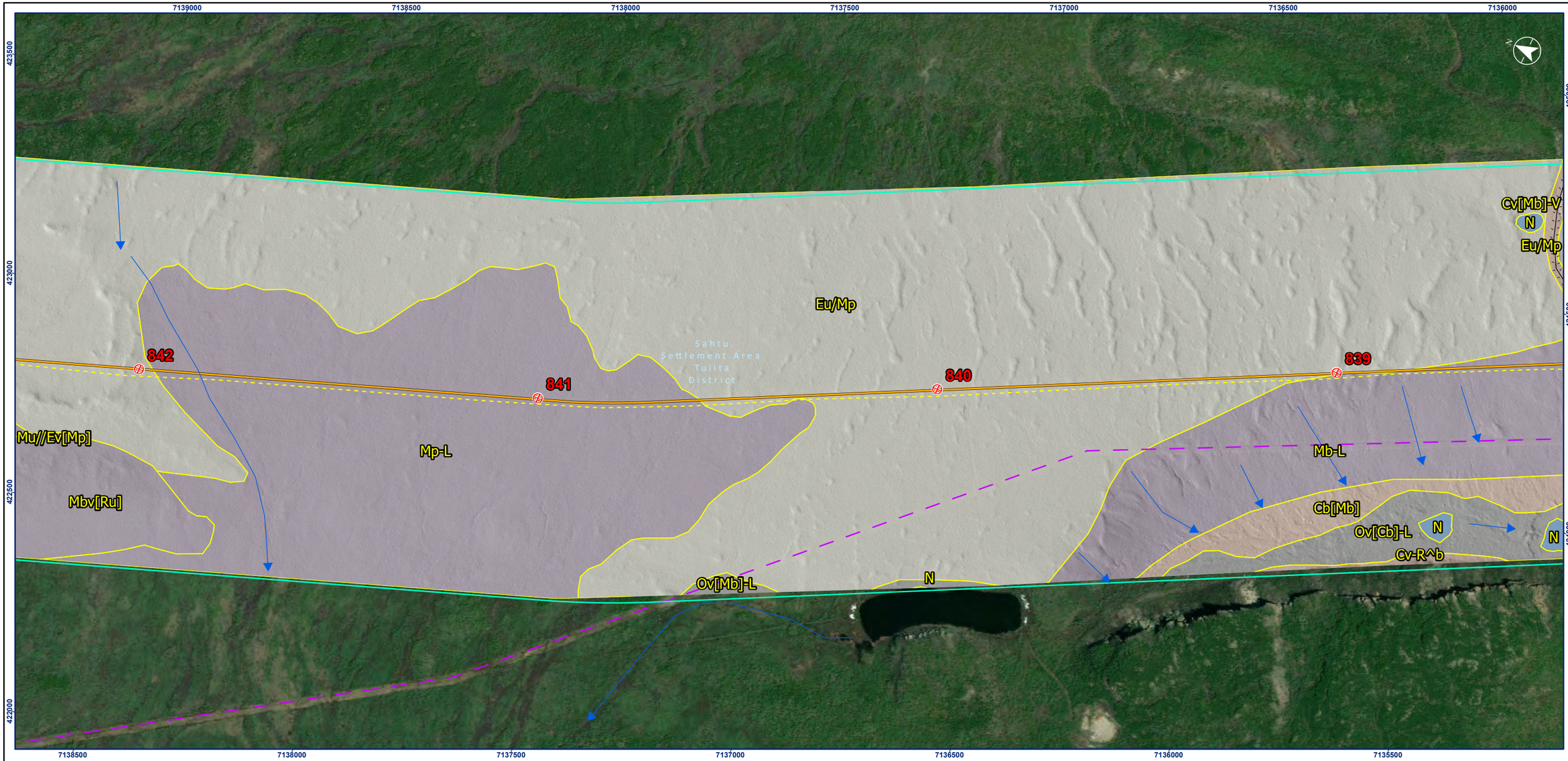

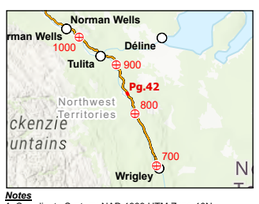

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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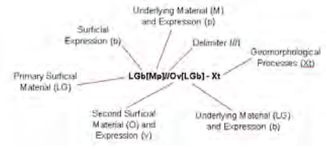
A Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.42

Title
LSA Terrain Mapping

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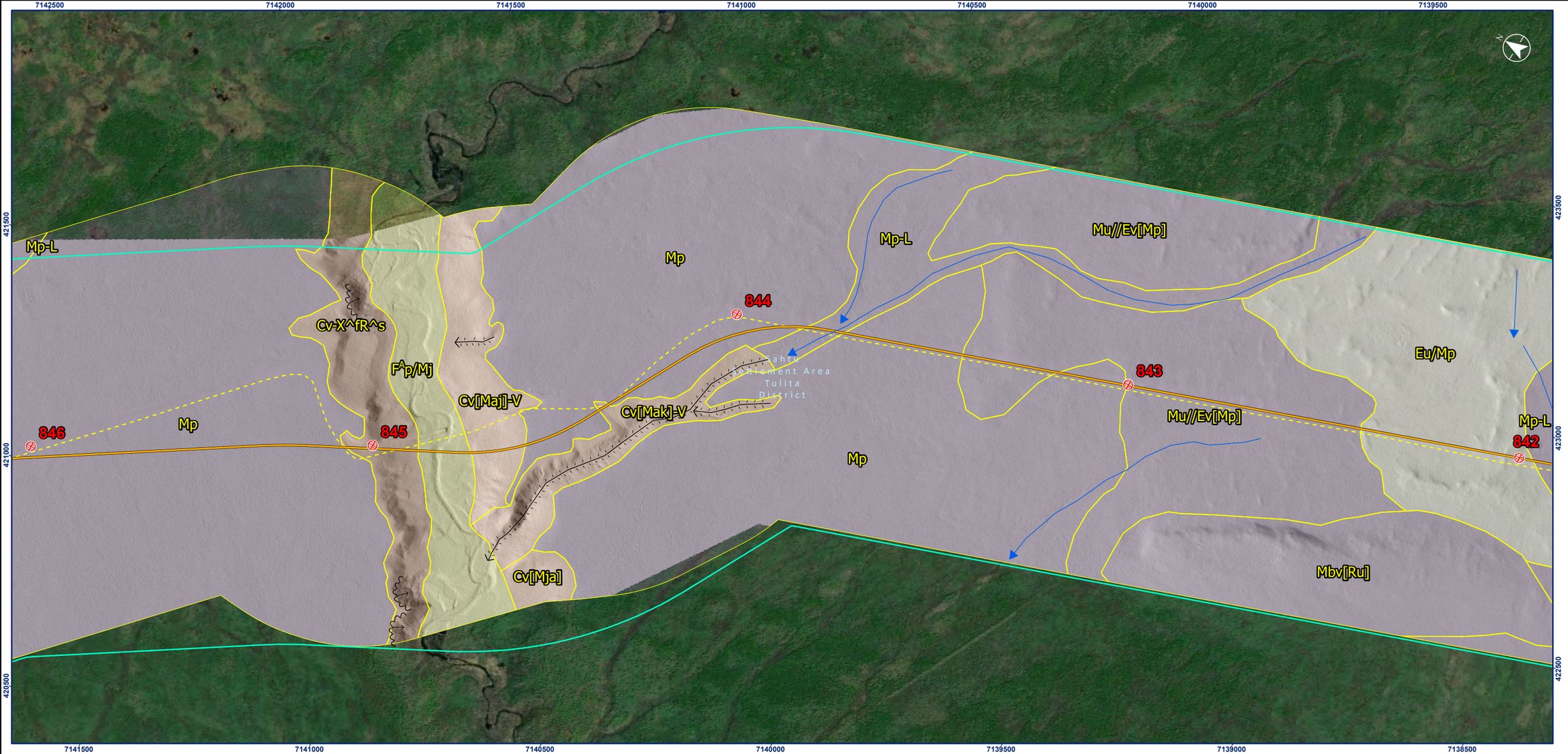

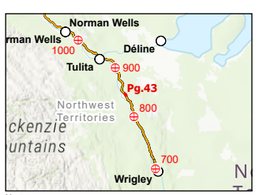

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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A Active

Geomorphological Process

Permafrost Process

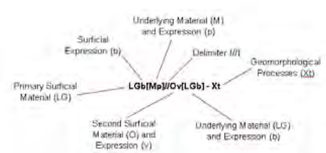
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.43

Title
LSA Terrain Mapping

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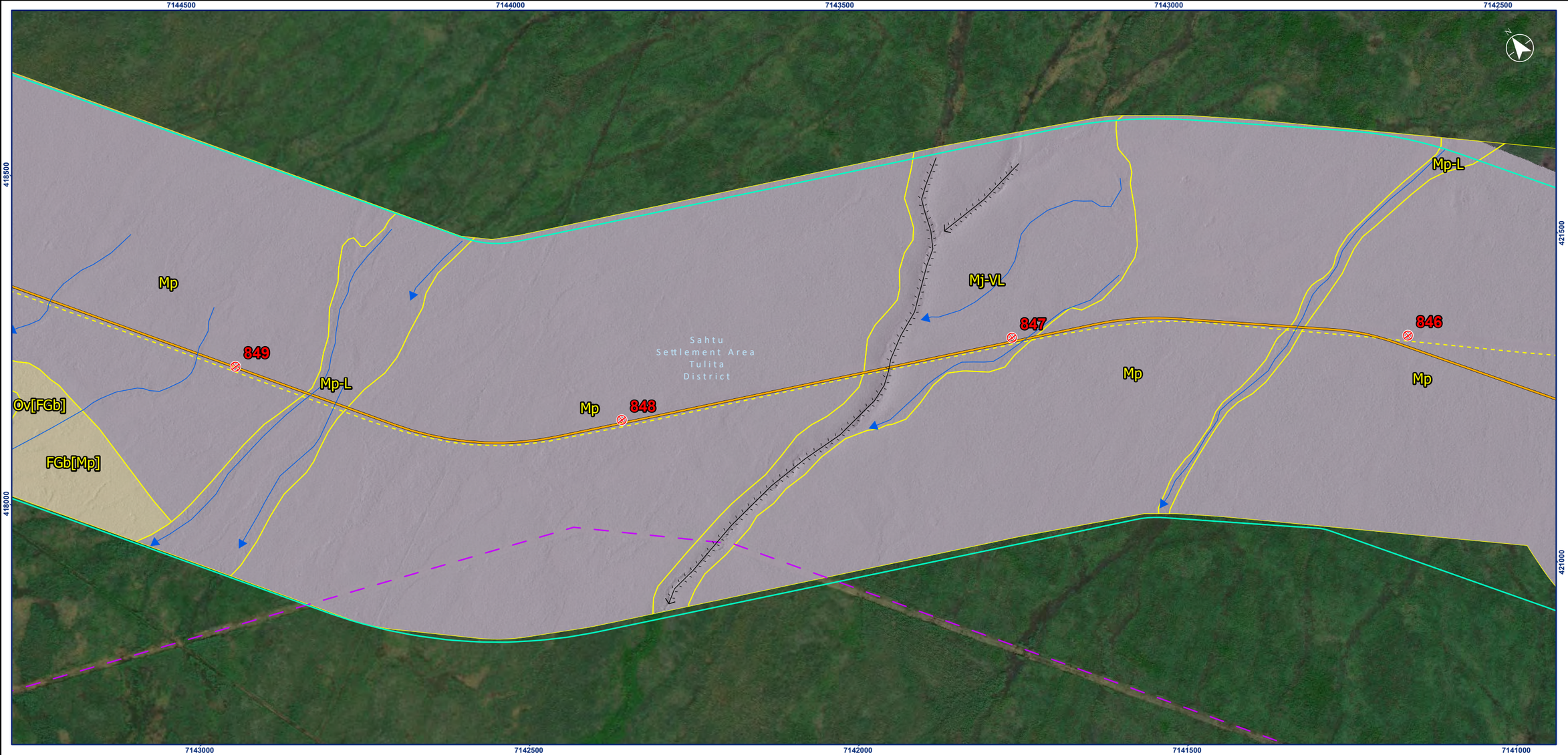

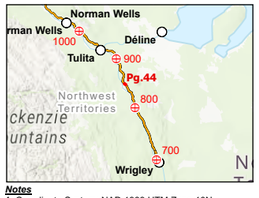

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/	The component in front of the symbol is more extensive than the one that follows
//	The component in front of the symbol is considerably more extensive than the component that follows
^	Geomorphological process initiation zone
A	Active

Geomorphological Process

Permafrost Process

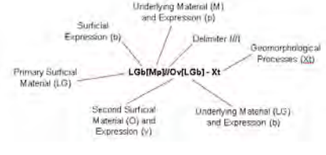
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location

Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project

144903025-0065 REV A

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.

B.44

Title

LSA Terrain Mapping

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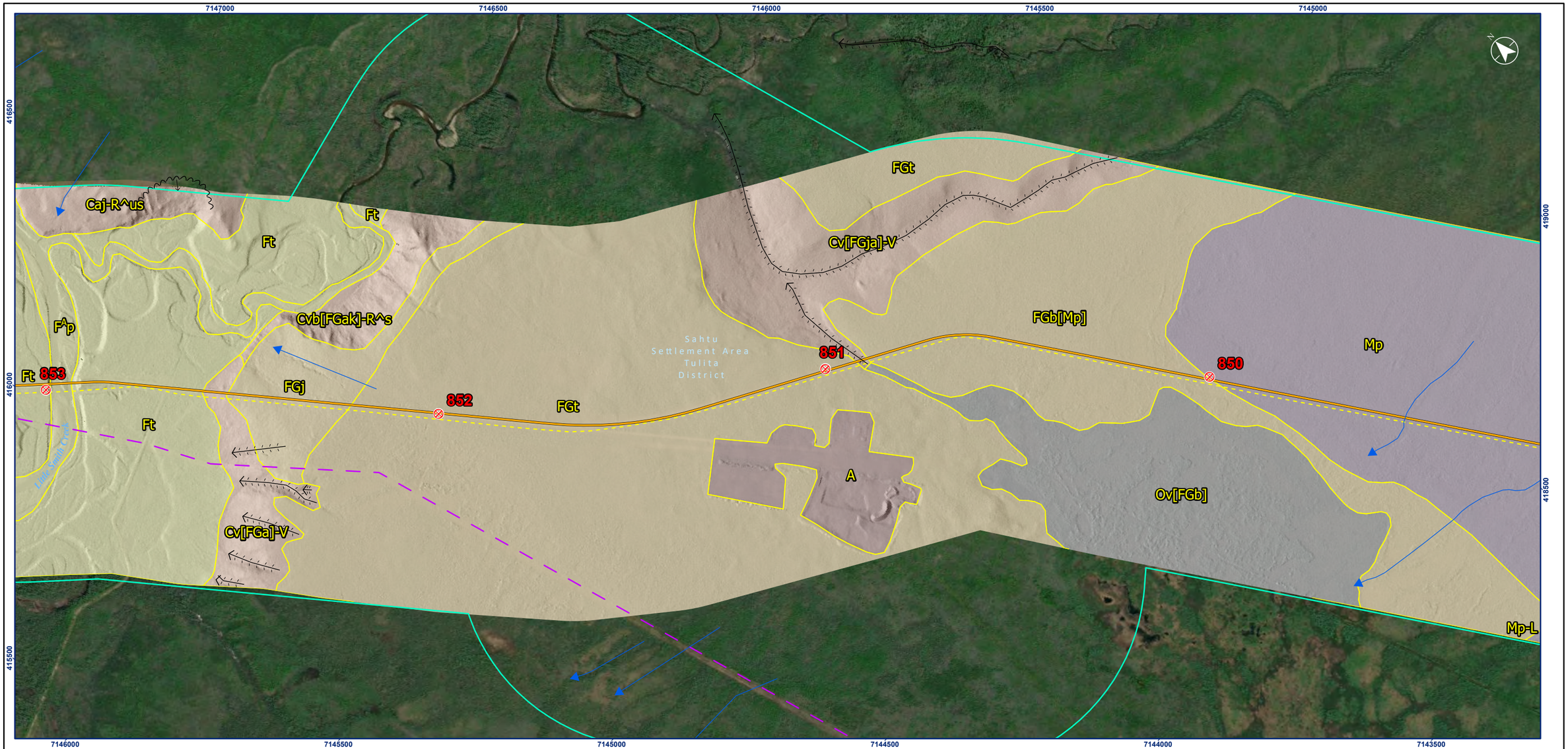

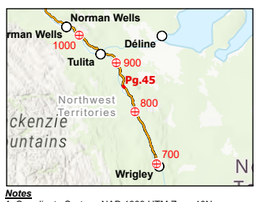

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

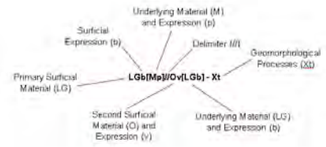
moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
// The component in front of the symbol is considerably more extensive than the component that follows
^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.45

Title
LSA Terrain Mapping

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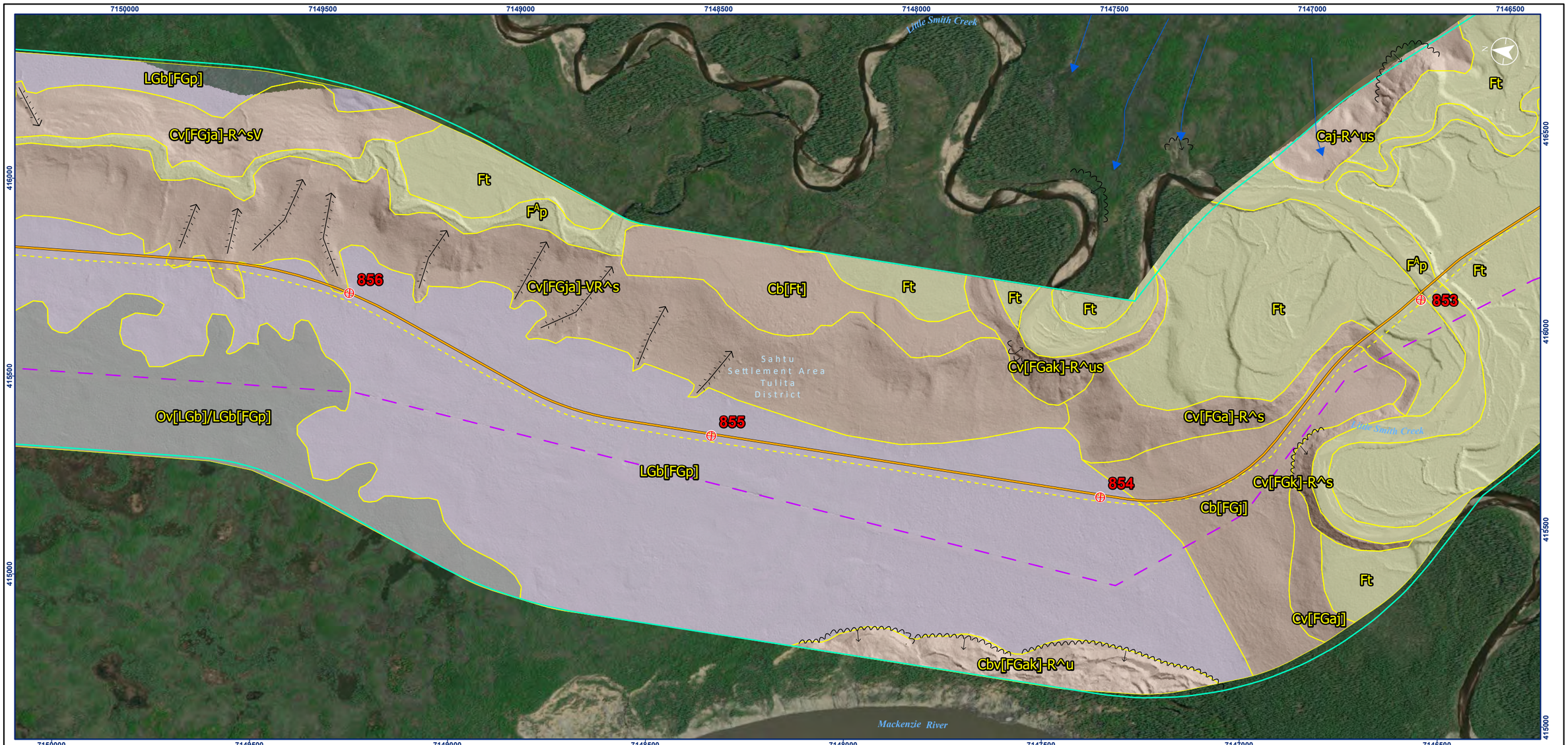

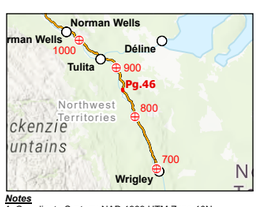

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
ᴬ Active

Geomorphological Process

Permafrost Process

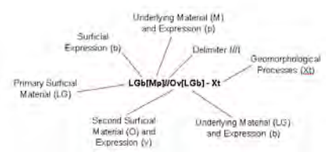
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.46

Title
LSA Terrain Mapping

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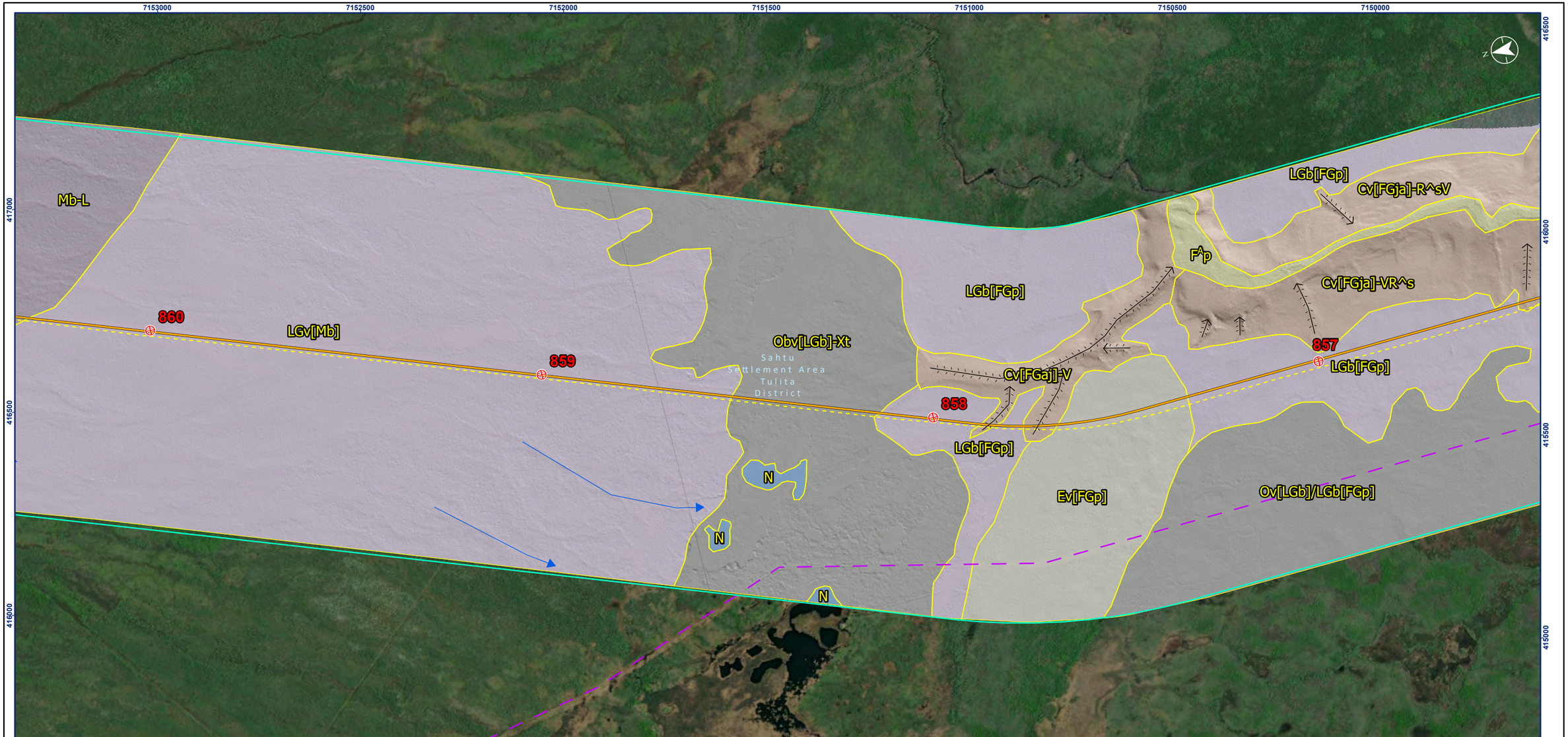

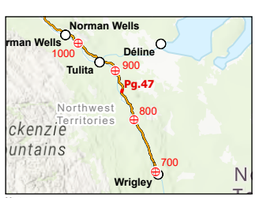

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material
- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

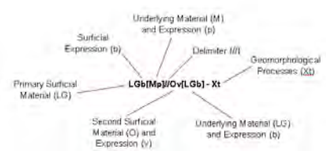
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REV.A

Figure No.
B.47

Title
LSA Terrain Mapping

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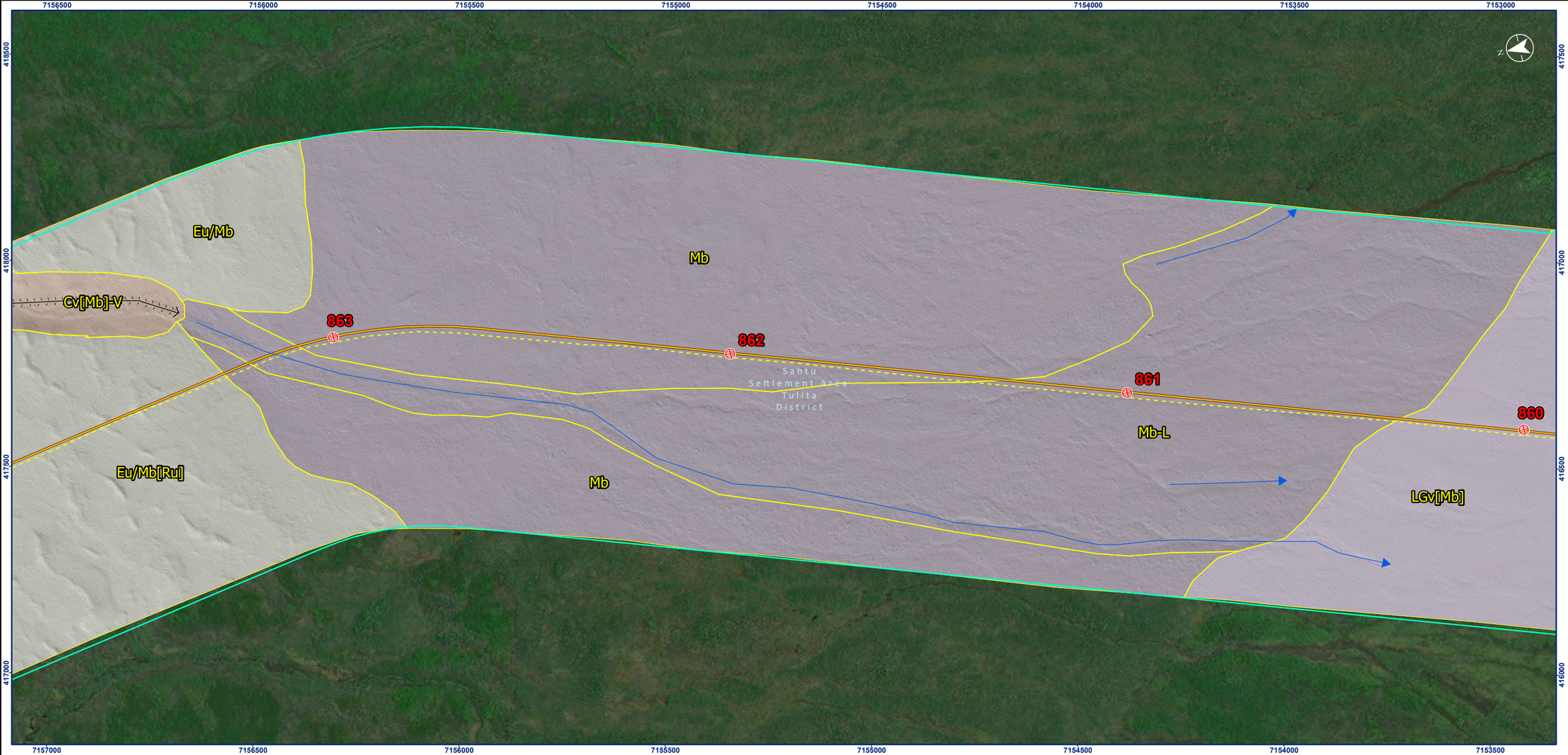

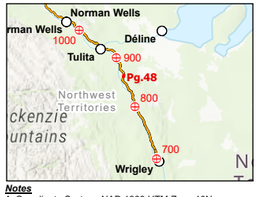

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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ᴬ Active

Geomorphological Process

Permafrost Process

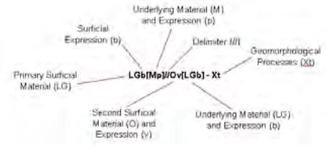
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.48

Title
LSA Terrain Mapping

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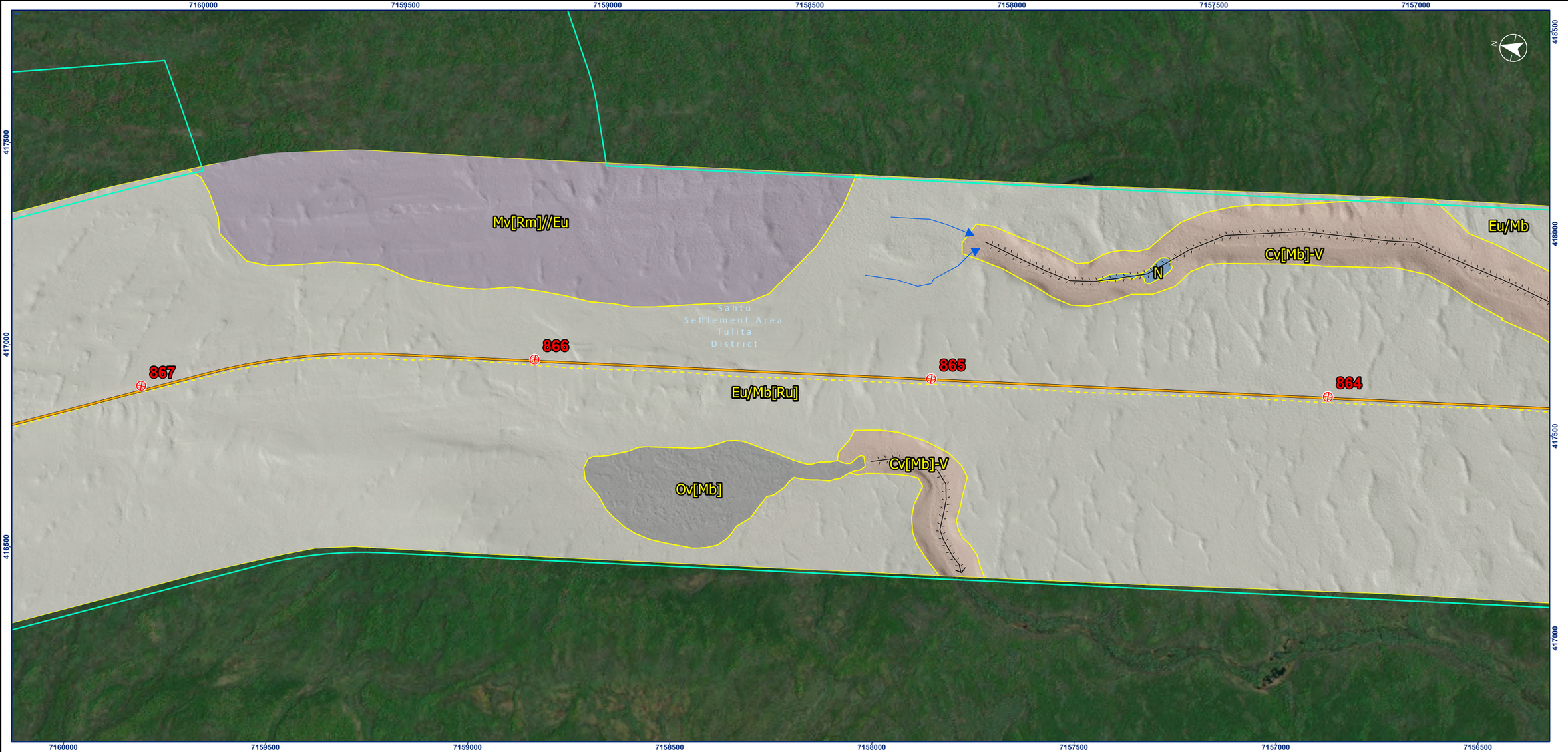

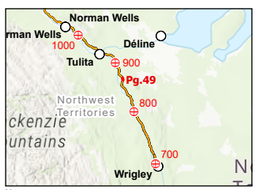

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material
- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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A Active

Geomorphological Process

Permafrost Process

Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V

0 0.15 0.3 Kilometres
1:10,000 (at original document size of 11x17)

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REV.A

Figure No.
B.49

Title
LSA Terrain Mapping

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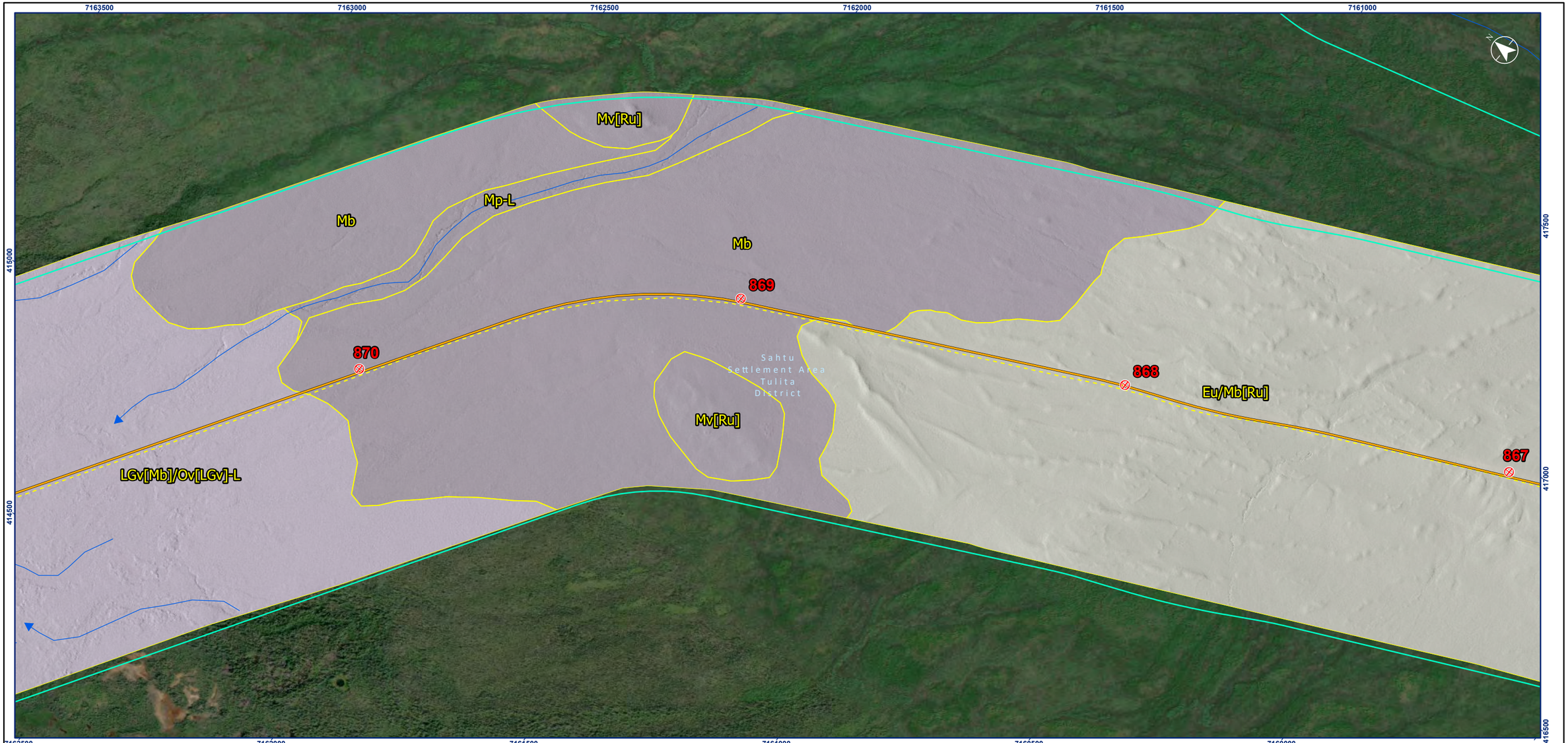

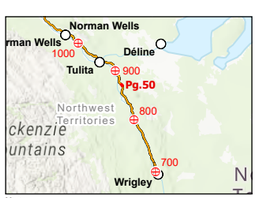

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
// The component in front of the symbol is considerably more extensive than the component that follows
^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

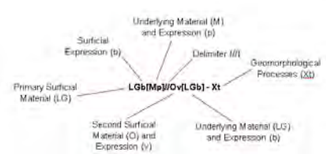
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
144903025-0065 REV.A

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.50

Title
LSA Terrain Mapping

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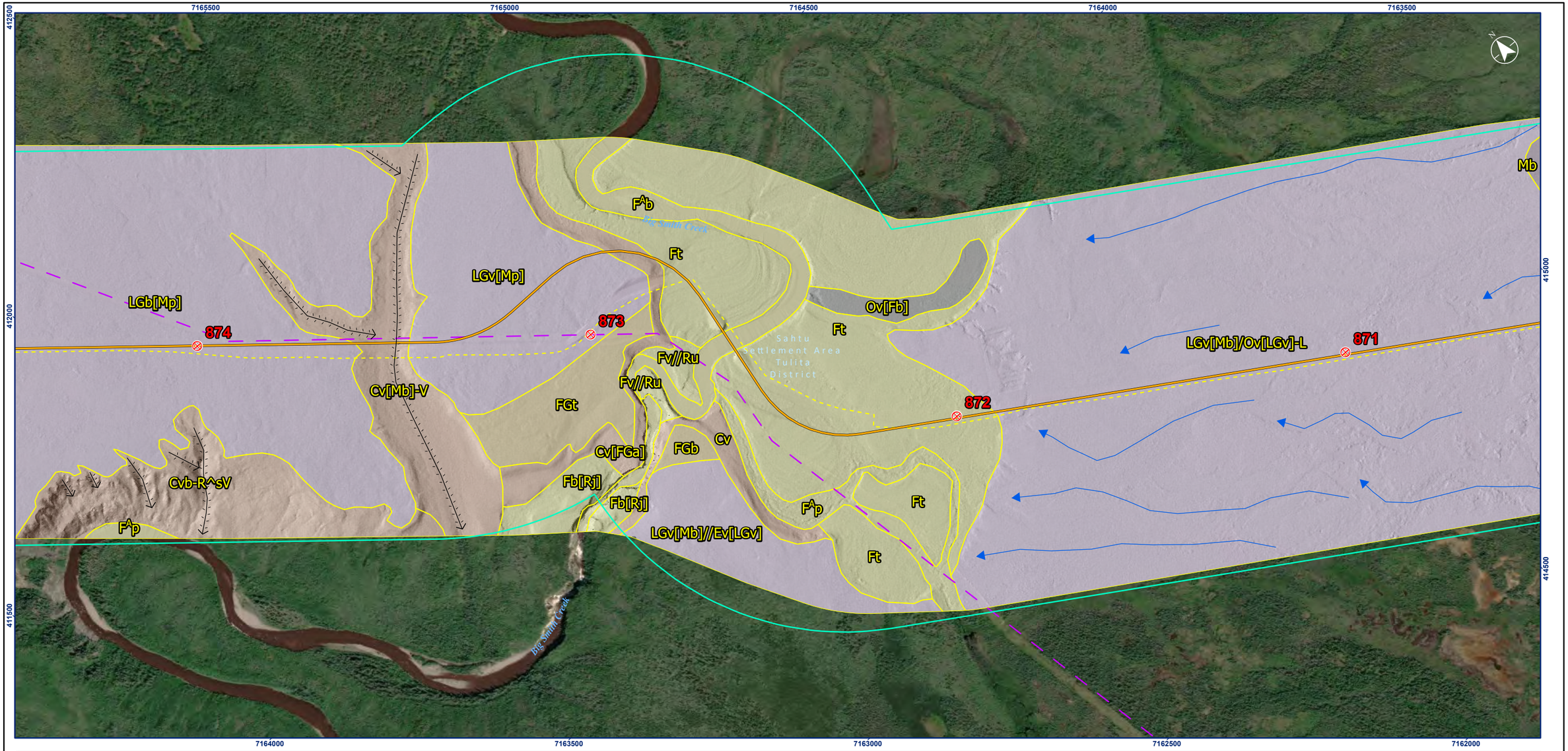

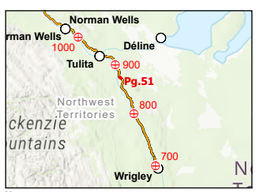

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

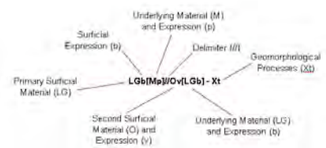
moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/	The component in front of the symbol is more extensive than the one that follows
//	The component in front of the symbol is considerably more extensive than the component that follows
^	Geomorphological process initiation zone
^	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.51

Title
LSA Terrain Mapping

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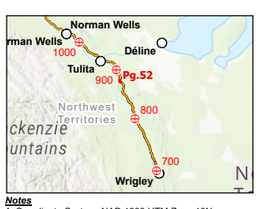

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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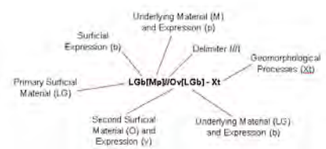
ᴬ	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
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Client/Project
144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.52

Title
LSA Terrain Mapping

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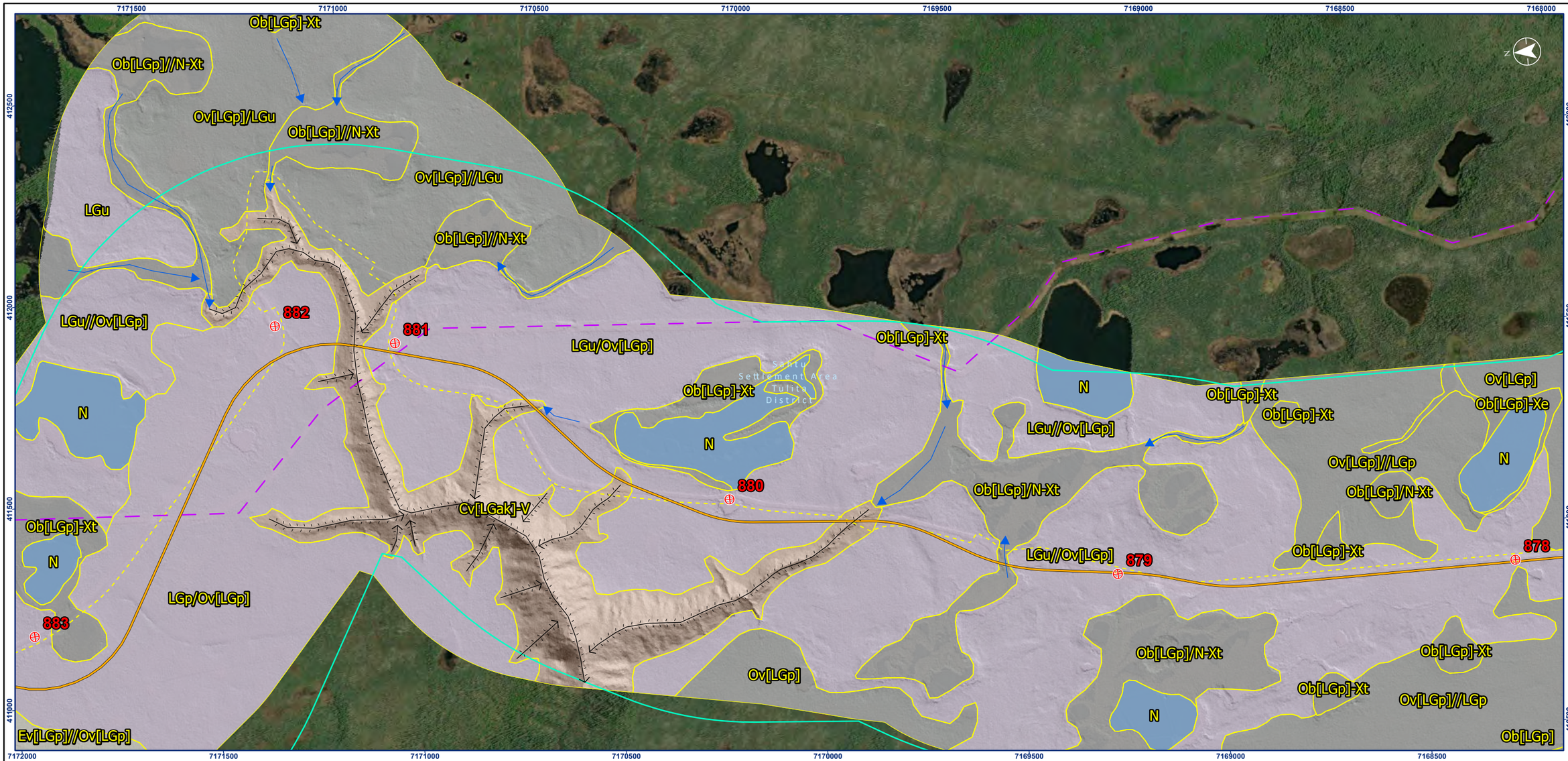

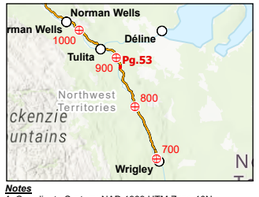

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

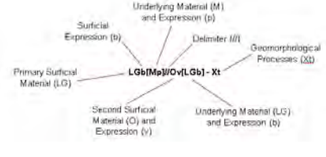
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location

Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project

144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.

B.53

Title

LSA Terrain Mapping

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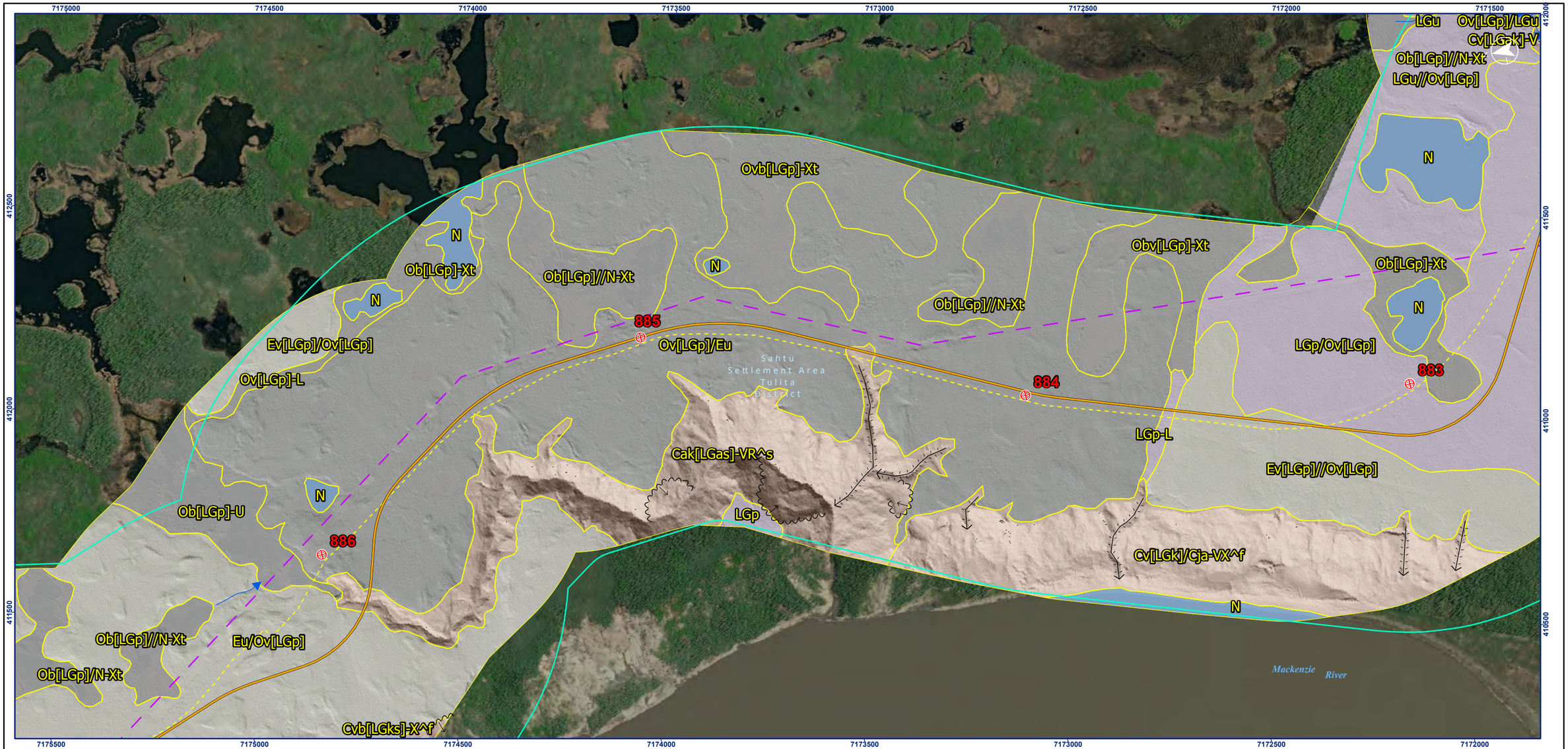

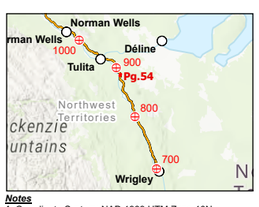

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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ᴬ Active

Geomorphological Process

Permafrost Process

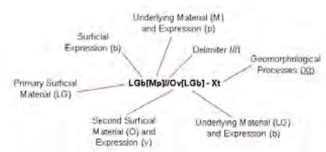
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.54

Title
LSA Terrain Mapping

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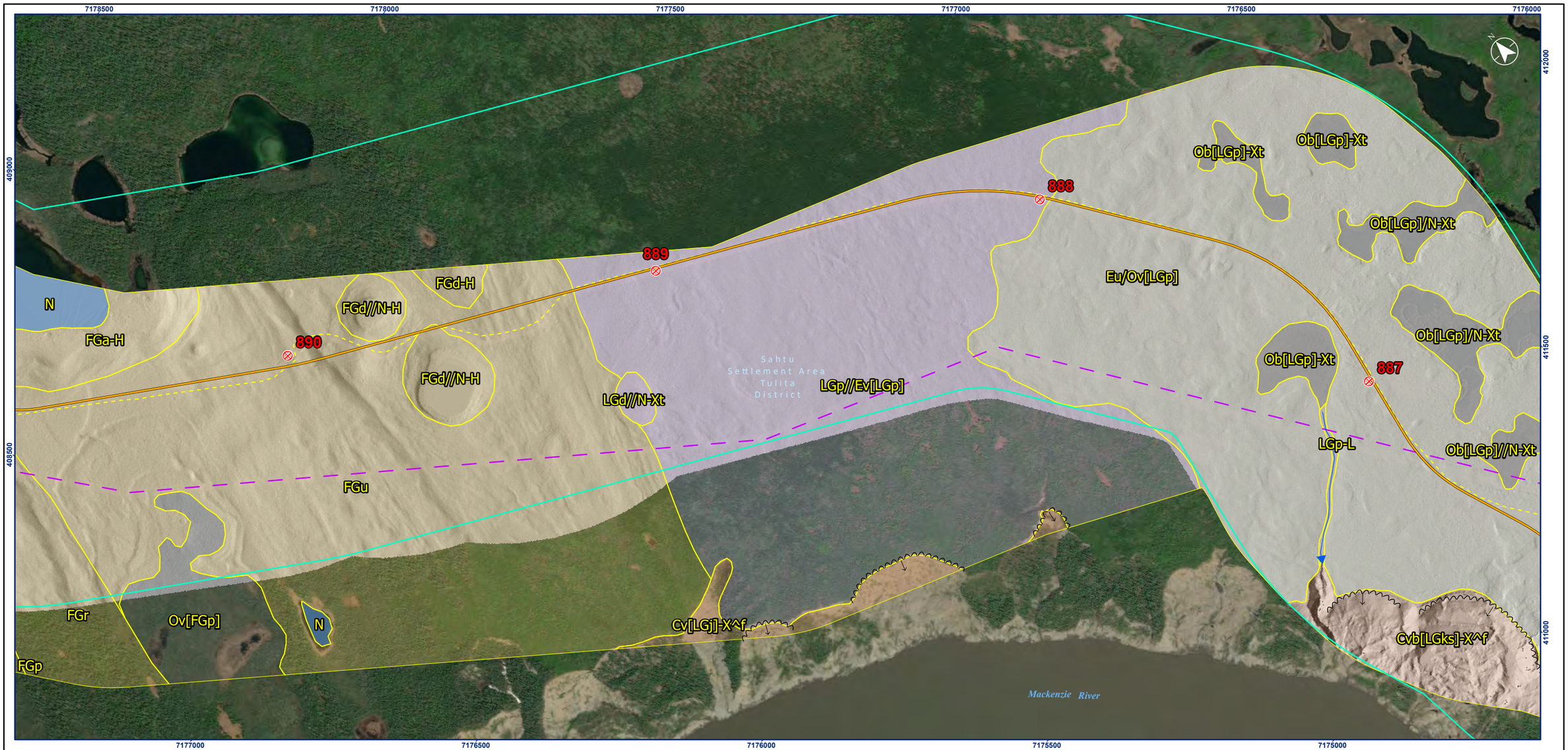

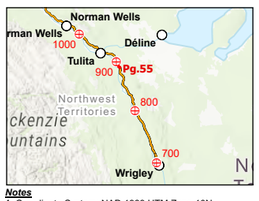

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material
- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
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rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

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A Active

Geomorphological Process

Permafrost Process

Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V

0 0.15 0.3 Kilometres
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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

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Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REV.A

Figure No.
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LSA Terrain Mapping

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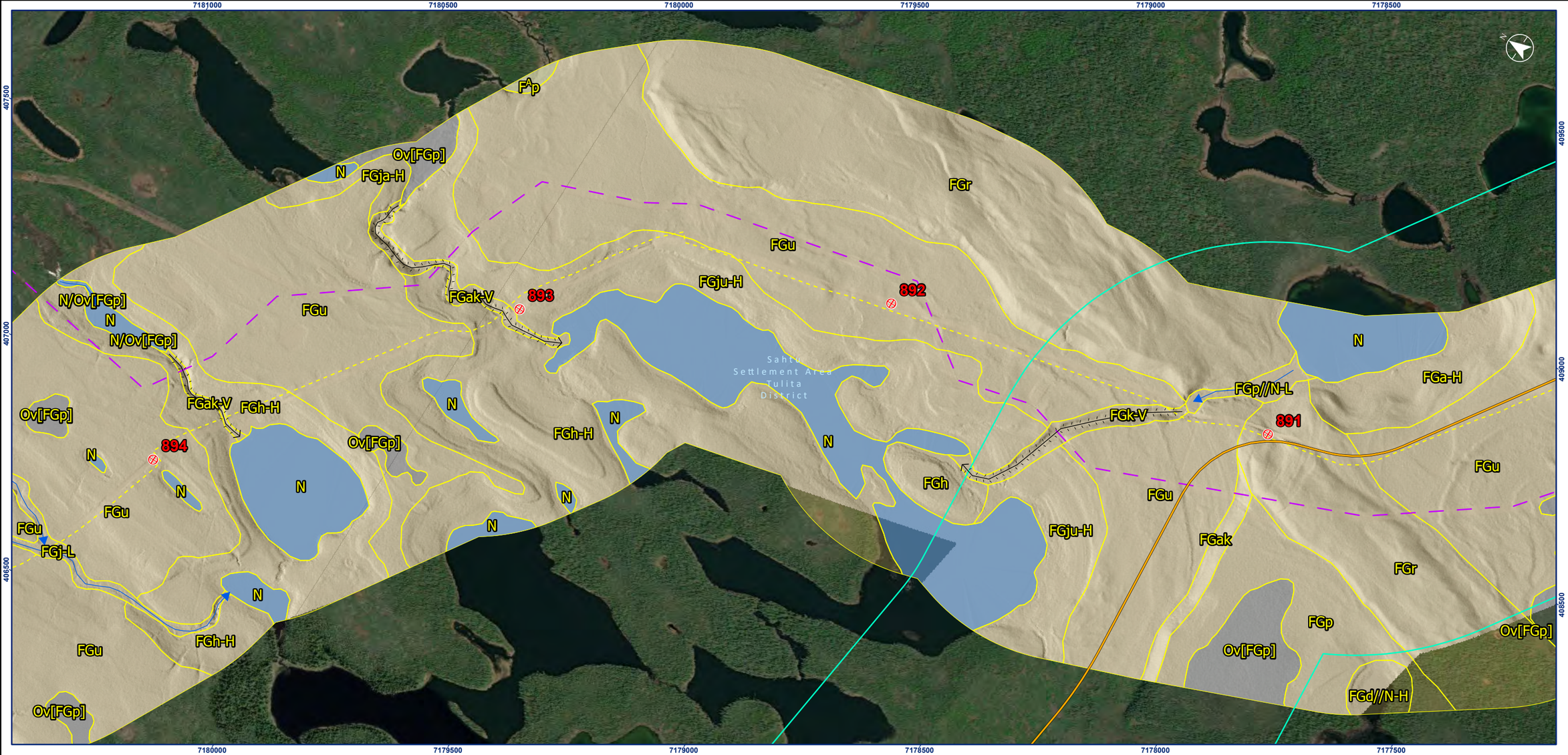

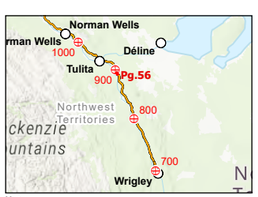

Notes

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4. Terrain mapping conducted in 2D using available airphotos, ortho-imagery and LiDAR data. Refer to Soils, Terrain and Permafrost TDR for detailed methodology

- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

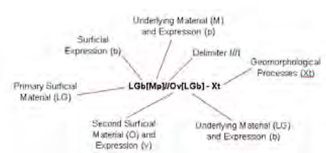
moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
// The component in front of the symbol is considerably more extensive than the component that follows
^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
144903025-0065 REV.A

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.56

Title
LSA Terrain Mapping

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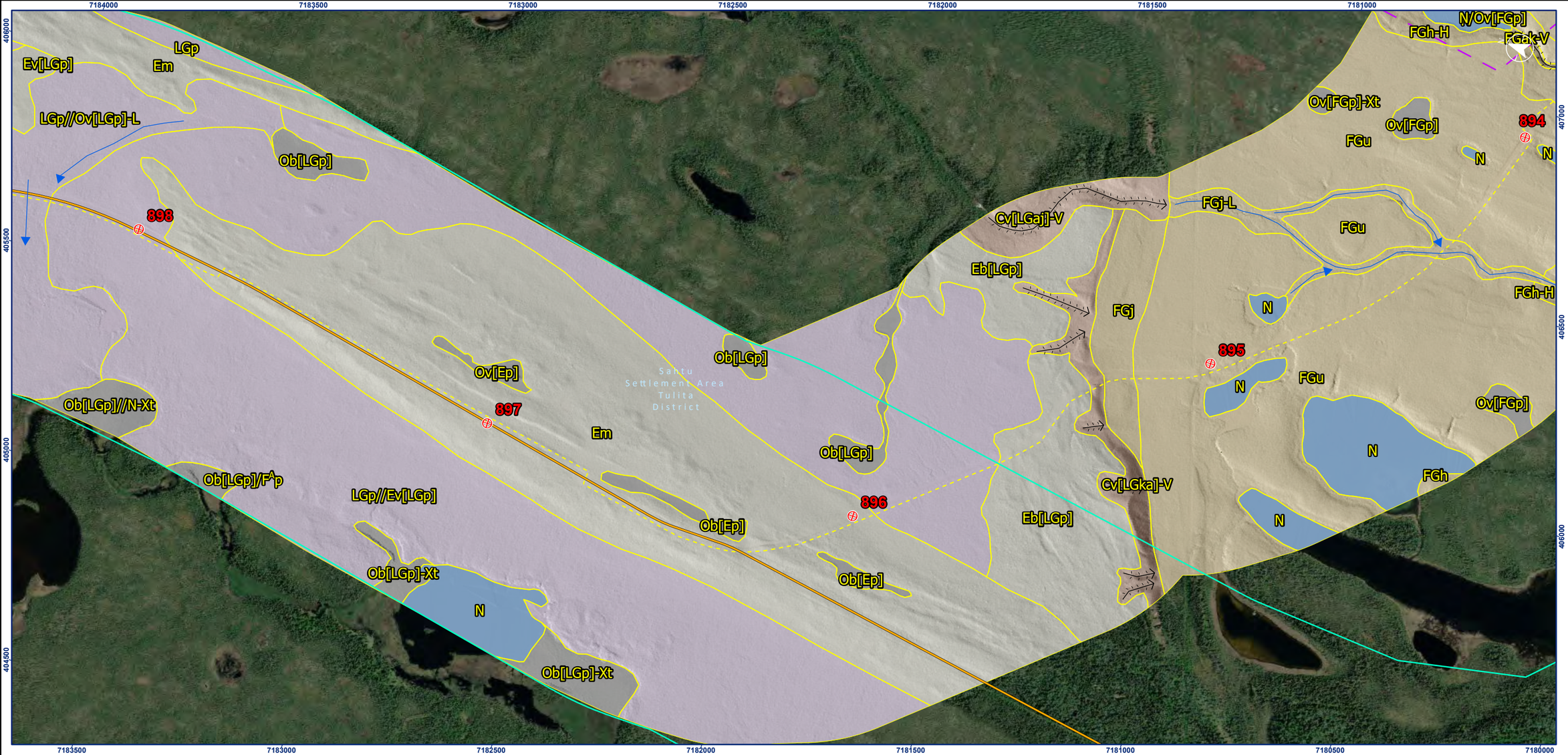

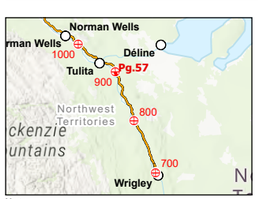

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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// The component in front of the symbol is considerably more extensive than the component that follows
^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

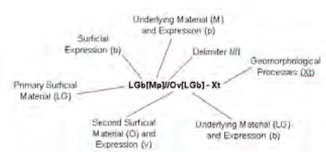
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

1 44903025-0065 REV A

Figure No.
B.57

Title
LSA Terrain Mapping

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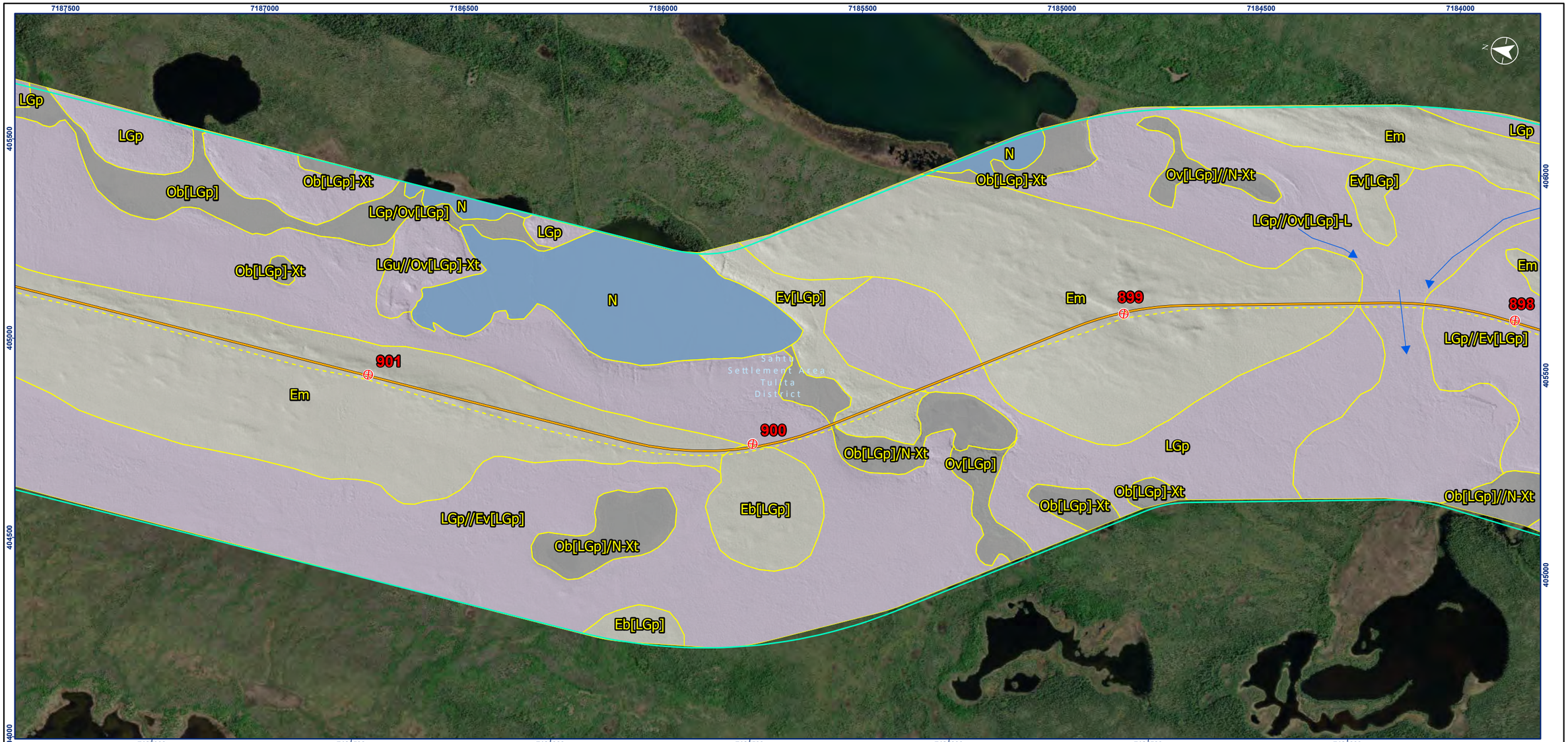

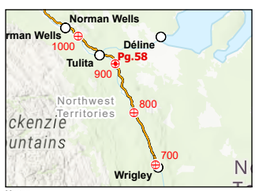

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
// The component in front of the symbol is considerably more extensive than the component that follows
^ Geomorphological process initiation zone
ᴬ Active

Geomorphological Process

Permafrost Process

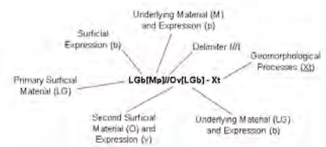
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.58

Title
LSA Terrain Mapping

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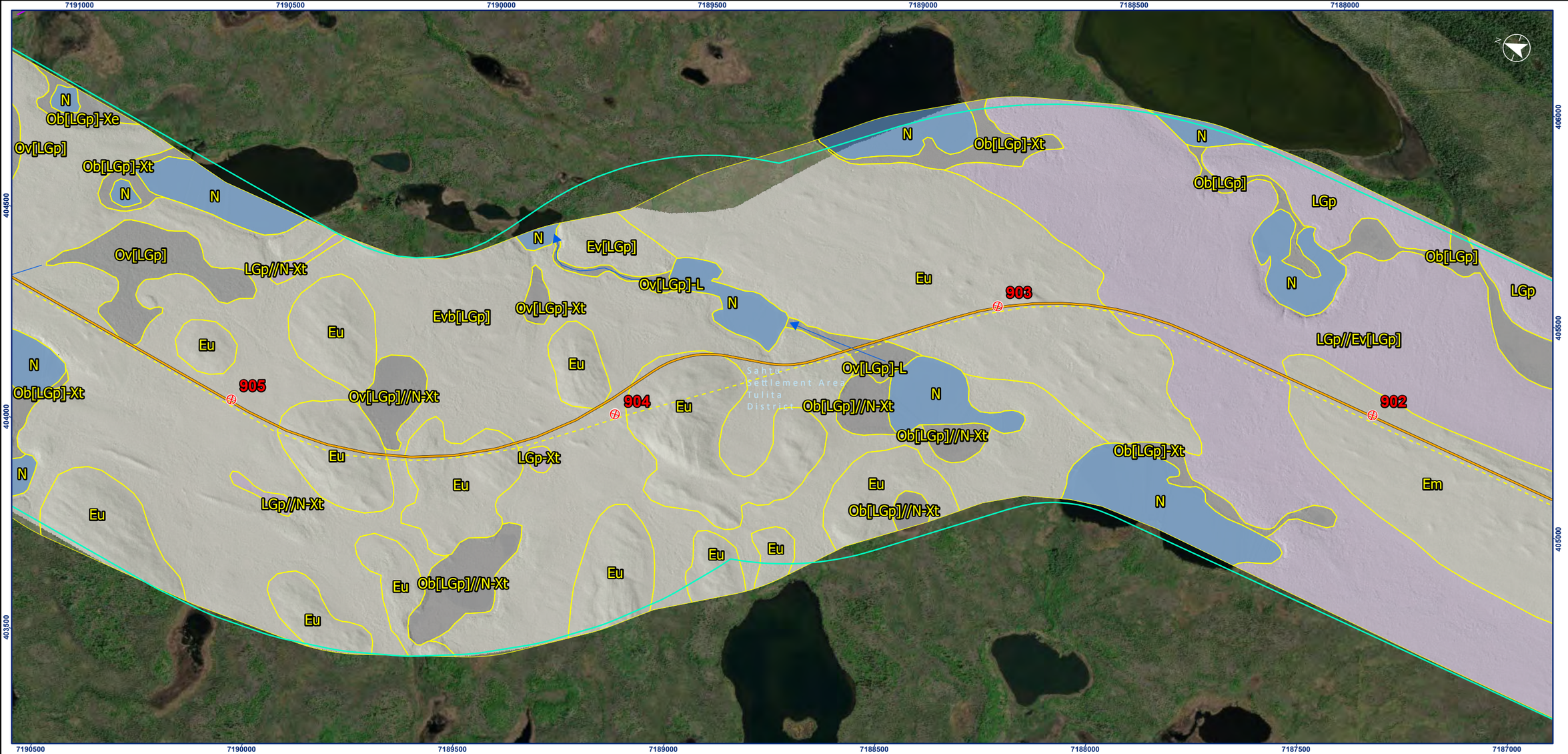

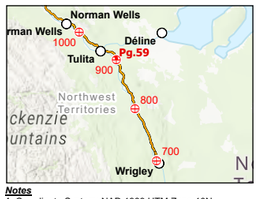

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V

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Kálo-Stantec

Project Location

Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project

144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.

B.59

Title

LSA Terrain Mapping

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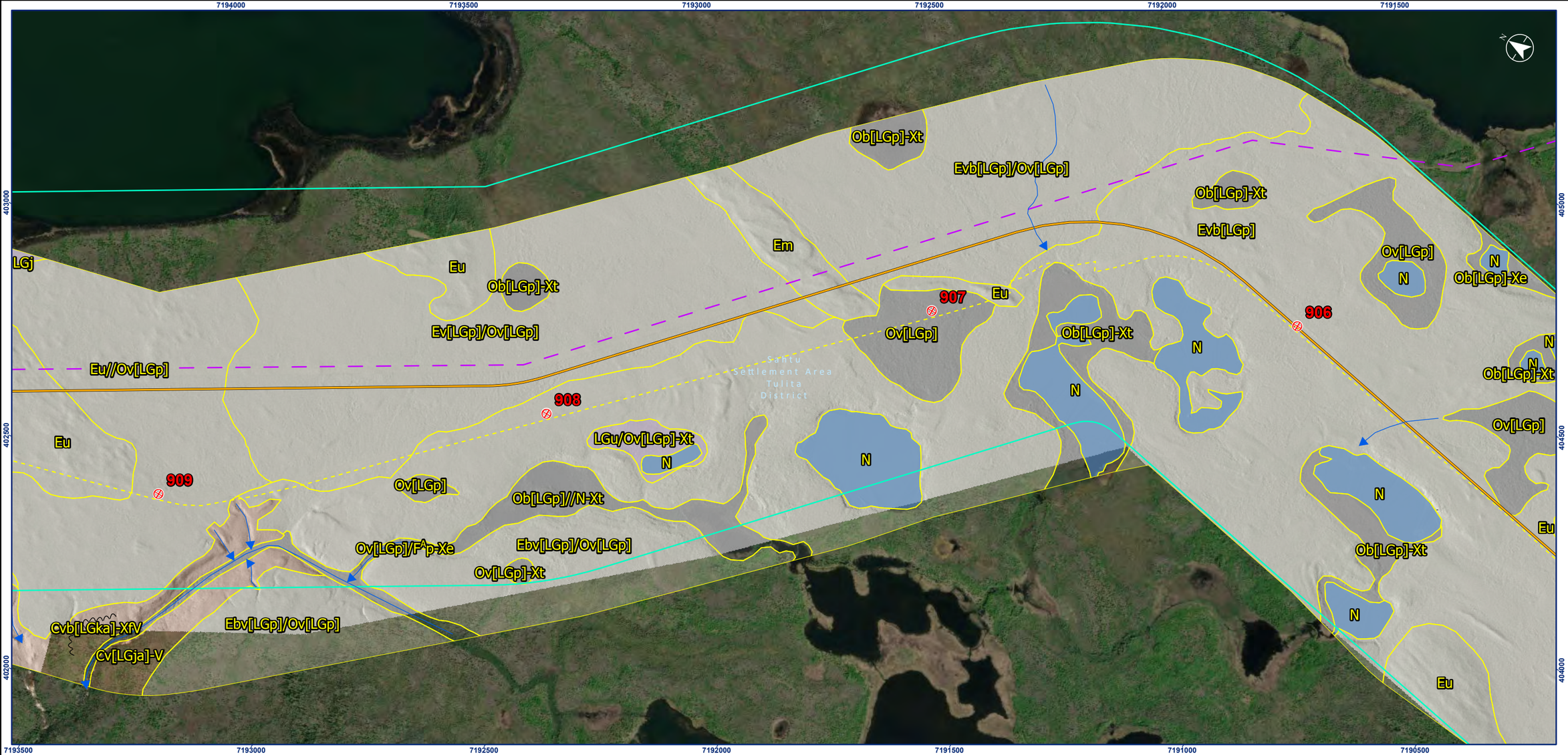

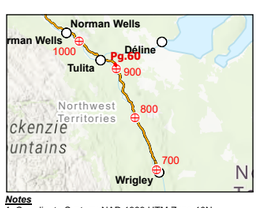

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

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^A	Active

Geomorphological Process

Permafrost Process

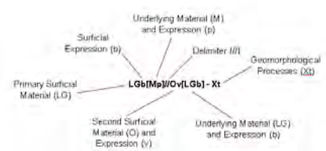
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.60

Title
LSA Terrain Mapping

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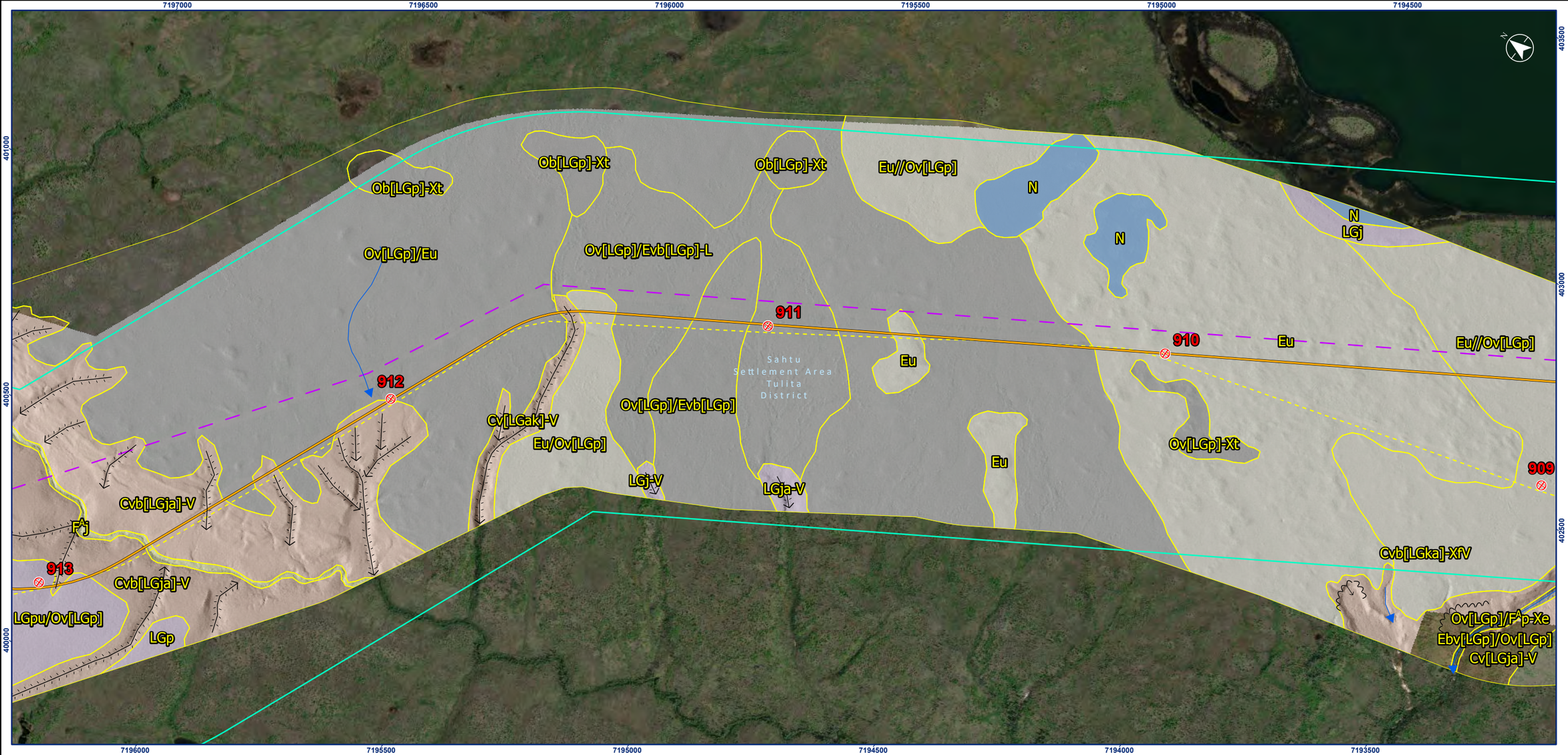

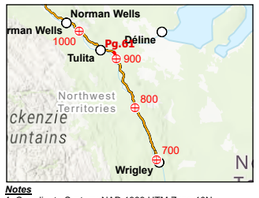

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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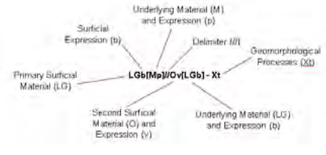
A	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.61

Title
LSA Terrain Mapping

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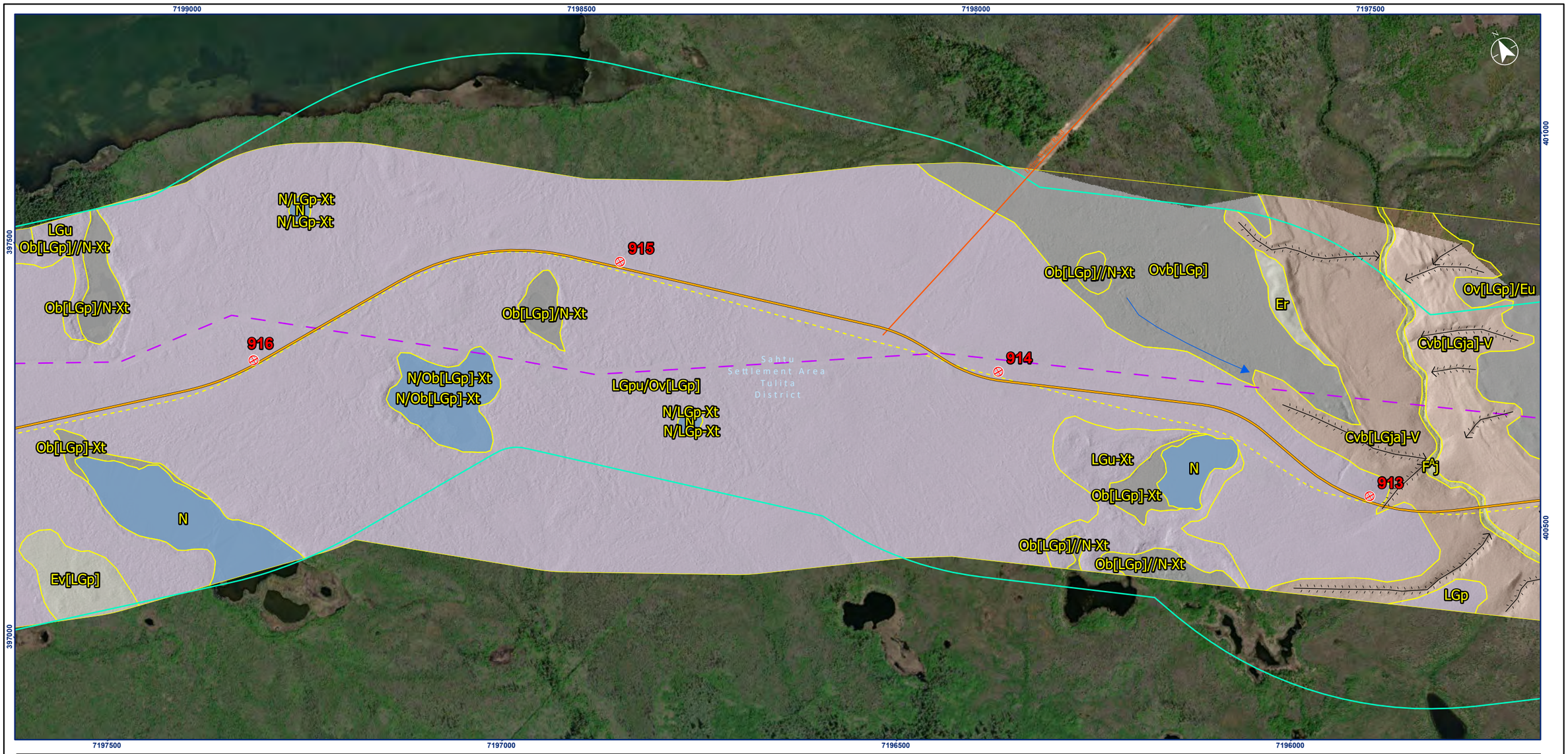

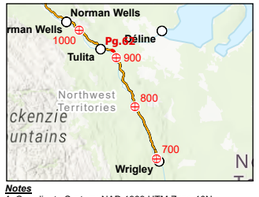

Notes

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4. Terrain mapping conducted in 2D using available airphotos, ortho-imagery and LiDAR data. Refer to Soils, Terrain and Permafrost TDR for detailed methodology

- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/	The component in front of the symbol is more extensive than the one that follows
//	The component in front of the symbol is considerably more extensive than the component that follows
^	Geomorphological process initiation zone
A	Active

Geomorphological Process

Permafrost Process

Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V

0 0.15 0.3 Kilometres

1:10,000 (at original document size of 11x17)

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.62

Title
LSA Terrain Mapping

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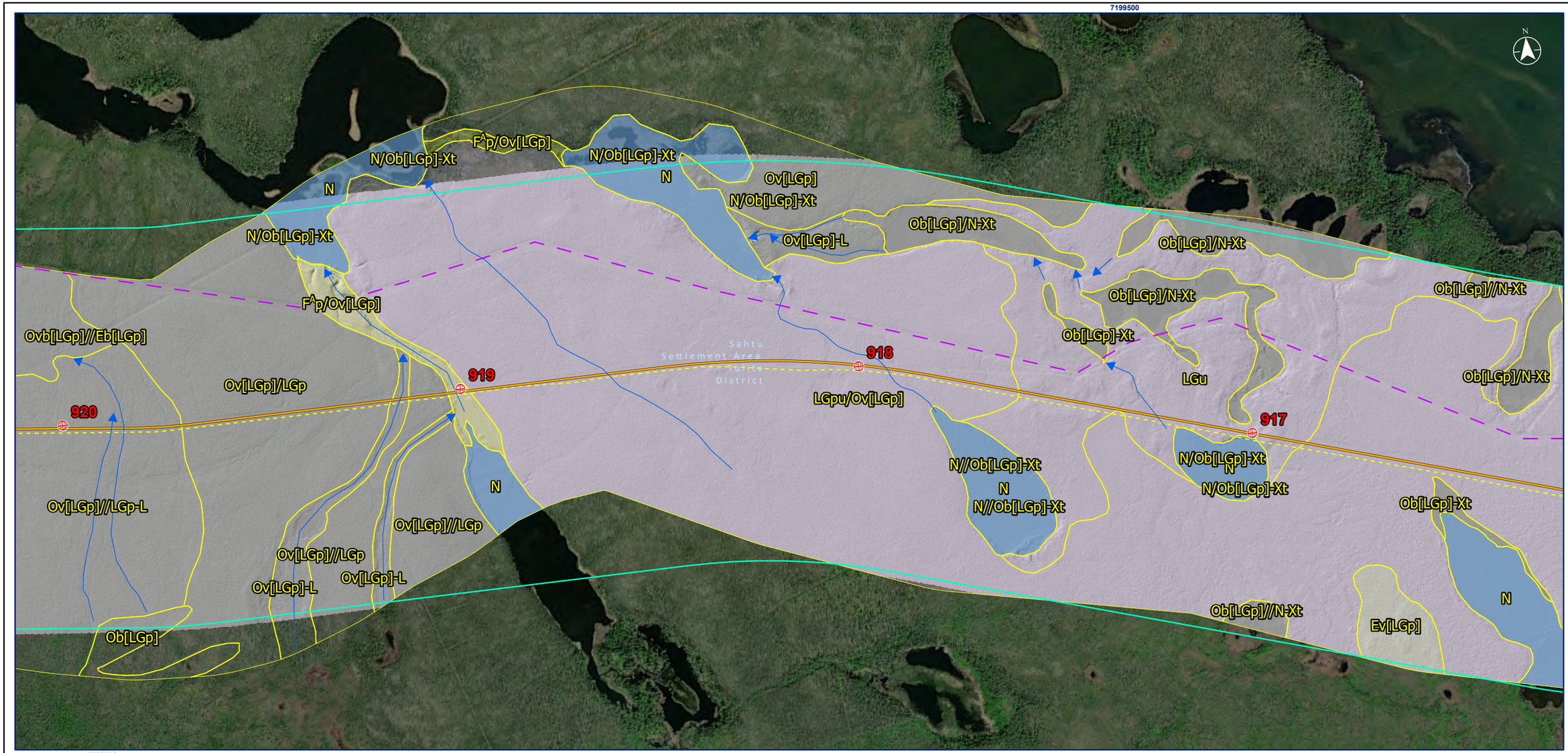

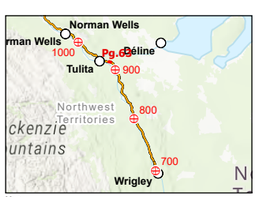

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

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- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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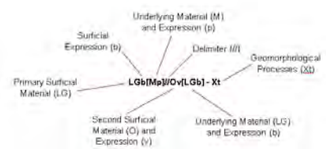
A	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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1:10,000 (at original document size of 11x17)

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.63

Title
LSA Terrain Mapping

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7200000

390500

N FAp LGp
N

Ov[LGp]
Cv[LGja]-V

LGpu//Ov[LGp]-L

923

Ov[LGp]//LGp

Obv[LGp]/N-Xt

Eu

LGpu//Ov[LGp]

LGj-V

Cv[LGaj]-V

FAj

922

Cv[LGajj]-V

Sahtu
Settlement Area
Tulita
District

N

Ob[LGp]/N-Xt

Ovb[LGp]//Eb[LGp]

N

N

Ov[LGp]/LGp

921

Ov[LGp]/LGp

Ob[LGp]/N-Xt

920

Ov[LGp]//LGp-L

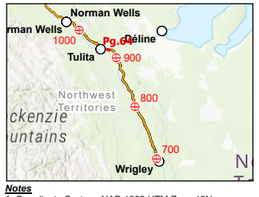
LGp

LGp

LGp

Ob[LGp]

7198000



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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material
- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

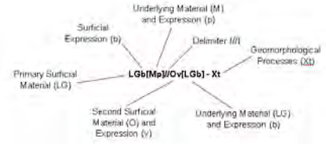
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.64

Title
LSA Terrain Mapping

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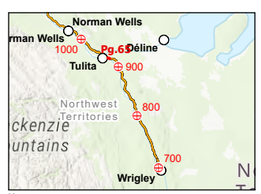
7201000 7200500 391000 387000 7199000 7198500

Ob[LGp]/N-Xt
LGp
F^p/N
N
F^p
N
LGp//Eb[LGp]
Ob[LGp]-Xt
LGpu//Ov[LGp]-L
Ov[LGpj]-L
927
926
925
924
LGpu//Ov[LGp]
LGpj
LGpj
Ovb[LGp]-L
LGu
LGu
Ov[LGp]//LGp
Ov[LGp]/N-Xt
Ob[LGp]/N-Xt
Obv[LGp]/N-Xt
Ov[LGp]/N-Xt
Ob[LGp]/N-Xt
LGu
Ob[LGp]//N-Xt
LGu
Ob[LGp]/N-Xt



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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material
- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
^A Active

Geomorphological Process

Permafrost Process

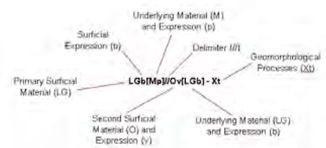
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



0 0.15 0.3 Kilometres
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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.65

Title
LSA Terrain Mapping

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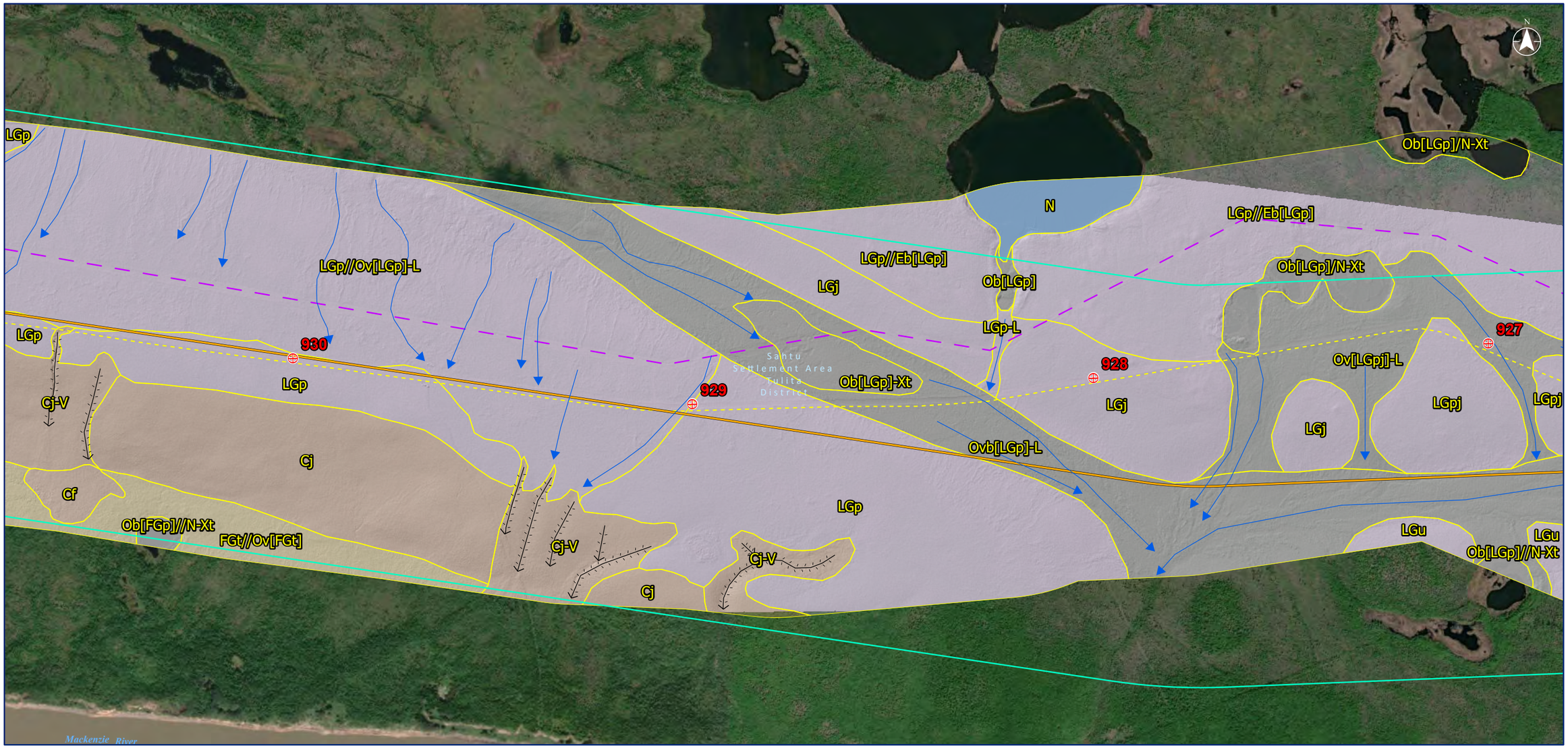

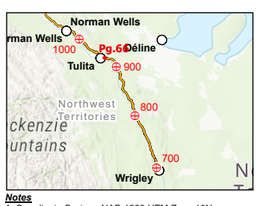

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material
- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
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- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
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- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
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rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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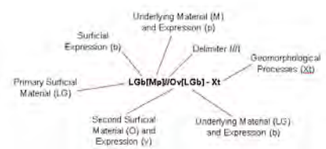
^	Geomorphological process initiation zone
A	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REV.A

Figure No.
B.66

Title
LSA Terrain Mapping

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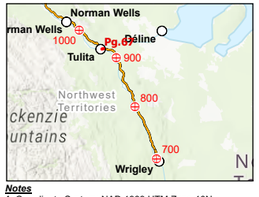
7201500

384000

7199500

Ov[LGp]
Ob[LGp]-Xt
Cvb[LGja]-VX^f
F^p
Cv[LGjk]-VX^f
Cbv[LGju]-X^f
LGp//Eu
LGu
LGp
LGp//Ov[LGp]-L
A
LGu-L
933
Cbv[LGju]-X^fV
Sahtu
Settlement Area
Tulita
District
931
934
Cj
LGp
Cj-V
FGt
Ob[FGp]/N-Xt
FGt
Cf
Cj-V
LGp
Ob[FGp]//N-Xt
FGt//Ov[FGt]
Cj
FGj-V
FGt
FGj-V
FGj-V
Cv[FGj]-Rs
FGj-V
Cv[FGj]-Rs
Cf
F^p
N
Ob[FGp]//N-Xt
Mackenzie River



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- Seepage Flow Direction
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Surficial Material

Anthropogenic	A
Colluvium	C
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Fluvial	F
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Water Body	N
Organic	O
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Surface Expression

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rolling	m
plain	p
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Delimiter and Qualifier

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A Active

Geomorphological Process

Permafrost Process

Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
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Rockfall	Rb
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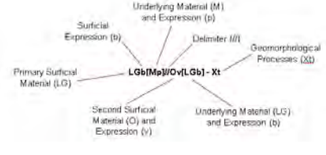
Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.67

Title
LSA Terrain Mapping

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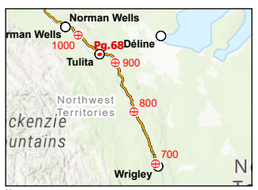
7200000 7200500 380500 377000 7198500 7199000

A
FAp
A
N
Tulita
Ob[FGt]
LGu-L
A
FGt
Ft
FGj
N
935
Sahtu
Settlement Area
Tulita
District
FAp
A
FGj-V
Cv[FGj]-Rs
Cv[FGj]-Rs
FGj-V
Mackenzie
River



Notes
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3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material
- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
// The component in front of the symbol is considerably more extensive than the component that follows
^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V

0 0.15 0.3 Kilometres
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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
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Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.68

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LSA Terrain Mapping

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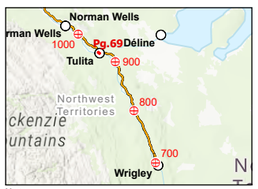

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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A Active

Geomorphological Process

Permafrost Process

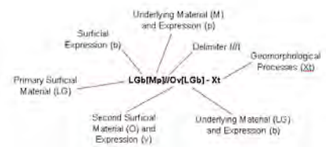
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location
Wrigley to Norman Wells, NWT

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Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.69

Title
LSA Terrain Mapping

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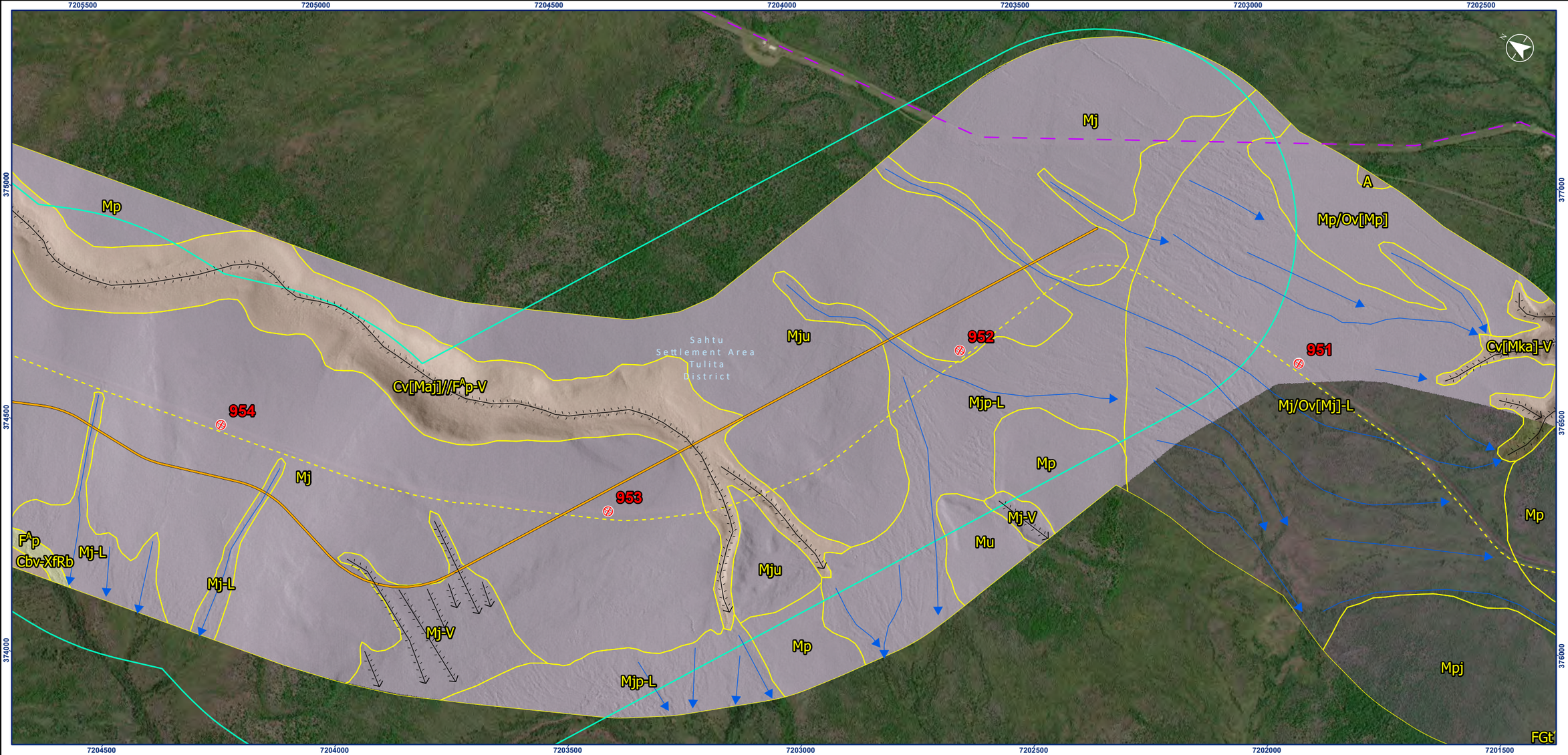

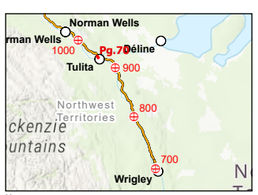

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

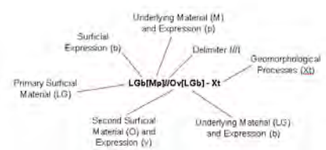
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.70

Title
LSA Terrain Mapping

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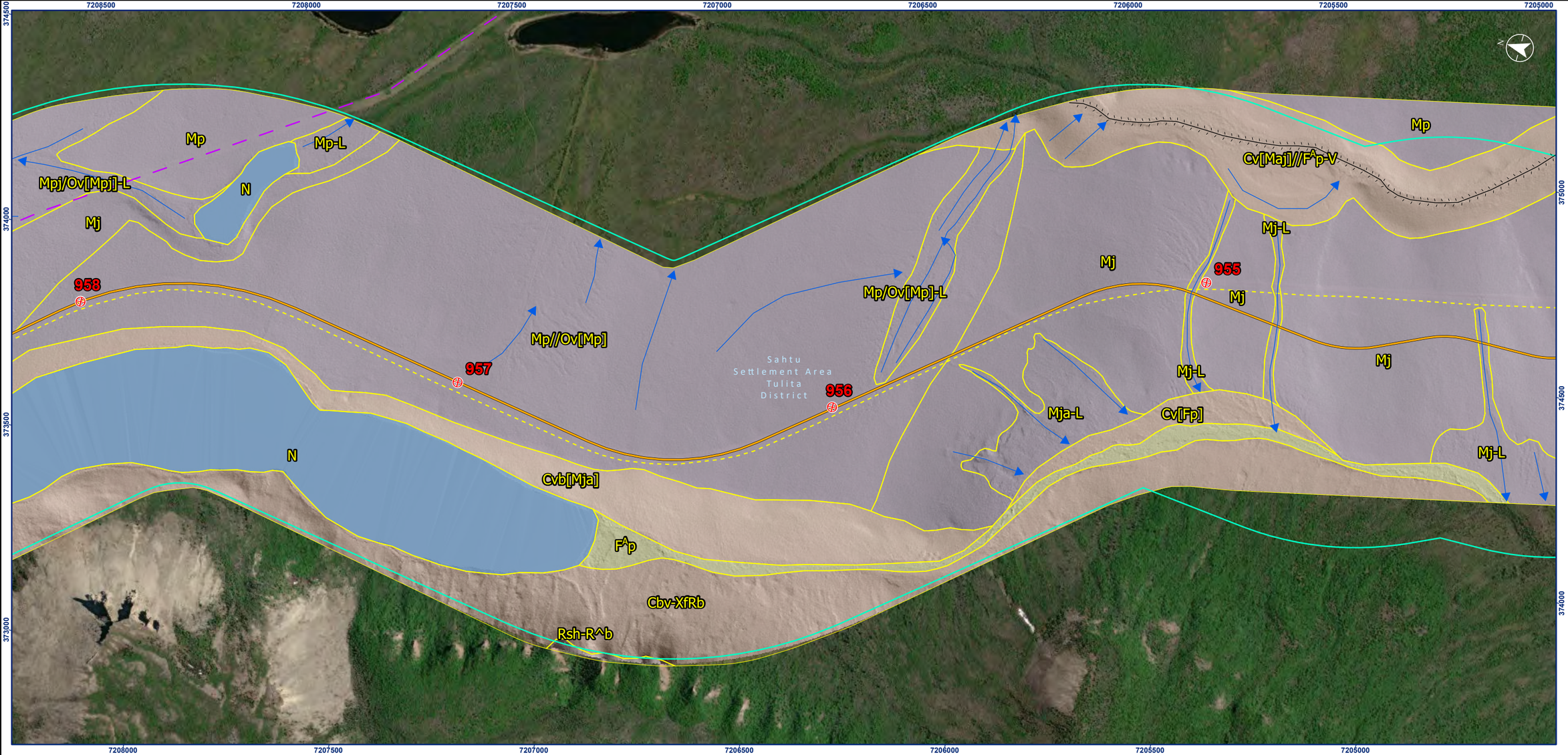

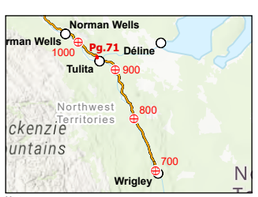

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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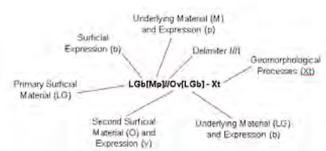
^	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location

Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
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Client/Project

144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.

B.71

Title

LSA Terrain Mapping

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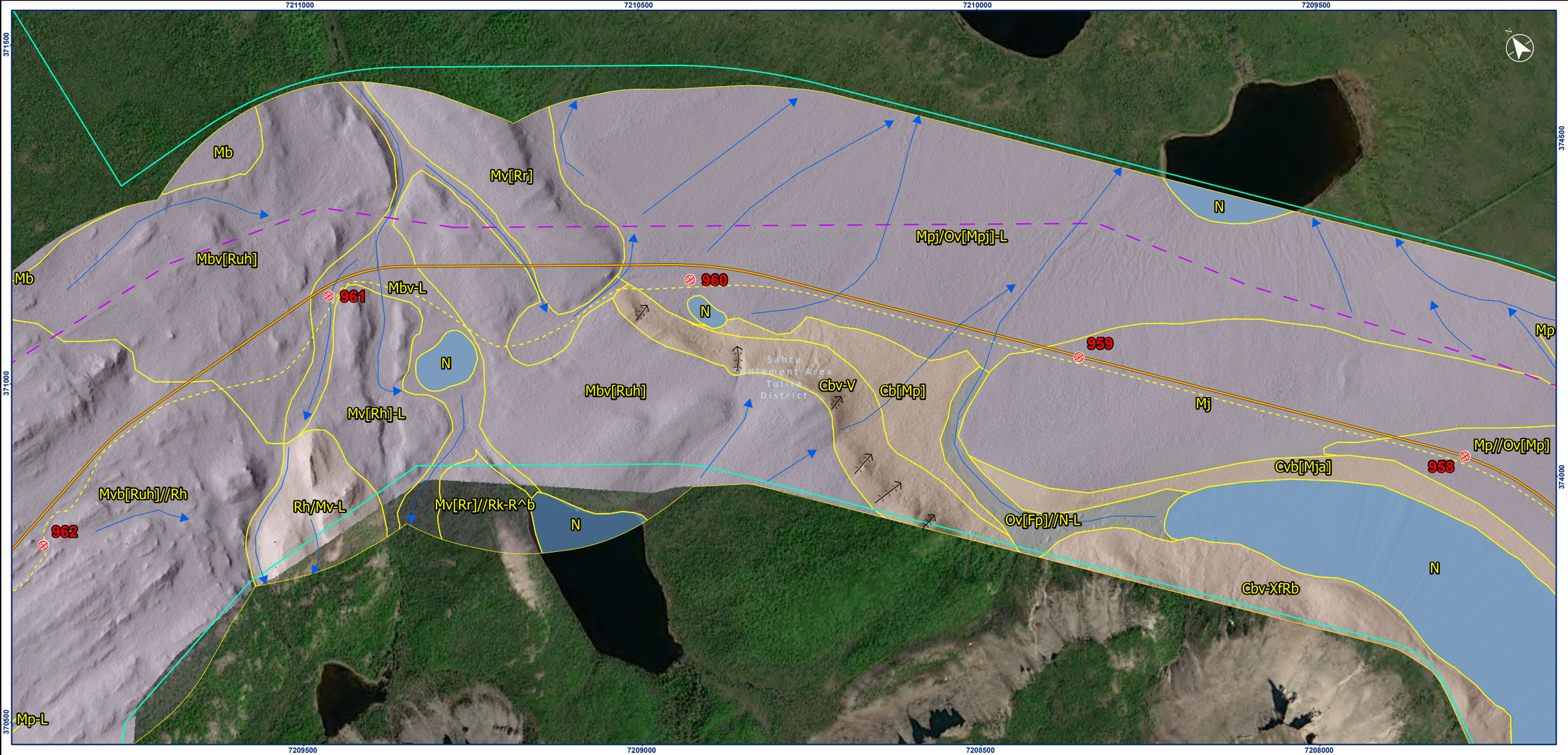

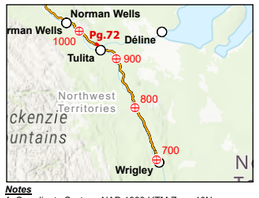

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material
- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^	Active

Geomorphological Process

Permafrost Process

Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V

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Project Location
Wrigley to Norman Wells, NWT

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Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.72

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LSA Terrain Mapping

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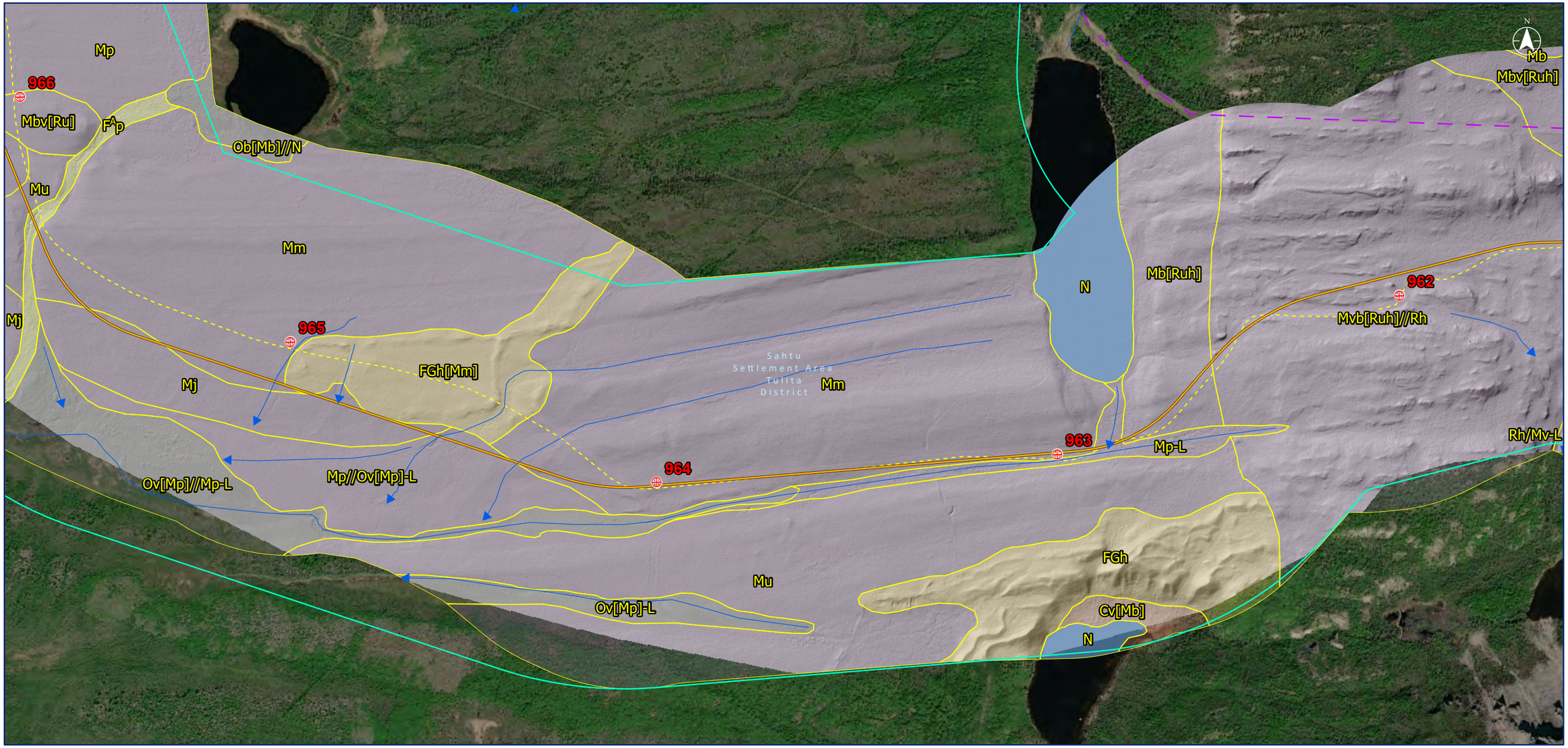

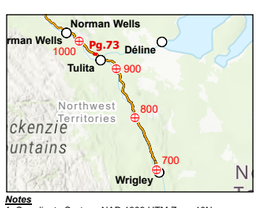

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
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Surficial Material

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steep slope (>70%)	s
terraced	t
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veneer (< 1 m)	v

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Geomorphological Process

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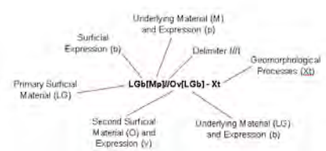

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Project Location
Wrigley to Norman Wells, NWT

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Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.73

Title
LSA Terrain Mapping

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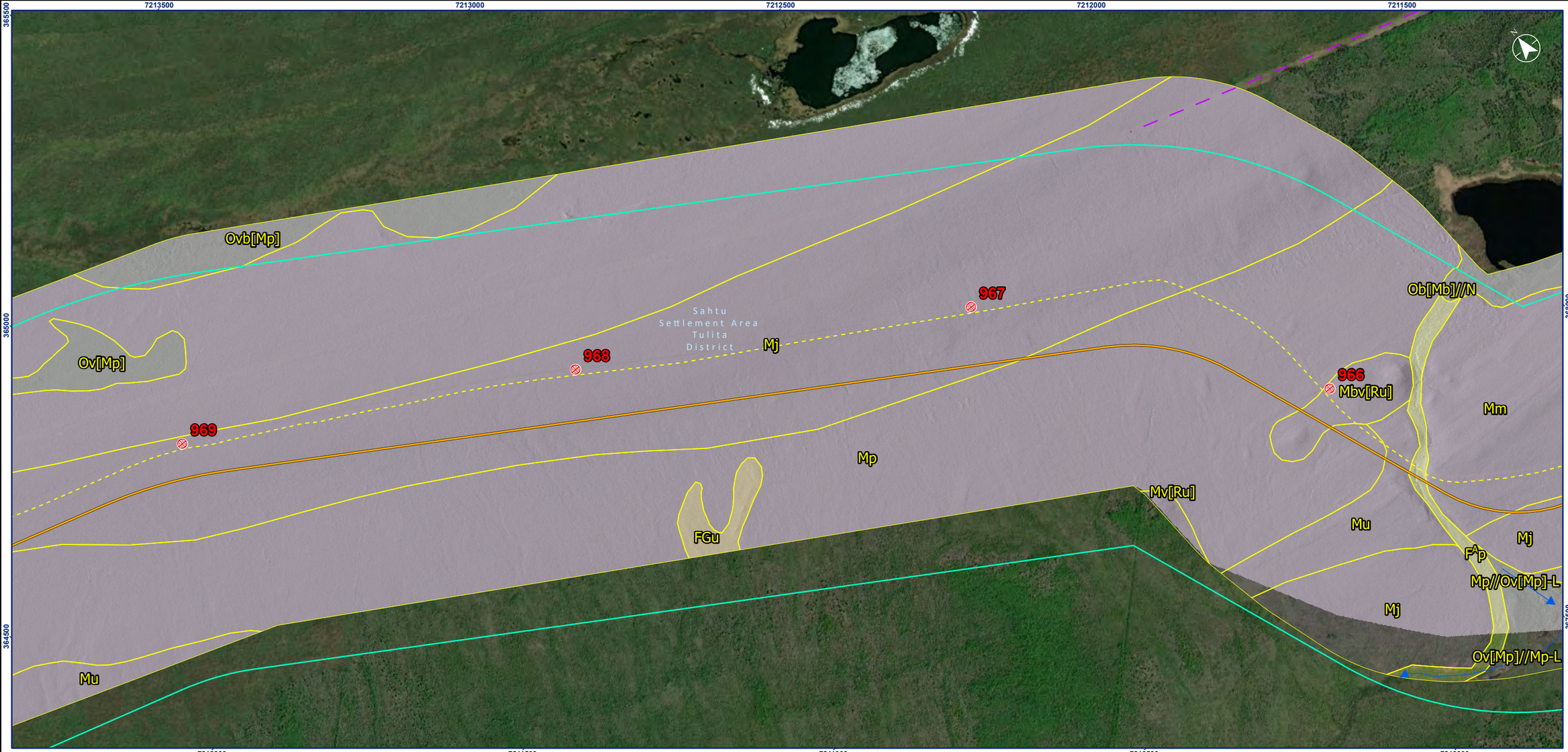

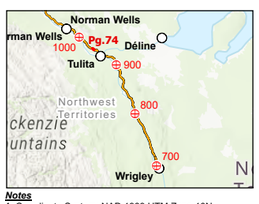

Notes

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4. Terrain mapping conducted in 2D using available airphotos, ortho-imagery and LiDAR data. Refer to Soils, Terrain and Permafrost TDR for detailed methodology

- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

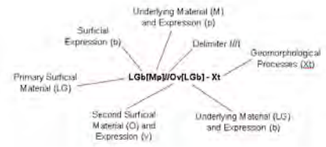
moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
// The component in front of the symbol is considerably more extensive than the component that follows
^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.74

Title
LSA Terrain Mapping

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7214500 7214000

361500

Ovb[Mp]

Ov[Mp]

Mb

Mj

970

971

Mp

Sahtu
Settlement Area
Tulita
District

972

Mp

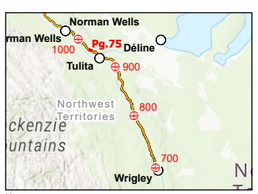
Mu

Mb-L

LGv[Mp]

365000

7212500 7212000



Notes
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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

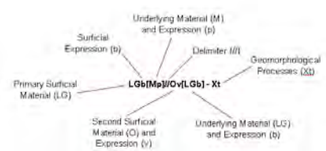
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REV.A

Figure No.
B.75

Title
LSA Terrain Mapping

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7216500 7216000 7215500 7215000 7214500

359000

Cv//Rs-R^b

Mbv

Mv

Mb

Mp

976

975

974

973

Sahtu
Settlement Area
Tulita
District

Mb-L

LGv[Mb]

Mv[Ru]

Mv[Ru]

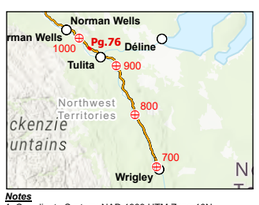
LGv[Mp]

358500

362000

361500

7215000 7214500 7214000 7213500 7213000



Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^	Geomorphological process initiation zone
A	Active

Geomorphological Process

Permafrost Process

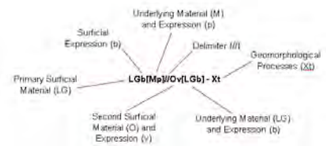
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.76

Title
LSA Terrain Mapping

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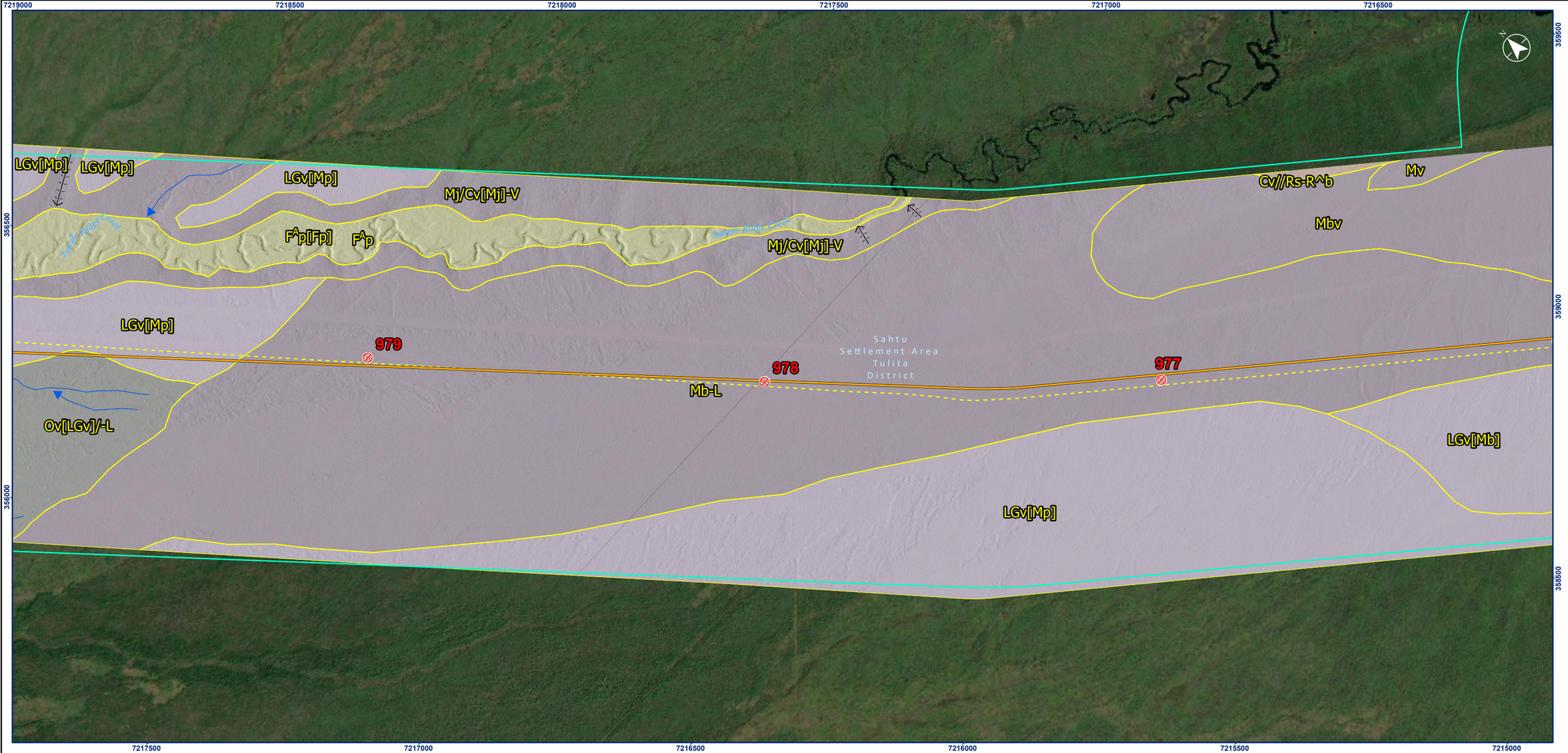

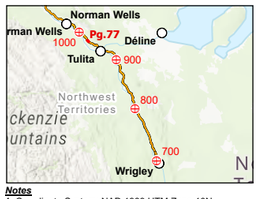

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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A Active

Geomorphological Process

Permafrost Process

Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V

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Kálo-Stantec

Project Location

Wrigley to Norman Wells, NWT

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Client/Project

144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.

B.77

Title

LSA Terrain Mapping

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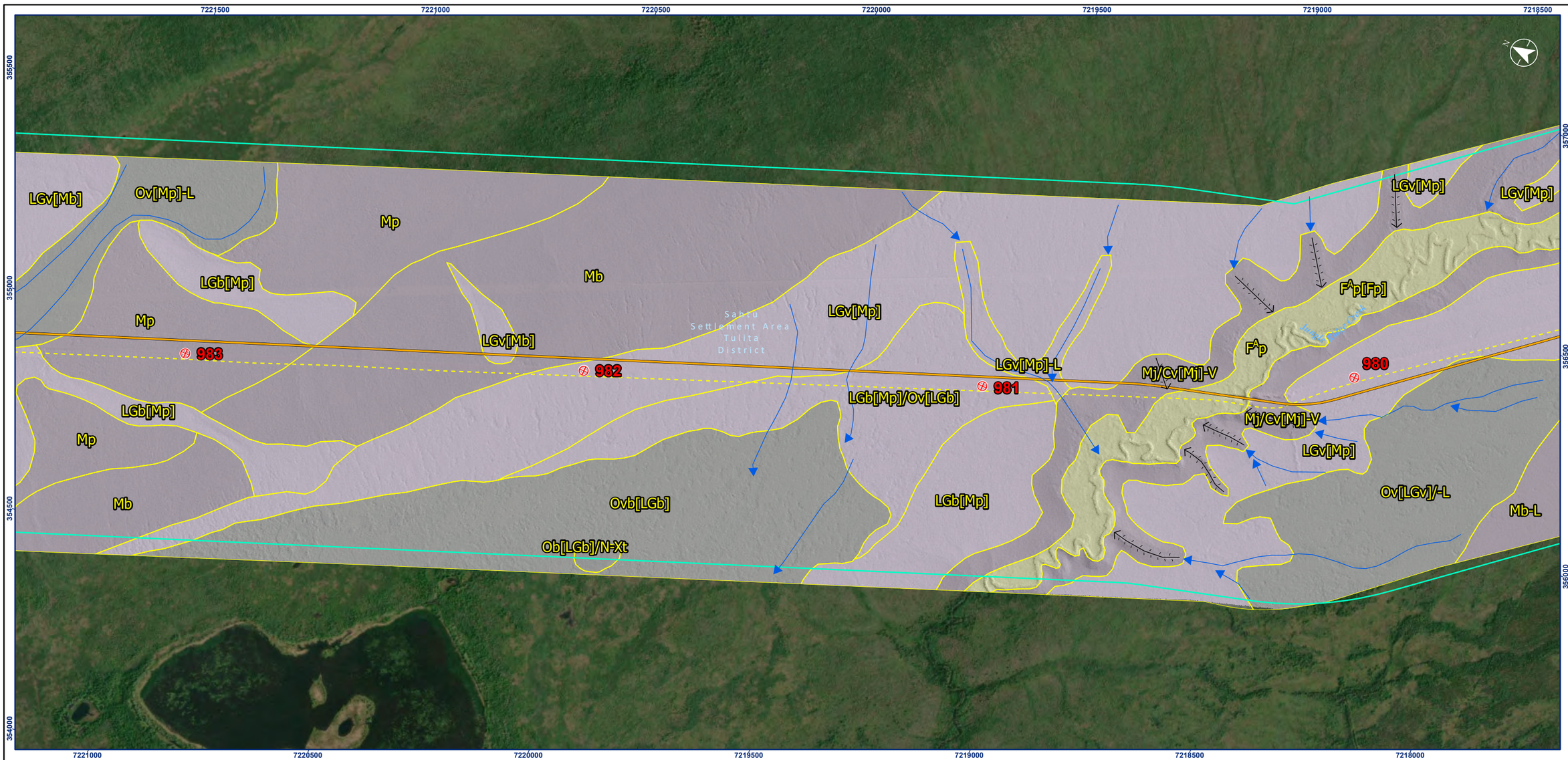

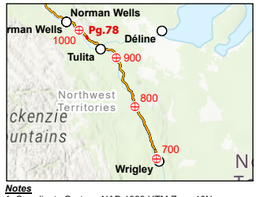

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Surficial Material

- Anthropogenic Material
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- Fluvial Material
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- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
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Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

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Geomorphological Process

Permafrost Process

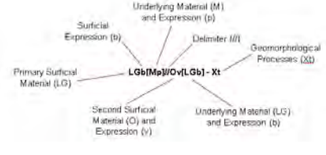
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location

Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project

144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.

B.78

Title

LSA Terrain Mapping

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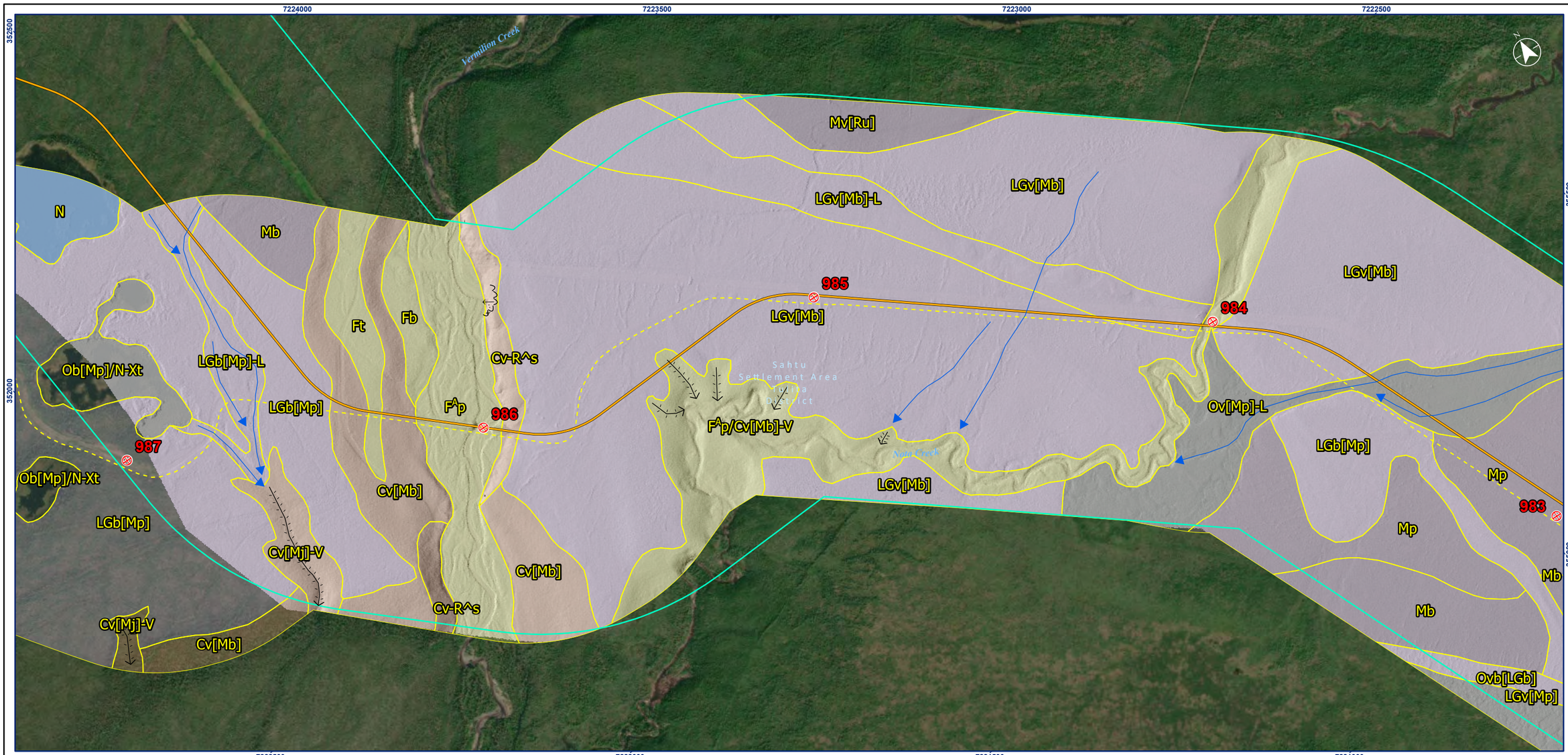

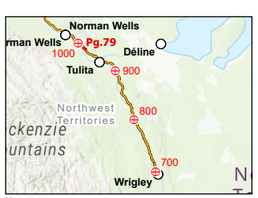

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material
- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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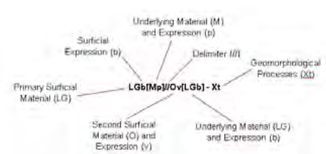
Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
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Client/Project
144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.79

Title
LSA Terrain Mapping

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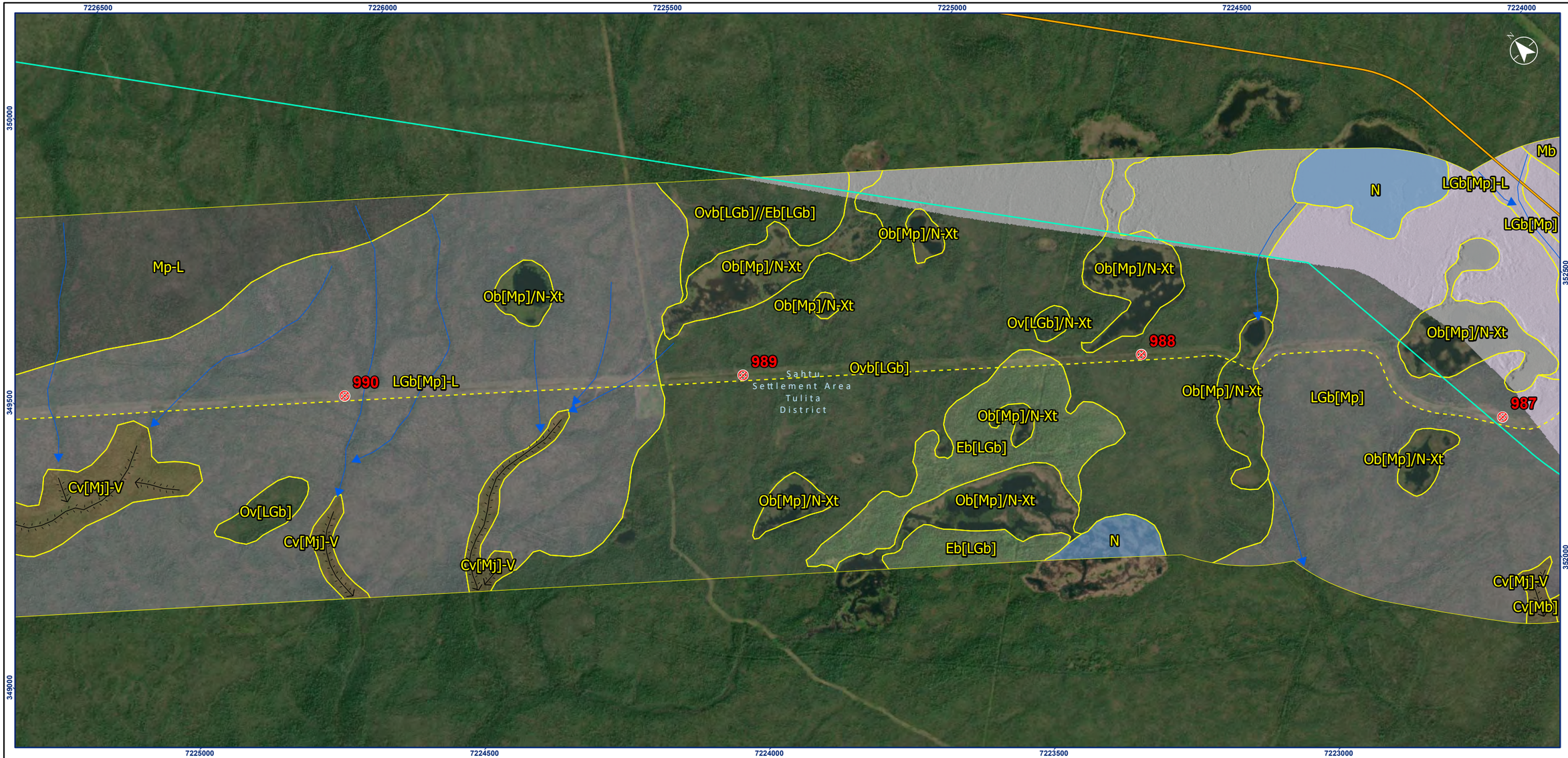

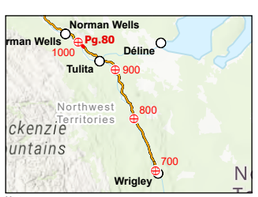

Notes

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4. Terrain mapping conducted in 2D using available airphotos, ortho-imagery and LiDAR data. Refer to Soils, Terrain and Permafrost TDR for detailed methodology

- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Moraine Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
// The component in front of the symbol is considerably more extensive than the component that follows
^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

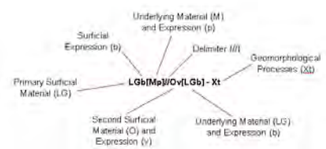
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.
B.80

Title
LSA Terrain Mapping

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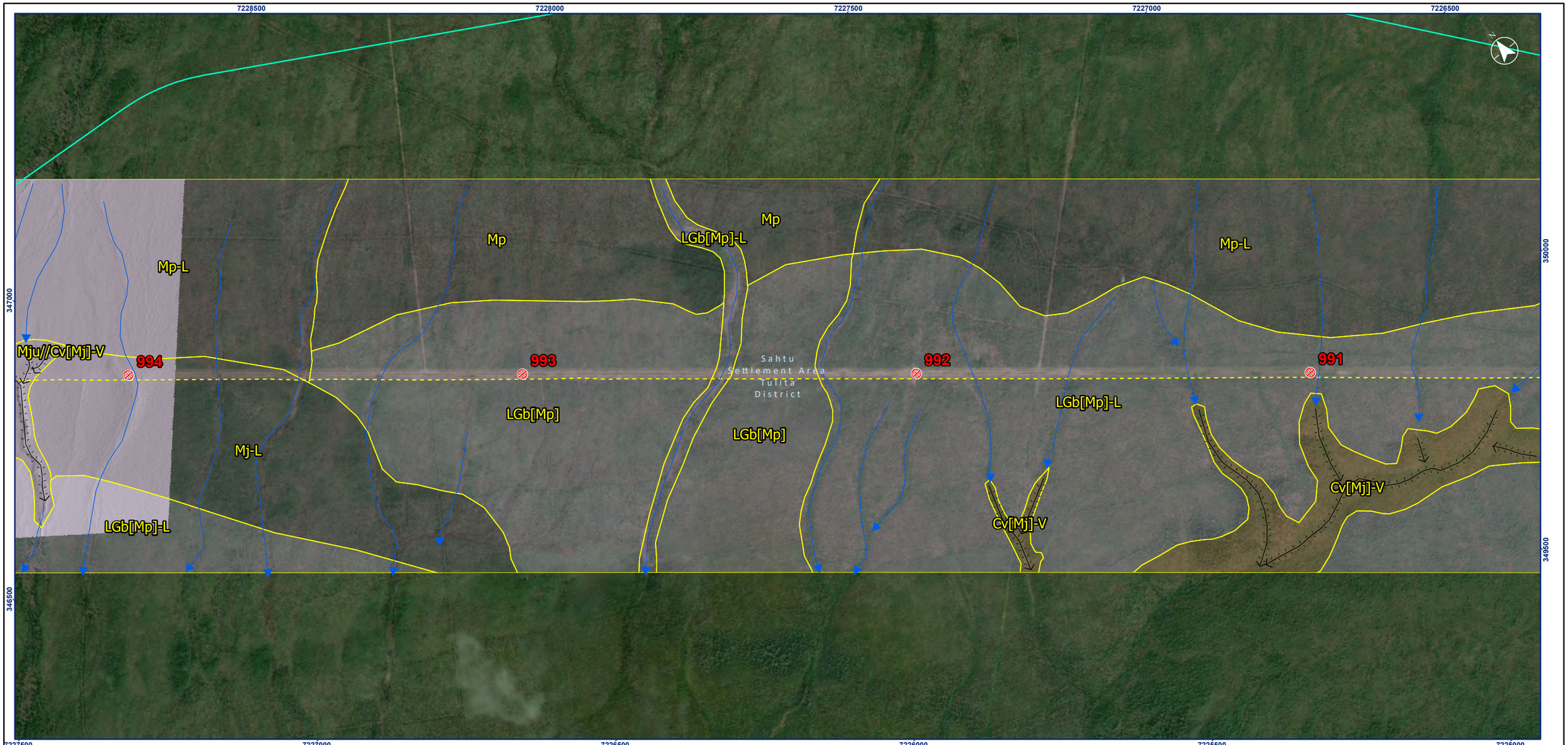

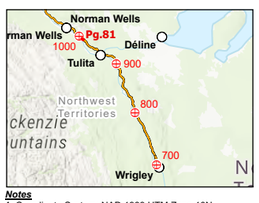

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
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^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V

0 0.15 0.3 Kilometres
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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

1 44903025-0065 REVA

Figure No.
B.81

Title
LSA Terrain Mapping

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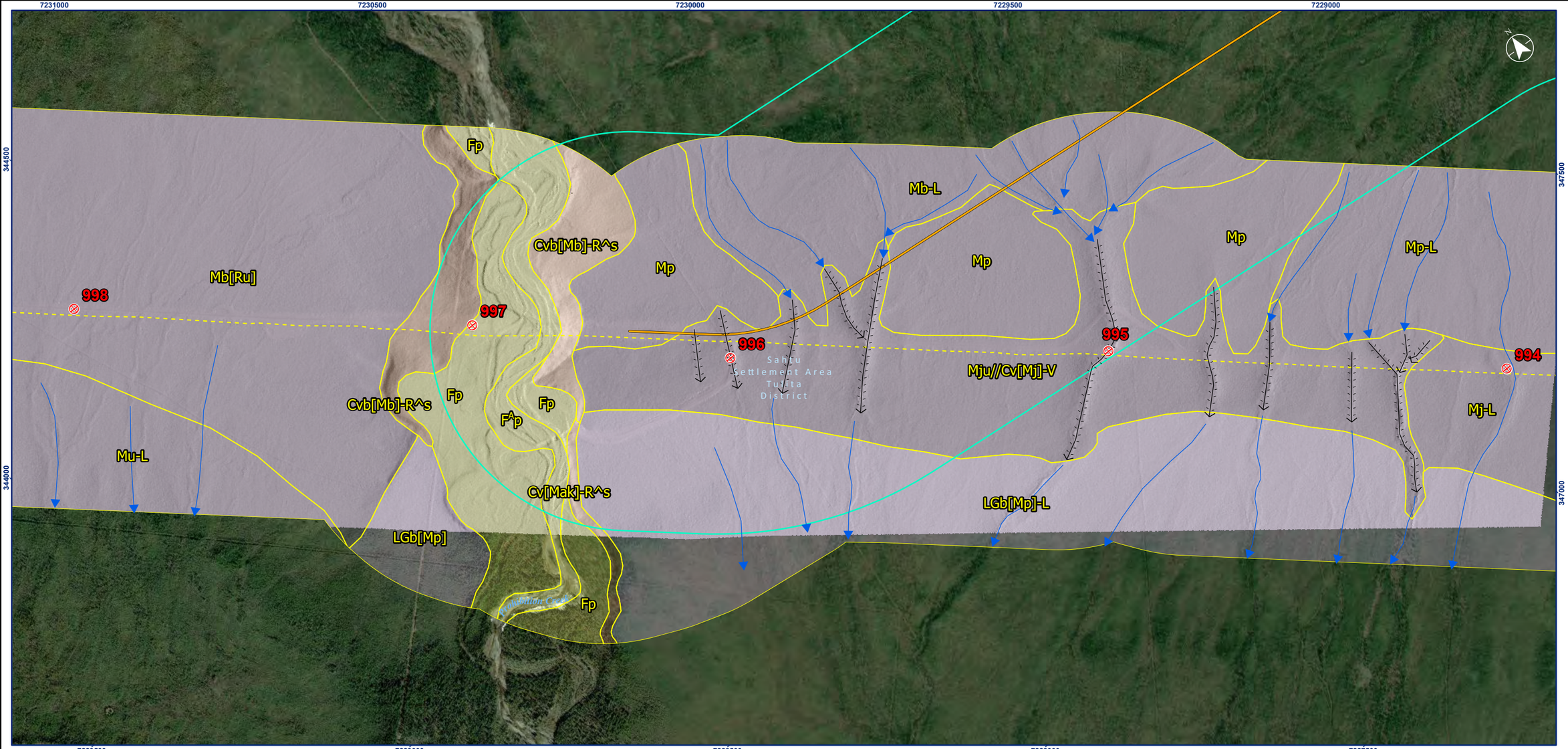

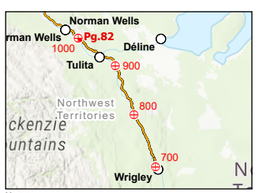

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- Local Study Area
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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^ Geomorphological process initiation zone
^A Active

Geomorphological Process

Permafrost Process

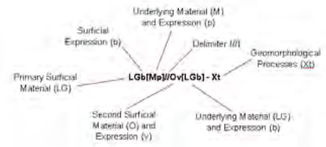
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project

144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
B.82

Title
LSA Terrain Mapping

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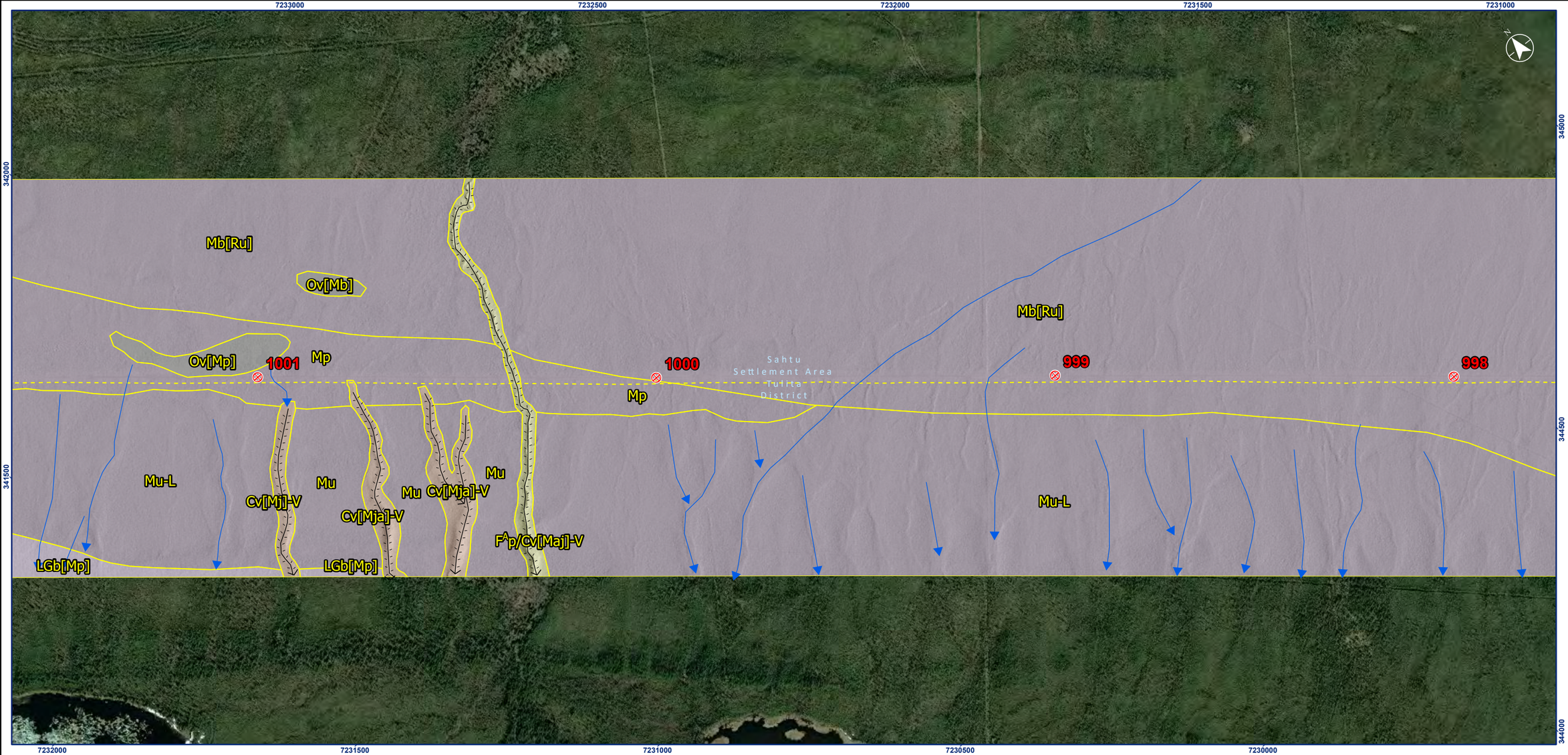

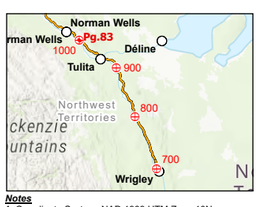

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/	The component in front of the symbol is more extensive than the one that follows
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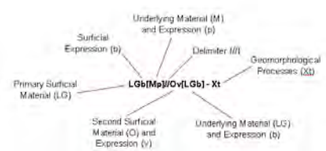
^	Geomorphological process initiation zone
^A	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REV.A

Figure No.
B.83

Title
LSA Terrain Mapping

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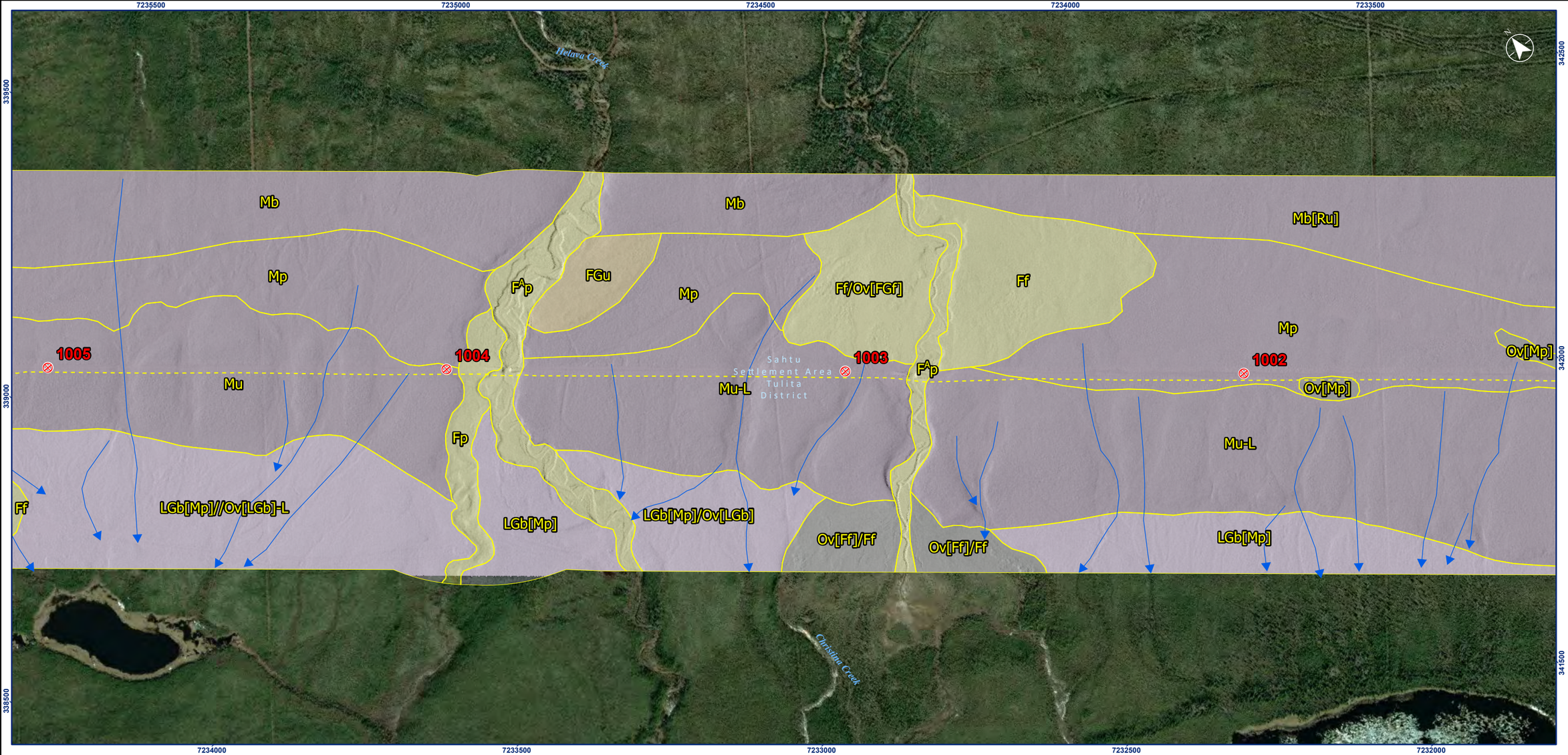

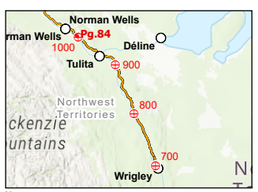

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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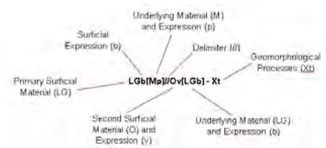
^	Geomorphological process initiation zone
A	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location

Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project

Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REVA

Figure No.

B.84

Title

LSA Terrain Mapping

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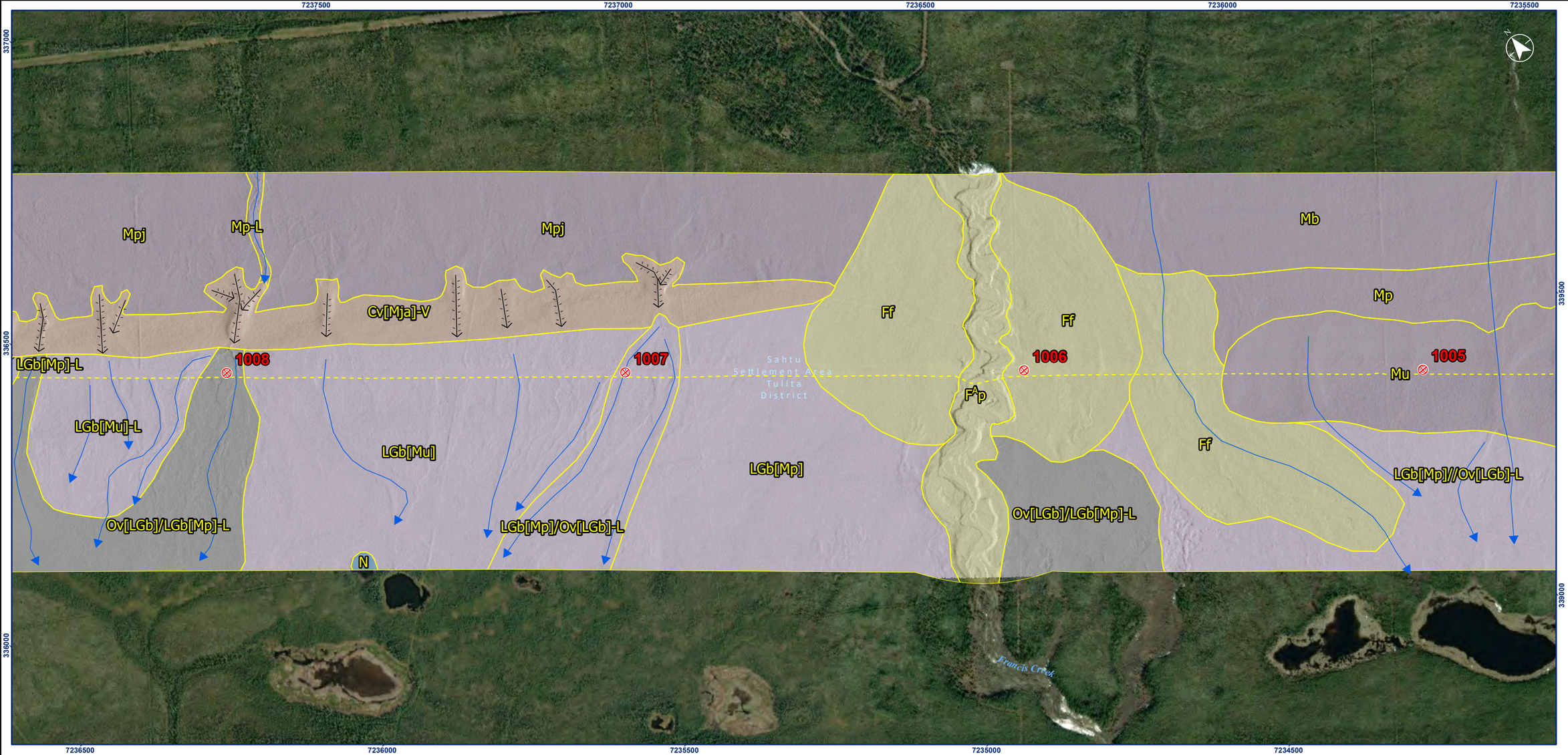

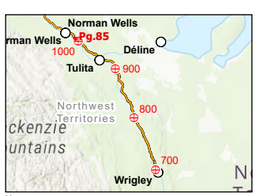

Notes

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- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Morainal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Morainal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

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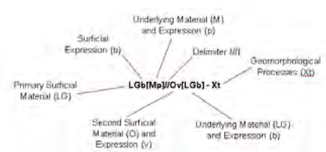
^	Geomorphological process initiation zone
A	Active

Geomorphological Process

Permafrost Process	
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe
Mass Movement Process	
Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru
Hydrological Process	
Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway

144903025-0065 REV.A

Figure No.
B.85

Title
LSA Terrain Mapping

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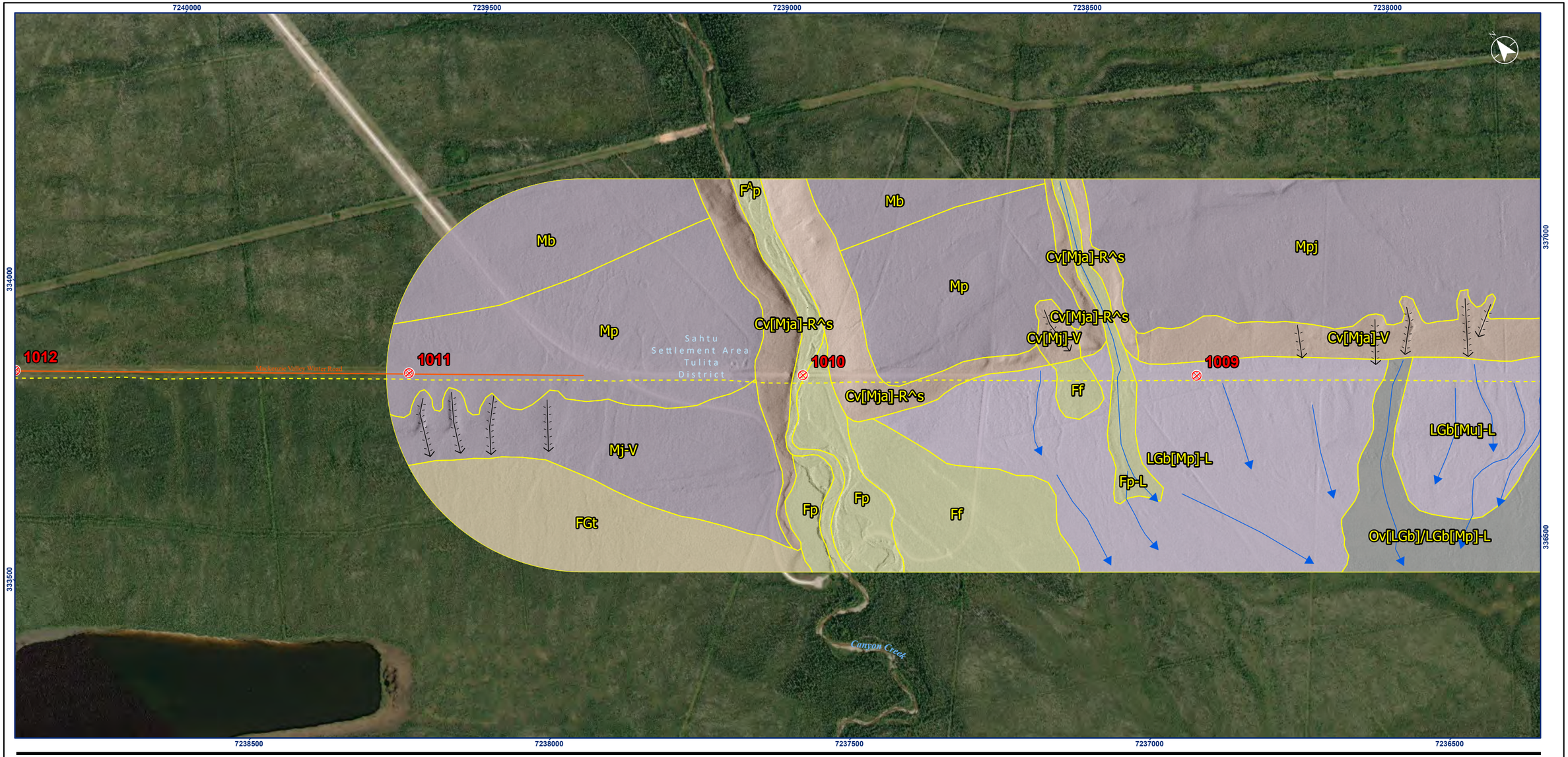
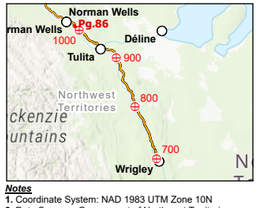




Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Government of Northwest Territories
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
   World Imagery: Maxar
   World Hillshade: Esri, USGS and LiDAR-derived hillshade provided by GNWT
4. Terrain mapping conducted in 2D using available airphotos, ortho-imagery and LiDAR data. Refer to Soils, Terrain and Permafrost TDR for detailed methodology

- Seepage Flow Direction
- Gully
- Landslide Scar

Surficial Material

- Anthropogenic Material
- Bedrock
- Colluvium
- Eolian
- Fluvial Material
- Glaciofluvial Material
- Glaciolacustrine Material
- Moraninal Material (till)
- Organic Material
- Water
- Terrain Mapping

- Mackenzie Valley Highway Kilometre Post
- Mackenzie Valley Highway Extension Project
- All-Season Road
- Winter Road
- Mackenzie Valley Fibre Link
- Norman Wells to Zama Lake Pipeline (Enbridge)
- District Boundary
- Region Boundary
- Settlement Area Boundary

Surficial Material

Anthropogenic	A
Colluvium	C
Eolian	E
Fluvial	F
Glaciofluvial	FG
Glaciolacustrine	LG
Moraninal (till)	M
Water Body	N
Organic	O
Bedrock	R

Surface Expression

moderate slope (27-49%)	a
blanket (> 1 m)	b
cone	c
depression	d
fan	f
hummocky	h
gentle slope (6-26%)	j
moderate steep slope (50-70%)	k
rolling	m
plain	p
ridged	r
steep slope (>70%)	s
terraced	t
undulating	u
veneer (< 1 m)	v

Delimiter and Qualifier

/ The component in front of the symbol is more extensive than the one that follows
// The component in front of the symbol is considerably more extensive than the component that follows
^ Geomorphological process initiation zone
A Active

Geomorphological Process

Permafrost Process

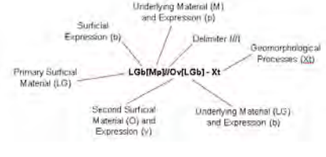
Thermokarst	Xt
Thaw flow	Xf
Ice wedge	Xw
Thermo-erosion	Xe

Mass Movement Process

Slow mass movement	F
Tension crack	Fk
Rapid mass movement	R
Rockfall	Rb
Debris flow	Rd
Debris slide/avalanche	Rs
Rotational slump	Ru

Hydrological Process

Channeled by meltwater	E
Kettled	H
Surface seepage	L
Inundation	U
Gullying	V



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Project Location

Wrigley to Norman Wells, NWT

Prepared by CES on 2021-02-08
TR by OP on 2023-03-14

Client/Project

144903025-0065 REVA

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.

B.86

Title

LSA Terrain Mapping

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APPENDIX 15A

Surface Water Quantity Technical Data Report

Mackenzie Valley Highway Project
Technical Data Report—Surface Water Quantity

Prepared for:

Government of the Northwest Territories

Prepared by:

K'alo-Stantec Limited

December 2022

Project No.: 144903025

K'alo-Stantec

Limitations and Sign-off

This document entitled Mackenzie Valley Highway Project Technical Data Report—Surface Water Quantity was prepared by K'alo-Stantec Limited ("K'alo-Stantec") for the account of Government of the Northwest Territories (the "Client") to support the regulatory review process for its Developer's Assessment Report (the "DAR") for the Mackenzie Valley Highway Project (the "Project"). In connection therewith, this document may be reviewed and used by the Government of the Northwest Territories Department of Infrastructure participating in the review process in the normal course of its duties. Except as set forth in the previous sentence, any reliance on this document by any other party or use of it for any other purpose is strictly prohibited. The material in it reflects K'alo-Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between K'alo-Stantec and the Client. The information and conclusions in the document are based on the conditions existing at the time the document was published and does not take into account any subsequent changes. In preparing the document, K'alo-Stantec did not verify information supplied to it by the Client or others, unless expressly stated otherwise in the document. Any use which another party makes of this document is the responsibility and risk of such party. Such party agrees that K'alo-Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other party as a result of decisions made or actions taken based on this document.

Prepared by Digitally signed by Ali Naghibi
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Ali Naghibi, Ph.D., P.Eng.
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Reviewed by Digitally signed by Luzi, David
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Senior Geomorphologist

Approved by Digitally signed by Bonhomme, Erica
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Erica Bonhomme, M.Sc., P.Geo.
Principal, Environmental Services

K'alo-Stantec

Executive Summary

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Valley Highway (MVH) from Wrigley to Norman Wells. The Project consists of a 321 kilometre (km) all-season highway that largely follows the route of the existing Mackenzie Valley Winter Road (MVWR), and the construction and operation of temporary and permanent borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Settlement Area (SSA) within the Northwest Territories (NT).

This technical data report (TDR) presents existing surface water quantity data to support the Developer's Assessment Report (DAR). Existing data were collected from Water Survey of Canada (WSC) hydrometric stations in the region; published documents were also reviewed for relevant data. Hydrologic indices (i.e., mean annual runoff, monthly distribution of annual runoff, peak flows, and low flows) were characterized for 10 watersheds identified within the RSA. These watersheds contain the major streams (i.e., tributaries of the Mackenzie River) that the project highway alignment will cross.

The mean annual runoff (MAR) in the MVH Project Area is 151 millimetre [mm] to 220 mm. Although it is known that the watersheds with drainage areas of greater than 100 km^2 are perennial, it is not known with certainty which watersheds with drainage areas of less than 100 km^2 are perennial and which ones are seasonal. It is anticipated that the surface water quantity effects assessment would not be sensitive to these uncertainties. If the affects assessment analyses show that this assumption is not valid, or if more precise estimates for the MAR and monthly distribution of runoff are needed by other disciplines, further field and/or desktop work will be required.

Engineering design and analysis of crossings (e.g., conveyance capacity and channel stability) would require a separate study tailored for such purposes. Data presented in this TDR are intended to support the surface water quantity effects assessment of the DAR; they do not provide engineering design parameters.

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Abbreviations

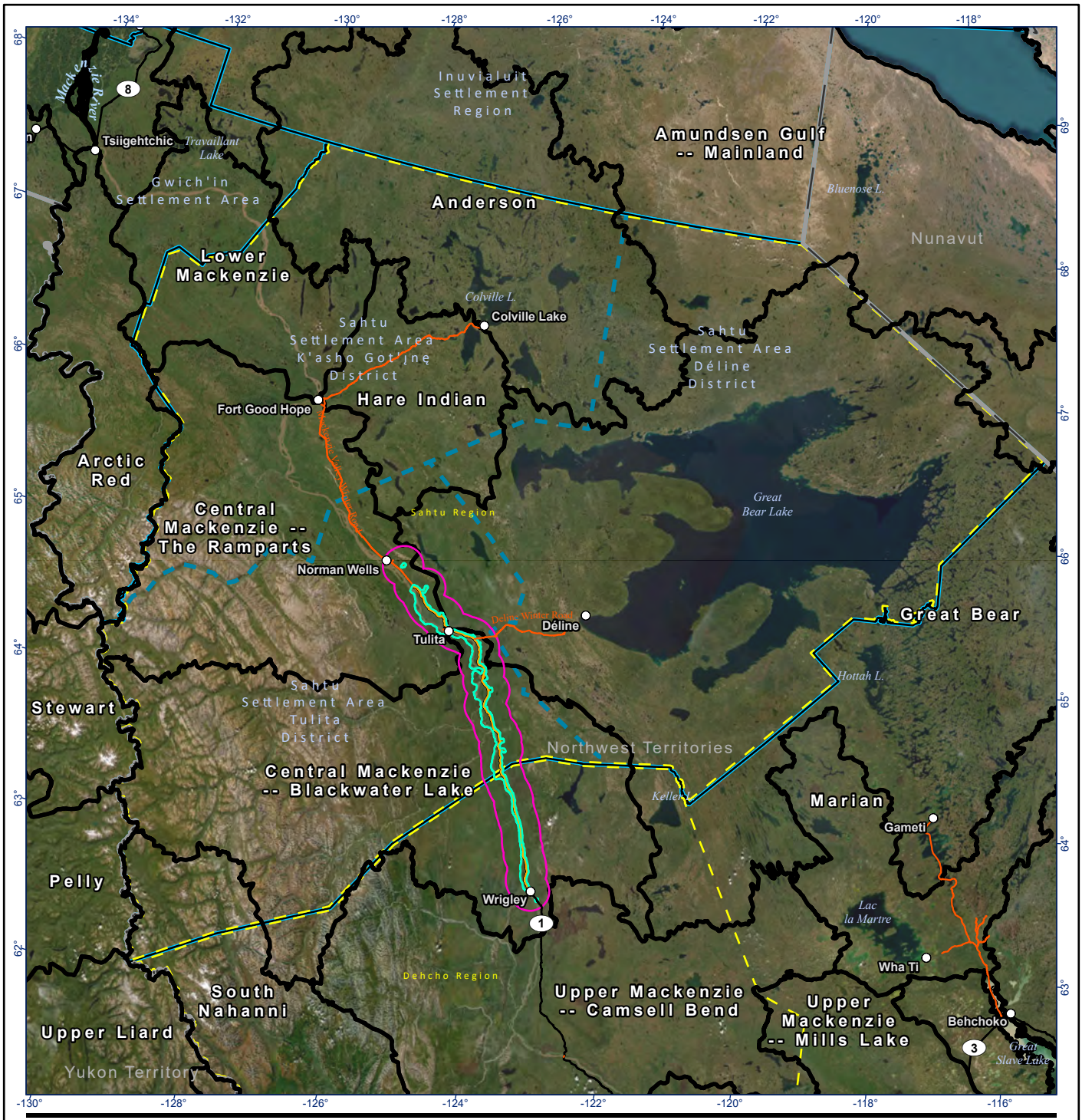
7Q10a	Annual 7-day low flow with 10-year return period
7Q10s	June to September 7-day low flow with 10-year return period
DA	drainage area
DAR	Developer's Assessment Report
GNWT	Government of the Northwest Territories
INF	Department of Infrastructure
km	kilometre
KM	kilometre marker
km^2	square kilometre
LSA	Local Study Area
m	metre
m^3	cubic metre
m^3/s	cubic metre per second
MAR	mean annual runoff
mm	millimetre
MVH	Mackenzie Valley Highway
MVLWB	Mackenzie Valley Land and Water Board
MVWR	Mackenzie Valley Winter Road
NT	Northwest Territories
RSA	Regional Study Area
SSA	Sahtu Settlement Area
TDR	technical data report
the Project	Mackenzie Valley Highway Project
TK	traditional knowledge
TLRU	traditional land and resource use
WSC	Water Survey of Canada

1 Introduction

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Valley Highway (MVH) from Wrigley to Norman Wells, Northwest Territories (NT). The Project consists of a 321 kilometre (km) all-season highway that largely follows the route of the existing Mackenzie Valley Winter Road (MVWR), and the construction and operation of temporary and permanent borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Settlement Area (SSA) within the NT (Figure 1.1).

The Project is subject to an environmental assessment and the requirements of Part 5 of *the Mackenzie Valley Resource Management Act*. This technical data report (TDR) presents the baseline surface water quantity data to support the Developer's Assessment Report (DAR), as required by the Terms of Reference (MVEIRB, 2015).

The study area is described in Section 2 and existing data are reviewed in Section 3. Hydrologic indices for the study area are characterized in Section 4 and recommendations are provided in Section 5.



- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Sub-Basin
- Territorial Boundary

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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0063 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
1.1

Title
MVH Project Overview

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
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World Hillshade: Esri, USGS

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2 Study Area

The Project is located in the Mackenzie Valley region of the NT between the current terminus of the existing all-weather highway in Wrigley (Highway #1, kilometre marker [KM] 690 of the MVWR) and Norman Wells (KM 1011 of the MVWR). The project highway alignment parallels the Mackenzie River to its west and passes through the community of Tulita (KM 938 of the MVWR). The Project is in the Mackenzie River basin and within the Central Mackenzie-Blackwater Lake, Central Mackenzie-the Ramparts, and Great Bear sub-basins, as defined by the Standard Drainage Area Classification (NRCan, 2003; Figure 2.1). The Project Development Area is defined as the area to be utilized by the Project and includes a 100 metre (m) buffer on either side of the project highway alignment between Wrigley and Norman Wells. It also includes the temporary and permanent borrow sources and associated access roads once these are made available.

The local and regional study areas presented in this TDR are the areas where data was compiled/collected to allow for an understanding of the environment in support of the project-specific effects assessment and the cumulative effects assessment. The study area does not include potential borrow sources as these were not identified at the time of writing.

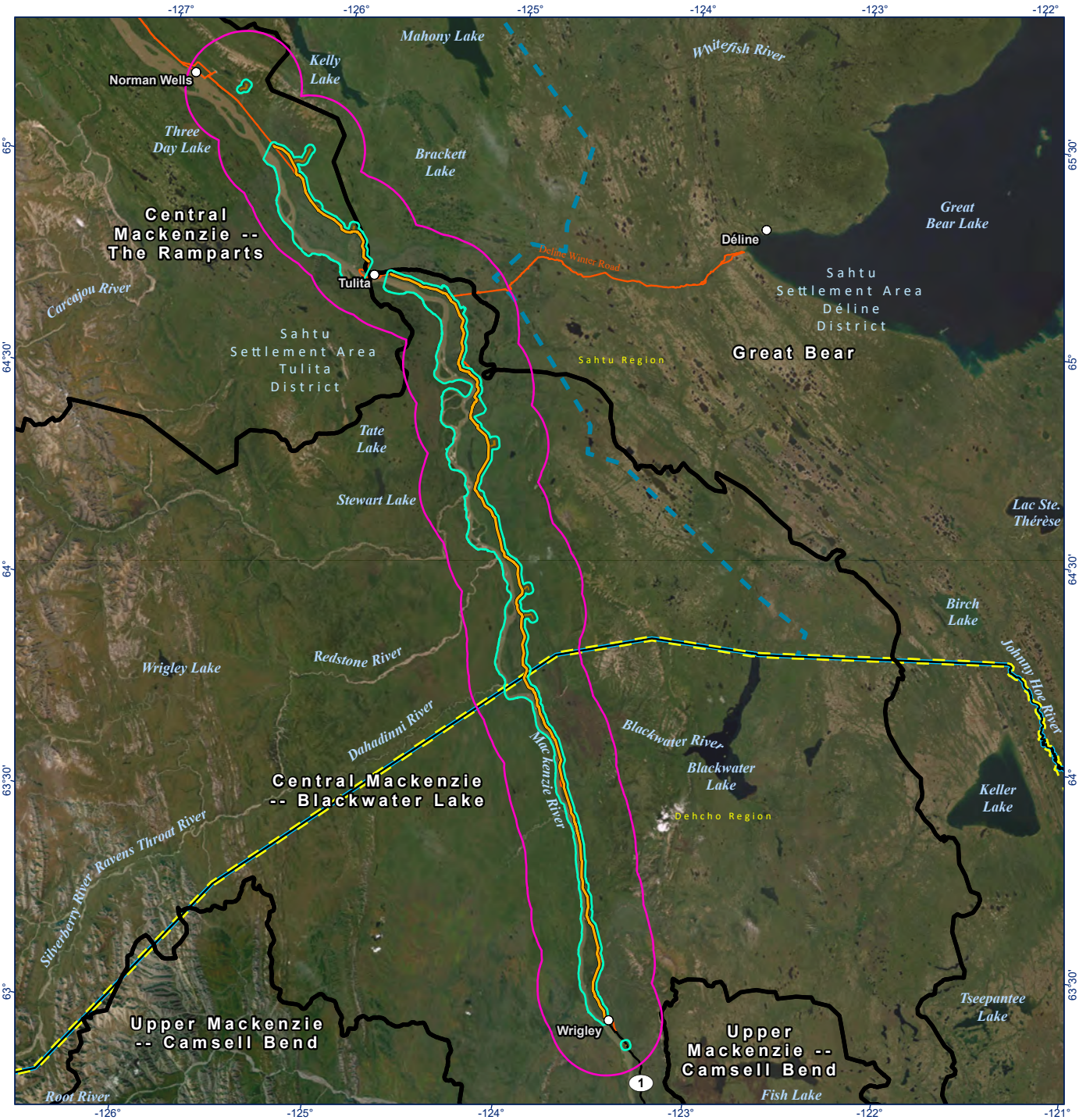
2.1 Local Study Area

The Local Study Area (LSA) is a 1 km buffer centred on the Project Development Area (which is currently the alignment of the MVWR). This buffer was extended to include the mainstem of Mackenzie River and potential water sources for construction of the MVH to encompass the anticipated extent of Project-related direct and indirect effects on surface water quantity (Figure 2.1).

2.2 Regional Study Area

The Regional Study Area (RSA) is a 15 km buffer centred on the Project Development Area. The RSA includes surface water quantity-related features that could be affected by the cumulative effects of Project activities interacting with the activities of other existing, past or reasonably foreseeable projects in the area. The RSA does not include the entire Central Mackenzie-Blackwater Lake, Central Mackenzie-the Ramparts, and Great Bear sub-basins because:

- the majority of the Central Mackenzie-Blackwater Lake and Central Mackenzie-the Ramparts sub-basins are to the west of the Mackenzie River, which is not affected by the Project.
- the majority of the Great Bear sub-basin is upstream of the Project and, therefore, not affected by the Project. Only a short segment (4 km) of the Project is in the Great Bear sub-basin. This segment includes a proposed bridge over the Great Bear River, which is undergoing a separate regulatory process. Therefore, the Great Bear sub-basin is not be discussed further in this report.



- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Sub-Basin

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Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2023-03-07
TR by CS on 2023-03-07

Client/Project
144903025-0064 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
2.1

Title
Water and Sediment Quality Assessment Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
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3 Review of Existing Data

A review of existing traditional knowledge (TK) and traditional land and resource use (TLRU) and a literature review of relevant information is presented in this section for characterizing the existing conditions for surface water quantity.

3.1 Traditional Knowledge and Traditional Use

The GNWT has been collecting TK and TLRU information relevant to the Project since 2021. Older TK and TLRU information, as described in the following sections, supplement the more recent data.

3.1.1 Sahtu Region

As described in the Cultural and Traditional Land Use TDR, Sahtu harvesters mentioned powerful ice breaks during the spring break around the area the Great Bear River Bridge (TRRC, 2019).

In addition to the TK and TLRU information described in the Cultural and Traditional Land Use TDR, older information documented by Golder (2015) are helpful in characterizing the existing surface water quantity conditions. Golder (2015) provides TK and TLRU information about surface water quantity in the Sahtu Region. Golder (2015) indicates that in the Sahtu Region:

- The waters of the Sahtu have traditionally supplied water for drinking and cooking, provided food (e.g., fish), and have been major travel routes.
- Local land users and elders are familiar with their surroundings, including the lands and waters, and with flood conditions caused by ice jams or intense rainstorms.
- Residents have expressed concerns about lowered water levels due to past developments that included water withdrawals.
- During the past decades, residents observed lake water levels decreasing, even without the impact of development.
- Creation of artificial streams along the winter roads have been observed during spring melt. Beaver dams were believed to add to the drainage problem.
- Less spring debris has been noted in the Mackenzie River.

Results from the Project-specific TLRU study developed by the Tulita Renewable Resources Council (TRRC, 2022) indicates that:

- Overflows have resulted from previous road construction and operation and has affected valued resources.
- Overflow within the LSA and along existing portions of the MVWR has affected undertaking of TLRU.
- There are many beaver dams within the LSA that have caused overflow.

- All the water resources within the LSA are still used and accessed for TLRU.
- More water and wildlife monitoring in the LSA should be used to mitigate potential Project effects.
- There are concerns about potential Project effects on water flowing into the Bear River (community drinking water source).
- The sewer lagoon seeps towards the winter road between Tulita and Four Mile Creek, which causes the overflow on winter road access.
- There are concerns about potential Project effects from vehicle breakdown near open-water sources, specifically near Bear Rock, which is of interest to the community, that have potential to contaminate water sources.
- MVWR flooding occurs near Frank Yalle cabin area, and between the community of Tulita and Four Mile Creek.
- Bear River floods in the spring during the Mackenzie River ice breakup.
- Water is collected from any river or lake nearby the construction of the Bear River Bridge Project which has potential to affect community drinking because the community of Tulita requires a water truck to access water intake from Bear River on the other Bear River Bridge (all year round).

3.1.2 Dehcho Region

Cultural and Traditional Land Use TDR mentions that during the Wrigley Community Consultation, participants identified concerns about impacts of the Project on water in general and the Mackenzie River in particular (Dessau, 2012).

In addition to the TK and TLRU information described in the Cultural and Traditional Land Use TDR, older information documented by Dehcho First Nations (2011) are helpful in characterizing the existing surface water quantity conditions. Dehcho First Nations (2011) provides TK and TLRU information about surface water quantity in the Dehcho Region:

- The region is getting warmer and wetter overall, with more rainfall in August and September and even into October.
- Climate change is creating more incidences of ice crusting along the ground, which may make it more difficult for boreal caribou to forage for ground lichens.
- Wetter summers and falls result in higher water levels on smaller rivers and streams.
- Lower lake levels (possibly due to increased capacity of the ground to absorb water) impact animals.

3.2 Literature Review

A literature review was completed to understand existing surface water quantity conditions along the project highway alignment. Background information on surface water quantity for the Sahtu and Dehcho Regions were obtained from the following resources:

- Water Survey of Canada (WSC) archived hydrometric data (WSC, 2021)
- Mackenzie Valley Land and Water Board (MVLWB) public registry (www.https://mvlwb.com/registry)
- Central Mackenzie Surface Water and Groundwater Baseline Assessment. Report 1: Technical State of Knowledge (Golder, 2015)
- Environmental Impact Statement for Mackenzie Gas Project Volume 3, Section 5 (IORVL, 2004)
- Three Hydrotechnical Assessment reports for Mackenzie Valley Highway: Dehcho Segment (Tetra Tech, 2020a), Mount Gaudet Access Road (Tetra Tech, 2020b), and Prohibition Creek Access Road (Tetra Tech, 2020c)
- Mackenzie Valley Highway Extension Pehdzeh Ki Ndeh – Dehcho Region. Project Description Report (Dessau, 2012)

Surface water quantity information from the abovementioned resources are summarized in the following sections.

3.2.1 Regional Hydrology

The Mackenzie River drains an approximate area of 1.8 million square kilometres (km^2); its mainstem is more than 1,700 km between the outlet of Great Slave Lake and the Beaufort Sea in Canada's Arctic (Golder, 2015).

The hydrologic regime of streams in the Central Mackenzie-Blackwater Lake and Central Mackenzie-the Ramparts sub-basins of the Mackenzie River basin is dominated by snowmelt, producing high streamflows in late-May and early-June. Streamflows normally recede during the summer and may be augmented by scattered rainfall events in summer and fall. A noticeable reduction in streamflow occurs when the streams and lakes experience freeze-up in late fall. The ice cover persists until late spring (IORVL, 2004). Smaller streams may freeze to the bottom, with zero winter flow. IORVL (2004) showed that streams with drainage areas of greater than 100 km^2 are perennial, and those with drainage areas of less than 100 km^2 may be perennial or seasonal (i.e., freeze to the bottom in winter).

Lakes are less turbulent than the rivers; therefore, they tend to freeze earlier than rivers and thaw later than rivers.

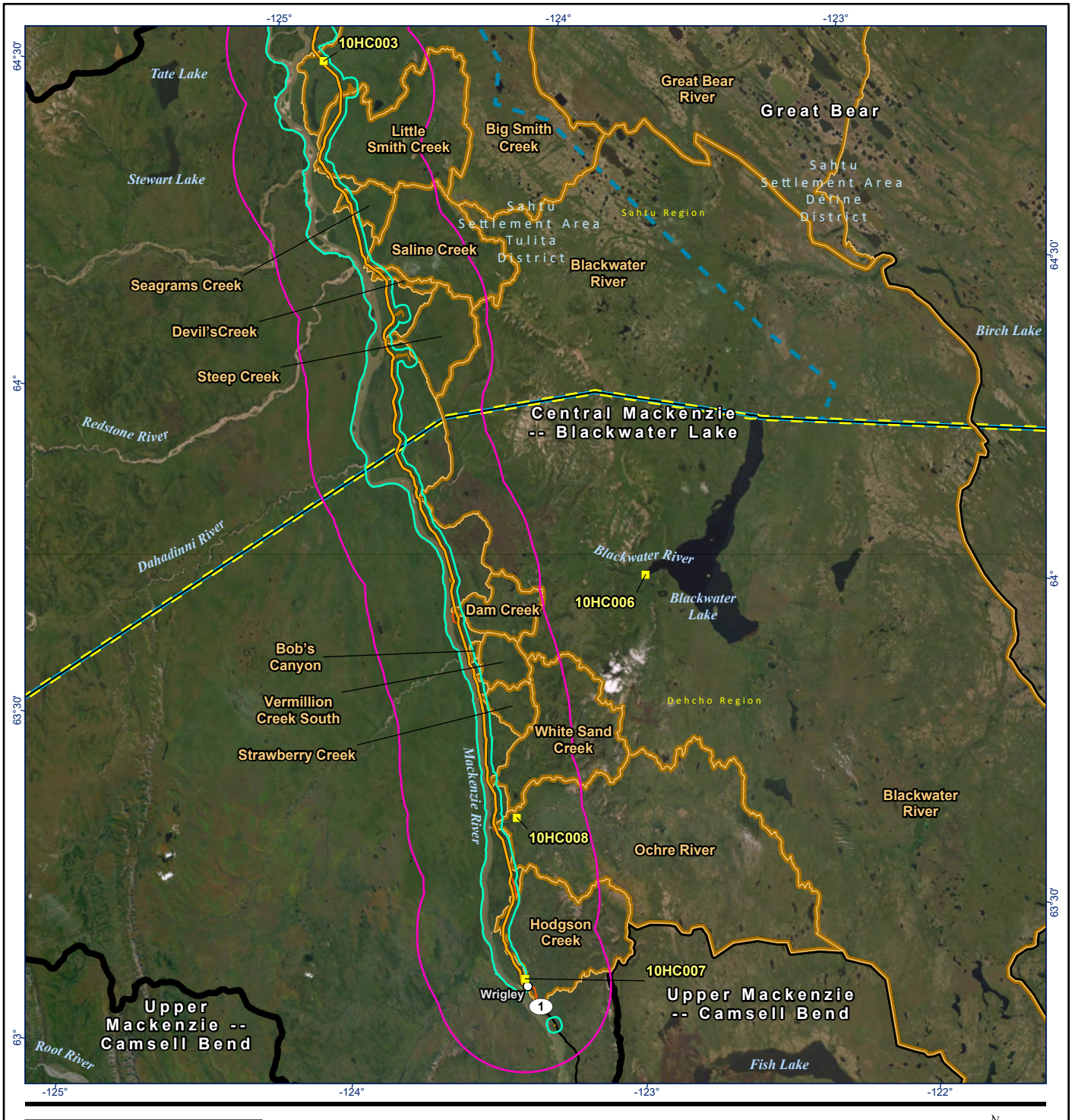
Typically, ice on the Mackenzie River at Norman Wells first appears in mid-October and freeze-up is complete by mid-November. The ice cover starts deteriorating in mid-May and break-up is complete by end of May. Average maximum ice thickness is 1.5 m in this region (IORVL, 2004; Golder, 2015).

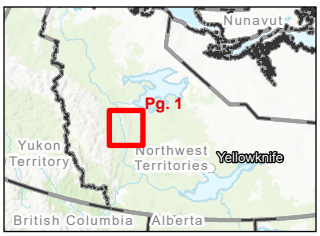
Freeze and melt dates are usually earlier for smaller streams. Therefore, ice jamming occurs in the Mackenzie River when spring snowmelt from the tributaries flow into the Mackenzie River before the ice on the Mackenzie River has decayed due to temperature (Golder, 2015).

Annual snowmelt-driven peak flows typically occur in late-May and early-June, but they can also occur in summer or fall after intense rainfall events (IORVL, 2004).

3.2.2 Local Watersheds

The watershed area of major streams that the project highway alignment crosses are shown in Figure 3.1 and Table 3.1. Stream names are based on those identified in previous surface water quantity studies (Golder, 2015; IORVL, 2004).





- Hydrometric Station
- Sub-Basin
- Watershed
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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0059 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.1

Title
Watersheds and Hydrometric Stations

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
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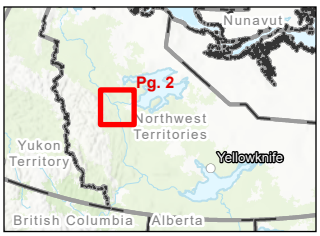

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Project Location
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Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0059 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
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Table 3.1 Local Watersheds - Identified Tributaries of the Mackenzie River in the Local Study Area

Local Watershed[1]	Coordinates of Confluence with Mackenzie River			Drainage Area[2] (km^2)
	Zone	Latitude	Longitude	
Hodgson Creek	10	63.233667	123.482833	358
Ochre River	10	63.467167	123.690000	1,207
White Sand Creek	10	63.535167	123.731833	346
Strawberry Creek	10	63.660000	123.818667	59
Vermillion Creek South	10	63.691500	123.850000	68
Bob's Canyon	10	63.717333	123.869500	5.4
Dam Creek	10	63.790167	123.964833	110
Blackwater River	10	63.945556	124.157778	10,716
Steep Creek	10	64.183500	124.391667	154
Devil's Creek	10	64.278333	124.439500	21
Saline Creek	10	64.292667	124.502667	317
Seagrams Creek	10	64.386000	124.624167	57
Little Smith Creek	10	64.434833	124.742000	439
Big Smith Creek	10	64.590000	124.811167	1,076
Gotcha Creek	10	64.875833	125.103500	155
Four Miles Creek	10	64.910833	125.475500	17
No name creek	10	64.905333	125.652833	13
Bluefish Creek	10	64.934329	125.851403	118
Jungle Ridge Creek	9	65.061167	126.060667	60-97[3]
Nota Creek	9	65.090167	126.095333	65
Vermillion Creek North	9	65.096667	126.131333	92
Prohibition Creek	9	65.151167	126.303833	126
Christina Creek	9	65.186667	126.402167	22
Hellava Creek	9	65.192333	126.419167	27
Francis Creek	9	65.205000	126.456833	24
Canyon Creek	9	65.226500	126.523167	53
Bosworth Creek	9	65.280462	126.869560	132

Notes:

1 Local watersheds are sorted from south to north

2 The ArcGIS watershed tool was used with 1:250,000 Canadian Digital Elevation Model to delineate the watersheds.

3 The ArcGIS watershed tool delineates a watershed area of 97 km^2 (as shown in Figure 3.1). However, based on WSC (2021) and runoff calculations in Section 4.1, the correct watershed area is 60 km^2.

3.2.3 Hydrometric Stations

Streamflow records from ten Water Survey of Canada (WSC) hydrometric stations within or in the vicinity of the RSA were downloaded and used to characterize surface water quantity. These WSC hydrometric stations are shown in Table 3.2 and Figure 3.1. The WSC hydrometric stations 10HC007 (Hodgson Creek near the mouth), 10HC003 (Big Smith Creek near Highway no. 1), 10KA006 (Jungle Ridge Creek near the mouth), and 10KA009 (Canyon Creek at Pipeline Crossing) are within the LSA, and 10KA001 (Mackenzie River at Norman Wells) is the most downstream location of the RSA.

Table 3.2 Water Survey of Canada (WSC) Hydrometric Stations in the RSA

WSC Station ID	WSC Station Name	Longitude	Latitude	Period of Record	Drainage Area (km^2)
10HC007	Hodgson Creek near the mouth	123° 28' 52" W	63° 14' 39" N	2006 - 2014	358
10HC008	Ochre River near the mouth	123° 36' 45" W	63° 29' 22" N	2006 - 2017[1]	1,207
10HC006	Blackwater River at outlet of Blackwater Lake	123° 19' 22" W	63° 54' 01" N	1986 - 1994	7,850
10HC003	Big Smith Creek near Highway no. 1	124° 48' 46" W	64° 35' 33" N	1973 - 1994	980
10KA006	Jungle Ridge Creek near the mouth	126° 07' 17" W	65° 03' 27" N	1980 - 2017[1]	60
10KA009	Canyon Creek at Pipeline Crossing	126° 31' 05" W	65° 13' 54" N	2005 - 2018[2]	53
10KA005	Seepage Creek at Norman Wells	126° 43' 20" W	65° 15' 50" N	1974 - 1978	31
10KA007	Bosworth Creek near Norman Wells	126° 52' 38" W	65° 19' 25" N	1980 - 2017[1]	125
10KA001	Mackenzie River at Norman Wells	126° 51' 00" W	65° 16' 19" N	1943 - 2017[1]	1,590,000
10LD002	Jackfish Creek near Fort Good Hope	128° 38' 23" W	66° 15' 23" N	1980 - 1986	63

Notes:
[1] WSC data after 2017 were provisional at the time of development of this report.
[2] WSC data after 2018 were provisional at the time of development of this report.

3.2.4 Channel Assessment

Channel assessments were conducted for the majority of watersheds identified in Table 3.1 as part of the IORVL (2004) field study. A summary of the assessments is provided in Table 3.3. Tetra Tech (2020a, 2020b, 2020c) and K'alo-Stantec Limited (2020a, 2020b, 2022a) completed hydrotechnical and fish habitat assessments for crossings along segments of the project highway alignment. Although surface water hydrology characterization was not the main objective of those studies, channel information for some watersheds of this surface water quantity TDR were assessed and reported in Tetra Tech (2020a, 2020b, 2020c) and K'alo-Stantec Limited (2020a, 2020b, 2022a). Such channel information are provided in Table 3.3. Hydrotechnical assessments are planned for the remainder of the alignment, including channel assessment at the bridge crossings, for engineering design and for fish habitat assessment purposes.

Table 3.3 Channel Assessment

Stream	Width[1] (m)	Slope (m/m)	Dominant Substrate
Hodgson Creek	7–13 (17–42)[5]	0.0087 (0.01–0.02)[5]	Gravel (Gravel and cobble)[5]
Ochre River	23–55	0.011	Boulder and cobble
White Sand Creek	15–24	0.015	Boulder and cobble
Strawberry Creek	(8)[7]	n/a[2]	(Boulder)[7]
Vermillion Creek South	n/a[2]	n/a[2]	n/a[2]
Bob's Canyon	(2–6)[3,7]	(0.076)[3]	(Boulders)[3]
Dam Creek	6–8	0.0003	Silt and boulder
Blackwater River	90–110	0.0044	Boulder and cobble
Steep Creek	5–12	0.018	Boulder and cobble
Devil's Creek	n/a[2]	n/a[2]	n/a[2]
Saline Creek	10–20	0.011	Cobble
Seagrams Creek	9–12	0.017	Cobble
Little Smith Creek	5–10	0.005	Gravel and cobble
Big Smith Creek	30–40	0.0001	Sand and cobble
Gotcha Creek	n/a[2]	n/a[2]	n/a[2]
Four Miles Creek	(3)[7]	n/a[2]	(Sand and Gravel)[7]
No name creek	n/a[2]	n/a[2]	n/a[2]
Bluefish Creek	n/a[2]	n/a[2]	n/a[2]
Jungle Ridge Creek	4–9	0.005	Gravel and silt
Nota Creek	4–7	0.009	Cobble and boulder
Vermillion Creek North	7–14	0.011	Gravel
Prohibition Creek	5–9 (6–30)[6]	0.014 (0.01–0.04)[6]	Gravel and cobble (Cobble and gravel)[6]
Christina Creek	2–3 (4–6)[4,6]	0.015 (0.01–0.02)[4,6]	Gravel (Cobble and gravel)[4,6]
Hellava Creek	2–4 (5–7)[6]	0.012 (0.01–0.03)[6]	Gravel and cobble (Cobble and gravel)[6]
Francis Creek	1.5–3 (5–10)[6]	0.016 (0.01–0.04)[6]	Cobble and gravel (Cobble and gravel)[6]
Canyon Creek	5–12 (8–22)[6]	0.014 (0.01–0.04)[6]	Gravel and cobble (Cobble and gravel)[6]
Bosworth Creek	6–15	0.005	Gravel and cobble

Notes:

1 Range of values reflects different widths measured.

2 n/a: Channel assessment was not documented by IOVL (2004) or Tetra Tech (2020a, 2020b, 2020c) or K'alo-Stantec Limited (2020a, 2020b, 2022a)

3 Source: Tetra Tech (2020a)

4 Source: Tetra Tech (2020c)

5 Source: K'alo-Stantec Limited (2020a)

6 Source: K'alo-Stantec Limited (2020b)

7 Source: K'alo-Stantec Limited (2022a)

Source: Unless specified otherwise, information is from IORVL (2004). When information is from other sources, they are provided in parentheses and data sources are provided as footnotes.

3.2.5 Exiting Water Uses

3.2.5.1 Municipal

The town of Norman Wells has a water license (S18L3-003) to withdraw up to 250,000 m^3/year from the Mackenzie River. Actual annual water withdrawal volumes in the last 10 years, based on data available via the MVLWB public registry, are summarized in Table 3.4.

The Hamlet of Tulita has a water license (S16L3-001) to withdraw up to 21,300 m^3/year from Great Bear River. Actual annual water withdrawal volumes, based on data available via the MVLWB public registry, are also summarized in Table 3.4.

Table 3.4 Municipal Water Use (m^3/year)

Year	Norman Wells[1] (m^3/year)	Tulita[2] (m^3/year)
Current WL	**250,000**	**21,300**
2010	143,243	n/a[3]
2011	146,794	n/a[3]
2012	110,049	17,686
2013	106,272	14,771
2014	97,384	16,059
2015	93,974	n/a[3]
2016	97,212	n/a[3]
2017	94,226	n/a[3]
2018	95,837	n/a[3]
2019	101,974	n/a[3]

Notes:
[1] source of water: Mackenzie River
[2] source of water: Great Bear River
[3] n/a: data not available in the MVLWB public registry
Source: MVLWB public registry (www. https://mvlwb.com/registry)

3.2.5.2 Winter Road Construction

Potential sources of water for construction and maintenance of the MVH are shown in Table 3.5 and Figure 3.2.

Table 3.5 Potential Sources of Water Withdrawal for the MVH

Potential Source	Coordinates		Winter Volume (m^3)[1]	Watershed[2]
	Latitude	Longitude		
Lake Sources				
WR2	63.275341	123.557336	n/a[3]	Mackenzie River
WR3	63.420145	123.599667	n/a[3]	Ochre River
WR4	63.442750	123.635704	n/a[3]	Mackenzie River
Unlisted	63.986730	124.214965	n/a[3]	Mackenzie River
WR5	64.039404	124.291238	n/a[3]	Mackenzie River
WR6	64.086078	124.305009	n/a[3]	Mackenzie River
WR7	64.135345	124.337608	n/a[3]	Mackenzie River
WR8	64.205625	124.366274	1,265,354	Mackenzie River
WR9	64.263546	124.422416	n/a[3]	Mackenzie River
WR10	64.308888	124.532090	30,844	Mackenzie River
WR11	64.347861	124.590955	n/a[3]	Mackenzie River
WR12	64.517247	124.818424	987,269	Big Smith Creek
WR13	64.615688	124.853169	n/a[3]	Mackenzie River
WR14	64.626953	124.803118	39	Mackenzie River
WR16	64.659051	124.849634	48,991	Mackenzie River
WR18	64.727041	124.932269	229,369	Mackenzie River
Unlisted	64.733542	124.948591	n/a[3]	Mackenzie River
WR19	64.810597	125.005113	11,811	Gotcha Creek
WR20	64.854876	125.033013	n/a[3]	Gotcha Creek
WR22	64.904004	125.153103	n/a[3]	Mackenzie River
WR21	64.898394	125.268561	n/a[3]	Mackenzie River
WR23	64.905544	125.339083	n/a[3]	Mackenzie River
WR25	64.973830	125.677098	3,163,813	No Name Creek
WR26	64.983848	125.675238	n/a[3]	Great Bear River
Unlisted	64.989632	125.715442	n/a[3]	Bluefish Creek
WR28	64.992169	125.756327	n/a[3]	Bluefish Creek
WR31	65.230104	126.556707	n/a[3]	Mackenzie River
Stream Sources				
Blackwater River	63.942657	124.166387	n/ap[4]	Blackwater River
Steep Creek	64.183409	124.390230	n/ap[4]	Steep Creek
Mackenzie River	64.293336	124.537820	n/ap[4]	Mackenzie River
Little Smith Creek	64.435138	124.741597	n/ap[4]	Little Smith Creek

Potential Source	Coordinates		Winter Volume (m^3)[1]	Watershed[2]
	Latitude	Longitude		
Big Smith Creek	64.589887	124.810756	n/ap[4]	Big Smith Creek
Unnamed	64.686122	124.856868	n/ap[4]	Mackenzie River
Gotcha Creek	64.877619	125.103641	n/ap[4]	Gotcha Creek
Mackenzie River	64.899480	125.620172	n/ap[4]	Mackenzie River
Vermillion Creek	65.097815	126.130088	n/ap[4]	Vermilion Creek
Prohibition Creek	65.149557	126.302291	n/ap[4]	Prohibition Creek
Christina Creek	65.186854	126.401435	n/ap[4]	Christina Creek

Notes:

[1] Bathymetric surveys based on Golder (2008)

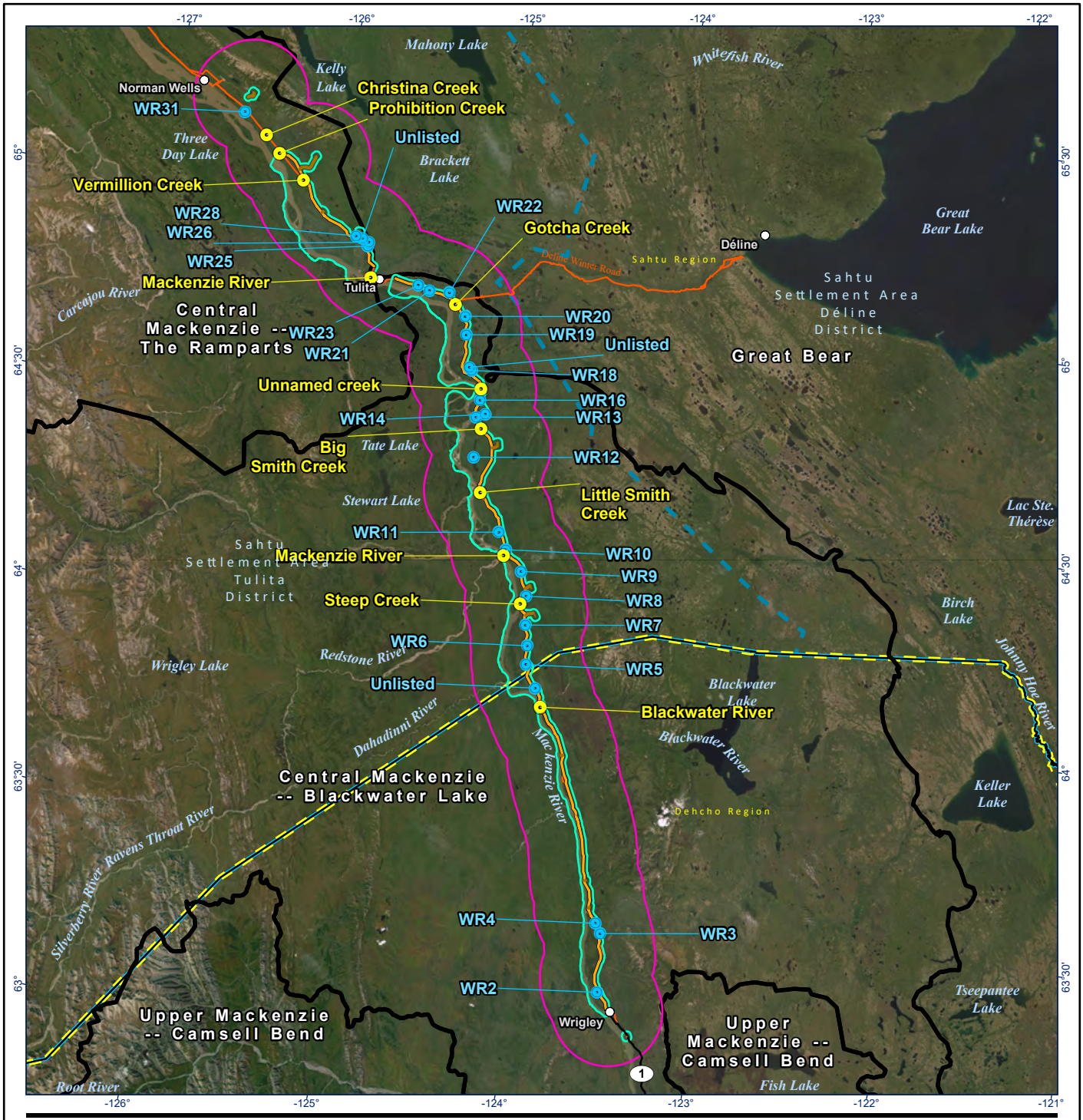
[2] All potential water sources are within the LSA. The water sources which are not within the identified watersheds (Table 3.1; Figure 3.1) are marked as within Mackenzie River watershed.

[3] n/a: Not available in Golder (2008)

[4] n/ap: Not applicable – Stream source

A preliminary assessment of water availability from stream and lake sources is provided in DAR Appendix 15C (K'alo-Stantec, 2022b). Final list of sources will be identified in the project description and updated in future revisions of this TDR.

Source: GNWT (2020, pers. comm.)



Potential Water Source
- Lake
- Stream
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area

- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Sub-Basin

0 10 20 Kilometres
(At original document size of 8.5x11)
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N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0068 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.2

Title
Potential Sources of Water Withdrawal for Winter Road Construction

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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4 Hydrologic Indices

4.1 Annual and Monthly Runoff

Annual runoff (a normalized representation of streamflow expressed as depth; millimetre [mm]) is the volume of water passing through a stream's cross section per year divided by the watershed area drained to that cross section. Because annual runoff is normalized by watershed area, it is a useful index for comparing the hydrologic response of watersheds of different sizes.

Historical monthly streamflow data from the WSC hydrometric stations (Table 3.2) during their period of record were downloaded from WSC (2021) and used to estimate the mean annual runoff (MAR), as well as monthly distribution of runoff at these WSC hydrometric stations (Table 4.1).

The MAR estimate for the watersheds with WSC stations are between 151 mm and 220 mm (Table 4.2). For ungauged watersheds, the MAR within this range is recommended for surface water quantity effects assessment.

Monthly distribution of runoff for the watersheds with WSC stations are presented in Table 4.1, and those of perennial and seasonal ungauged watersheds are shown in Table 4.2. As explained in Section 3.2.1, watersheds with drainage areas of greater than 100 km^2 are assumed to be perennial, and those with drainage areas of less than 100 km^2 may be perennial or seasonal.

Table 4.1 Mean Annual Runoff and Monthly Distribution of Runoff at the WSC Hydrometric Stations

WSC Station ID	WSC Station Name	Drainage Area (km^2)	Monthly Runoff (% of Annual Runoff)												MAR[1] (mm)
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
10HC007	Hodgson Creek	358	1.2%	0.9%	0.8%	2.2%	39.9%	11.7%	12.3%	11.0%	9.0%	6.1%	3.0%	1.9%	**151**
10HC008	Ochre River	1,207	0.5%	0.3%	0.3%	2.8%	44.0%	10.0%	11.0%	11.8%	12.7%	4.8%	1.3%	0.6%	**220**
10HC006	Blackwater River	7,850	0.7%	0.4%	0.4%	0.6%	28.9%	29.8%	15.9%	8.0%	6.9%	5.0%	2.1%	1.3%	**187**
10HC003	Big Smith Creek	980	0.4%	0.3%	0.3%	0.6%	44.5%	22.4%	7.1%	8.5%	9.7%	4.1%	1.4%	0.7%	**188**
10KA006	Jungle Ridge Creek	60	0.0%	0.0%	0.0%	0.7%	54.6%	17.2%	6.0%	7.9%	8.7%	4.0%	0.9%	0.1%	**213**
10KA009	Canyon Creek	53	3.0%	2.4%	2.2%	2.9%	38.8%	8.1%	9.3%	7.8%	9.4%	6.6%	4.8%	4.6%	**219**
10KA005	Seepage Creek	31	0.0%	0.0%	0.0%	1.1%	66.4%	10.3%	3.4%	15.4%	3.4%	0.0%	0.0%	0.0%	**n/a[2]**
10KA007	Bosworth Creek	125	3.0%	2.3%	2.1%	4.0%	40.4%	12.6%	7.4%	6.4%	7.8%	6.4%	4.0%	3.3%	**166**
10KA001	Mackenzie River	1,590,000	3.8%	3.1%	3.3%	3.5%	13.5%	16.8%	15.5%	12.4%	10.2%	8.8%	4.9%	4.2%	**168**
10LD002	Jackfish Creek	63	0.0%	0.0%	0.0%	0.0%	43.1%	27.0%	6.5%	6.4%	11.6%	5.3%	0.1%	0.0%	**n/a[2]**

Notes:

1 Mean Annual Runoff

2 Sufficient data was not available to estimate the MAR

Source: WSC (2021)

Table 4.2 Monthly Distribution of Runoff for Ungauged Streams

Streams	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Perennial Streams[1]	1.6%	1.2%	1.1%	2.5%	42%	13%	9.4%	9.1%	9.7%	5.6%	2.9%	2.2%
Seasonal Streams[2]	0.0%	0.0%	0.0%	0.6%	55%	18%	5.3%	9.9%	7.9%	3.1%	0.3%	0.0%

Notes:

[1] based on the average of data from WSC stations with drainage area of equal to or less than 1,207 km^2 in Table 4.2

[2] based on the average of data from WSC stations with seasonal flow and drainage area of equal to or less than 63 km^2 in Table 4.2

4.2 Peak Flows

Tetra Tech (2020a, 2020b, 2020c) performed hydrotechnical assessments along segments of the project highway alignment. As part of these assessments, Tetra Tech (2020a, 2020b, 2020c) derived the following regression-based equations for instantaneous peak flow with 2-year and 100-year return periods:

$Q_{100} = 0.7685\ DA^{0.7638}$; ($R^2$=0.78) and $Q_2 = 0.2893\ DA^{0.7458}$; ($R^2$=0.68) *Equation 4-1*

where

Q_{100} = Instantaneous peak with 100-year return period (m^3/s)

Q_2 = Instantaneous peak with 2-year return period (m^3/s)

DA = Drainage area (km^2)

R^2 = Coefficient of determination

These peak flow equations will be used in the surface water quantity effects assessment. These equations may be updated and similar equations may be developed for other return periods as further hydrotechnical assessment for other segments of the project highway alignment become available and as engineering design for new crossings become available.

4.3 Low Flows

The minimum seven-day average flow, calculated by averaging flows over a seven-day period and calculating the minimum seven-day average flow over a period of time (annual or June to September) was used for low flow characterization.

Minimum annual seven-day average flow with a 10-year return period (7Q10a) and minimum June to September seven-day average flow with a 10-year return period (7Q10s) are used as indicators of extreme low flow conditions in this study.

Historical daily streamflow data from the WSC hydrometric stations (Table 3.2) during their period of record were downloaded from WSC (2021). The Hyfran Plus software package was used to conduct frequency analyses on the annual and June to September 7-day low flows. The timeseries were evaluated with the independence, stationary, and homogeneity tests and probability distribution functions were fitted to these timeseries to estimate the 7Q10a and 7Q10s for each WSC hydrometric station (Table 4.3).

For each of the 7Q10a and 7Q10s, a regression analysis was conducted with drainage area being the independent variable. The regression analysis did not find a correlation between 7Q10a and drainage area, but identified a strong correlation between 7Q10s and drainage area in the form of:

$7Q10s = 0.0028\ DA^{0.8189}$; ($R^2$=0.87) *Equation 4-2*

where

7Q10s = June to September 7-day low flow with 10-year return period (m^3/s)

DA = Drainage area (km^2)

R^2 = Coefficient of determination

Table 4.3 Low Flow Estimates for Water Survey of Canada (WSC) Hydrometric Stations

WSC Station ID	WSC Station Name	Drainage Area (km^2)	7Q10a[1] (m^3/s)	7Q10s[2] (m^3/s)
10HC007	Hodgson Creek	358	0.053	0.510
10HC008	Ochre River	1,207	0.069	0.966
10HC006	Blackwater River	7,850	0.525	7.92
10HC003	Big Smith Creek	980	n/a[3]	0.600
10KA006	Jungle Ridge Creek	60	0	0.040
10KA009	Canyon Creek	53	n/a[4]	0.115
10KA005	Seepage Creek	31	0	0
10KA007	Bosworth Creek	125	0.059	0.164
10KA001	Mackenzie River	1,590,000	2,050	8,100
10LD002	Jackfish Creek	63	0	n/a[4]

Notes:
1 annual seven-day low flow with 10-year return period
2 June through September seven-day low flow with 10-year return period
3 available data did not pass the independence, stationarity, and homogeneity tests
4 sufficient data was not available to estimate 7Q10
Source: data downloaded from WSC (2021)

While Table 4.3 can be used for the 7Q10a and 7Q10s estimate for the watersheds with WSC stations, the 7Q10s for ungauged watersheds can be estimated with the regression-based Equation 4-2.

5 Summary

This TDR presents existing surface water quantity data to support the DAR. Existing data were collected from WSC hydrometric stations in the region, as well as previously published documents. Hydrologic indices (i.e., MAR, monthly distribution of annual runoff, peak flows, and low flows) were characterized for ten watersheds identified within the RSA. These watersheds contain the major streams (i.e., tributaries of the Mackenzie River) that the project highway alignment will cross.

The MAR identified is 151 mm to 220 mm. Likewise, although it is known that the watersheds with drainage area of greater than 100 km^2 are assumed to be perennial, it is not known with certainty what watersheds with drainage areas of less than 100 km^2 are perennial and which ones are seasonal. It is anticipated that surface water quantity effects assessment will not be sensitive to these uncertainties.

Data presented in this TDR are intended for surface water quantity effects assessment of the DAR and do not provide engineering design parameters. Engineering design and analysis of crossings (e.g., conveyance capacity and channel stability) will require a separate study tailored for such purposes.

The Terms of Reference (MVEIRB, 2015) requires a description of water courses that have year-round flow. This information will also support the cumulative effects assessment of the Project.

6 Closure

This TDR was prepared for the sole benefit of GNWT to describe existing conditions related to surface water quantity within the Project LSA and RSA. If you have any questions, please do not hesitate to contact the undersigned.

Respectfully submitted,

K'alo-Stantec Limited

7 References

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APPENDIX 15B

Hydrogeology Technical Data Report

Mackenzie Valley Highway Project
Technical Data Report—Hydrogeology

Prepared for:

Government of the Northwest Territories

Prepared by:

K'alo-Stantec Limited

December 2022

Project No.: 144903025

K'alo-Stantec

Limitations and Sign-off

This document entitled Mackenzie Valley Highway Project Technical Data Report—Hydrogeology was prepared by K'alo-Stantec Limited ("K'alo-Stantec") for the account of Government of the Northwest Territories (the "Client") to support the regulatory review process for its Developer's Assessment Report (the "DAR") for the Mackenzie Valley Highway (Wrigley to Norman Wells) Project (the "Project"). In connection therewith, this document may be reviewed and used by the Government of the Northwest Territories Department of Infrastructure participating in the review process in the normal course of its duties. Except as set forth in the previous sentence, any reliance on this document by any other party or use of it for any other purpose is strictly prohibited. The material in it reflects K'alo-Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between K'alo-Stantec and the Client. The information and conclusions in the document are based on the conditions existing at the time the document was published and does not take into account any subsequent changes. In preparing the document, K'alo-Stantec did not verify information supplied to it by the Client or others, unless expressly stated otherwise in the document. Any use which another party makes of this document is the responsibility and risk of such party. Such party agrees that K'alo-Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other party as a result of decisions made or actions taken based on this document.

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Principal, Environmental Services

Executive Summary

The Government of the Northwest Territories (GNWT) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Valley Highway (MVH) from Wrigley to Norman Wells. The Project consists of a 321 kilometre (km) all-season highway that largely follows the route of the existing Mackenzie Valley Winter Road (MVWR), and the construction and operation of temporary and permanent quarries and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT).

This technical data report (TDR) presents existing groundwater quantity and quality conditions to support the Developer's Assessment Report (DAR). Based on existing available data, conceptual models of regional and local groundwater flow within the RSA and LSA were developed. Effects of the Project on groundwater within the LSA and RSfA will be assessed in the DAR using the conceptual framework provided by these models. Potential quarries and borrow sources have yet to be identified and, therefore, characterization of these areas has not been included in this TDR.

East of the Mackenzie River, regional groundwater systems flow from the Franklin Mountains to the Mackenzie River. Permafrost, where it exists, acts as a confining layer and a barrier to groundwater recharge. Within limestone, dolostone, and evaporite lithologies of the Franklin Mountains, however, recharge can occur by infiltration through taliks beneath high-permeability weathered bedrock exposures and karst landforms including sinkholes, ponors, and dry valleys (Van Everdingen, 1981; Hamilton, 1995).

Regional groundwater discharge occurs along the western slopes of the Franklin Mountains and along stream channels draining these slopes. Depending on the scale of discharge, streams crossed by the project highway alignment are perennially ice-free, experience icings, or annually freeze to ground surface (IORVL, 2004). In contrast to recharge, permafrost is not a barrier to regional groundwater discharge because the discharge temperature likely maintains perennial open taliks (Michel, 1986). Discharge from regional flow paths tend to have high concentrations of major ions that reflect the solubility of the bedrock encountered along the groundwater flow path.

Local groundwater flow in the LSA and RSA is strongly impacted by the distribution of permafrost and low-permeability sediments that act as barriers to groundwater flow. Where permafrost exists, local groundwater flow paths in the LSA and RSA are generally limited to seasonal supra-permafrost flow in the active layer. However, the Bear Rock Conservation Zone is one area within the LSA and RSA where deeper localized groundwater flow paths have developed.

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APPENDIX C BEDROCK GEOLOGY IN THE LSA AND RSA

APPENDIX D GROUNDWATER QUALITY DATA

Abbreviations

%	percent
°C	degrees Celsius
µS/cm	microsiemens per centimetre
‰	permil
CMV	Central Mackenzie Valley
DAR	Developer's Assessment Report
EC	electrical conductivity
GNWT	Government of the Northwest Territories
INF	Department of Infrastructure
ka BP	thousand years before present
km	kilometre
km^2	square kilometre
L/s	litres per second
LSA	local study area
m	metre
ma BP	million years before present
masl	metres above sea level
mg/L	milligrams per litre
MVEIRB	Mackenzie Valley Environmental Impact Review Board
MVH	Mackenzie Valley Highway
NT	Northwest Territories
PDA	Project Development Area
PDR	Project Description Report
RSA	regional study area
SMOW	standard mean ocean water
SSA	Sahtu Settlement Area
TDLC	Tulita District Land Corporation

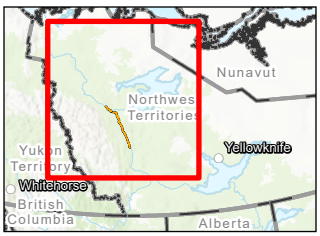
TDR ..... Technical Data Report

the Project ..... Mackenzie Valley Highway Project

1 Introduction

The Government of the Northwest Territories (GNWT) is proposing the Mackenzie Valley Highway Project (the "Project") that will extend the Mackenzie Highway from Wrigley to Norman Wells, Northwest Territories (NT). The Project consists of a planned 321 kilometre (km) all-season gravel highway that largely follows the route of the existing Mackenzie Valley Winter Road (MVWR). The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the NT (Figure 1.1).

The Project is subject to an environmental assessment and the requirements of Part 5 of *the Mackenzie Valley Resource Management Act*. This Technical Data Report (TDR) presents a description of existing hydrogeological (groundwater) conditions to support the information required to be presented in the Project's Developer's Assessment Report (DAR), as described in the Terms of Reference (MVEIRB, 2015).



- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Settlement Area Boundary
- Region Boundary
- Territorial Boundary

0 40 80 Kilometres

(At original document size of 8.5x11)
1:4,500,000

N

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Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Imagery: Earthstar Geographics
World Topographic Map: Esri, FAO, NOAA, NRCan
World Hillshade: Esri, USGS
Name: NAD 1983 UTM Zone 10N
PCS: NAD 1983 UTM Zone 10N

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2022-04-08
TR by AJ on 2022-04-08

Client/Project
144903025-0061 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
1.1

Title
MVH Project Overview

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2 Study Area

The Project is located in the Mackenzie Valley region of the NT between the current terminus of the existing all-weather highway in Wrigley (Highway #1, KM 690) and Norman Wells (MVWR, KM 1,011). The project highway alignment generally follows the MVWR along the east side of the Mackenzie River within the Mackenzie Plain physiographic region and passes through the community of Tulita (MVWR, KM 938; Figure 2.1).

The Project Development Area (PDA) is the area of direct Project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 m wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps and quarry/borrow sites with access roads on a 30 m ROW. The PDA is defined as the area to be used by the Project from Wrigley to approximately 25 km Southeast of Norman Wells. The PDA does not include a section of Project (less than 10 km in length) that passes through the hamlet of Tulita.

The local and regional study areas presented in this TDR are where K'alo-Stantec focused data compilation/collection efforts to understand groundwater conditions in support of the project-specific effects assessment and the cumulative effects assessment. However, some groundwater-related studies completed within the larger Central Mackenzie Valley (CMV) provide important context on regional groundwater flow conditions. These studies have been included in the literature review. The area of the CMV varies depending on the reference (e.g., Michel, 1986 vs. Golder, 2015), but for this TDR the CMV extends east-to-west from the Franklin to the Mackenzie Mountains and north-to-south from Norman Wells to Wrigley (Figure 2.1).

2.1 Local Study Area

The Local Study Area (LSA) is a 1 km buffer centred on the PDA, which is the alignment of the MVWR (Figure 2.1). Observable, Project-related direct and indirect effects to groundwater and groundwater-influenced valued components (VCs) are expected to be limited to this area.

2.2 Regional Study Area

The Regional Study Area (RSA) is a 10 km buffer centred on the PDA (Figure 2.1). The RSA was selected to include groundwater-related features and groundwater-influenced VCs that could be affected by the effects of project activities interacting with the effects of other existing, past or reasonably foreseeable projects in the area.

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- Conservation Area
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres
(At original document size of 8.5x11)
1:600,000

N

Kálo-Stantec

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Imagery: Earthstar Geographics
World Topographic Map: Esri, FAO, NOAA, NRCan
World Hillshade: Esri, USGS

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2022-04-08
TR by AJ on 2022-04-08

Client/Project
144903025-0062 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
2.1

Title
Regional and Local Study Area for Hydrogeology

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3 Methods

K'alo-Stantec completed a review of existing traditional knowledge (TK) and traditional land and resource use (TLRU) and a literature review of groundwater-related information to characterize existing hydrogeological conditions within the LSA and RSA.

Based on the data compiled during the TK, TLRU, and literature review, K'alo-Stantec completed hydrostratigraphic interpretations of soils and bedrock geological units intersected by the project highway alignment and developed a conceptual hydrogeological model. The objective of the model is to provide a simplified but defensible representation of local and regional groundwater flow systems that will help with the identification of potential environmental effects and effect pathways of the Project on groundwater quality and quantity.

3.1 Traditional Knowledge and Traditional Land and Resource Use

Groundwater-related TK and TLRU in the Sahtu and Dehcho regions are summarized in the following sections. Section 3.1, Traditional Knowledge and Traditional Land and Resource Use, will be updated as additional information TK and TLRU information relevant to the Project becomes available.

3.1.1 Sahtu Region

The Petınıʔah (Bear Rock) Conservation Zone is an important sacred site in Denendeh and is of cultural value to Dene groups within and outside of the Sahtu (SLUB, 2013). Physically, it is composed of exposed karst landforms of considerable importance to the local groundwater system, and local groundwater discharge zones are crossed by the PDA, LSA, and RSA (Figure 2.1). The groundwater flow system at Petınıʔah (Bear Rock) Conservation Zone is discussed in Section 4.4.3, Karst, and in Section 5.2, RSA and LSA Groundwater Flow.

3.1.2 Dehcho Region

K'alo-Stantec did not find any documentation of groundwater-related TK or TLRU in the Dehcho Region.

Until 2014, the community water source for Wrigley was reported as a groundwater well (GNWT, 2013). The well diverted groundwater from glaciofluvial sands and gravels beneath a 40 m to 50 m thick permafrost horizon (IORVL, 2004). In 2015, the community water source for Wrigley was reported as the Mackenzie River (GNWT, 2015).

3.2 Literature Review

K'alo-Stantec completed a literature review to understand existing groundwater conditions along the project highway alignment. Primary sources reviewed for groundwater information in the Sahtu and Dehcho regions included:

- Hydrogeology of the Central Mackenzie Valley (Michel, 1986)
- Morphology, Hydrology, and Hydrochemistry of Karst in Permafrost Terrain near Great Bear Lake, Northwest Territories (Van Everdingen, 1981)
- Karst Geomorphology and Hydrogeology of the Northeastern Mackenzie Mountains (Hamilton, 1995)
- The Physical Environment of the Mackenzie Valley, Northwest Territories: A Base Line for the Assessment of Environmental Change (Dyke and Brooks, 2000)
- Environmental Impact Statement for Mackenzie Gas Project Volume 3, Part B – Aquatic Resources: Groundwater, Hydrology, and Water Quality (IORVL, 2004)
- Mapping Known and Potential Karst Areas in the Northwest Territories, Canada (Ford, 2009)
- Mackenzie Valley Highway Extension Pehdzéh Kį́ Ndeh – Dehcho Region. Project Description Report (PDR) (Dessau, 2012)
- Central Mackenzie Valley Subsurface Groundwater Baseline Study (AMEC, 2014; NWT Open File 2014-07).
- Geological Compilation of the Western Mainland and Southern Arctic Islands Regions, Northwest Territories (Okulitch and Irwin, 2014)
- Central Mackenzie Surface Water and Groundwater Baseline Assessment. Report 1: Technical State of Knowledge (Golder, 2015)
- Hydrologic Impacts of Thawing Permafrost – A Review (Walvoord and Kurylyk, 2016).

The complete list of literature reviewed, including files retrieved from Northwest Territories Open Files for the TDR is provided in Section 7, References.

3.3 Hydrostratigraphic Interpretations

Hydrostratigraphic interpretations are the classification of units of subsurface material and their associated characteristics (e.g., lithologies, geologic facies, permafrost distribution) into groups of similar hydrogeologic behavior. Regional and local assessments of groundwater flow conditions can then be made based on the distribution of these hydrostratigraphic units. Subsurface materials identified within the LSA, RSA, and CMV have been classified as a confining layer or as potential aquifer material (Section 4, Review of Existing Data).

A confining layer is a low-permeability hydrostratigraphic unit that acts as a barrier to groundwater flow. Higher permeability units below a confining layer will be hydraulically uncoupled, to various degrees, to overlying higher permeability units and to surface water features.

Potential aquifers are higher-permeability hydrostratigraphic units of sufficient extent and thickness to be considered for groundwater extraction.

3.4 Conceptual Groundwater Flow Models

A conceptual groundwater flow model is a summary of inferred groundwater system characteristics, including hydrostratigraphic units, groundwater flow boundaries, preferential flow paths, and recharge and discharge conditions (Beale and Read, 2013). Based on the information compiled during the literature review, conceptual models of groundwater flow within the LSA and RSA were developed. Effects of the Project on groundwater within the LSA and RSA will be assessed in the DAR using the conceptual framework provided by these models.

4 Review of Existing Data

The results of the literature review are organized by subject in the following sections. Some subjects are discussed in greater detail in other TDRs; here, they are discussed as they relate to existing groundwater conditions. Hydrology is discussed in the TDR, Surface Water Quantity (K'alo-Stantec, 2022a), and the water quality of surface water bodies is discussed in the TDR, Surface Water Quality (K'alo-Stantec, 2022b). Bedrock geology, surficial geology and permafrost is discussed in the TDR, Soils, Terrain and Permafrost (K'alo-Stantec, 2021).

4.1 Physiography

The project highway alignment follows the MVWR east of the Mackenzie River within the Mackenzie Plain physiographic region (Figure 2.1). Topography is a key driver of groundwater flow. Elevations within the Mackenzie Plain, in the CMV, range from about 100 metres above sea level (m asl) to 350 m asl. The Mackenzie River and major tributaries are incised approximately 50 m to 150 m below the plain (Hamilton, 1995). Topography within the plain consists of gently undulating hills, hummocks and plateaus. Elevation decreases from south to north along the mainstem of the Mackenzie River (IORVL, 2004).

The Mackenzie Plain is bound to the west and east by the Mackenzie and Franklin Mountains, respectively. The Franklin Mountains are series of northwest to southeast trending thrust and fold ranges consisting of the Norman Range north of Great Bear River, and the McConnell Range south of Great Bear River (Figure 2.1). The maximum elevation along the Norman Range is approximately 975 m asl, while Clark Mountain within the McConnell Range rises to approximately 1,500 m asl (NRCan, 2016).

4.2 Permafrost

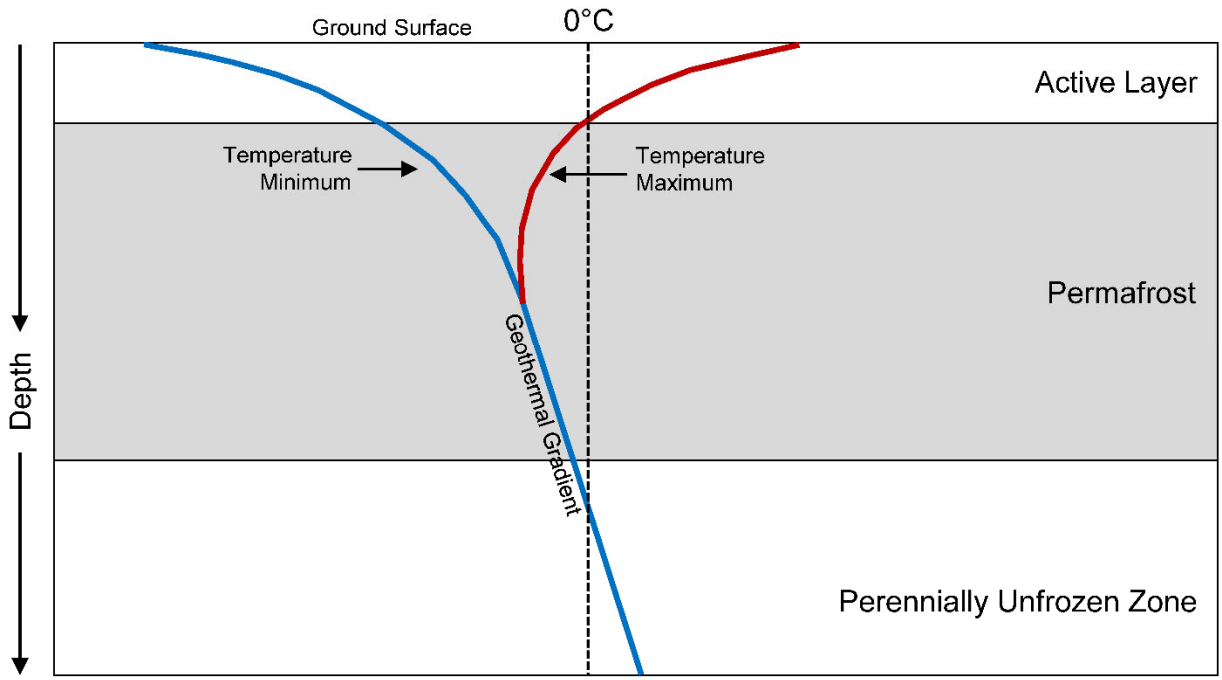
4.2.1 Thermal Ground Regime

A simplified ground thermal regime typical in permafrost regions is provided on Figure 4.1. The vertical temperature profile results from the long-term balance between incident solar radiation and reflected and re-radiated radiation from the ground surface (i.e., climate), and the input of geothermal heat from the Earth's interior. Other factors influencing the ground thermal regime include elevation, soil type, soil moisture content, slope aspect, overlying vegetation, and snow cover (Burgess and Smith, 2000).

Permafrost is soil or rock with a temperature below zero degrees Celsius (0°C) for at least two consecutive years (Dobinski, 2011). In permafrost terrain, the active layer is the horizon immediately below ground surface that freezes and thaws each year, coincident with annual atmospheric temperature variations (Burgess and Smith, 2000). Permafrost is the zone below the active layer and above the perennially unfrozen zone.

The thickness of the permafrost zone can range from less than a metre to hundreds of metres at depending on location and conditions (Walvoord and Kurylyk, 2016). The permafrost zone is thin or absent at Fort Simpson, about 185 km southeast of Wrigley, and it ranges from 35 m to 135 m thick near Norman Wells (Taylor et al., 2000).

Figure 4.1 Typical Ground Thermal Profile



The thickness of the active layer depends on seasonal atmospheric temperature variations, longer-term climate trends, topography of the ground surface, the heat conductivity and water content of the subsurface material, and ground cover conditions (Burgess and Smith, 2000).

Between 1993 and 1998, the active layer thickness in the Mackenzie Valley, at monitoring sites instrumented with thaw tubes by the Geological Survey of Canada (GSC), ranged from 0.38 m to 1.82 m (Nixon, 2000). In 2017, the active layer thickness at monitoring sites, where permafrost was encountered and instrumented with thaw tubes and thermistor strings, ranged from 0.78 m to 7.68 m (Duchesne et al., 2020).

There is broad consensus among authors that climate change will result in a decrease in permafrost thickness and, potentially, an increase in the thickness of the active layer (Nixon, 2000; Wright et al., 2000, Bense et al., 2009, Walvoord and Kurylyk, 2016). The active layer at sites instrumented by Nixon (2000) generally increased in thickness between 1993 and 1998 but, due to thaw settlement, not always.

The hydrogeological effects of a thicker active layer are discussed in Section 5.3, Climate Change.

4.2.2 Distribution

The regional distributions of permafrost and of ice-content within the Mackenzie Plain were mapped by Heginbottom et al. (1995) and Heginbottom (2000) and are provided on Figure 4.2 (from K'alo-Stantec, 2021). The distribution of permafrost is classified as *extensive*, *intermediate*, or *sporadic discontinuous permafrost*. Extensive permafrost is generally associated with the higher altitudes of the Norman and McConnell Ranges (Heginbottom, 2000). Sporadic permafrost occurs primarily east of the Mackenzie River and to about 50 km north of Wrigley (Figure 4.2).

The distribution of ground ice content near the project highway alignment has been reported as low or moderate, indicating distributions of 0 percent (%) to 5% or 5% to 15%, respectively (Heginbottom, 2000). Higher moisture content is associated with flatter, lower permeability surficial sediments blanketing the Mackenzie Plain. Lower moisture content is associated with higher permeability surficial sediments, where they exist, and with higher permeability bedrock exposures and better-drained terrain of the Norman and McConnell Ranges (Figure 4.2).

4.2.3 Permafrost Influence on Groundwater Flow

4.2.3.1 Confining Layer

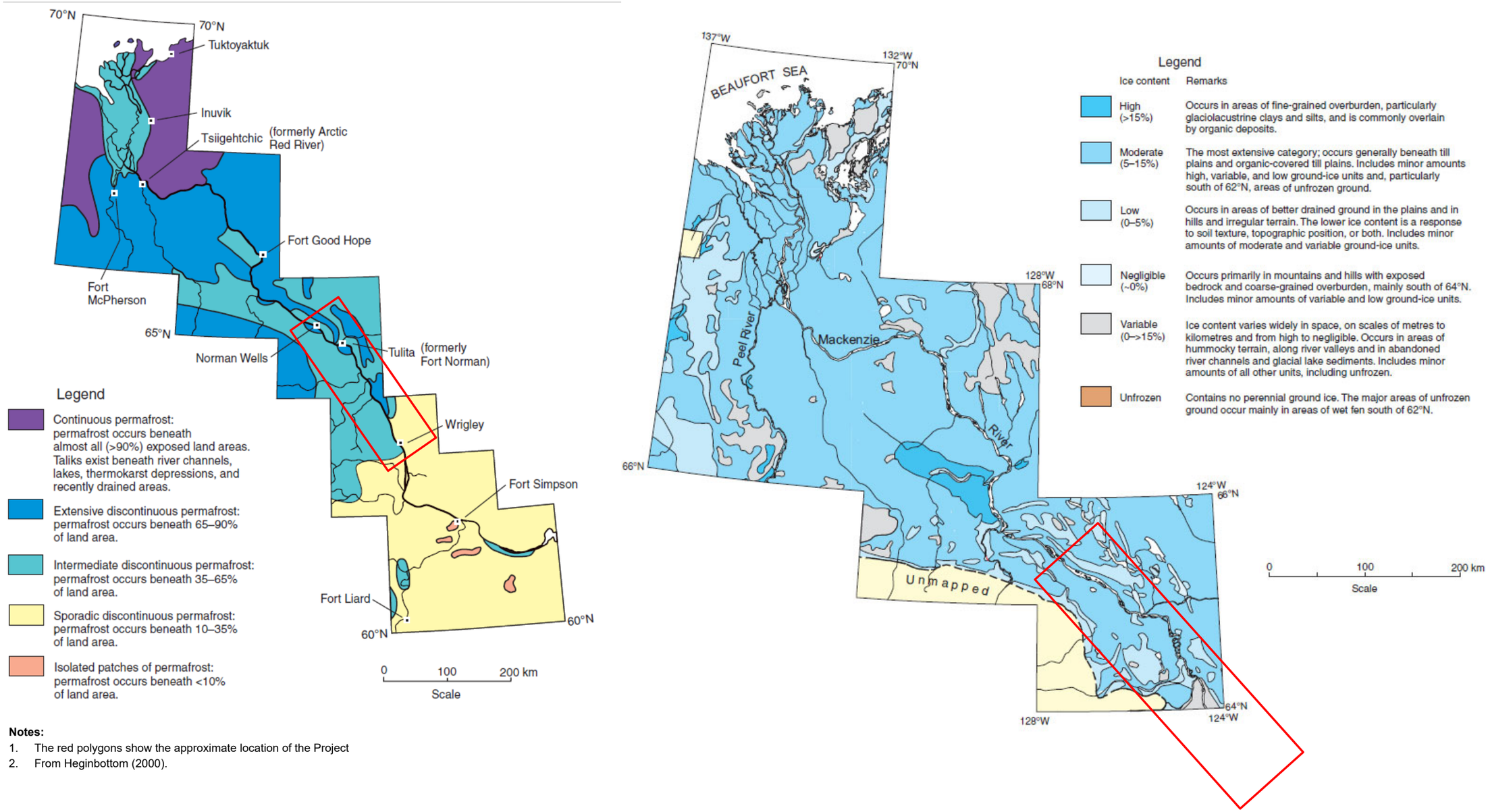
The distribution of permafrost and moisture content has a considerable impact on surface and groundwater hydrological processes in northern climates (Walvoord and Kurylyk, 2016). Moisture content is particularly important because the transition from unfrozen to frozen ground and the associated phase change from liquid to ice reduces the permeability of saturated porous media by several orders of magnitude (McCauley et al., 2002 *in* Walvoord and Kurylyk, 2016; Bense et al., 2009, 2012). As a result, ice-saturated permafrost is generally regarded as a confining layer and a barrier to groundwater flow (Bense et al., 2009, 2012; Walvoord et al., 2012). Groundwater flow that occurs seasonally or perennially above the permafrost horizon is supra-permafrost flow, while flow that occurs in the perennially thawed zone below permafrost is sub-permafrost flow (Walvoord and Kurylyk, 2016).

Figure 4.2 presents the permafrost distribution and the expected distribution of ground-ice within the Mackenzie Valley, based on mapping by Heginbottom (2000). The red rectangles indicate the approximate location of the project highway alignment.

The effect of permafrost as a confining layer and barrier to groundwater flow will be greater along the northern two thirds of the project highway alignment than along the southern third: permafrost is expected to underlie 35% to 90% of the land surface (northern two thirds) compared to 10% to 35% of the land surface (southern third); see Figure 4.2.

The degree to which permafrost acts as a confining layer depends on the direction of groundwater flow, the permeability of the hydrostratigraphic unit where flow occurs, and the magnitude of the flow gradient. Where flow has a downward component (i.e., recharge areas), permafrost may considerably limit vertical flow (Michel, 1986). Where flow has a minor upward component (i.e., local discharge areas) permafrost may act as a confining layer. Where flow gradients have a stronger upward component in relatively permeable material (i.e., regional discharge areas) advective heat transport from upwelling groundwater can produce and maintain open taliks (Bense et al., 2012).

Figure 4.2 Permafrost and Ice Content Distribution in the Mackenzie Plain



Notes:
1. The red polygons show the approximate location of the Project
2. From Heginbottom (2000).

4.2.3.2 Supra-Permafrost Flow in the Active Layer

Where permafrost exists, the seasonal active layer exerts control on surface and near-surface water storage, drainage, and routing (Walvoord and Kurylyk, 2016). In general, the active layer begins to thaw after snowmelt. Due to the limited thickness of the layer, most of the initial melt is rejected as recharge, which results in extensive surface ponding and runoff (Woo, 1986). As the thawing front advances and the active layer deepens, the storage capacity of the active layer increases and water levels may decline below ground surface. Key drivers in the maximum thickness of the active layer include climate, vegetation, and soil conditions (grainsize distribution and ice-content) (Walvoord and Kurylyk, 2016).

Water held in the active layer includes snowmelt, precipitation, and subsurface ice contributions (Woo, 1986). Groundwater flow within the active layer is governed by permeability and gradient. Shallow or near flow gradients are generally topography driven, and minor changes in slope may cause groundwater–surface water exchange: water will fluctuate from just above to just below ground surface as it moves downslope (Nielson et al., 2018). Minor topographic lows or areas where slope drainage is obstructed may cause ponding (Woo, 1986). Ponding, in turn, may result in a deepened active layer, increased ground-ice melting, and settlement of thaw (Mu et al., 2018). Thermokarst are processes and landforms that result from collapse of the ground surface due to melting ground ice (Kokelj and Jorgenson, 2013).

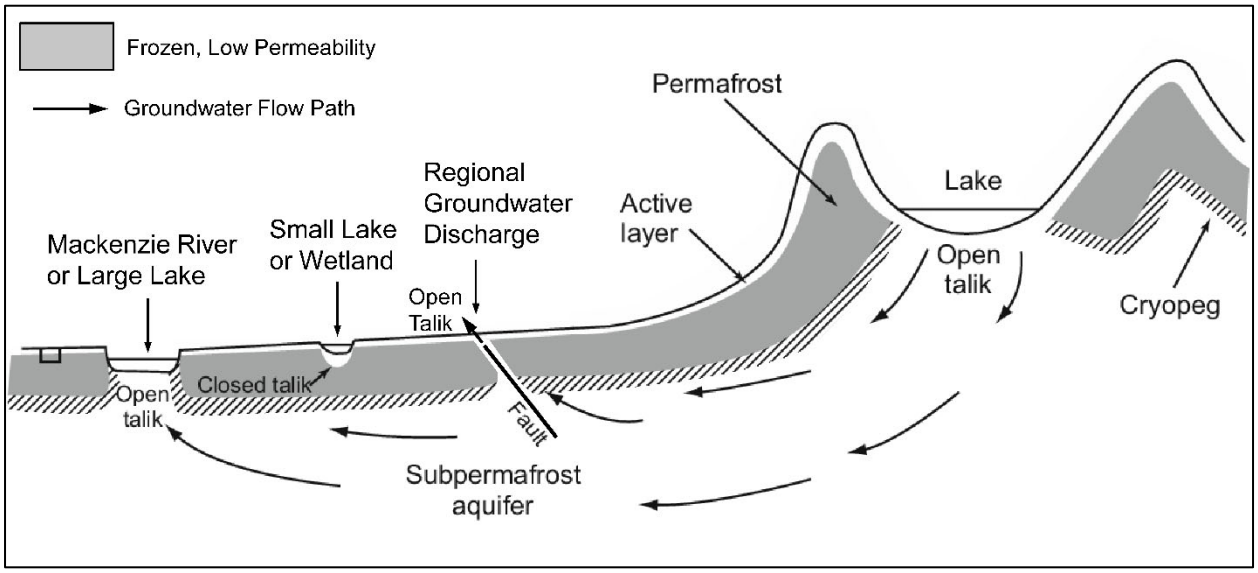
Summer precipitation events may rapidly exceed the limited storage capacity of the active layer and precipitation rapidly drains as surface runoff, forming shallow drainage features as a result (Mu et al., 2018). Within the LSA, apparent drainage flow paths (gullies) were mapped at a 1:10,000 scale using available aerial photography, ortho-imagery, and LiDAR-derived data available for the project (Appendix B, K'alo-Stantec, 2021).

Supra-permafrost groundwater begins to freeze in fall as the freezing front penetrates the ground surface. Groundwater can be confined between underlying permafrost and the descending freezing front, which causes groundwater to flow to areas of lowest hydraulic potential (pressure). Where pressure exceeds overlying lithostatic pressure, the ground surface may be lifted at points of weakness and frost blisters may form (Woo, 1986).

4.2.3.3 Taliks

Taliks are areas of unfrozen, saturated subsurface material beneath surface water features in regions underlain by extensive permafrost (Walvoord and Kurylyk, 2016). Closed taliks are unfrozen areas that penetrate deeper into the permafrost horizon than the surrounding active layer. Open taliks are unfrozen areas that completely penetrate the permafrost horizon and are hydraulically connected to the underlying sub-permafrost groundwater system. A schematic adapted from Lemieux et al. (2016) illustrating open and closed taliks in continuous permafrost is provided on Figure 4.3. In those parts of the LSA and RSA where permafrost is discontinuous, sub and supra-permafrost groundwater flow systems are considerably more hydraulically connected.

Figure 4.3 Schematic of Open and Closed Taliks (Adapted from Lemieux et al., 2016)



An open talik underlies the mainstem of the Mackenzie River (Taylor et al., 1998; Dyke, 2000) and connects the river to regional groundwater flow paths. Other open taliks in the region and within the RSA likely exist beneath streams and lakes of sufficient size. Open taliks may exist where there is regional groundwater discharge along the base of the Franklin Mountains (Michel, 1986). Closed taliks likely exist beneath smaller lakes and wetlands and, at these features, groundwater-interactions may be limited to the supra-permafrost flow.

4.2.3.4 Baseflow

Permafrost minimizes spring melt or precipitation event storage in the subsurface by restricting water storage to the active layer, and stream hydrographs in permafrost regions may show rapid streamflow response to these events (Brooks, 2000). Baseflow may also be severely limited where regional groundwater discharge pathways are absent and, in the CMV, many streams seasonally freeze to ground surface during the winter. In general, IORVL (2004) showed that streams draining watershed areas greater than 100 square kilometres (km^2) sustain perennial flow. Streams draining watershed areas less than 100 km^2 may be perennial or seasonal (i.e., freeze to the bottom in winter), depending on the scale of groundwater discharge.

IORVL (2004) completed visual surveys along the Mackenzie Gas Project route in April 2002 and noted that if streams at right-of-way crossings were frozen to ground, then they contained icings (accumulations of layered ice formed by continuous freezing of slow discharge water) or ice jams or contained open water. Ice jams and open water were considered strong evidence of groundwater contribution to baseflow.

Visual survey results completed by IORVL (2004) at right-of-way stream crossings are summarized in Appendix A.

Open water was observed at Hodgson, Steep, and Vermillion Creeks. Icings were noted at Ochre and Blackwater Rivers, and at White Sand, Big Smith, Christina, Hellava, Francis, and Canyon Creeks (Appendix A, Table A.1).

4.3 Surficial Geology

The surficial geology within the RSA includes till, glaciolacustrine, glaciofluvial, alluvial, eolian, colluvium and organic deposits that have formed during and since the last continental glaciation (Alysworth et al., 2000; Duk-Rodkin and Lemmen, 2000). The maximum extent of the Laurentide ice sheet in the Mackenzie Valley reached the Beaufort Sea about 30 thousand years before present (30 ka BP), depositing ice-contact till and glaciofluvial sediments as it moved northward (Duk-Rodkin and Lemmen, 2000). Subsequent glacial retreat to 13 ka BP resulted in the formation of Glacial Lake Mackenzie, which extended from about Fort Good Hope to south of Wrigley. By 10 ka BP the lake was completely drained, leaving extensive deposits of glaciolacustrine silts and clays overlying the till deposited by the glacial advance (Duk-Rodkin and Lemmen, 2000).

Subsequent erosion through these glacial and glaciolacustrine materials by the Mackenzie River and tributaries resulted in alluvial sediment deposition along their channels. Mass wasting processes resulted in colluvium deposition along escarpments and steeper topography. Organic bog and fen materials have gradually accumulated in areas of flatter topography (K'alo-Stantec, 2021).

Sediment descriptions, thickness, qualitative permeability estimates, and hydrostratigraphic interpretations of these deposits are summarized in Table 4.1. K'alo-Stantec has inferred hydrogeological characteristics from the general grainsize distribution implied by each sediment description.

The distribution of surficial geology within the RSA is provided in Appendix B, Figures B.1 to B.16, based on maps released by the GSC (Rutter et al., 1993; Duk-Rodkin, 2002; Duk-Rodkin and Couch, 2004; Duk-Rodkin and Huntley, 2009; Côté et al., 2013; GSC, 2019a, 2019b). Brief descriptions of these sediments based on the GSC maps are provided below, focusing on their distribution and relationship to groundwater flow paths. More detailed mapping and descriptions of these sediments are provided in the TDR, Soils, Terrain, and Permafrost (K'alo-Stantec, 2021).

Table 4.1 RSA Sediment Hydrostratigraphy

Deposit[1]	Sediment Description[1]	Thickness[2]	Qualitative Saturated Permeability[3]	Hydrostratigraphic Interpretation
Glaciolacustrine	Silt, sand, minor clay	to 50 m	Low	Confining layer
Till	Dominantly silt and clay-matrix till	To 30 m	Very low to low	Confining layer
Colluvium	Rubble, gravel, sand	to 10's of metres	Moderate to very high	Potential aquifer
Alluvial	Gravel, sand, silt	-[4]	Moderate to high	Potential aquifer
Glaciofluvial	Gravel, sand, silt	to >30 m	Moderate	Potential aquifer
Organic	Fens and bogs	1.5 m to 7 m	Low to high	-
Eolian	Sand, minor silt	to 20 m	Moderate	Potential aquifer

Notes:
1. Deposit types and sediment descriptions from Rutter et al., 1993.
2. Thickness from maps and reports by the GSC.
3. Qualitative permeability based on permeability ranges for sediment types in Freeze and Cherry (1979).
4. "-"denotes not available or applicable.

4.3.1 Low Permeability Sediments

Till deposits are found over a large portion the Mackenzie Plain (Rutter et al., 1993). These deposits cover 19% of the area within the RSA, generally overly bedrock and are up to 30 m thick (K'alo-Stantec, 2021). These tills are clay-and-silt matrix supported and compact (Savigny, 1989) and, based on literature values of permeability for similar tills (Freeze and Cherry, 1979), likely low-permeability.

Glaciolacustrine deposits are found over a large portion of the Mackenzie Plain (Rutter et al., 1993). These deposits cover 38% of the area within the RSA, generally overlie till, and are up to 50 m thick. Deposits of silt and fine sand are common in the south and central portions of the RSA, while clay sediment is more common in the northern portion (K'alo-Stantec, 2021). Clay-dominated deposits generally have very low permeabilities. Silt and fine sand deposits will tend to have low-to-moderate permeabilities that decrease with the increasing fraction of silt (Freeze and Cherry, 1979).

Due to their low permeability and broad distribution across the Mackenzie Plain and RSA, till and glaciolacustrine deposits likely act as regional confining layers and barriers to groundwater flow. Locally, these sediments will restrict groundwater recharge and encourage ponding and near-surface saturated conditions, conditions that will be exacerbated where permafrost exists. Regionally, these sediments will restrict groundwater discharge and artesian pressures may form in underlying aquifer units.

4.3.2 Moderate Permeability Sediments

Glaciofluvial deposits are found sporadically across the Mackenzie Plain (Rutter et al., 1993). These deposits cover about 5% of the area within the RSA (K'alo Stantec, 2021) and are up to more than 30 m thick. Deposition directly or close to glacial ice tends to produce a well-graded deposit; there is a distributed range of silt, sand, and gravel grainsize fractions. As a result, the permeability of glaciofluvial sediments will decrease with increasing silt fraction and increase with increasing sand and gravel fractions (Freeze and Cherry, 1979).

The limited distribution of glaciofluvial sediment within the RSA and the Mackenzie Plain will limit the effect these sediments have on regional groundwater flow. Locally, deposits with higher silt content may act as confining layers and barriers to groundwater flow. Deposits with higher sand and gravel content may encourage groundwater recharge and, where permafrost is limited or where these deposits exist beneath permafrost, may constitute good-quality aquifers for potable water.

Eolian deposits are found to a limited extent within the Mackenzie Plain and cover less than one percent of the RSA (K'alo-Stantec, 2021). Transport by wind energy limits these deposits to silt and fine sand, and, as a result, permeabilities tend to be low to moderate (Freeze and Cherry, 1979). Due to their limited extent, these deposits will have minimal influence on the regional and local hydrogeology within the LSA and RSA.

4.3.3 High Permeability Sediments

Alluvial sediments are found along modern stream channels and valley floors within Mackenzie Plain, covering about 14% of the RSA (K'alo Stantec, 2021). These sediments are poorly graded relative to glaciofluvial sediments and till, and permeabilities will depend on primary grain size fractions. Deposits dominated by silt and fine sand will have moderately low permeability. Deposits with primarily sand and/or gravel grainsize fractions will have high and potentially very high permeabilities (Freeze and Cherry, 1979).

Locally, alluvial sediments will encourage groundwater recharge where permafrost is limited and may constitute good-quality aquifers for potable water. Sand and gravel deposits will be substantially better aquifers than silt dominated deposits. The degree of hydraulic connection with nearby surface water bodies will generally need to be considered.

Colluvium deposits cover about 8% of the RSA and are generally found along the base of slopes in the Franklin Mountains (K'alo-Stantec, 2021). These deposits include surficial material that has reached its present position from gravity-induced movement: by slow mass movement or slow-to-fast moving landslides. Colluvium is derived from both bedrock and from pre-existing deposits of other surficial materials.

Also mapped in the RSA, as colluvium on level to gently sloping surfaces, are materials that could be more appropriately identified as in-situ weathered bedrock. Karst features have developed in areas where dolostone or limestone bedrock is weathering, and these materials may have very high permeabilities (Michel, 1986; Ford, 2009).

The hydrostratigraphic properties of colluvium will depend on the parent material and local depositional setting. Regionally, because of their exposure across higher elevations and association with karst landforms, colluvium deposits are important areas of regional groundwater recharge (Ford, 2009).

Organic deposits cover about 2% of the RSA and are mainly composed of organic materials resulting from the accumulation of vegetative matter, typically in poorly to very poorly drained, level and depressional areas (K'alo-Stantec, 2021). These materials may have a range of permeabilities depending on the material structure and degree of decomposition (Attila et al., 2005).

4.4 Bedrock Geology

4.4.1 Structure

Bedrock near the project highway alignment comprise clastic and chemical sedimentary rocks of the Mackenzie Fold Belt, which includes the Mackenzie Mountains, the Mackenzie Plain, and the Franklin Mountains (Douglas et al., 1970, *in* Michel, 1986). Large-scale, regional folding during the Cretaceous is the main structural stress that has folded Cambrian to Cretaceous strata into a broad, asymmetric, northwest-southeast oriented syncline beneath the Mackenzie Plain. The western limb forms the eastern margin of the Mackenzie Mountains, and the eastern limb forms the western slopes of the Franklin Mountains (Hayes and Dunn, 2012; Golder, 2015).

Faulting has also occurred: the Franklin mountains largely consist of isolated ridges of sedimentary stratigraphy thrust upwards and exposed at surface (Hannigan et al., 2011). Exposed bedding planes strike approximately northwest to southeast and dip westwards towards the Mackenzie River (i.e., the eastern limb of the regional syncline). Exposed bedding planes and associated thrust faults are regionally important for groundwater recharge and movement (Van Everdingen, 1981; Michel, 1986; Hamilton, 1995; Ford, 2009).

4.4.2 Outcrop

Bedrock formations within the RSA and the Mackenzie Plain are generally covered by surficial deposits and only about one percent of the RSA area is exposed bedrock (K'alo-Stantec, 2021). The Bear Rock Conservation Zone, immediately north of the confluence of the Great Bear and Mackenzie Rivers, is the location of the largest area of outcrop within the RSA (Appendix B, Figure B.13), although smaller exposures have been mapped throughout the RSA (K'alo-Stantec, 2021). Outcropping bedrock formations include the Bear Rock Group and the Hume, Franklin Mountain, and Saline River formations (Appendix B, Figures B.1 to B.16).

4.4.3 Karst

The Franklin Mountains contains formations with thick sequences of limestone, dolostone, and evaporites that have undergone dissolution weathering and produced extensive karst sinkhole and ponor landforms (Ford, 2008, 2009). These landforms exert considerable influence on the regional groundwater system and on baseflow in streams east of the Mackenzie River (Michel, 1977 *in* Michel, 1986; Heginbottom, 2000; IORVL, 2004; Ford, 2009; Dessau, 2012; Golder, 2015). As a result, karst hydrogeology has a considerable influence on local groundwater conditions within the groundwater LSA and RSA.

In well-developed karst regions, a large percentage of precipitation commonly infiltrates the subsurface as recharge (Van Everdingen, 1981). In colder climates, permafrost can reduce recharge into karst and in many areas of widespread or continuous permafrost karst groundwater recharge conduits become inert (Ford, 2008). However, inert karst features within the Franklin Mountains were covered by the Laurentide ice sheet during the last glaciation, which may have resulted in permafrost degradation (Hamilton, 1995). As a result, numerous karst recharge features and groundwater flow paths have been re-activated since the last glaciation and, at these locations, permafrost has not re-established as a barrier to groundwater flow (Hamilton, 1995).

An important karst environment is located within the Bear Rock Conservation Zone (SLUB, 2013) where pinnacle, ponor, and sinkhole karst landforms have developed (Ford, 2008). Permafrost locally perches surface water in small ponds, but these ponds generally drain through summer and fall, indicating that the permafrost is only a partial confining layer. Many of the sinkholes and ponors apparently function as seasonal recharge taliks to sub-permafrost groundwater systems (Hamilton, 1995).

4.4.4 Stratigraphy

A general stratigraphic column and lithologic descriptions of the sedimentary bedrock formations underlying the CMV in the RSA is provided in Table 4.1. The complete Cambrian to Tertiary stratigraphy in the area is approximately 3,000 m thick.

A summary of permeability and a hydrostratigraphic interpretation, where possible, of each bedrock formation is also provided in Table 4.1. The distribution of bedrock formations in the RSA is shown in Appendix C, Figures C.1 to C.16.

The Saline River, Franklin, and Mount Kindle Formations and the Bear Rock Group inferred by K'alo-Stantec as important to groundwater flow in the LSA and RSA are described in more detail in the following sections. The development of extensive karst landforms and preferential dissolution flow paths considerably influences the hydrostratigraphic interpretations of these units (Table 4.2).

Other formations, in particular the Early Cretaceous to Paleocene stratigraphy outlined in Table 4.2, may be regionally important aquifers (Hayes and Dunn, 2012). However, these formations within the RSA and LSA are generally covered by low permeability till, glaciolacustrine deposits, and permafrost. K'alo-Stantec infers potential effects from the Project on these potential bedrock aquifers will be negligible; therefore, these formations are not currently described in further detail in this TDR.

Table 4.2 RSA Bedrock Hydrostratigraphy

Age (Ma BP)[1]	Period[2]	Formation or *Group*[2,3,4]	Lithology[2]	Maximum thickness[2]	Permeability[2]	Hydrostratigraphy[2]
100 to 56	Late Cretaceous and Paleocene	Summit Creek	Conglomerate, sandstone, coal	400	Moderate to High	Potential regional aquifer
100 to 68	Late Cretaceous	East Fork	Shale	500	-[6]	Confining layer[5]
Unconformity[8]						
100 to 68	Late Cretaceous	Little Bear	Sandstone, coal	560	High	Potential regional aquifer
		Slater River	Shale, sandstone	400	Low[5]	Confining layer[5]
Unconformity[8]						
145 to 100	Early Cretaceous	Mahony Lake	Sandstone, siltstone, shale	-	-	-
		Sans Sault Member	Sandstone, siltstone, shale	100	-	-
		Arctic Red	sandstone, shale, interbedded siltstone	400	-	Potential regional aquifer in sandstone units. Confining layer in shale units[5]
		Martin House	Interbedded sandstone, siltstone, shale	100	-	Potential regional aquifer
Unconformity[8]						
385 to 355	Late Devonian	Imperial	shale, sandstone, minor limestone	400	Low[5]	Confining layer[5]
395 to 355	Middle to Late Devonian	*Horn River*	Shale, siltstone, limestone,	565	Low	Contains porous intervals[5]
		Hume	Limestone and shale	300	Low[5]	Confining layer[5]
420 to 385	Early to Middle Devonian	***Bear Rock***[5]	Limestone, dolostone, gypsum, and anhydrite breccias	470	High (Karst)[7]	Karst Features. Presence of dissolution channels. The major bedrock aquifer in the CMV.
		Tsetso	Siltstone, sandstone, dolostone	100	-	-

Age (Ma BP)[1]	Period[2]	Formation or *Group*[2,3,4]	Lithology[2]	Maximum thickness[2]	Permeability[2]	Hydrostratigraphy[2]
Unconformity[8]						
460 to 440	Middle Ordovician to Early Silurian	**Mount Kindle**[5]	Dolostone, sandstone	250	High, (Karst)[7]	Potential regional aquifer
Unconformity[8]						
540 to 450	Cambrian to Ordovician	**Franklin Mountain**[5]	Dolostone	300	Low to High (Karst)[7]	Potential regional aquifer
510 to 490	Middle to Late Cambrian	**Saline River**[5]	Gypsum, anhydrite, halite, shale, siltstone, dolostone	500 to 750[7]	Low to High (Karst)[7]	Potential regional aquifer
Unconformity[8]						
540 to 500	Early to Middle Cambrian	Mount Cap	Shale, siltstone, dolostone, sandstone	-	Low to High (Karst)[7]	Potential local aquifer
		Nainlin	Shale, sandstone, conglomerate	-	-	-
		Mount Clark	Sandstone	50	-	-

Notes:

1. "Ma" is million years before present; approximate age ranges only; provided for context; based on the formation period age.
2. Based on Tables 3-8 and 3-10 in Golder (2015). Information from Golder (2015) unless otherwise noted.
3. *Underlined and italicized* indicates a group rather than a formation.
4. **Bolded** formations indicate those K'alo-Stantec infer are important for groundwater flow pathways within the LSA and RSA.
5. Identified as an aquifer or confining layer in AMEC, 2014 (Figure 5).
6. "-" denotes information not available or interpretation was not possible.
7. From on Michel (1986) and Hamilton (1995).
8. "Unconformity" is a break in an otherwise continuous rock record caused by erosion or a pause in sediment accumulation.

4.4.4.1 Saline River Formation

North of Great Bear River, the Saline River Formation outcrops along the east slopes of the Norman Range. South of Great Bear River, the formation outcrops on the west flank of the McConnell Range. Within the groundwater LSA and RSA, the formation is largely covered by till or colluvium, and it is composed of evaporites (halite and gypsum), shale, dolomite, and anhydrite (Serié et al., 2013). Beneath the western slopes of Norman Range, the evaporite sequences are more than 750 m thick (Michel, 1986).

Recessive weathering where the evaporites outcrop indicates that regional dissolution is occurring that likely produces high-permeability preferential flow paths (Michel, 1986). Halite (sodium chloride) is "*hypersoluble*" (Van Everdingen, 1981), and dissolution of thick halite sequences tend to markedly increase sodium and chloride ions in solution. As a result, the Saline River Formation is generally regarded as a major but poor-quality bedrock aquifer in the region (Golder, 2015).

4.4.4.2 Franklin Mountain Formation

The Franklin Mountain Formation is composed of about 300 m thickness of dolostone and displays considerable development of sinkhole, ponor, and river-sink karst landforms where the formation intersects ground surface. The formation primarily outcrops east of the Norman Range, but also outcrops within the Bear Rock Conservation Zone and within the Norman Range north of Great Bear River (Michel, 1986; Hamilton, 1995). The formation outcrops along the project highway alignment in the Bear Rock Conservation Zone (Appendix C, Figure C.13). The aquifer potential of this formation is primarily a result of karst feature development and dissolution weathering.

4.4.4.3 Mount Kindle Formation

The Mount Kindle Formation is composed of about 500 m thickness of thick-bedded, fossiliferous dark grey dolostone (Hannigan et al., 2011) that develops considerable karst landforms (Van Everdingen, 1981) The aquifer potential of this formation is primarily a result of karst feature development and dissolution weathering. The Mount Kindle Formation does not outcrop within the groundwater LSA or RSA.

4.4.4.4 Bear Rock Group

The Bear Rock Group summarized in Table 4.2 combines the Arnica, Landry, and Fort Norman Formations (Golder, 2015). These formations are composed of limestone, dolomite, gypsum, and solution breccia (Morrell et al., 1995). The Bear Rock Group is described as having "*cavernous porosity*" in the subsurface (Hume, 1954 *in* Hamilton, 1995) and the Bear Rock Group is generally regarded as a major bedrock aquifer in the region (Golder, 2015). The aquifer potential of this formation is primarily a result of karst feature development and dissolution weathering.

The Bear Rock Group outcrops within the groundwater LSA and RSA, primarily within the Bear Rock Conservation Zone (Appendix B, Figure B.13), and sporadic outcrop has also been mapped within the LSA and RSA along the project highway alignment (Appendix B, Figure B.1 to B.16). The largest exposures outside of the Bear Rock Conservation Zone are near Wrigley (Appendix B, Figures B.1 and B.2).

4.5 Groundwater Quality

Groundwater sampling completed within the CMV include efforts to understand karst hydrology (e.g., Van Everdingen, 1981; Michel, 1986; Hamilton, 1995), efforts to assess effects from the Mackenzie Gas Project (IORVL, 2004) , and efforts to characterize deep groundwater aquifers for oil and gas exploration support (AMEC, 2014).

Summaries of the chemistry analyses reported by Michel (1986) and by IORVL (2004) are provided in Appendix D1, Table D1.1 and Table D1.2, respectively.

Michel (1986) reported major ion and environmental isotope chemistry analyses from 12 groundwater discharge locations sampled by Michel (1977) between the Mackenzie River and the Franklin Mountains, from Wrigley to Norman Wells (Table 4.3). Figure D2.1 in Appendix D2 provides a plan map of the sampled locations.

Concentrations of major ions in seep discharge are relatively high, reflecting the solubility of the bedrock minerals encountered along the groundwater flow path. Michel (1986) showed that the concentrations of sodium (Na^+) and chloride (Cl^-), calcium (Ca^{2+}), and sulfate (SO_4^{2-}) ions closely approximate linear relationships. This suggests the source of these ions are primarily halite ($NaCl_{(s)}$) and gypsum ($CaSO_4 \cdot 2H_2O_{(s)}$) and anhydrite ($CaSO_{4(s)}$), respectively, which occur within the Saline River Formation and Bear Rock Group (Appendix D1, Table D1.1).

Oxygen-18 (^{18}O) and Deuterium (^{2}H) isotope fractionation ratios for the springs sampled by Michel (1986) ranged from -22.8 permil (‰) to -23.7 ‰, consistent with modern precipitation values for cooler climates (Appendix D1, Table D1.1). This indicates the springs were sourced from relatively recent recharge events after the last glacial period. In contrast, Michel (1982), as reported in Michel (1986), showed that ground ice from drill core retrieved from four locations between Wrigley and Norman Wells contained oxygen-18 fractionation ratios depleted to about -31‰, indicating recharge that took place during a cooler climate, inferred to be late Wisconsian age (about 10 ka BP). These oxygen-18 vs. depth profiles from Michel (1982), as reported in Michel (1986), are provided in Appendix D2 for context.

IORVL (2004) sampled springs between Wrigley and Norman Wells in spring and summer 2002 and 2003, aiming to re-sample locations first sampled by Michel (1977). Tabulated chemistry analysis results were not provided, but the groundwater quality of various springs was discussed in some detail. Appendix D1, Table D1.2 provides a summary of the groundwater quality information provided in IORVL (2004), including water type, discharge rate measurements, and concentrations of total dissolved solids (TDS). Location maps for the springs are provided in Appendix D3.

Chemistry analyses reported by AMEC (2014) are provided in Appendix D4, Table D4.1. These samples were generally collected from wells installed at a considerable depth below ground surface and within early cretaceous and younger stratigraphy west of the Mackenzie River (outside the groundwater RSA). As discussed in Section 4.4.4, Stratigraphy, the potential aquifers within these formations are not expected to be affected by the Project and these samples are not discussed in further detail in this TDR.

4.6 The Groundwater Resource

4.6.1 Potable Water

Until 2014, Wrigley relied on a groundwater for the community water source (GNWT, 2013). Michel (1986) and IROVL (2004) indicated that two wells have been drilled for the community. Both are completed in surficial sediments. The "*airport*" well is screened in unfrozen sand and gravel and provides high-quality potable water (Michel, 1986). The Wrigley town well is screened in glaciolacustrine silts and produces much lower-quality water (Michel, 1986). IORVL (2004) notes "*a deeper well was drilled for the community in about 1970*", which may be the well screened in glaciolacustrine silts referenced by Michel (1986). This "*deeper well*" is 48.8 m deep, produces 0.92 litres per second (L/s) groundwater with chloride concentrations between 539 mg/L and 573 mg/L, which was described as unsuitable for community use (IORVL, 2004).

There are no references to bedrock aquifers exploited for potable water in the literature K'alo-Stantec reviewed.

4.6.2 Groundwater for Oil and Gas Exploration

Various desktop assessments have been completed with the aim of developing groundwater resources to support oil and gas exploration (Hayes and Dunn, 2012; AMEC, 2014; Golder, 2015). Table 4.3 summarizes the qualitative conclusions made by these authors on the viability and quality of specific bedrock formations for groundwater extraction, presumably for oil and gas exploration support.

Table 4.3 General Quality of Select Bedrock Aquifers in the CMV

Formation	Hayes and Dunn (2012)	AMEC (2014)	Golder (2015)
Summit Creek	Relatively fresh groundwater.	-	Most viable aquifer for fresh water, low TDS.
Little Bear	Formation waters are fresh to brackish. Optimal aquifer quality and water chemistry is found in Upper Cretaceous Little Bear sandstones that occur in the southern CMV.	Exceedances for some heavy metal parameters. Exceedances and detections of hydrocarbon parameters.	Optimal water quality and chemistry.
Martin House and Arctic Fox	Water analyses indicate variable salinity, with total dissolved solids ranging from 3,208 to 40,212 mg/L. Inferred that some units in these formations are exposed to recharge by meteoric waters while others are relatively isolated.	Exceedances for some heavy metal parameters. Exceedances and detections of hydrocarbon parameters.	Highly variable water quality.
Franklin Mountain	-	-	Generally poor water quality
Saline River	-	-	Major aquifer but generally poor water quality

Note:

1. "-" indicates formation was not discussed in the referenced report.

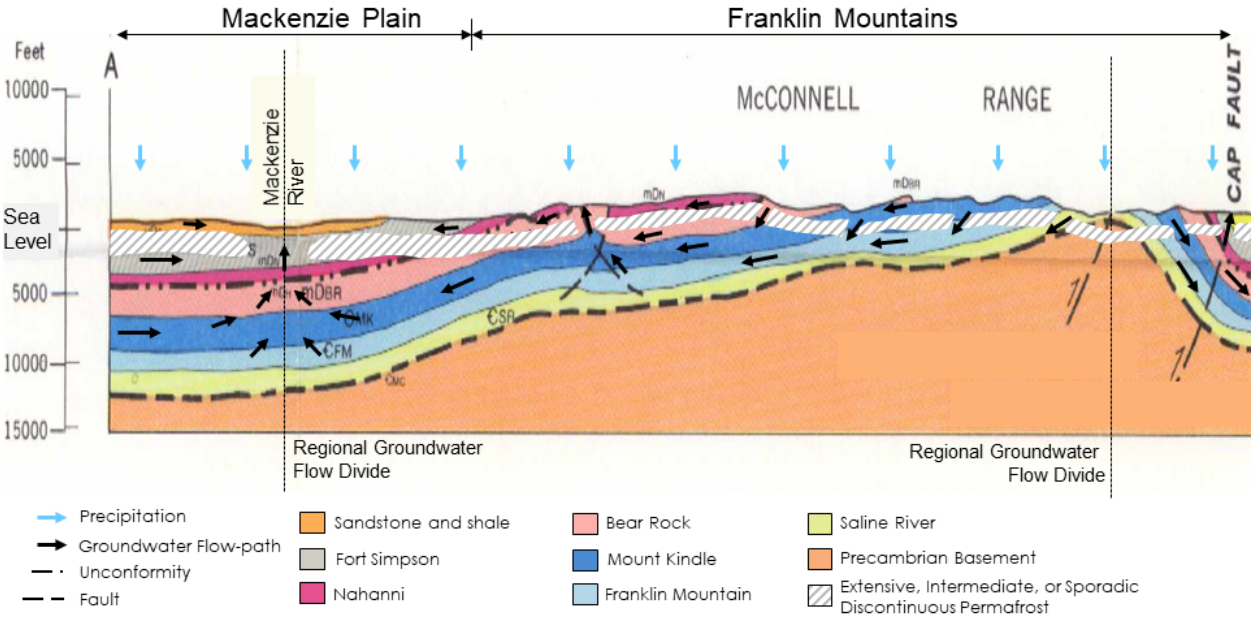
5 Conceptual Groundwater Flow Model

Groundwater flow systems are conceptualized as nested regional, intermediate, and local scale systems (Toth, 1963). Regional groundwater flow develops from large-scale topographic, physiographic, and geologic features: these features on the scale of the CMV. Local groundwater flow systems develop from smaller-scale variation of topography and geologic features; they are local flow, often dominated by one component of the regional flow system (Freeze and Cherry, 1979).

5.1 Regional CMV Groundwater Flow

Figure 5.1 (adapted from Map 1373A, GSC, 1993) summarizes K'alo-Stantec's general understanding of regional CMV groundwater flow along the project highway alignment.

Figure 5.1 Regional Groundwater Flow Schematic



5.1.1 Hydrostratigraphic Units

The major regional hydrostratigraphic units are bedrock units affected by dissolution weathering including the Saline River, Franklin, and Mount Kindle formations and the Bear Rock Group. Secondary porosity and permeability have been increased by continual groundwater circulation and dissolution of fractures, joints, and fault features in these units, therefore, they are expected to be the major conduits for regional groundwater flow.

Surficial deposits are much less important to regional groundwater flow because surficial deposits across the CMV are primarily low permeability till and glaciolacustrine sediments. Also, permafrost acts as a near-ground-surface barrier to groundwater flow and, therefore, primarily affects surficial deposits (Section 5.1.3, Groundwater Recharge).

5.1.2 Regional Flow Boundaries

The regional groundwater flow system relevant to the project highway alignment is bound by the Mackenzie River to the west and the Franklin Mountains to the east.

The Mackenzie River is a major surface water feature occupying the lowest topography within the Mackenzie Plain and is a regional groundwater discharge area and flow boundary. The Mackenzie River is underlain by an open talik (Taylor et al., 1998; Dyke, 2000) that connects the river to deeper sub-permafrost groundwater systems (Figure 5.1).

Regional groundwater flow from the west (Mackenzie Mountains) and from the east (Franklin Mountains) will converge at the Mackenzie River. Regional flow will not pass beneath the Mackenzie River unless induced by an artificial hydraulic gradient (e.g., pumping from a well) in a hydrostratigraphic unit disconnected from the overlying river (i.e., beneath a confining layer).

The Franklin Mountains is another regional groundwater flow divide. Groundwater flow paths diverge east and west along the mountain ranges following declining elevations. Groundwater discharge along the project highway alignment, where it occurs, likely will not originate from recharge areas farther eastward than the topographic highs of the Franklin Mountains (Figure 5.1).

5.1.3 Groundwater Recharge

Groundwater within the regional flow system will recharge primarily from melt and precipitation through karst landforms (e.g., sinkholes, ponors) within the Franklin Mountains. Recharge occurs through taliks beneath rapidly-draining weathered bedrock and karst landforms that perforate permafrost to underlying groundwater flow systems. These taliks may have been ice-filled and inert before the last glacial period, but they have been re-activated due to permafrost degradation from the insulating effect of the Laurentide ice sheet (Hamilton, 1995). The permeability of these taliks may be high enough that permafrost has not re-established a barrier to groundwater flow (Figure 5.1).

Groundwater recharge at lower elevations will be limited by extensive veneers/blankets of low permeability till and glaciolacustrine sediments covering much of the Mackenzie Plain. Where permafrost exists, groundwater recharge will be further reduced. Because groundwater recharge and subsurface storage is restricted by permafrost, many streamflow hydrographs in the area show a rapid increase to, and decline from, peak spring melt and peak summer precipitation events.

5.1.4 Groundwater Flow Paths

The permeability of sedimentary bedrock formations depends on the depositional environment, consolidation and cementation, and on subsequent deformational events that produce folds and faulting. In general, permeability along bedding planes will be higher than permeability across bedding planes (Freeze and Cherry, 1979). Between the Franklin Mountains and the Mackenzie River, the dominant structural feature is the eastern limb of the large-scale syncline underlying the Mackenzie Plain (Figure 5.1).

Regional groundwater flow paths are, therefore, down the eastern limb of the syncline, along western dipping stratigraphy, towards the Mackenzie River. Pore pressures increase along this flow path, and groundwater will flow upwards, following vertical joints and faulting upwards to areas of lower pressure. As a result, seep discharge at surface is often concentrated along fault traces, and thrust faults are a major mechanism by which deeper, regional groundwater flow paths discharge at surface (Michel, 1986).

The concentrations of chemical constituents increase along regional flow paths as bedrock dissolves and, in general, higher concentrations of major ions in seep discharge indicate a longer flow path and a greater “age” of groundwater recharge (Freeze and Cherry, 1979). Michel (1986) inferred from isotopic data that all the seeps sampled by Michel (1977) along the slopes of the Franklin Mountains were recharged since the last glacial period (about 10 ka BP).

5.1.5 Groundwater Discharge

Regional groundwater flow paths will discharge to surface through lower-elevation bedrock outcrops and higher permeability colluvial and/or alluvial deposits. Low permeability till and glaciomarine deposits, if present, will act as a barrier to discharge and artesian (above ground surface) pressure conditions may develop in underlying aquifer units. Permafrost, however, may not considerably impact regional groundwater discharge. Even where extensive discontinuous permafrost exists, the relatively higher temperature of groundwater discharge likely creates and maintains open taliks that connect deeper groundwater flow paths to the receiving surface environment. Areas of considerable regional groundwater discharge include the Mackenzie River and the western slopes and drainage channels of the Franklin Mountains.

5.2 RSA and LSA Groundwater Flow

Local groundwater recharge within the RSA is limited by the confining nature of extensive, low permeability till, glaciolacustrine sediments, and permafrost (where it exists). The confining effects of permafrost will be more important in the northern portion of the LSA than the southern due to its more extensive presence in northern areas of the LSA. Where it exists, permafrost will limit local groundwater flow paths and discharge to the supra-permafrost active layer.

Groundwater flow in the active layer is seasonal. In the spring, when the active layer is thinnest, slope drainage occurs as surface runoff that rapidly drains a large fraction of snowmelt (Woo, 1986). As the thawing front penetration continues, the active layer storage capacity increases and more flow occurs below ground surface. Summer precipitation events cause the water table in the active layer to rise, often rapidly. When the water table in the active zone rises above ground surface, surface runoff is generated, and ponding may occur in topographic lows or where slope drainage is obstructed. Where ponding occurs, the thawing front may advance deeper into permafrost, increasing the thickness of the active layer and potentially resulting in thaw settlement.

Regional groundwater discharge is also important within the LSA and RSA. Streams with considerable regional groundwater discharge may remain perennially ice free. These streams include Steep Creek in the Dehcho Region and Vermillion Creek in the Sahtu Region. Streams with smaller regional groundwater discharge contributions may experience the formations of icings. These streams include Ochre River, White Sand Creek and Blackwater River in the Dehcho Region and Big Smith Creek, Christina Creek, Hellava Creek, Francis Creek, and Canyon Creek in the Sahtu Region (IORVL, 2004).

The Bear Rock Conservation Zone has a local groundwater flow system where deeper, sub-permafrost flow paths have not been completely de-activated by permafrost or restricted by low permeability surficial sediments. Extensive weathered bedrock and karst sinkholes and ponors across a local topographic high composed of Saline River, Franklin, Kindle, and Hume formations, and the Bear Rock Group, resulting in groundwater recharge across a large local area (Hamilton, 1995). The PDA crosses a topographic saddle of exposed bedrock north of the Bear Rock recharge area, between Bear Rock and the greater extent of the Norman Range (Appendix B, Figure B.13). Groundwater discharge near the PDA may, therefore, consist of local recharge from Bear Rock mixed with deeper, regional groundwater discharge from the Franklin Mountains.

Estimates of groundwater travel time from recharge to discharge location are available for the Bear Rock Conservation Zone. Using dye tracer tests, Hamilton (1995) estimated groundwater travel time along shallow groundwater flow paths to be on the order of weeks. Van Everdingen (1981) constrained the travel time of deeper, regional flow paths in the area to be within the range of modern climactic conditions (e.g., less than 10 ka BP) using oxygen isotope tracers.

5.3 Climate Change

A warming climate (climate change) will likely affect both regional and local groundwater systems. The distribution of permafrost may be reduced, and regional recharge may increase, particularly along exposed bedrock in the Franklin Mountains and in areas not covered by till or glaciolacustrine sediments.

The local groundwater system, limited by permafrost (where it exists), is specifically susceptible to impacts of a warming climate. There is broad consensus among researchers that climate change will result in a decrease in permafrost thickness and, potentially, an increase in the thickness of the active layer (Nixon, 2000; Wright et al., 2000; Bense et al., 2009; Walvoord and Kurylyk, 2016). The thawing front, the depth at which frozen ground seasonally thaws, affects the distribution of runoff and baseflow (groundwater input) to streams from the shallow, supra-permafrost active layer (Yamazaki et al., 2005; Koch et al., 2014). As the thawing front deepens and the active layer becomes thicker, the direct runoff ratio may decrease (Yamazaki et al., 2005) and delayed contribution from baseflow may increase (Koch et al., 2014). This may fundamentally change streamflow in the North.

6 Closure

This TDR was prepared for the sole benefit of GNWT to describe existing conditions related to hydrogeology within the groundwater LSA and RSA. If you have any questions, please do not hesitate to contact the undersigned.

Respectfully submitted,

K'alo-Stantec Limited

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Appendix A IORVL (2004) Stream Open Water and Icings

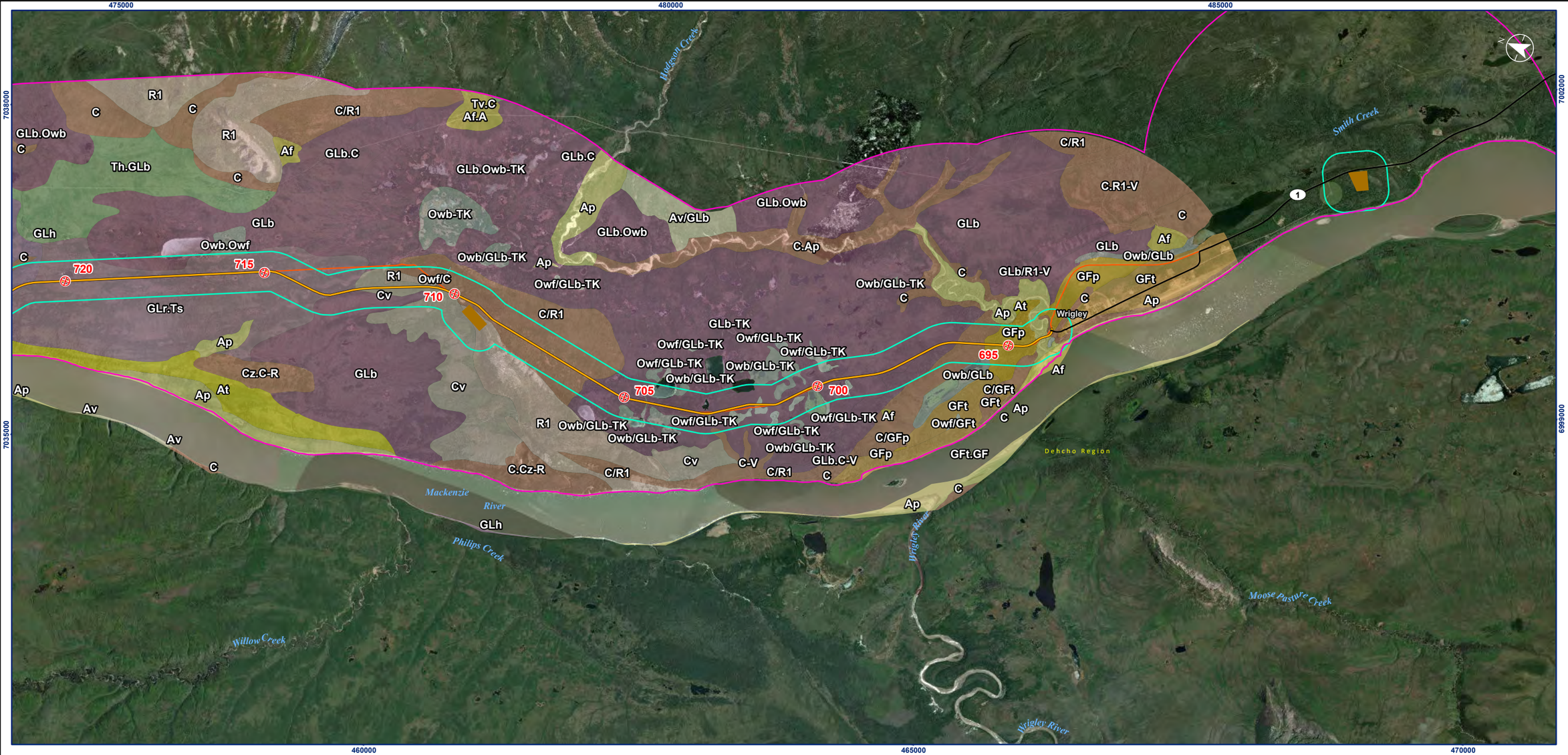
Table A.1 Observations of Open Water and Stream Icings from IORVL (2004)

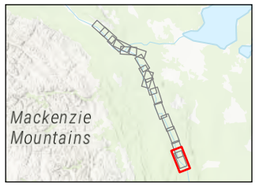
Stream[1]	Mid-April 2002 Observations
Great Bear River	-
Hodgson Creek	open water above crossing
Ochre River	Icings noted
White Sand Creek	Icings noted; substantial water on ice surface
Strawberry Creek	-
Vermillion Creek South	-
Bob's Canyon	-
Dam Creek	-
Blackwater River	Locals report icings common; not inspected
Steep Creek	2+ km open water; polynyas extending downstream; perennial flow ~0.47 m3/s
Devil's Creek	-
Saline Creek	Snow covered, no icings
Seagrams Creek	-
Little Smith Creek	Snow covered, no icings
Big Smith Creek	Icings noted
Gotcha Creek	-
Four Miles Creek	-
No name creek	Frozen to bottom
Bluefish Creek	-
Jungle Ridge Creek	Snow covered, no icings
Nota Creek	Snow covered, no icings
Vermillion Creek North	2+ km open water; polynyas extending downstream
Prohibition Creek	Not Augered; snow covered, no ice buildup
Christina Creek	Frozen to bottom; icings noted
Hellava Creek	Ice > 1.58 m thick; icings noted
Francis Creek	Standing water; icings noted
Canyon Creek	Ice > 1.58 m thick; icings noted
Bosworth Creek	Frozen to bottom

Note:

1. Streams are sorted south to north, following Table 3.1 in TDR – Surface Water Quantity (K'alo-Stantec, 2022a).

Appendix B Surficial Geology in the LSA and RSA





Surficial Geology [4]

- Af: Alluvial fan
- Ap: Alluvial floodplain sediment
- At: Alluvial terraced sediment
- Av: Alluvial veneer
- C: Colluvial deposit, undifferentiated
- Cv: Colluvial veneer
- Cz: Landslide deposit
- E: Eolian deposit, undifferentiated
- GFf: Glaciofluvial outwash-fan sediment
- GFh: Glaciofluvial hummocky sediment
- GFp: Glaciofluvial outwash-plain sediment
- GFr: Glaciofluvial esker sediment
- GFt: Glaciofluvial terraced sediment
- GFv: Glaciofluvial veneer
- GLb: Glaciolacustrine blanket
- GLh: Glaciolacustrine hummocky sediment
- GLr: Glaciolacustrine beach sediment
- GLv: Glaciolacustrine veneer
- Owb: Bog deposit
- Owf: Fen deposit
- R1: Sedimentary bedrock
- Tb: Till blanket
- Th: Hummocky till
- Tp: Till plain (all)
- Ts: Streamlined till
- Tv: Till veneer
- Mackenzie Valley Highway Kilometre Post

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Local Study Area
- Regional Study Area
- Granular Borrow / Rock Quarry Site and Access
- Canyon Creek All Season Access Road
- Prohibition Creek Access Road
- Proposed Great Bear River Bridge Project
- All-Season Road
- Winter Road
- Conservation Zone
- District Boundary
- Region Boundary
- Settlement Area Boundary

Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

Stratigraphic relationship
Two map-unit designators separated by a slash (/) are used where the stratigraphic relationship is observed or confidently inferred (e.g. GLv/T indicates glaciolacustrine veneer overlying till.)

0 1.5 3 Kilometres
1:100,000 (at original document size of 11x17)

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

Client/Project
14490302S-0080 REVC
Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
B.1

Title
RSA Surficial Geology

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Government of Canada
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
4. Terrain mapping was compiled and modified based on a series of maps including OpenFile 7289 - middle east section from Côté et al. (2013), maps 371 and 375 from GSC (2019), and MGAR and Great bear prohibition mapping from G.V.M. Geological Consultant Ltd. (2016, 2019). Some data gaps occur.

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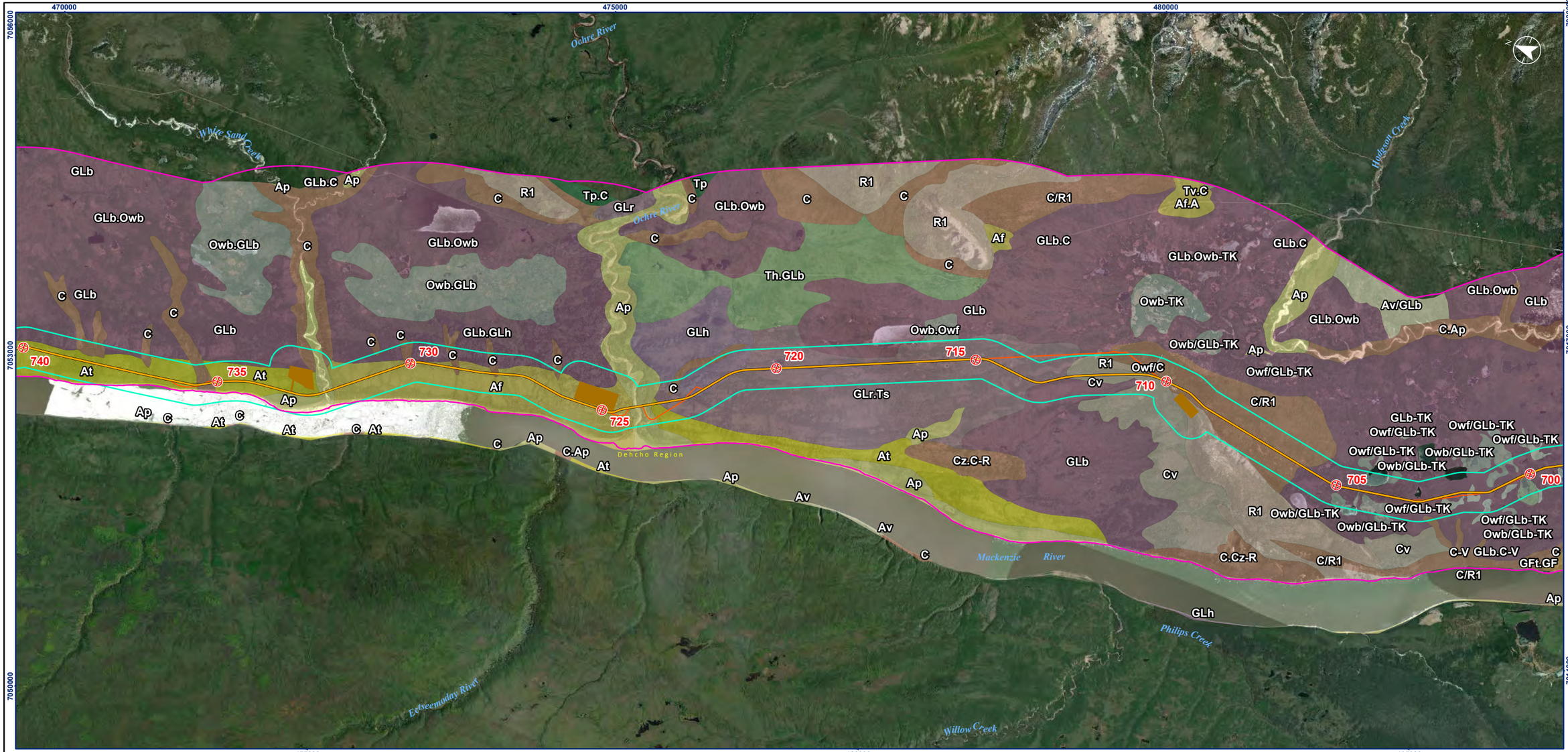
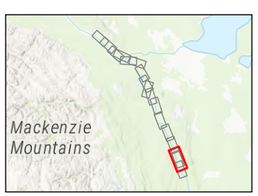
The recipient releases Stantec, its officers, employees, consultants and agents, from any and all claims arising in any way from the content or provision of the data.





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Example of terrain map unit symbol

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Stratigraphic relationship
Two map-unit designators separated by a slash (/) are used where the stratigraphic relationship is observed or confidently inferred (e.g. GLv/T indicates glaciolacustrine veneer overlying till.)

0 1.5 3 Kilometres
1:100,000 (at original document size of 11x17)

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

Client/Project
144903025-0080 REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
B.2

Title
RSA Surficial Geology

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Government of Canada
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
4. Terrain mapping was compiled and modified based on a series of maps including OpenFile 7289 - middle east section from Côté et al. (2013), maps 371 and 375 from GSC (2019), and MGAR and Great bear prohibition mapping from G.V.M. Geological Consultant Ltd. (2016, 2019). Some data gaps occur.

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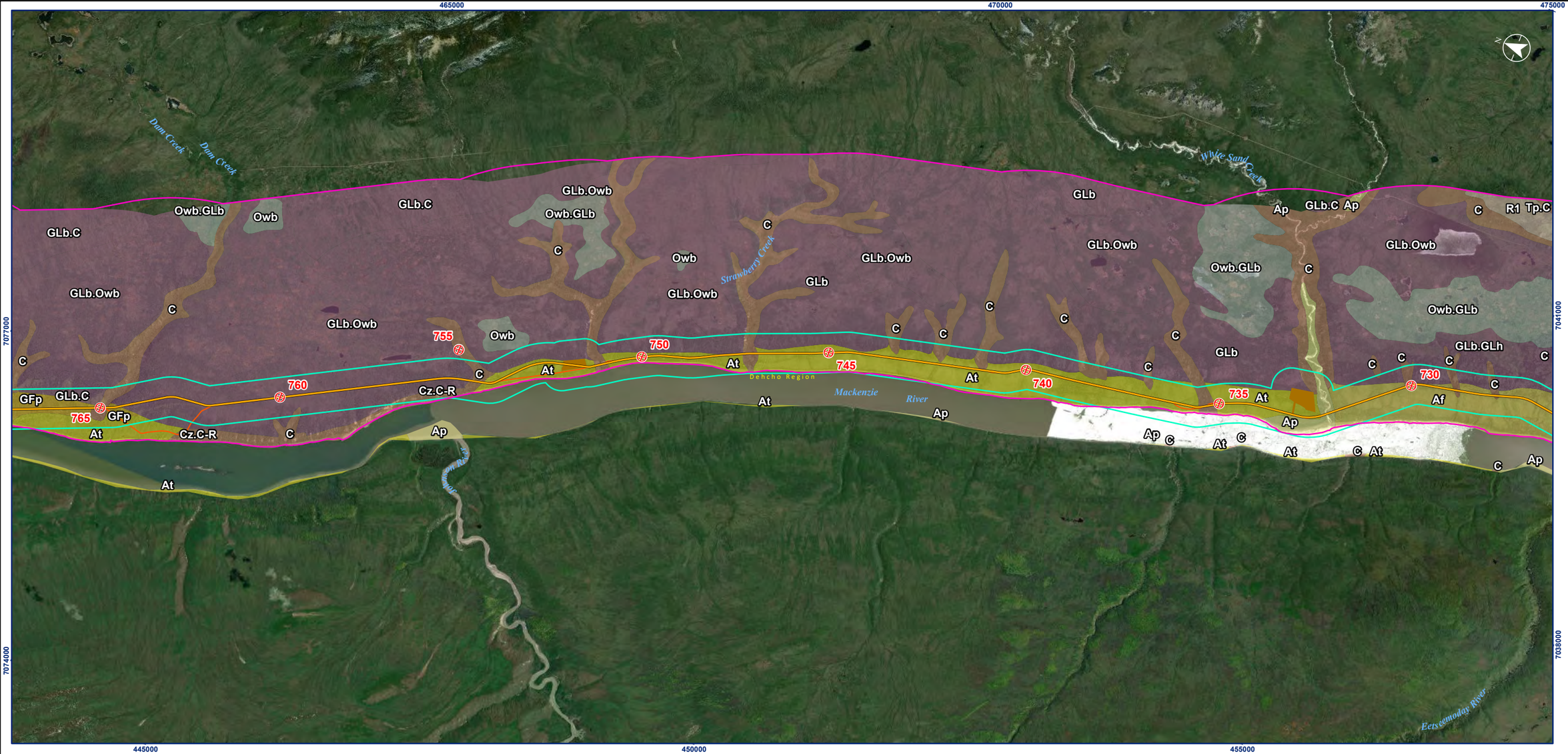

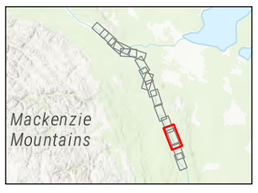

Surficial Geology [4]

- Af: Alluvial fan
- Ap: Alluvial floodplain sediment
- At: Alluvial terraced sediment
- Av: Alluvial veneer
- C: Colluvial deposit, undifferentiated
- Cv: Colluvial veneer
- Cz: Landslide deposit
- E: Eolian deposit, undifferentiated
- GFf: Glaciofluvial outwash-fan sediment
- GFh: Glaciofluvial hummocky sediment
- GFp: Glaciofluvial outwash-plain sediment
- GFr: Glaciofluvial esker sediment
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- Owb: Bog deposit
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- R1: Sedimentary bedrock
- Tb: Till blanket
- Th: Hummocky till
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- Mackenzie Valley Highway Kilometre Post

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
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- All-Season Road
- Winter Road
- Conservation Zone
- District Boundary
- Region Boundary
- Settlement Area Boundary

Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

Stratigraphic relationship
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Kálo-Stantec

Project Location
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Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

Client/Project
144903025-0080 REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
B.3

Title
RSA Surficial Geology

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Government of Canada
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
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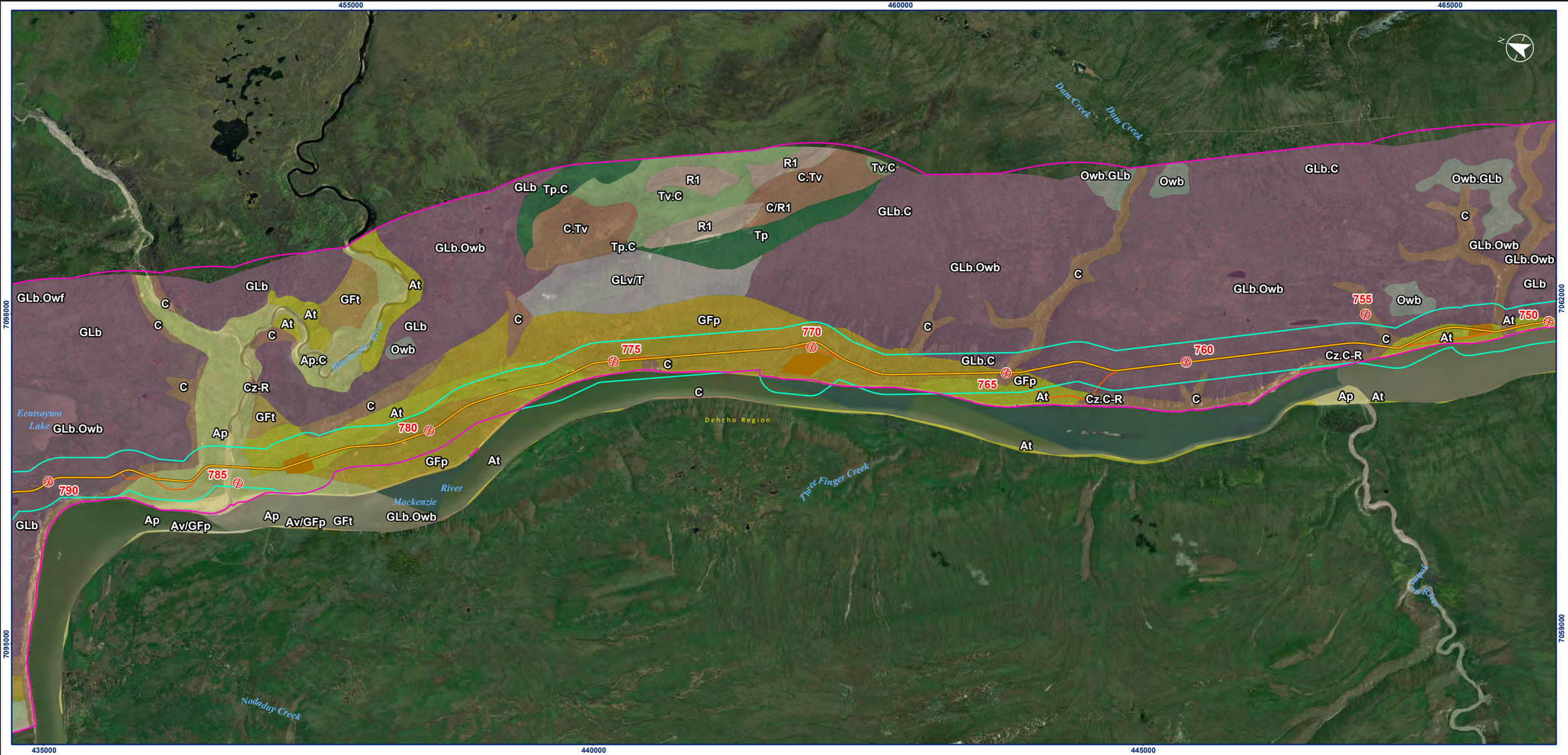

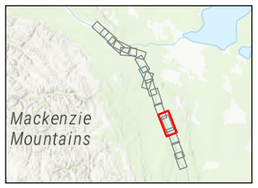

Surficial Geology [4]

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- Winter Road
- Conservation Zone
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- Settlement Area Boundary

Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

Stratigraphic relationship
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Kʼalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

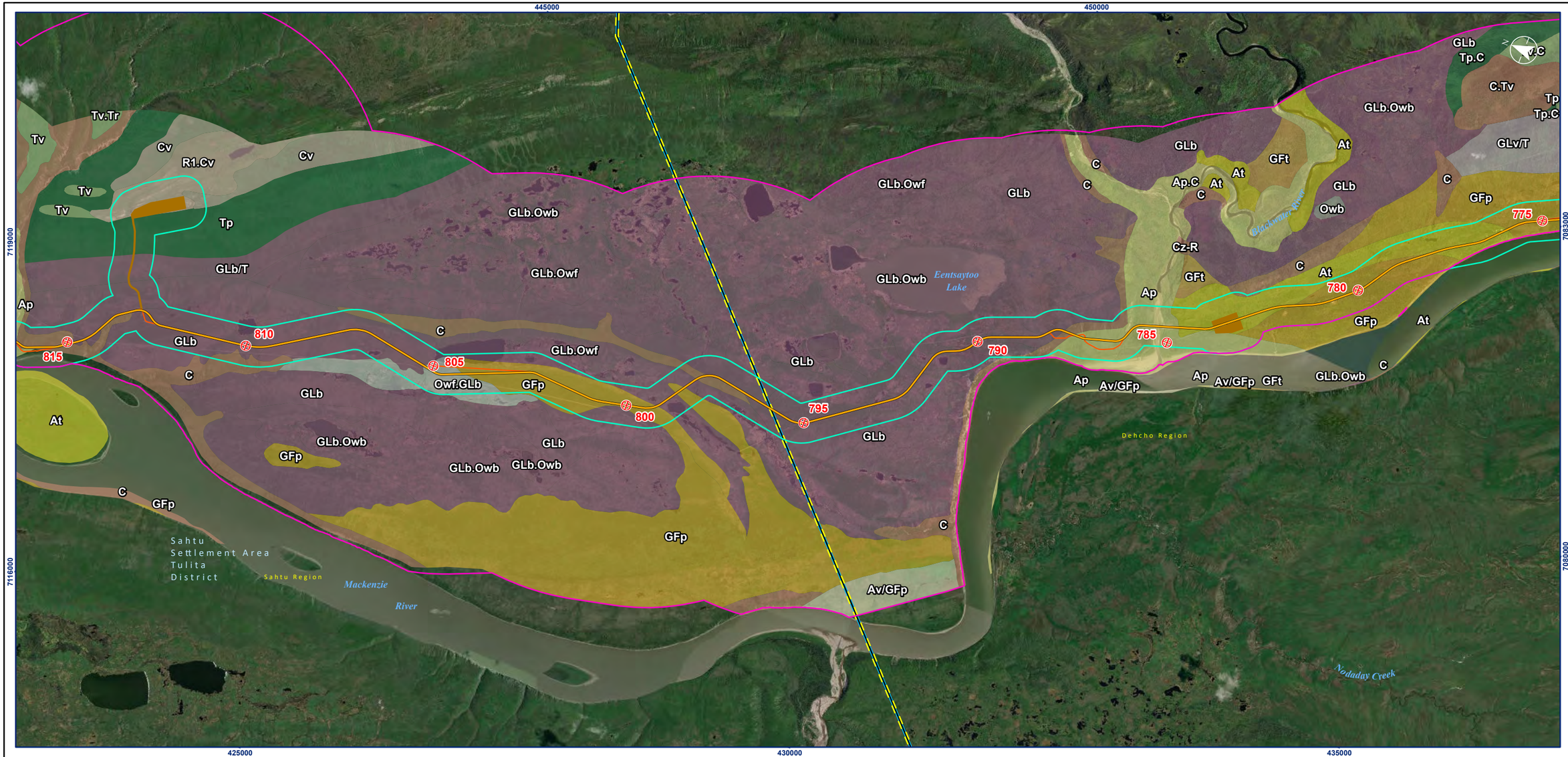
Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

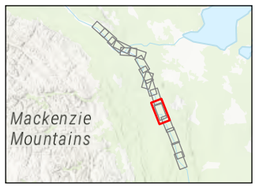
Client/Project
144903025-0080 REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
B.4

Title
RSA Surficial Geology





Surficial Geology [4]

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Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
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0 1.5 3 Kilometres
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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

Client/Project
144903025-0080 REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
B.5

Title
RSA Surficial Geology

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Government of Canada
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
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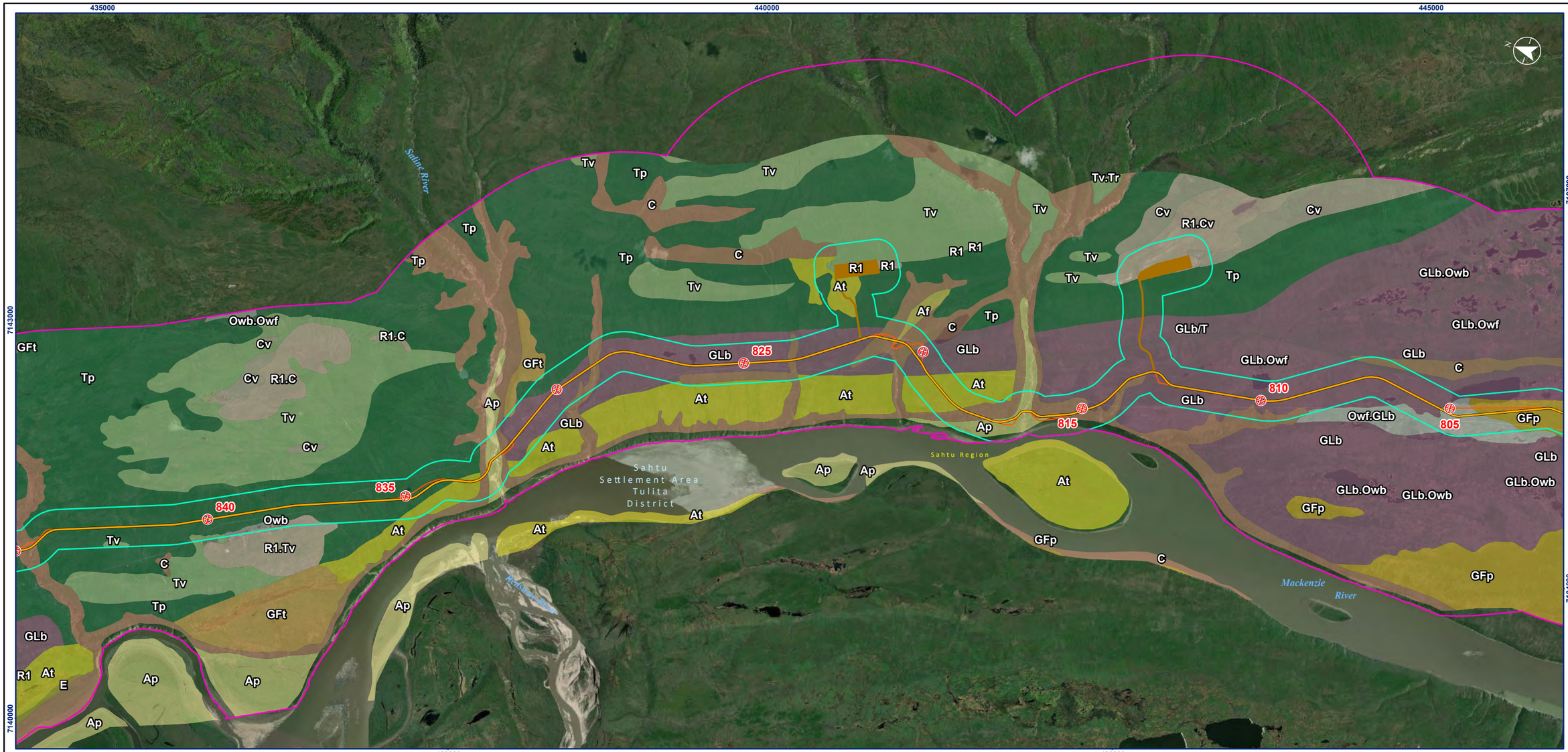

Surficial Geology [4]

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Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
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Stratigraphic relationship
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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

Client/Project
144903025-0080 REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
B.6

Title
RSA Surficial Geology

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
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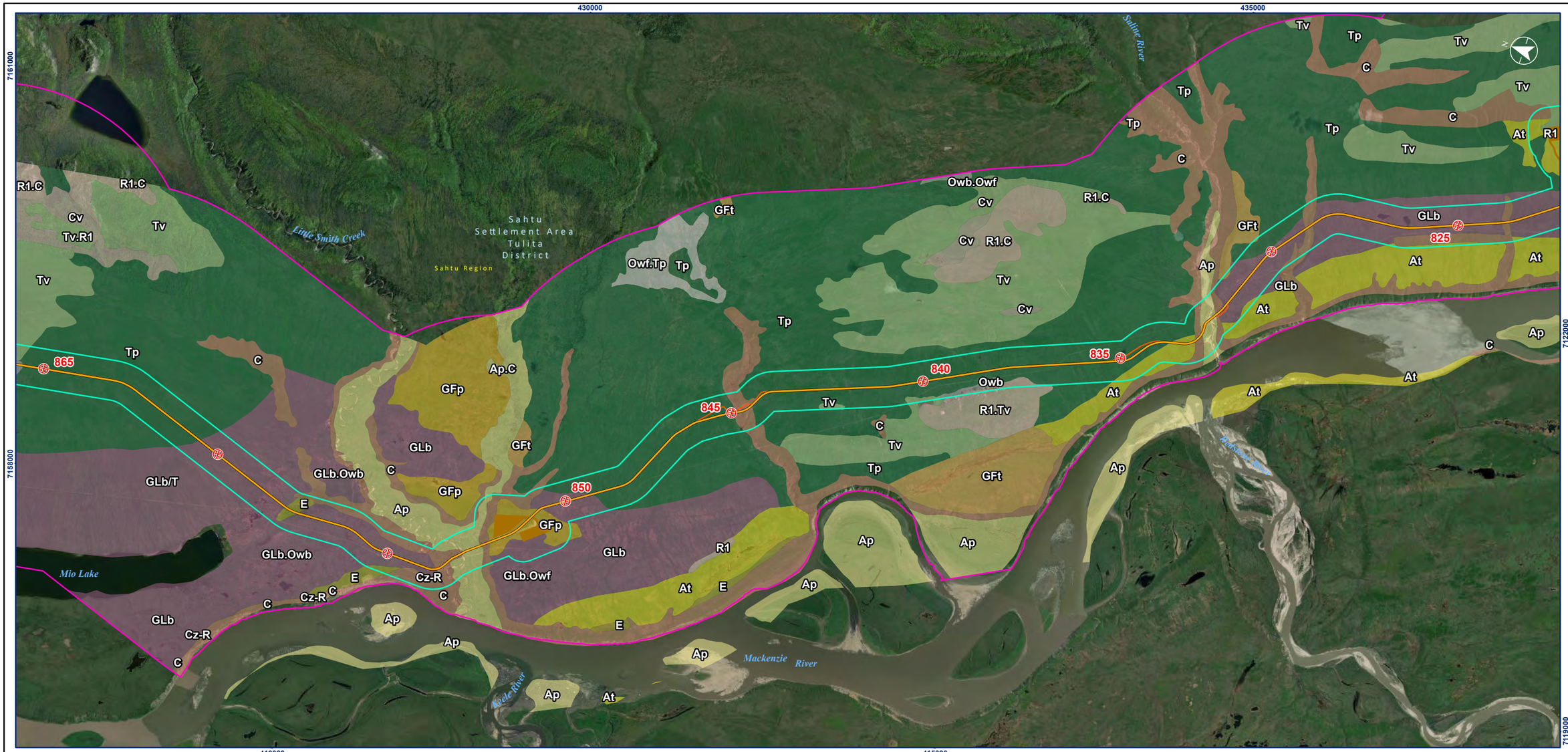
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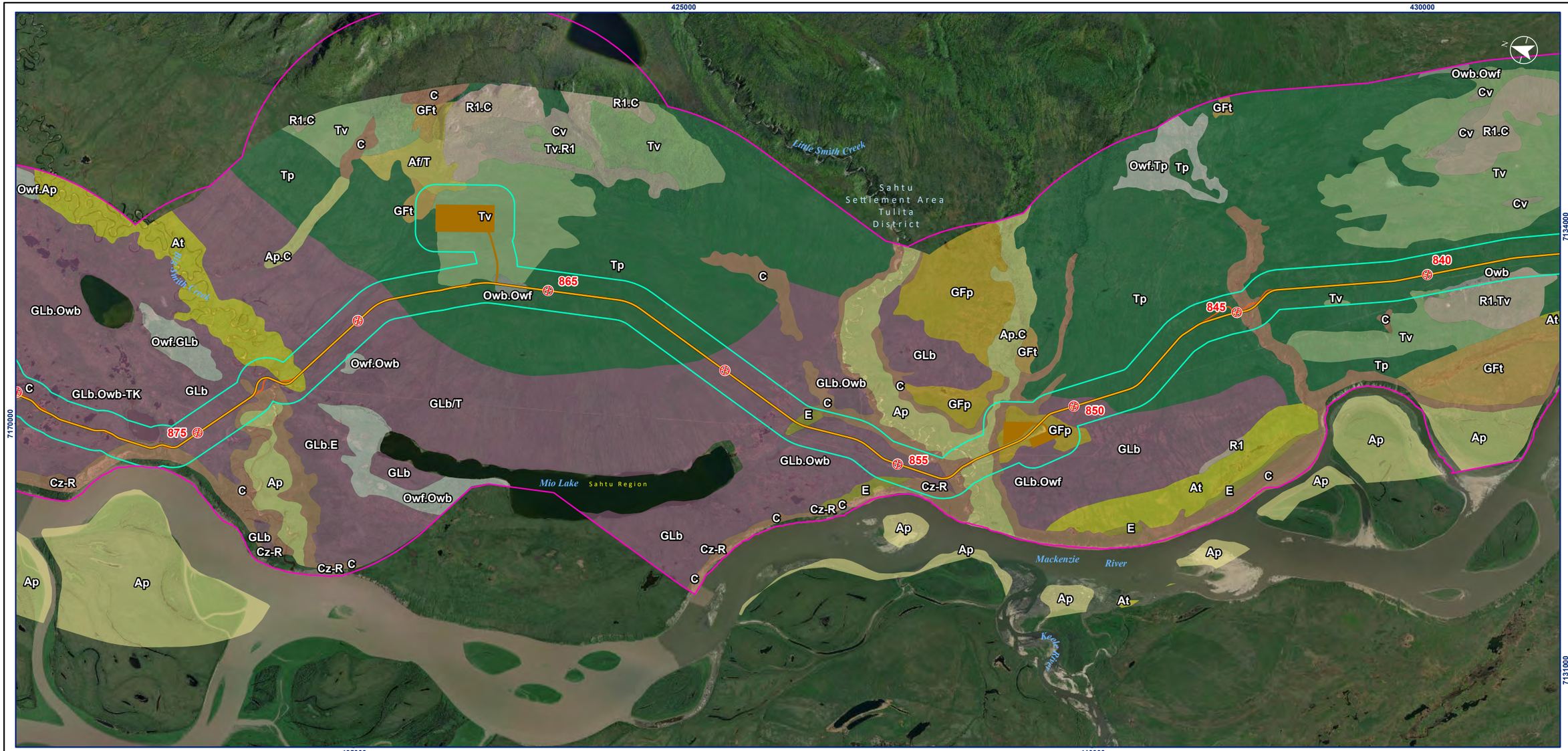
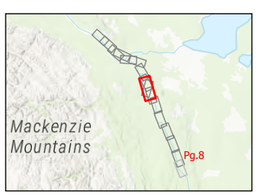
435000
7161000
7158000
7122000
7119000
410000
415000
Sahtu Settlement Area Tulita District
Sahtu Region
Little Smith Creek
Saline River
Mio Lake
Mackenzie River
Keele River
Redstone River
R1.C
Cv
Tv.R1
Tv
Tp
C
Ap.C
GFp
GLb
GFt
GLb/T
GLb.Owb
E
Ap
Cz-R
Owf:Tp
Owb.Owf
Cv
R1.C
Tv
Cv
Owb
R1.Tv
Tv
C
Tv
Tp
GFt
GLb.Owf
GLb
R1
At
E
Ap
Ap
Ap





Surficial Geology [4]

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Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
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Kálo-Stantec

Project Location
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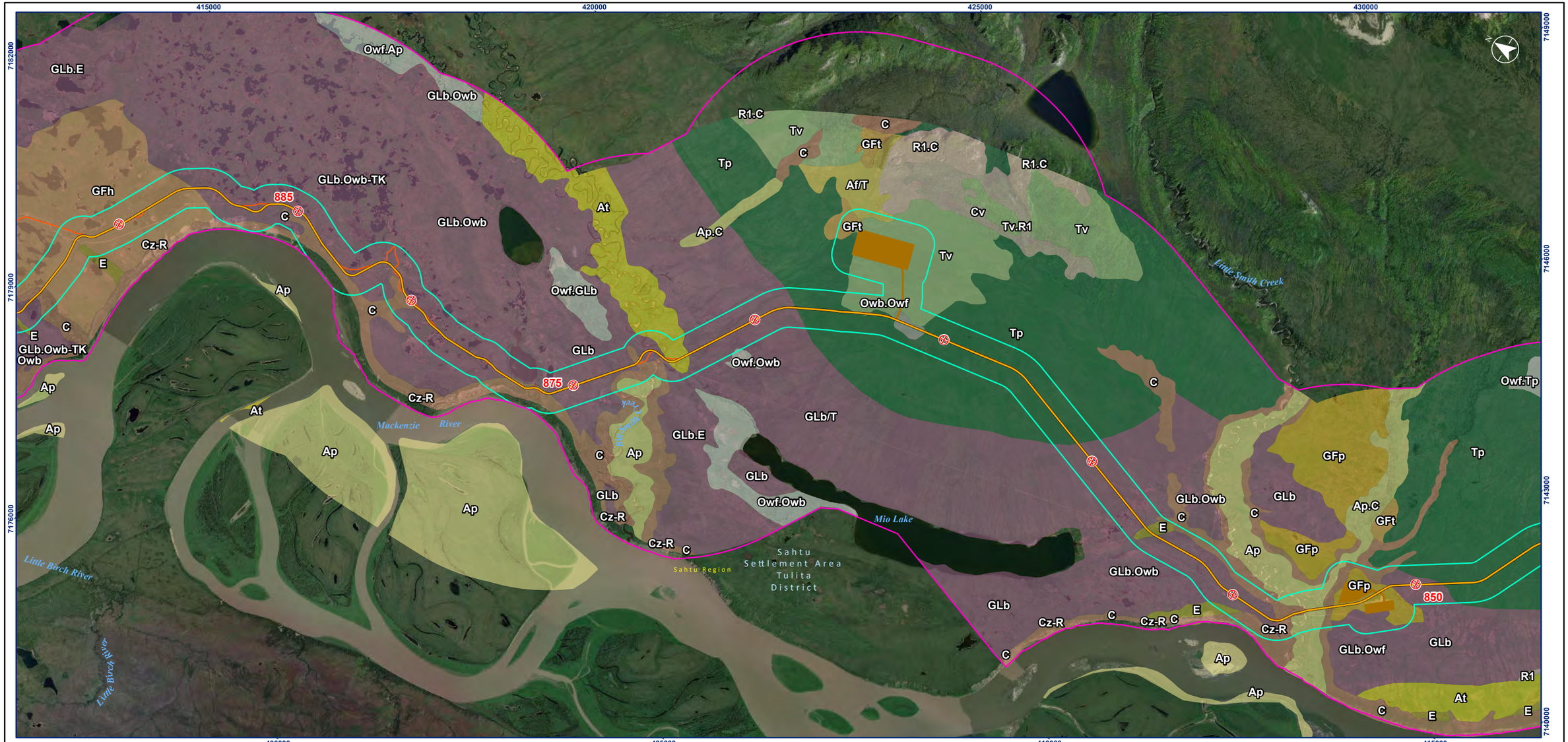
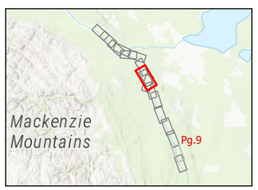
Client/Project
Government of Northwest Territories
Mackenzie Valley Highway Project

144903025-0080 REVC

Figure No.
B.8

Title
RSA Surficial Geology





Surficial Geology [4]

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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

Client/Project

14490302S-0080 REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
B.9

Title
RSA Surficial Geology

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Government of Canada
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
4. Terrain mapping was compiled and modified based on a series of maps including OpenFile 7289 - middle east section from Côté et al. (2013), maps 371 and 375 from GSC (2019), and MGAR and Great bear prohibition mapping from G.V.M. Geological Consultant Ltd. (2016, 2019). Some data gaps occur.

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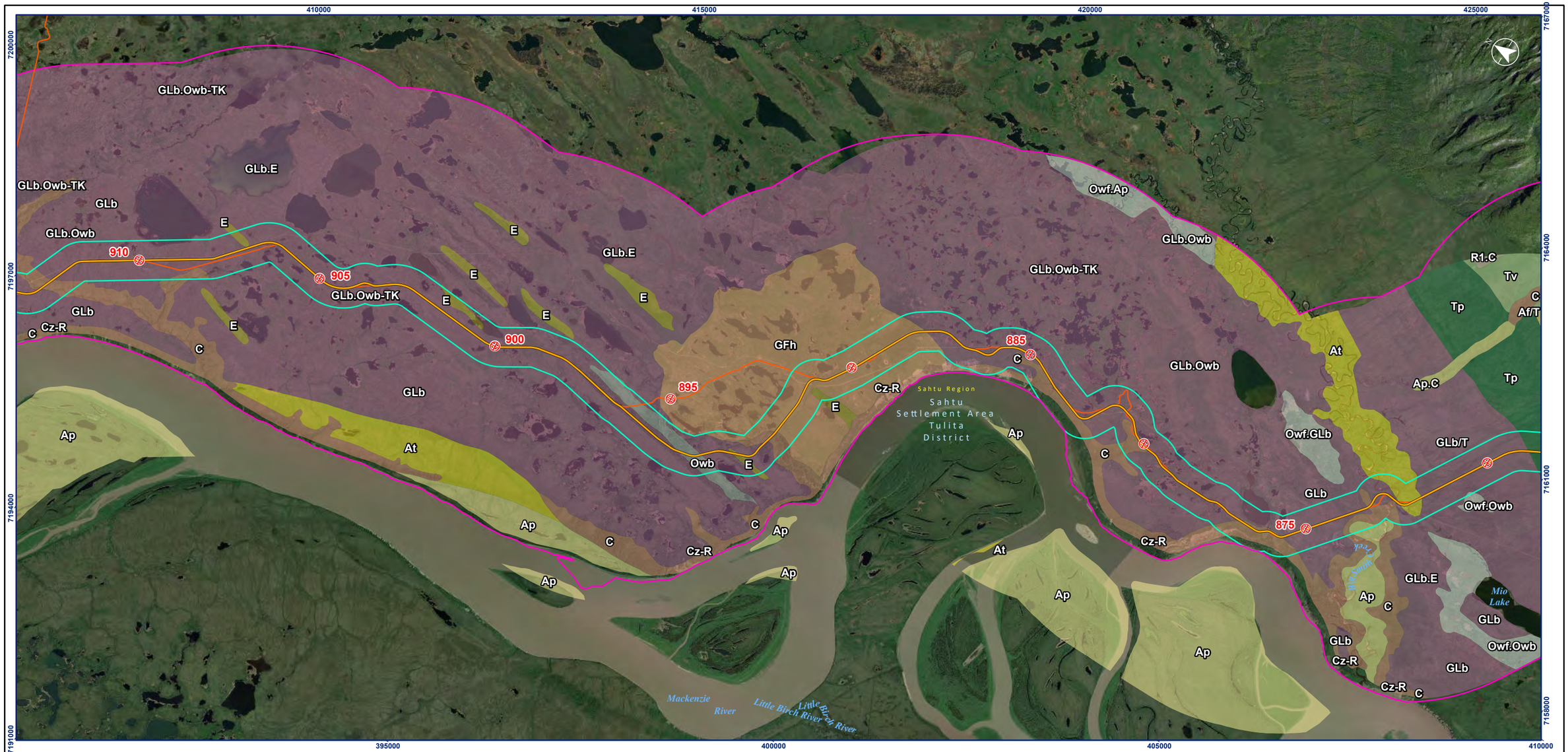

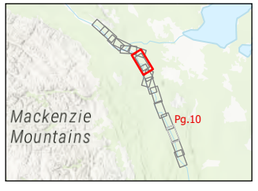

Surficial Geology [4]

- Af: Alluvial fan
- Ap: Alluvial floodplain sediment
- At: Alluvial terraced sediment
- Av: Alluvial veneer
- C: Colluvial deposit, undfferentiated
- Cv: Colluvial veneer
- Cz: Landslide deposit
- E: Eolian deposit, undifferentiated
- GFf: Glaciofluvial outwash-fan sediment
- GFh: Glaciofluvial hummocky sediment
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- GLv: Glaciolacustrine veneer
- Owb: Bog deposit
- Owf: Fen deposit
- R1: Sedimentary bedrock
- Tb: Till blanket
- Th: Hummocky till
- Tp: Till plain (all)
- Ts: Streamlined till
- Tv: Till veneer
- Mackenzie Valley Highway Kilometre Post

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Local Study Area
- Regional Study Area
- Granular Borrow / Rock Quarry Site and Access
- Canyon Creek All Season Access Road
- Prohibition Creek Access Road
- Proposed Great Bear River Bridge Project
- All-Season Road
- Winter Road
- Conservation Zone
- District Boundary
- Region Boundary
- Settlement Area Boundary

Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

Stratigraphic relationship
Two map-unit designators separated by a slash (/) are used where the stratigraphic relationship is observed or confidently inferred (e.g. GLv/T indicates glaciolacustrine veneer overlying till.)

0 1.5 3 Kilometres

1:100,000 (at original document size of 11x17)

Kalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

Client/Project
1:44903025-0080 REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
B.10

Title
RSA Surficial Geology

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Government of Canada
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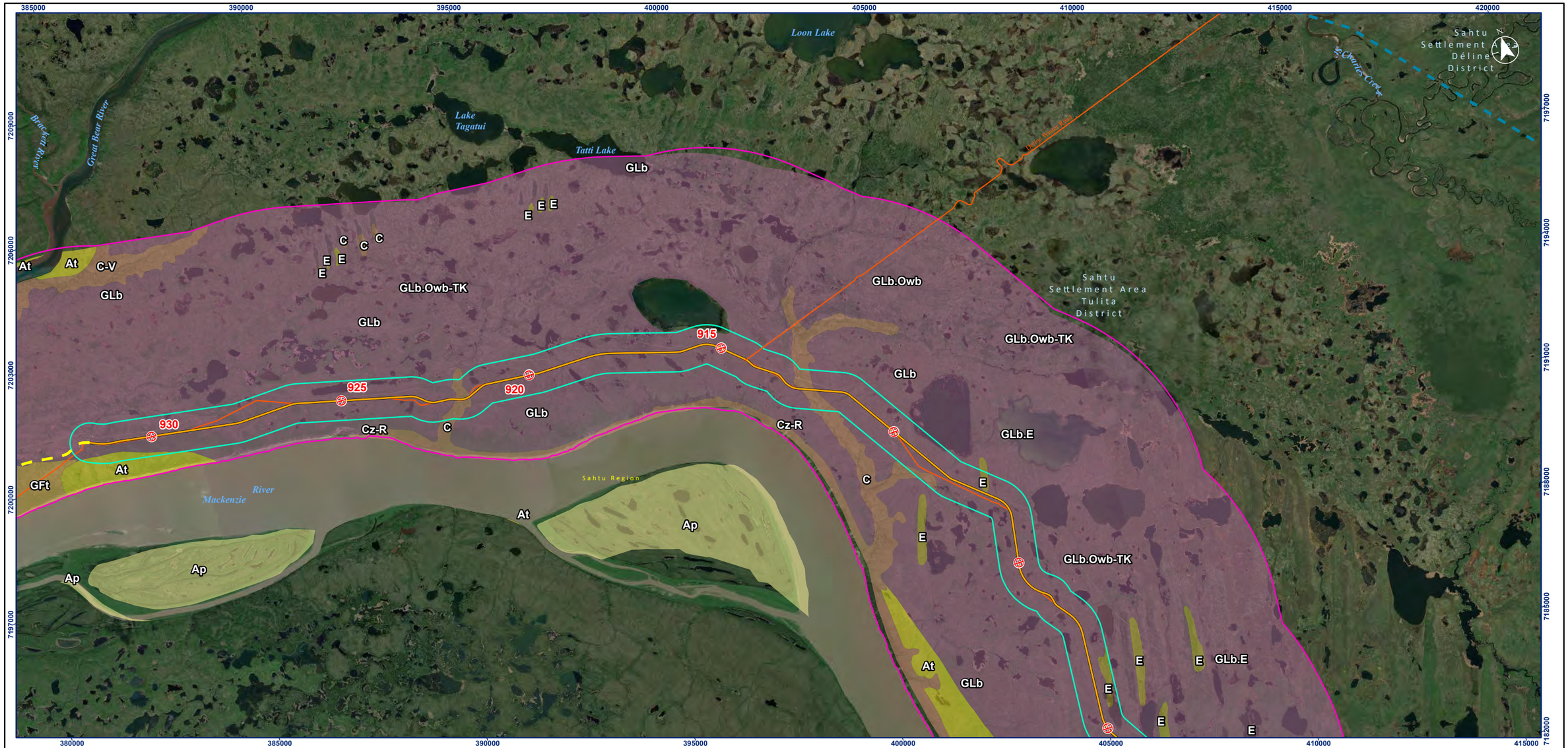

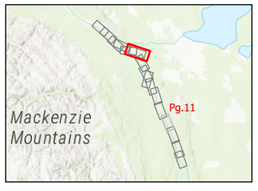

Surficial Geology [4]

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- Winter Road
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- Region Boundary
- Settlement Area Boundary

Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

Stratigraphic relationship
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0 1.5 3 Kilometres

1:100,000 (at original document size of 11x17)

Kalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

Client/Project
144903025-0080 REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
B.11

Title
RSA Surficial Geology

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Government of Canada
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
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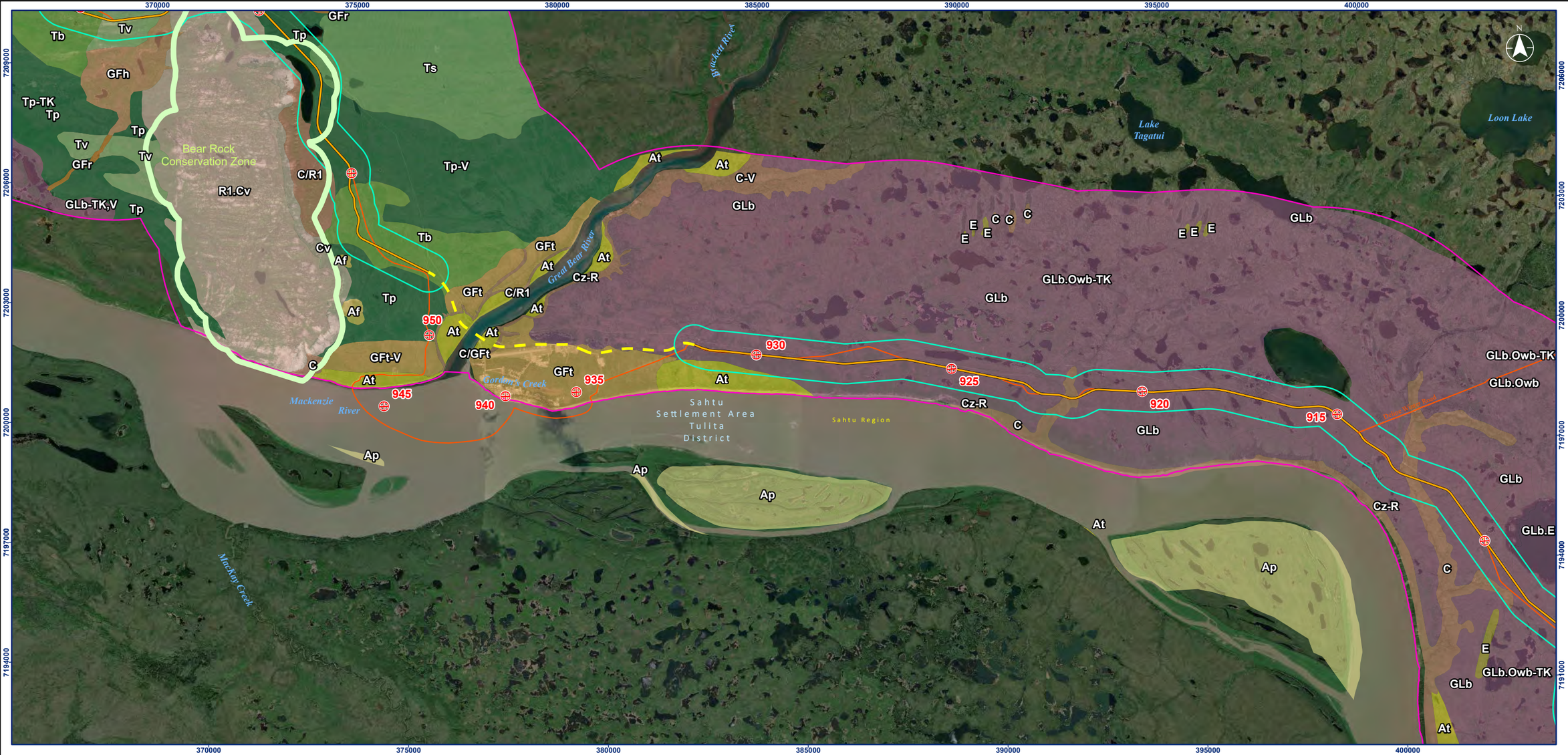

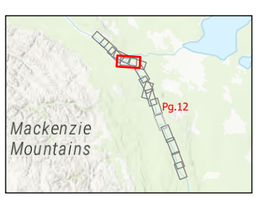

Surficial Geology [4]

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- Winter Road
- Conservation Zone
- District Boundary
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- Settlement Area Boundary

Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

Stratigraphic relationship
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0 1.5 3 Kilometres
1:100,000 (at original document size of 11x17)

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

Client/Project
144903025-0080 REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
B.12

Title
RSA Surficial Geology

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Government of Canada
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
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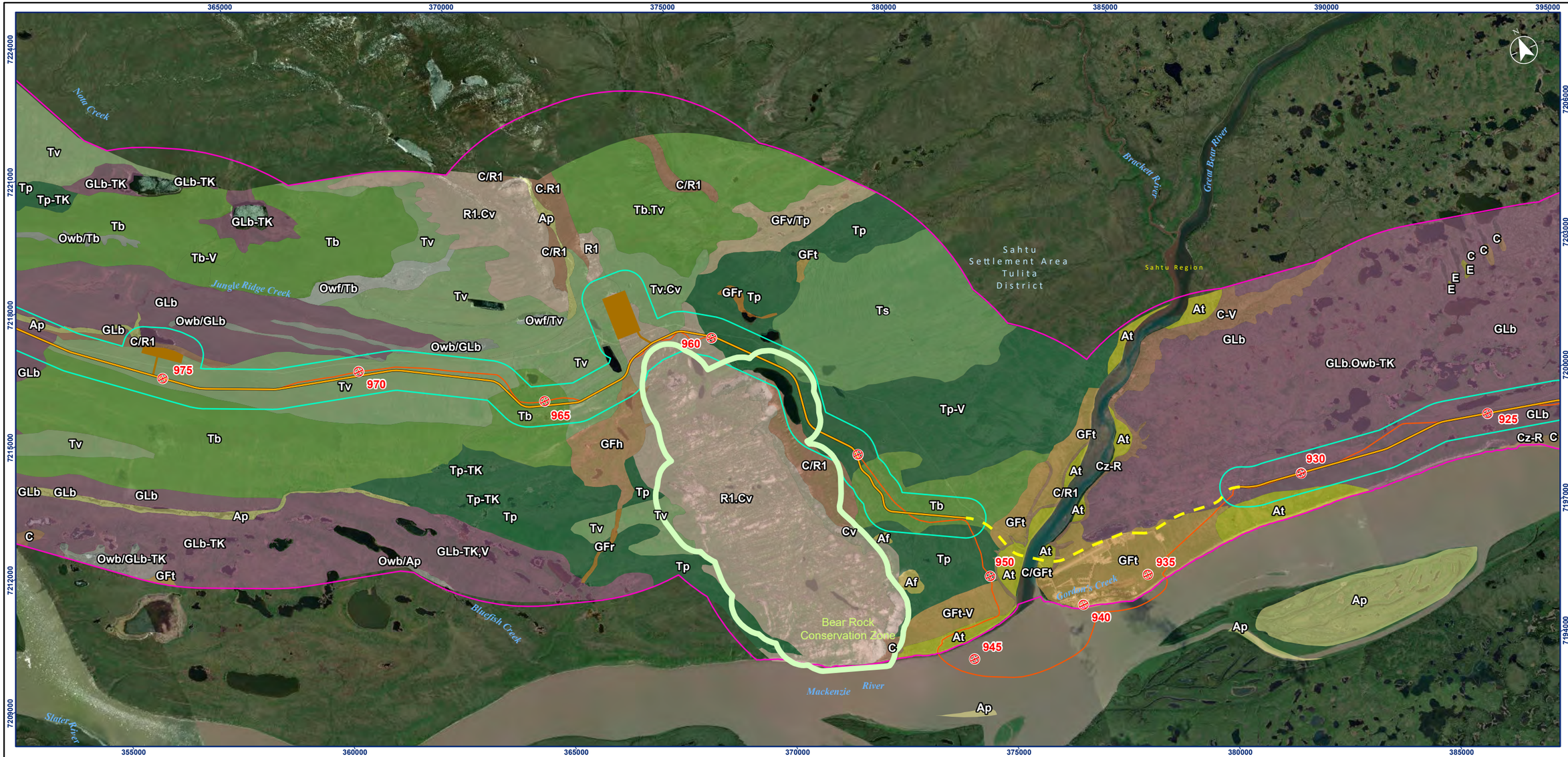

Surficial Geology [4]

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Geomorphological Process
R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

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Client/Project
Government of Northwest Territories
Mackenzie Valley Highway Project

144903025-0080 REVC

Figure No.
B.13

Title
RSA Surficial Geology

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
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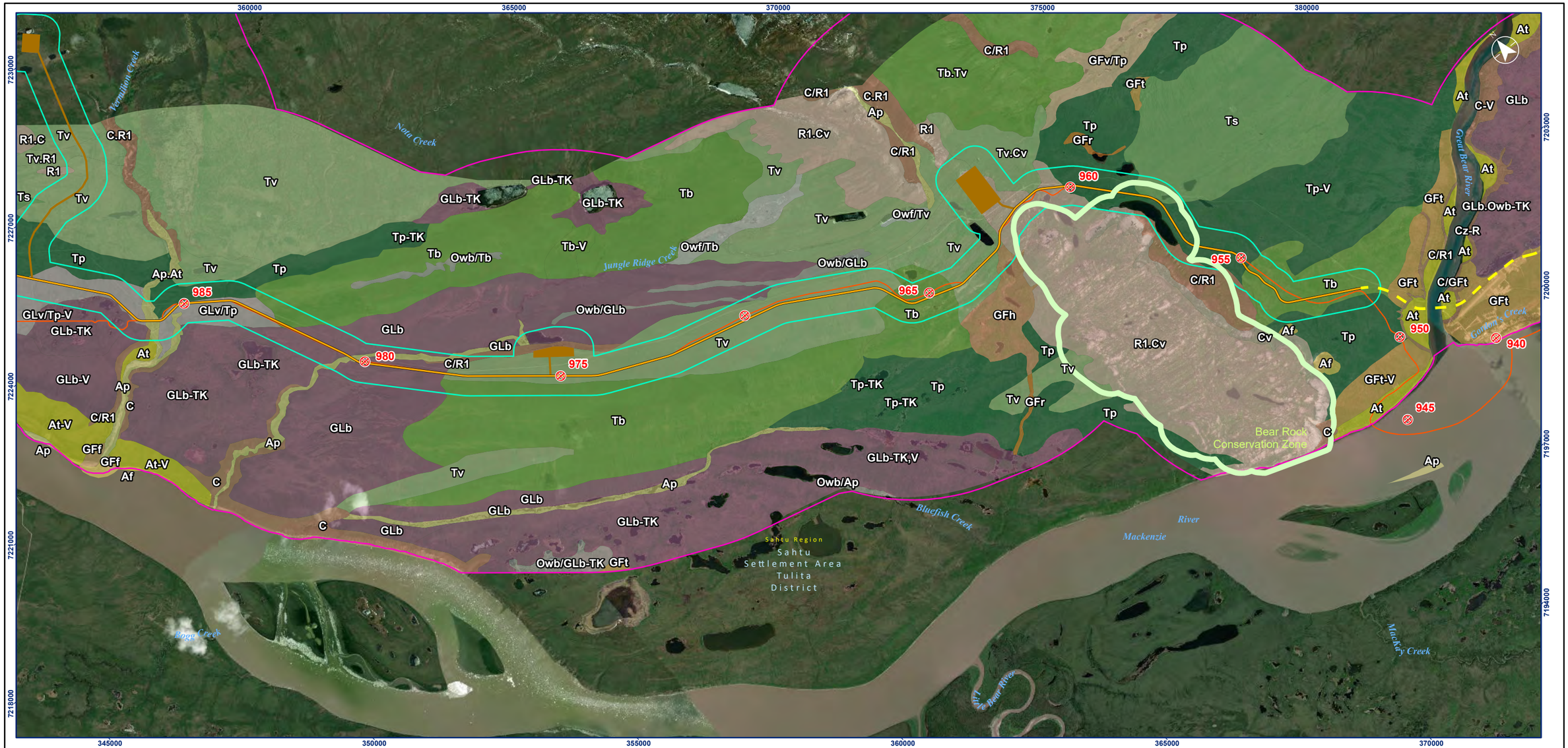

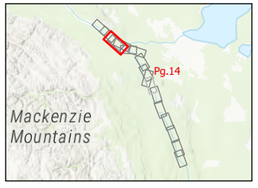

Surficial Geology [4]

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Geomorphological Process

- R: Mass movement
- TK: Thermokarst
- V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
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0 1.5 3 Kilometres
1:100,000 (at original document size of 11x17)

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-20
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Client/Project
144903025-0080 REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
B.14

Title
RSA Surficial Geology

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
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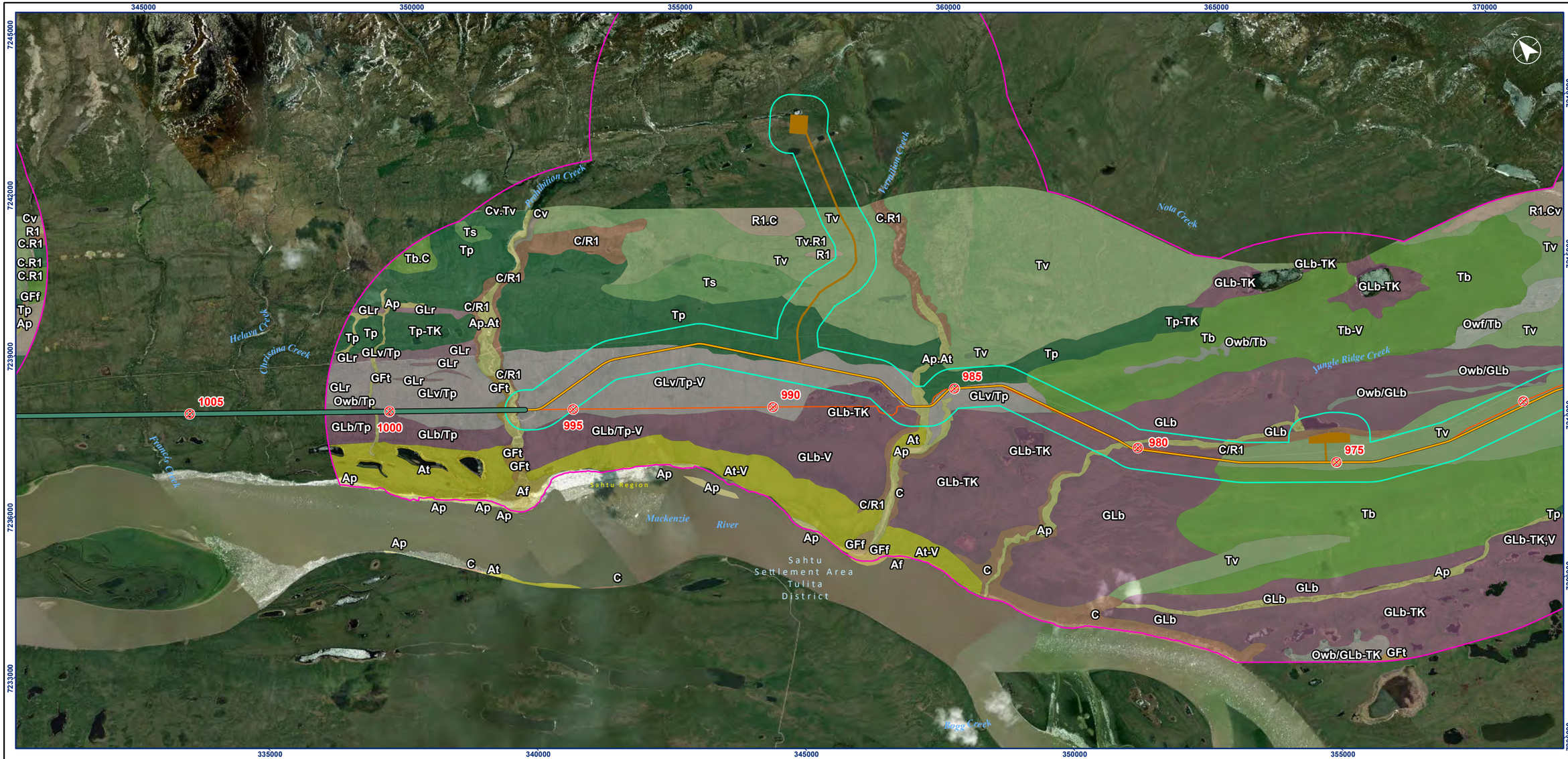

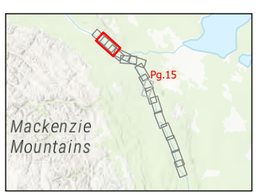

Surficial Geology [4]

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Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

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0 1.5 3 Kilometres
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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway Project

144903025-0080 REVC

Figure No.
B.15

Title
RSA Surficial Geology

Notes

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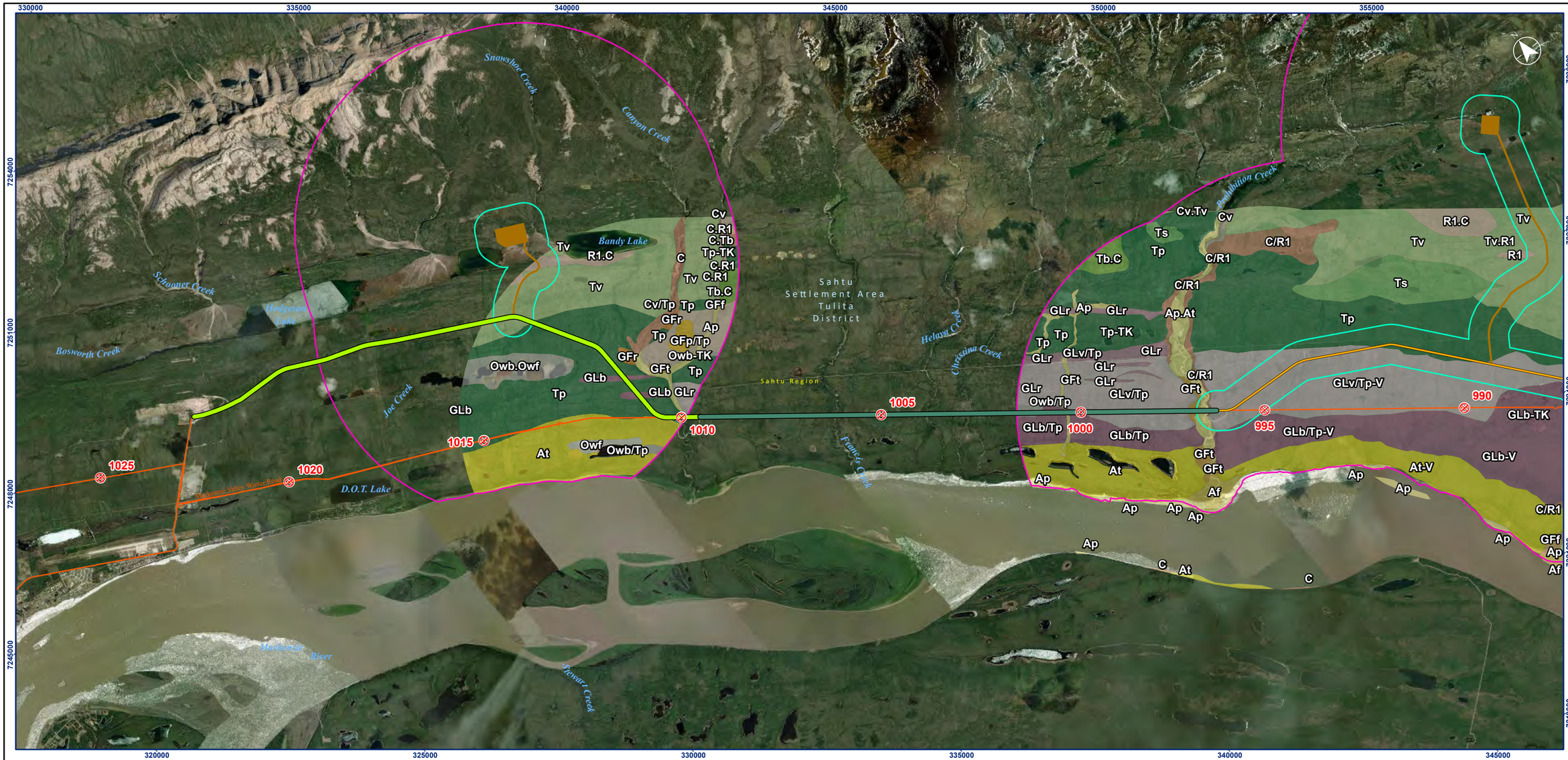

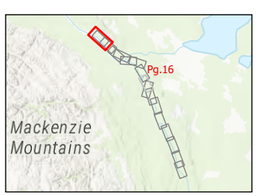

Surficial Geology [4]

- Af: Alluvial fan
- Ap: Alluvial floodplain sediment
- At: Alluvial terraced sediment
- Av: Alluvial veneer
- C: Colluvial deposit, undfferentiated
- Cv: Colluvial veneer
- Cz: Landslide deposit
- E: Eolian deposit, undifferentiated
- GFf: Glaciofluvial outwash-fan sediment
- GFh: Glaciofluvial hummocky sediment
- GFp: Glaciofluvial outwash-plain sediment
- GFr: Glaciofluvial esker sediment
- GFt: Glaciofluvial terraced sediment
- GFv: Glaciofluvial veneer
- GLb: Glaciolacustrine blanket
- GLh: Glaciolacustrine hummocky sediment
- GLr: Glaciolacustrine beach sediment
- GLv: Glaciolacustrine veneer
- Owb: Bog deposit
- Owf: Fen deposit
- R1: Sedimentary bedrock
- Tb: Till blanket
- Th: Hummocky till
- Tp: Till plain (all)
- Ts: Streamlined till
- Tv: Till veneer
- Mackenzie Valley Highway Kilometre Post

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Local Study Area
- Regional Study Area
- Granular Borrow / Rock Quarry Site and Access
- Canyon Creek All Season Access Road
- Prohibition Creek Access Road
- Proposed Great Bear River Bridge Project
- All-Season Road
- Winter Road
- Conservation Zone
- District Boundary
- Region Boundary
- Settlement Area Boundary

Geomorphological Process

R: Mass movement
TK: Thermokarst
V: Gullied

Example of terrain map unit symbol

Dominant surficial material and surface expression: Alluvial fan ⟹ AF/Tp - TK ⟸ Geomorphological process: Thermokarst (TK)

Dominant subsurface material and expression: till (M); plain (p)

Complex units
Two map-unit designators separated by a dot (.) are used where the surficial cover forms a complex area and the units are too small to be mapped individually (e.g. Ap.C designates an area of alluvial plain sediments with colluvial deposits).

Stratigraphic relationship
Two map-unit designators separated by a slash (/) are used where the stratigraphic relationship is observed or confidently inferred (e.g. GLv/T indicates glaciolacustrine veneer overlying till.)

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Government of Canada
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
4. Terrain mapping was compiled and modified based on a series of maps including OpenFile 7289 - middle east section from Côté et al. (2013), maps 371 and 375 from GSC (2019), and MGAR and Great bear prohibition mapping from G.V.M. Geological Consultant Ltd. (2016, 2019). Some data gaps occur.

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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-20
TR by AJ on 2023-03-20

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway Project

144903025-0080 REVC

Figure No.
B.16

Title
RSA Surficial Geology

Appendix C Bedrock Geology in the LSA and RSA

-13750000 -13745000 -13740000 -13735000 -13730000

9201000 9198000 9195000 9147000 9144000 9141000 9138000

-13775000 -13770000 -13765000 -13760000

Wrigley

Dehcho Region

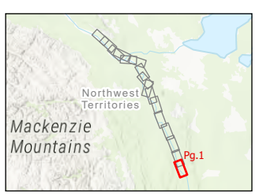
Mackenzie River

Philips Creek

Willow Creek

Higgley River

Moose Posture Creek



Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
- Canol
- Ramparts
- Hare Indian
- Hume
- Nahanni
- Headless
- Landry (Bear Rock Group)
- Arnica (Bear Rock Group)
- Fort Norman (Bear Rock Group)
- Mount Kindle
- Franklin Mountain
- Saline River
- Mount Cap

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- All-Season Road
- Winter Road
- Conservation Zone
- District Boundary
- Region Boundary
- Settlement Area Boundary

Notes

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2. Data Sources: Government of Canada
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
4. Bedrock formations Stantec infers are important aquifer hydrostratigraphic units relative to the Project LSA and RSA include the Saline River, Franklin Mountain, and Mount Kindle Formations and the Fort Norman, Arnica, and Landry Formations that constitute the Bear Rock Group.

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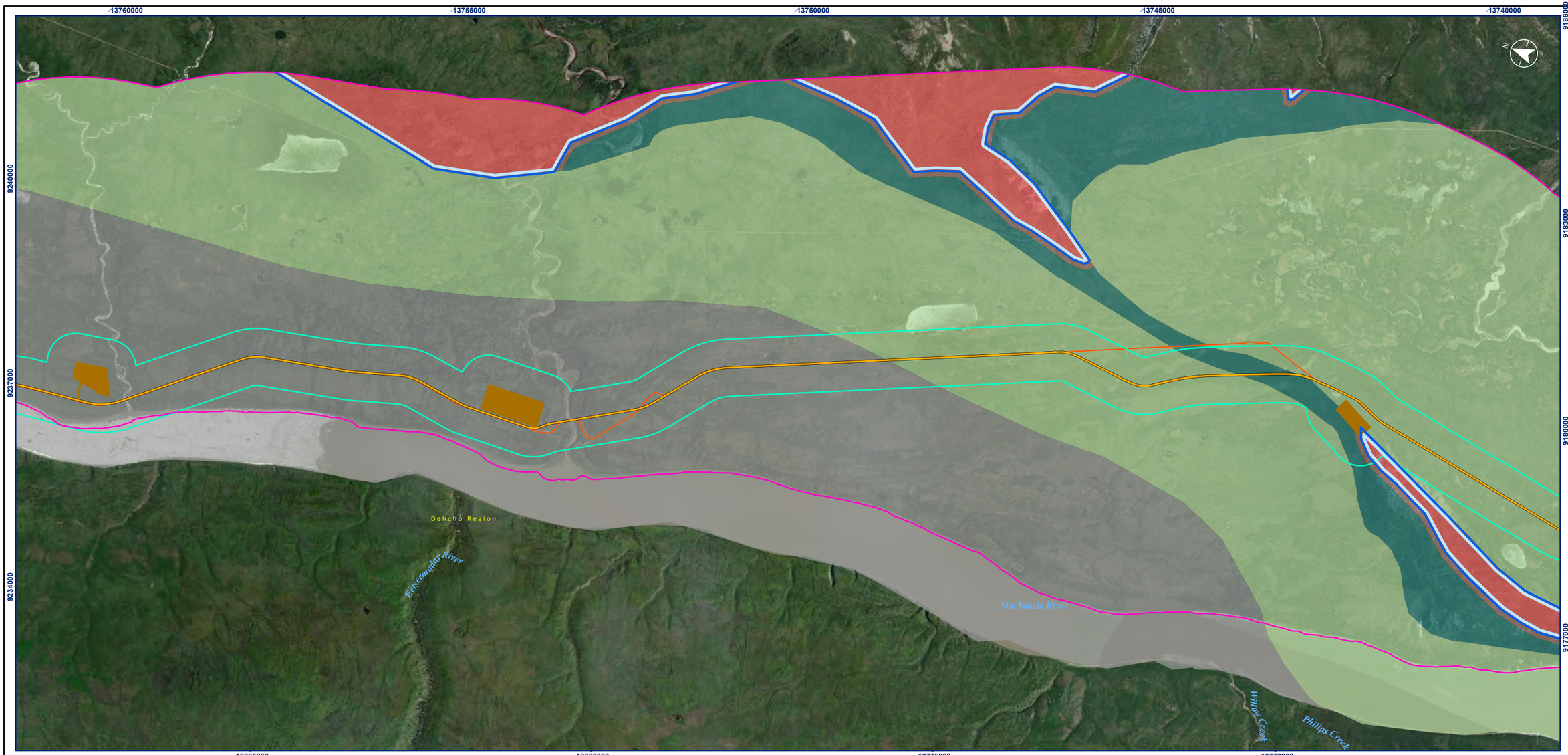
Client/Project
144903025-0072 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
C.1

Title
RSA Geologic Formations with Aquifers Noted



- Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
- Canol
- Ramparts
- Hare Indian
- Hume
- Nahanni
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- Arnica (Bear Rock Group)
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- Winter Road
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- Region Boundary
- Settlement Area Boundary

Notes

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TR by AJ on 2023-03-07

Client/Project
144903025-0072 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
C.2

Title
RSA Geologic Formations with Aquifers Noted

-13780000 -13775000 -13770000 -13765000 -13760000

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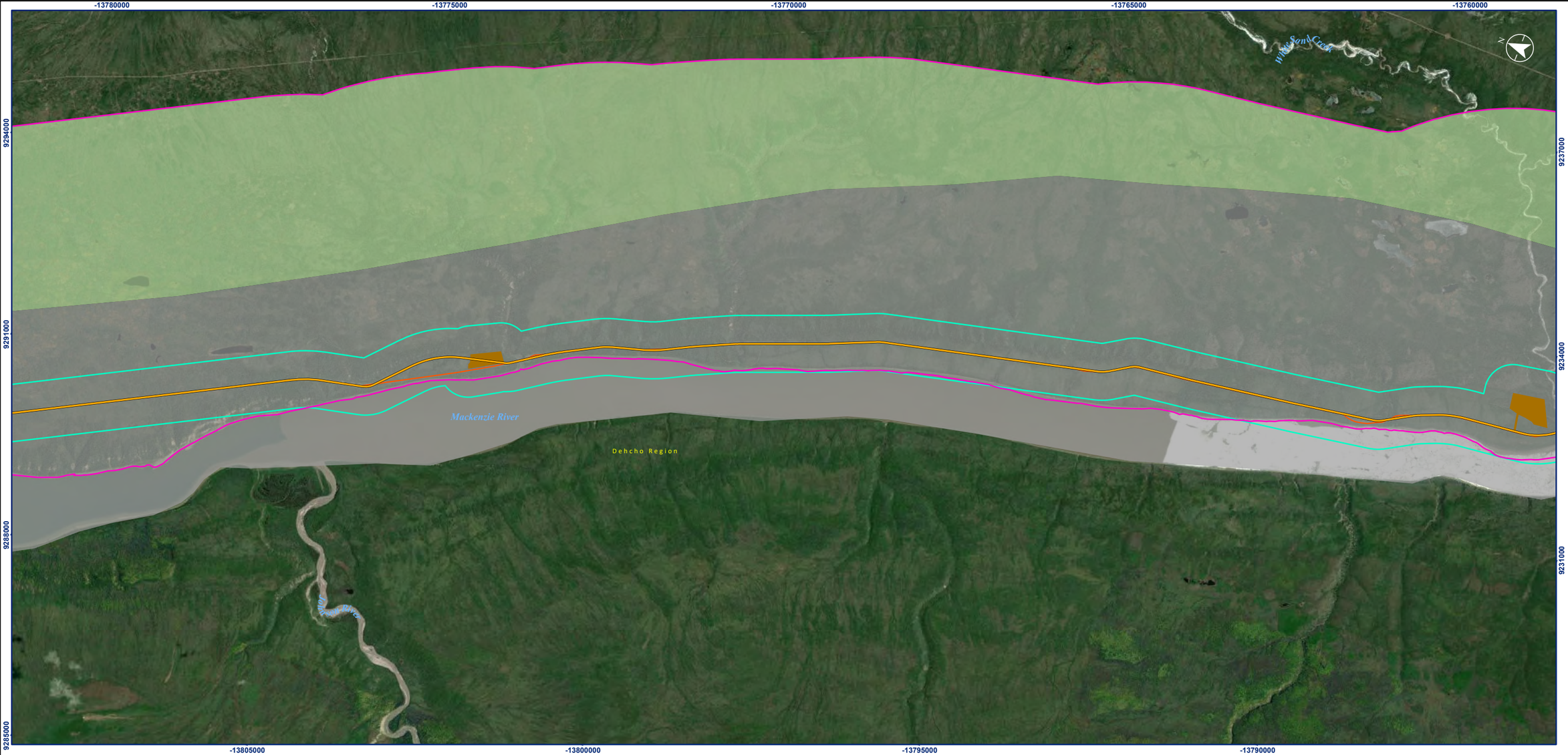
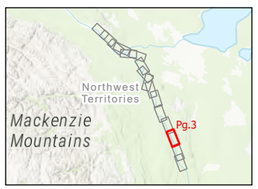
9237000 9234000 9231000

-13805000 -13800000 -13795000 -13790000





- Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
- Canol
- Ramparts
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- Hume
- Nahanni
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- Fort Norman (Bear Rock Group)
- Mount Kindle
- Franklin Mountain
- Saline River
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- Regional Study Area
- All-Season Road
- Winter Road
- Conservation Zone
- District Boundary
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- Settlement Area Boundary

Notes

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TR by AJ on 2023-03-07

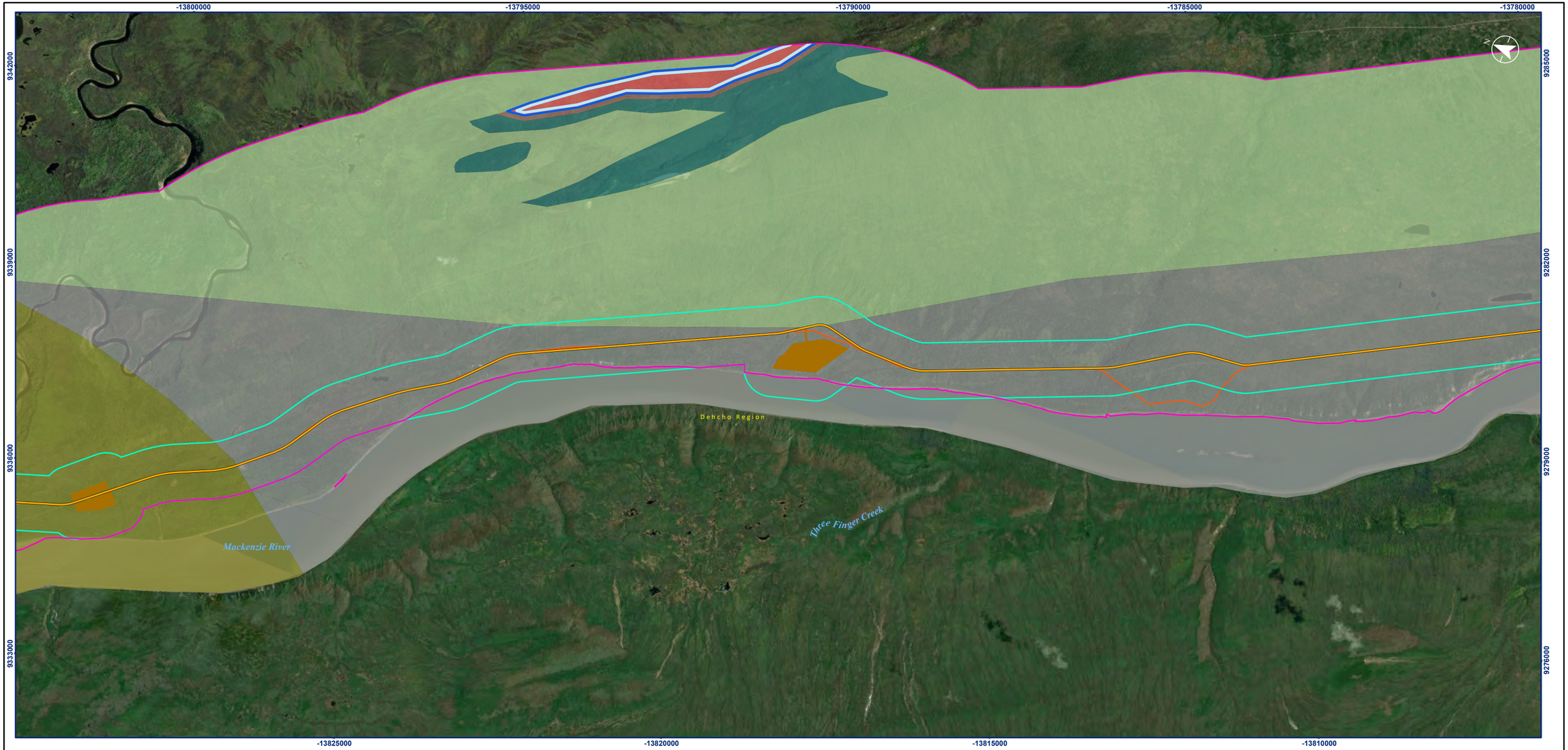
Client/Project

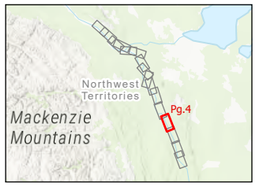
144903025-0072 REV8

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
C.3

Title
RSA Geologic Formations with Aquifers Noted





Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
- Canol
- Ramparts
- Hare Indian
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- Arnica (Bear Rock Group)
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- Franklin Mountain
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- Mount Cap

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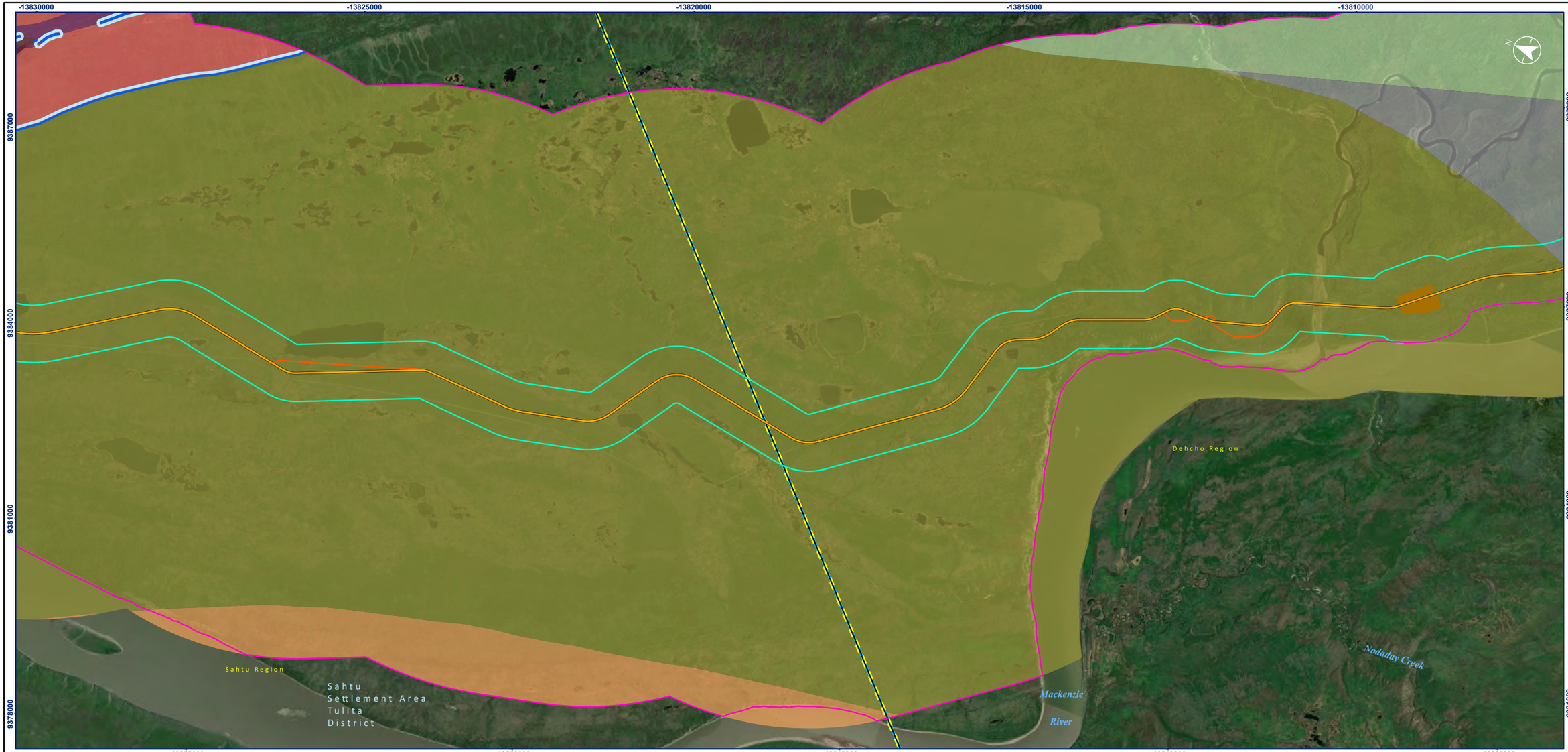
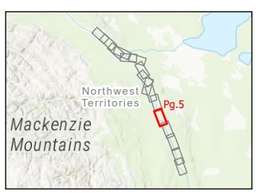
Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
C.4

Title
RSA Geologic Formations with Aquifers Noted





Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
- Canol
- Ramparts
- Hare Indian
- Hume
- Nahanni
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Project Location

Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
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Government of Northwest Territories
Mackenzie Valley Highway Project

144903025-0072 REV8

Figure No.

C.5

Title

RSA Geologic Formations with Aquifers Noted

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Government of Canada
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
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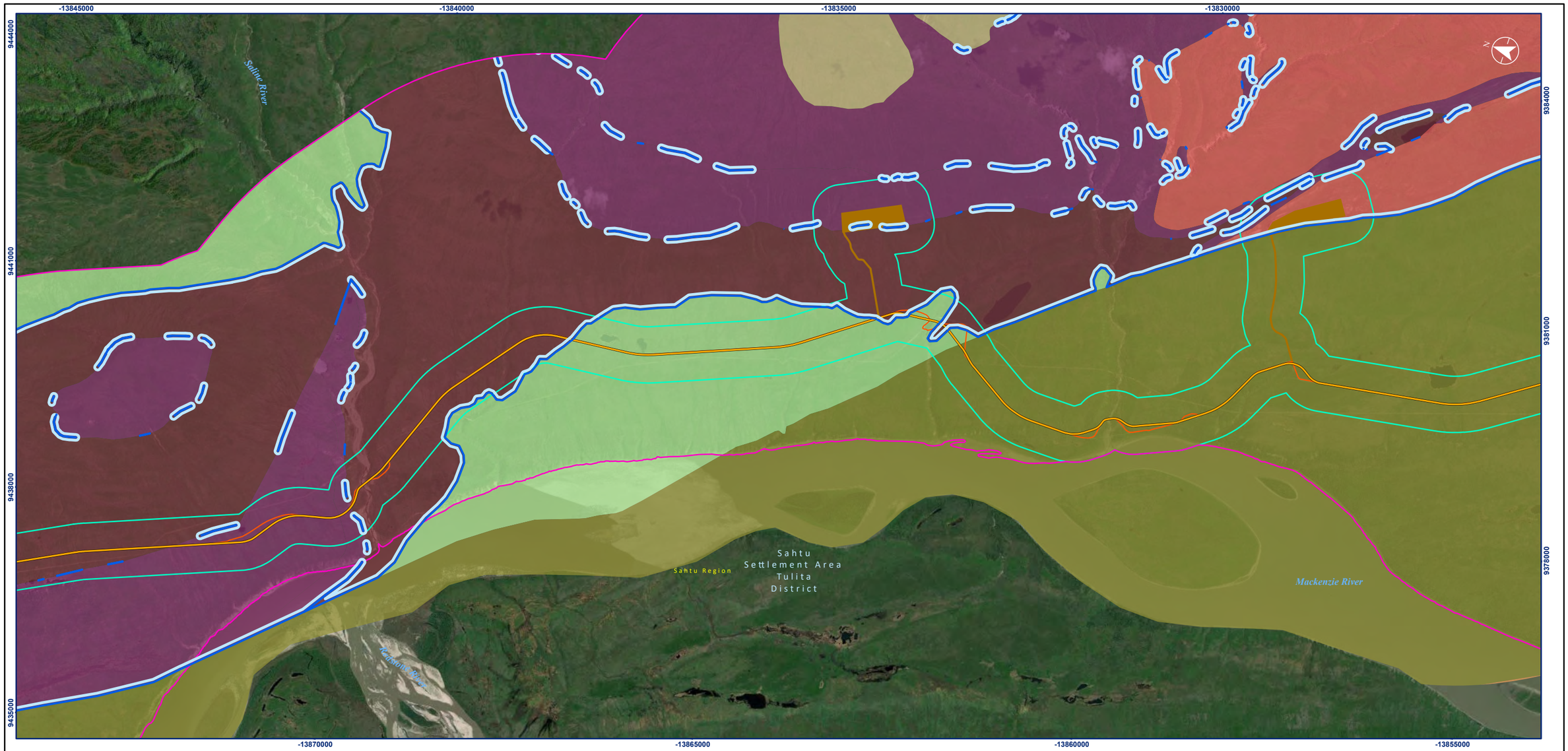

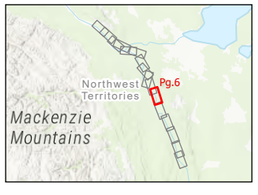

Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
- Canol
- Ramparts
- Hare Indian
- Hume
- Nahanni
- Headless
- Landry (Bear Rock Group)
- Arnica (Bear Rock Group)
- Fort Norman (Bear Rock Group)
- Mount Kindle
- Franklin Mountain
- Saline River
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Project Location
Wrigley to Norman Wells, NWT

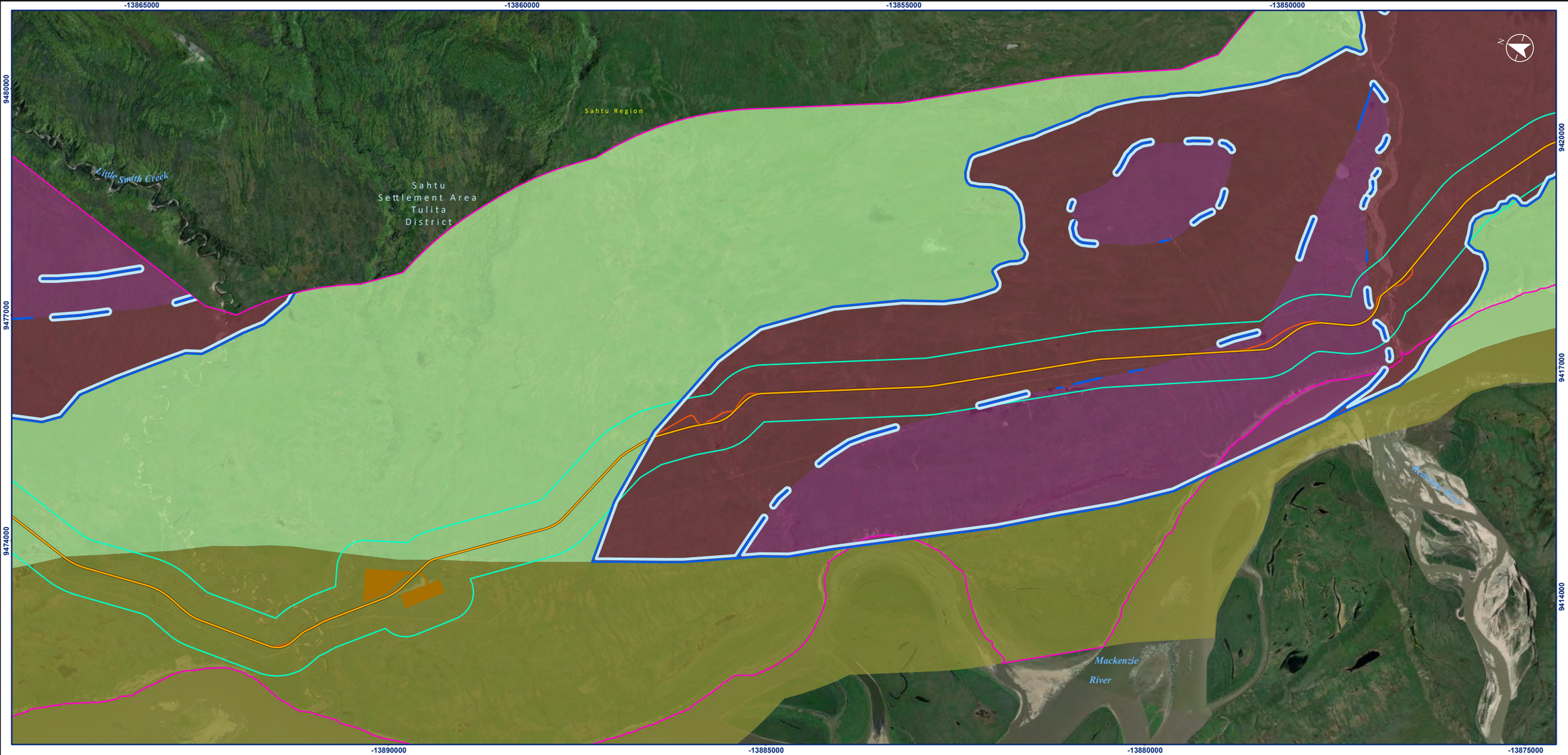
Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

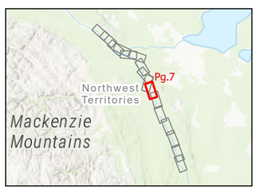
Client/Project
144903025-0072 REV8

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
C.6

Title
RSA Geologic Formations with Aquifers Noted





- Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
- Canol
- Ramparts
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Notes

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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0072 REV8

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
C.7

Title
RSA Geologic Formations with Aquifers Noted

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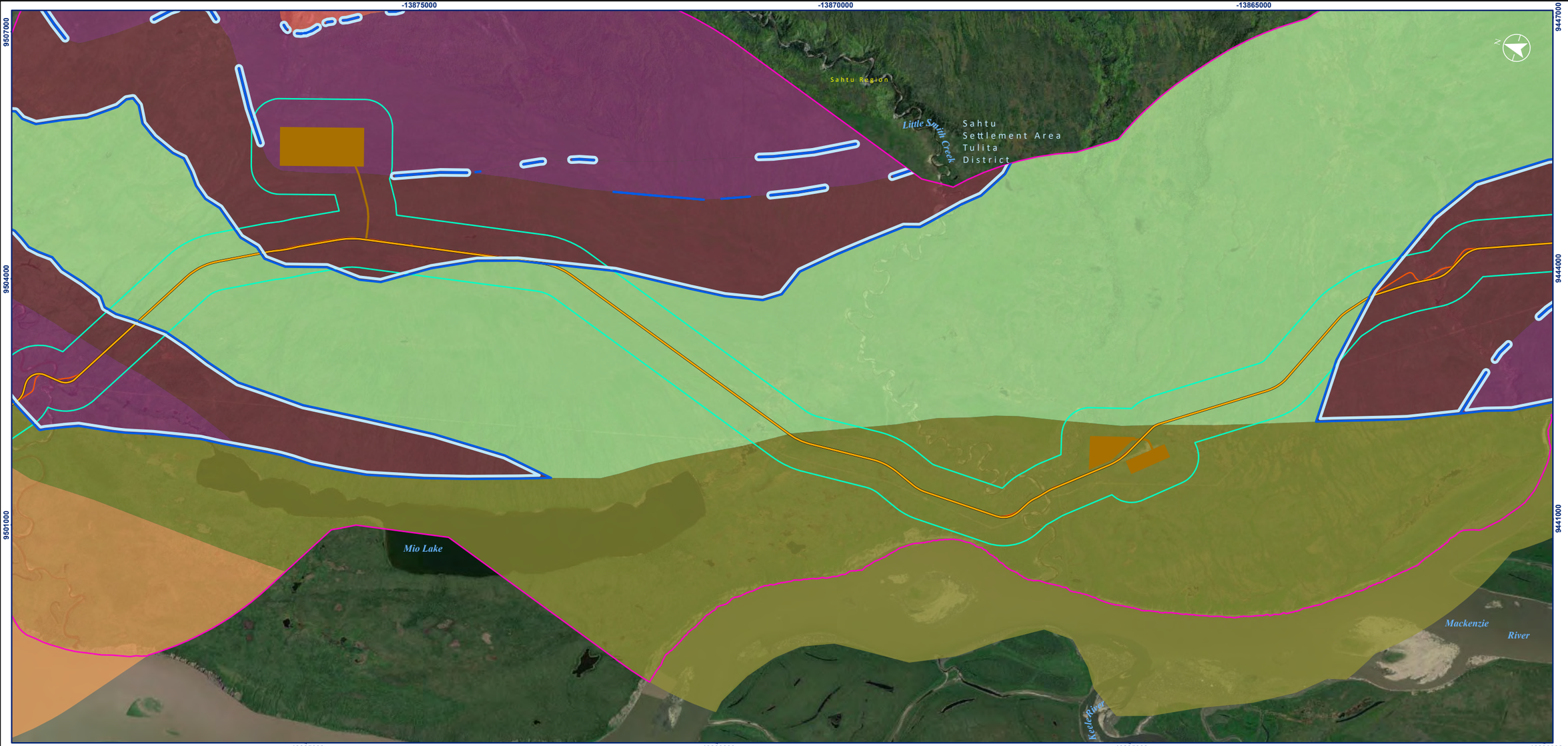
9447000 9444000 9441000



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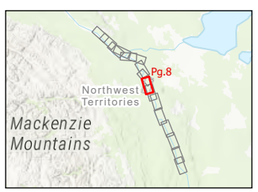

Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
- Canol
- Ramparts
- Hare Indian
- Hume
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- Settlement Area Boundary

0 1 2 Kilometres

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Kálo-Stantec

Project Location

Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project

144903025-0072 REV8

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.

C.8

Title

RSA Geologic Formations with Aquifers Noted

Notes

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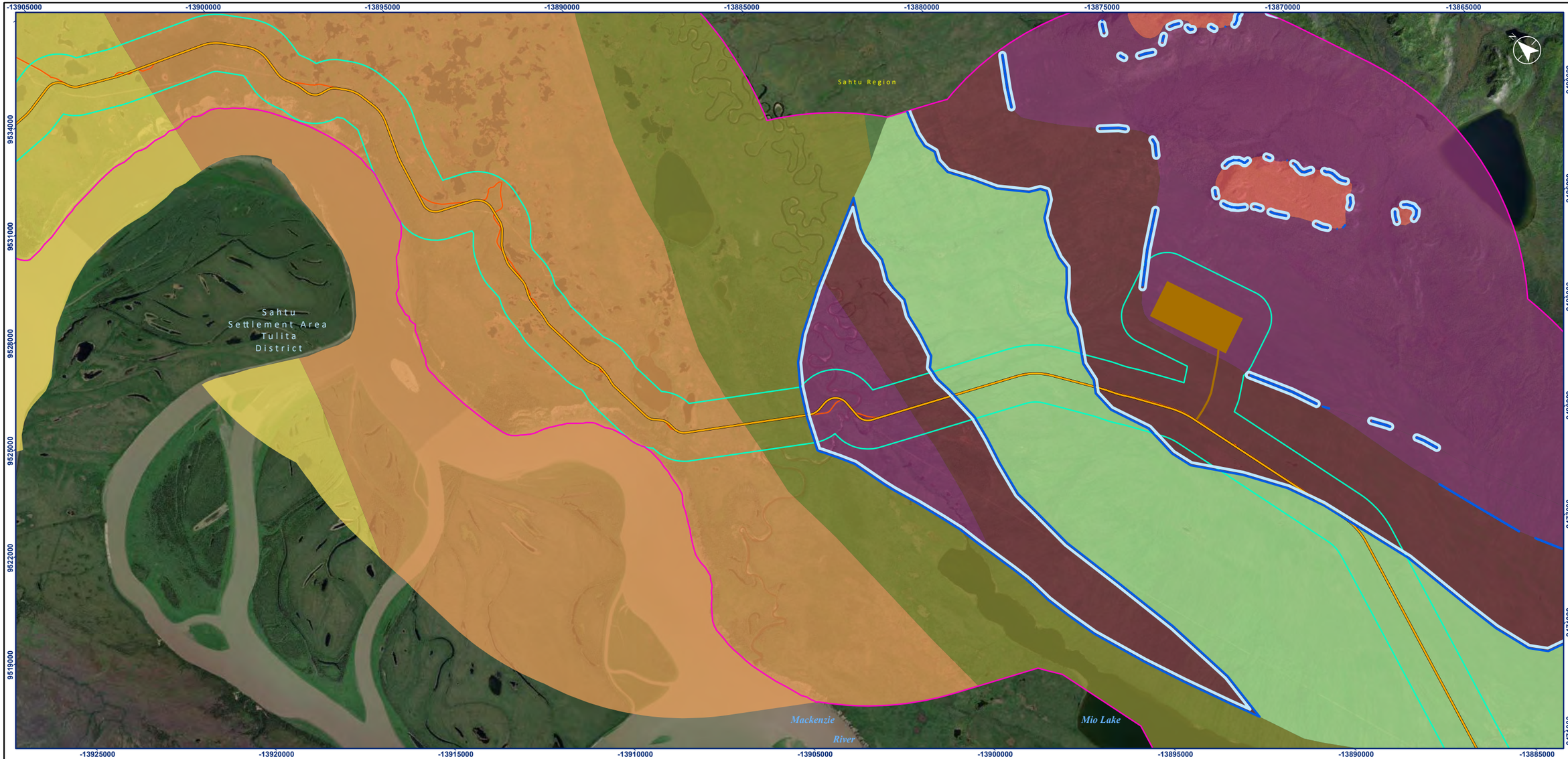

Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
- Canol
- Ramparts
- Hare Indian
- Hume
- Nahanni
- Headless
- Landry (Bear Rock Group)
- Arnica (Bear Rock Group)
- Fort Norman (Bear Rock Group)
- Mount Kindle
- Franklin Mountain
- Saline River
- Mount Cap

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- Regional Study Area
- All-Season Road
- Winter Road
- Conservation Zone
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 1 2 Kilometres

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Project Location

Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project

Government of Northwest Territories
Mackenzie Valley Highway Project

144903025-0072 REV8

Figure No.

C.9

Title

RSA Geologic Formations with Aquifers Noted

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Government of Canada
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
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World Hillshade: Esri, USGS
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-13910000 -13905000 -13900000 -13895000 -13890000 -13885000 -13880000

9570000 9567000 9564000 9561000 9558000 9555000

9516000 9513000 9510000 9507000 9504000

Sahtu Region

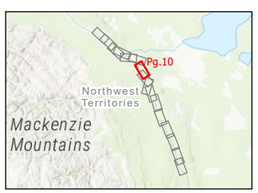
Big Smith Creek

N

Sahtu Settlement Area Tulita District

Mackenzie River

-13935000 -13930000 -13925000 -13920000 -13915000 -13910000 -13905000



- Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
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- Ramparts
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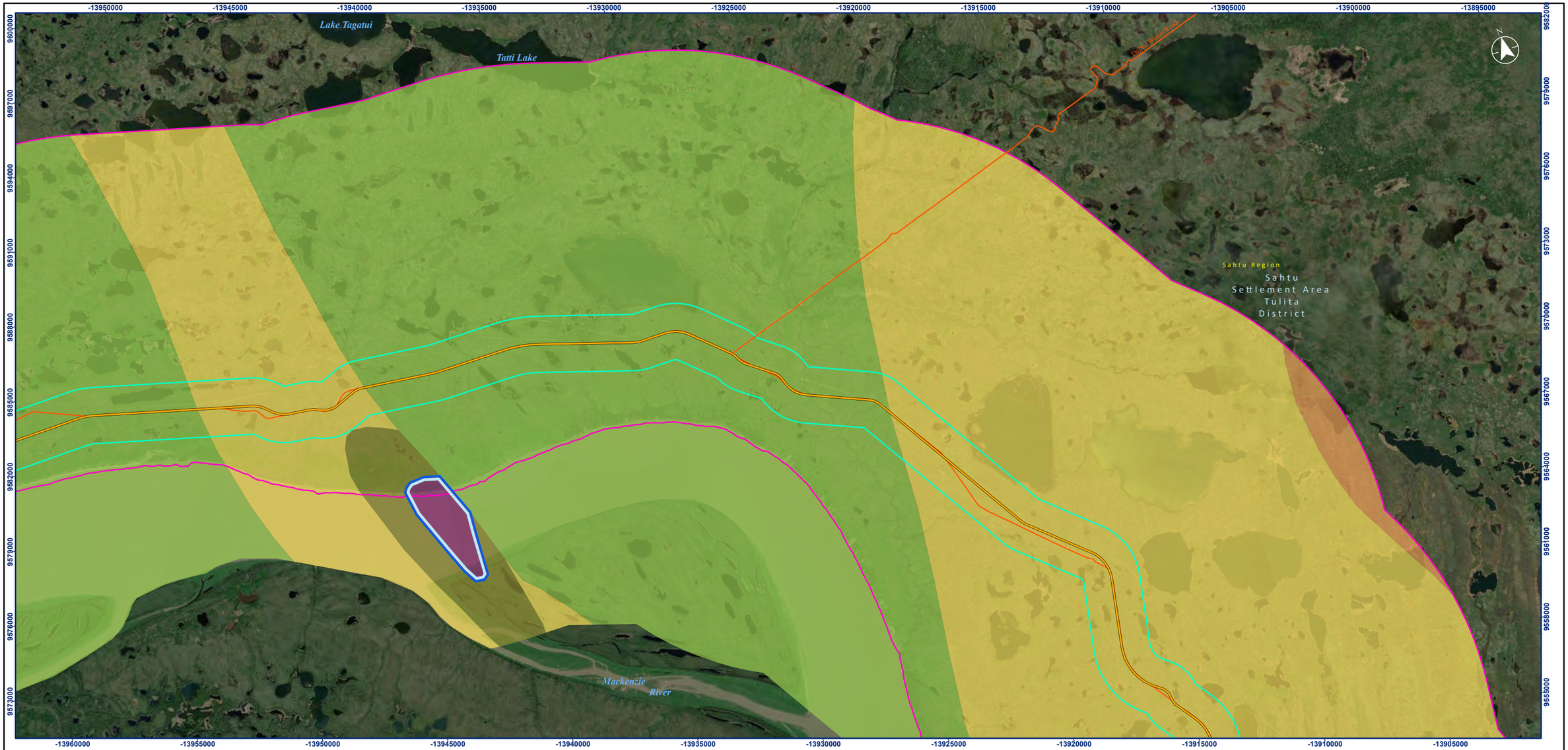
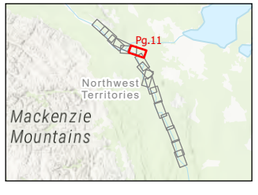
Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
C.10

Title
RSA Geologic Formations with Aquifers Noted





Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
- Canol
- Ramparts
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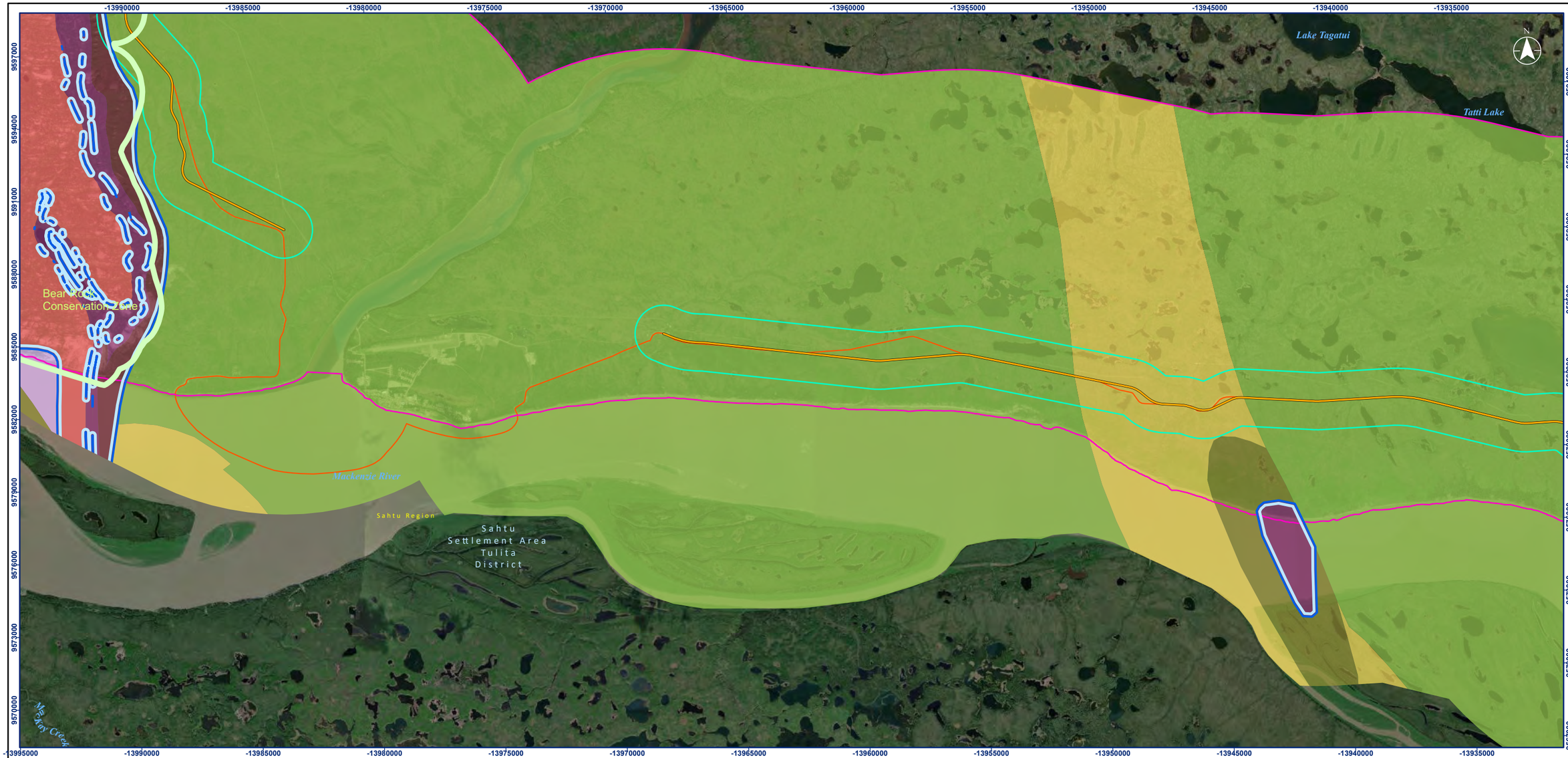
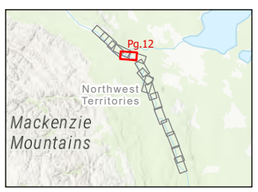
Client/Project
144903025-0072 REV8

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
C.11

Title
RSA Geologic Formations with Aquifers Noted





- Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
- Canol
- Ramparts
- Hare Indian
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Client/Project
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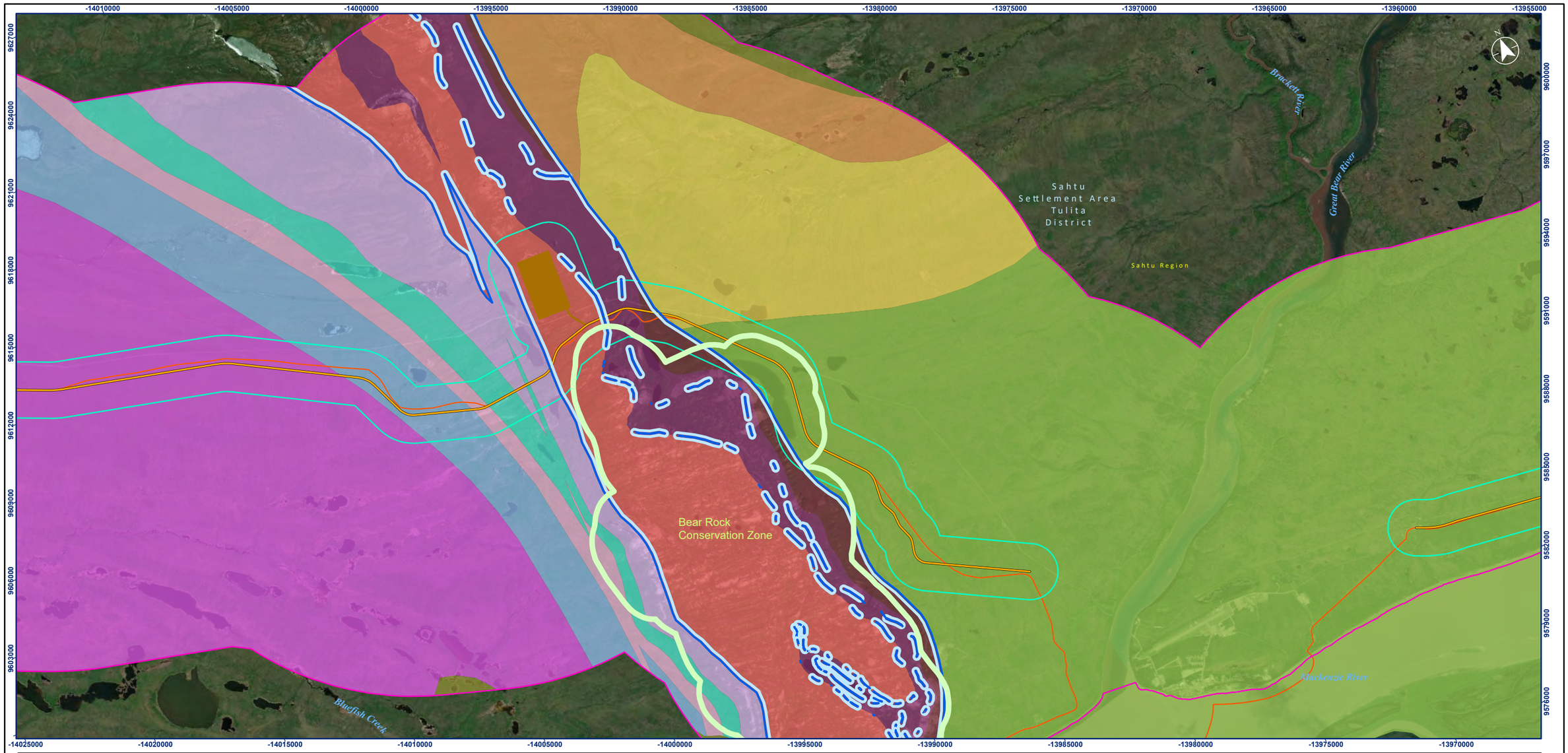
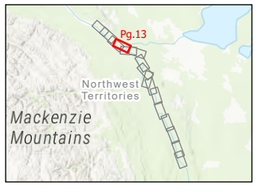
Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
C.12

Title
RSA Geologic Formations with Aquifers Noted





- Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
- Canol
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Client/Project
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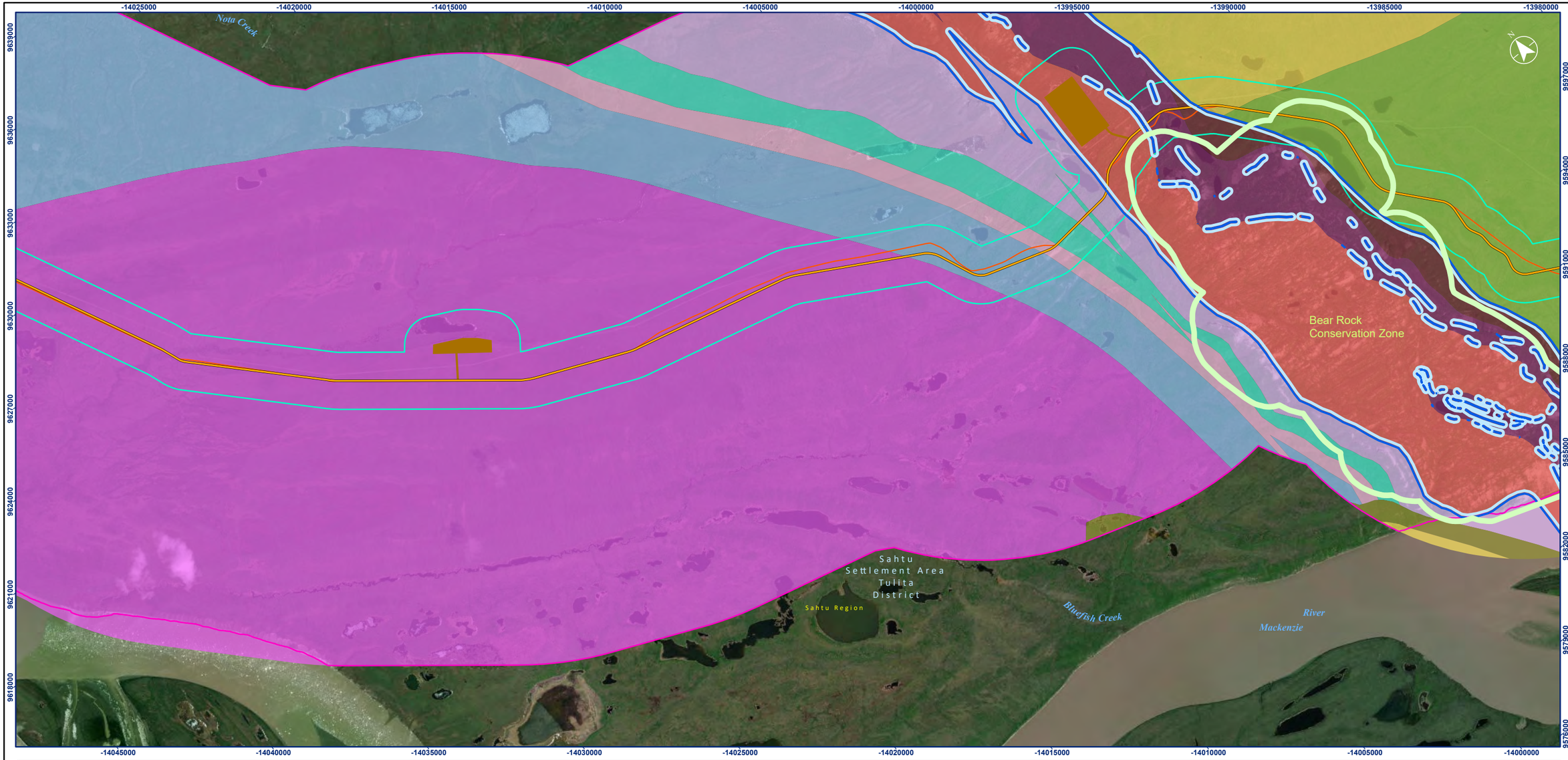
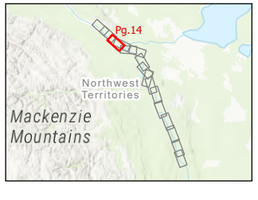
Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
C.13

Title
RSA Geologic Formations with Aquifers Noted





- Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
- Canol
- Ramparts
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Project Location
Wrigley to Norman Wells, NWT

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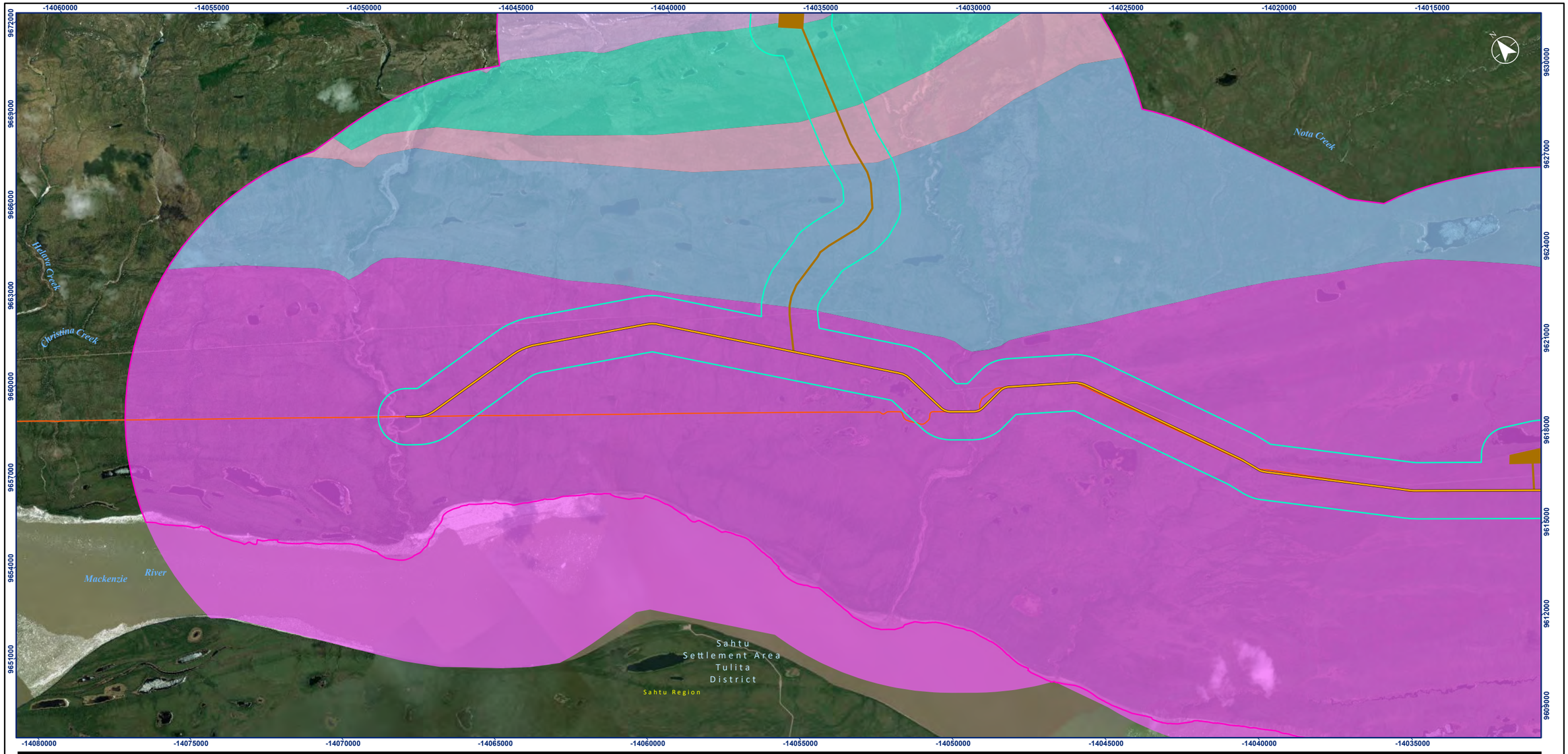
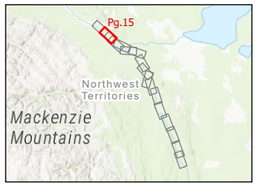
Client/Project
Government of Northwest Territories
Mackenzie Valley Highway Project

14903025-0072 REVB

Figure No.
C.14

Title
RSA Geologic Formations with Aquifers Noted





Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
- Canol
- Ramparts
- Hare Indian
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0 1 2 Kilometres

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Project Location

Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project

14490302S-0072 REV8

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.

C.15

Title

RSA Geologic Formations with Aquifers Noted

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Government of Canada
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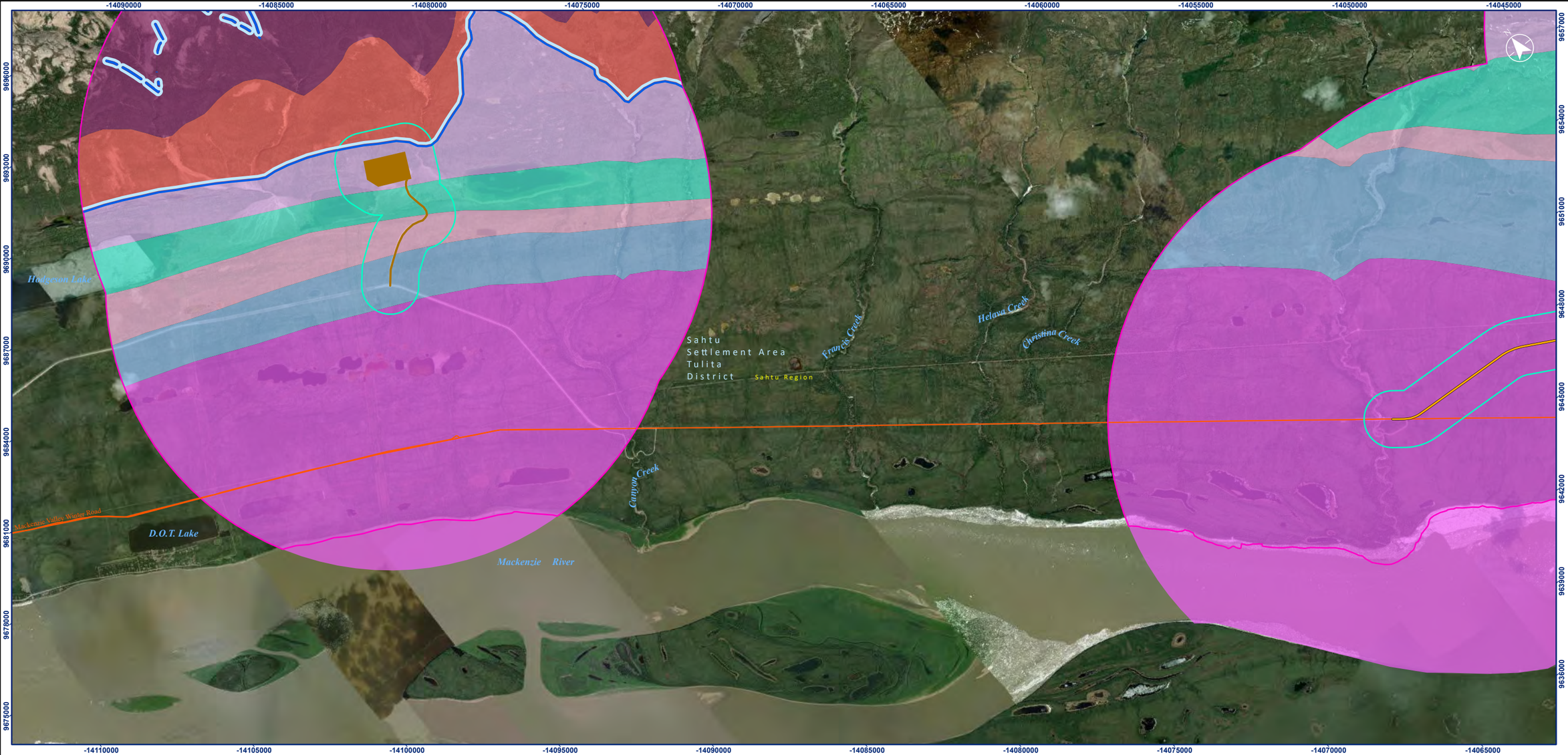

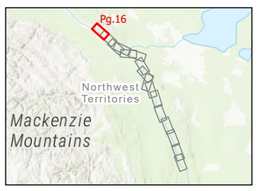

- Aquifer[4]

Geologic Formation

- Summit Creek
- East Fork
- Little Bear
- Slater River
- Arctic Red
- Fort Simpson
- Unnamed
- Imperial
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Client/Project
144903025-0072 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
C.16

Title
RSA Geologic Formations with Aquifers Noted

Appendix D Groundwater Quality Data

D1 Michel (1986) Seep Information and Sample Location Map

D2 Michel (1986) Oxygen-18 Profiles and Borehole Location Map

D3 IORVL (2004) Seep Information and Sample Location Maps

D4 AMEC (2014) Groundwater Sample Chemistry

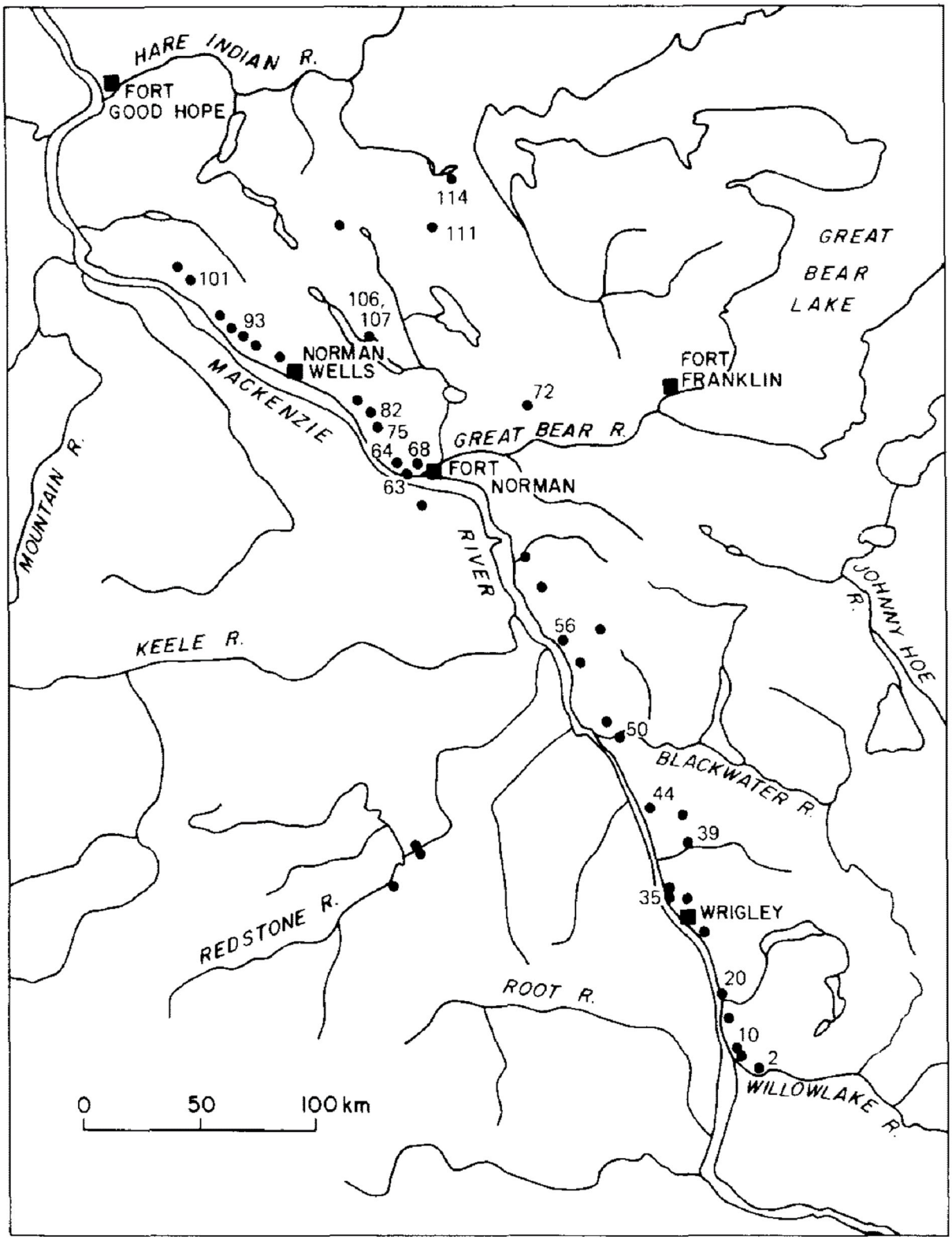
D1 Michel (1986) Seep Information and Sample Location Map

Table D1.1 Chemistry of Seeps Sampled by Michel (1977) between Wrigley and Norman Wells as Reported *in* Michel (1986)

Site ID	Site	T (°C)	pH	Cond. (µS/cm)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Fe (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	Cl (mg/L)	δO^{18} (‰ SMOW)	δH^2 (‰ SMOW)
35	Roche-Qui- Trempe-AL'eau, South	31.3	7.6	17,800	900	149	3,240	49	0.21	177	2,920	5,210	-23.2	-182
39	Ochre River Spring	5.8	7.6	9,000	429	115	1,130	10.3	0.21	283	1,325	1,730	-22.3	-174
44	Rainbow Creek Spring	3.6	7.9	3,900	297	88	561	5.5	<0.04	257	930	831	-22.8	-
50	Blackwater River Spring Field	1.5	-	2,500	341	72	231	2.8	0.04	266	870	342	-	-
56	Saline River Spring	0	8.4	3,160	112	36	480	1.2	<0.04	317	185	705	-	-
63	Bear Rock South Sulphur Spring	6.9	7.1	3,500	380	119	480	4.1	0.22	318	1,195	700	-23.5	--
64	Bear Rock West Sulphur Spring	4.2	7.2	2,650	297	78	31	2.5	0.04	272	830	38	-23.3	--
68	Bear Rock S.E. Springs	2.8	7.5	1,880	528	34	3	1.5	0.16	295	1,090	2.2	-23.2	-179
75	Nota Creek Spring	0.5	7.4	8,000	39	23	1,910	6.0	0.24	2,856	35	1,320	-	-
82	Vermilion Creek Sulphur	8.0	7.4	1,550	484	79	50	2.9	0.06	268	1,250	56	-	-
106	Kelly Lake Iron	3.3	7.4	7,710	192	109	1,450	7.5	1.0	266	800	2,250	-23.7	-
107	Kelly Lake Spring	4.3	7.9	2,800	65	111	475	35.0	0.04	270	400	710	-23.7	-

Notes:

1. Spring locations provided on map from Michel (1986) in Appendix D1, page D1-4.
2. "T" is temperature; "Cond." Is conductivity; "Ca" is calcium; "Mg" is magnesium; "Na" is sodium; "K" is potassium; "Fe" is iron; "HCO_3" is bicarbonate; "SO_4" is sulfate; "Cl" is chloride; "δO^{18}" is the oxygen-18, oxygen-16 fractionation ratio relative to standard mean ocean water (SMOW); "δH^2" is the deuterium, hydrogen fractionation ratio relative to standard mean ocean water (SMOW).


HARE INDIAN R.
FORT GOOD HOPE
114
111
GREAT BEAR LAKE
101
106, 107
93
NORMAN WELLS
MACKENZIE
FORT FRANKLIN
72
82
75
64
68
GREAT BEAR R.
FORT NORMAN
63
MOUNTAIN R.
RIVER
JOHNNY HOE R.
KEELE R.
56
50
BLACKWATER R.
44
39
35
WRIGLEY
REDSTONE R.
ROOT R.
20
10
2
WILLOWLAKE R.
0
50
100 km

D2 Michel (1986) Oxygen-18 Profiles and Borehole Location Map

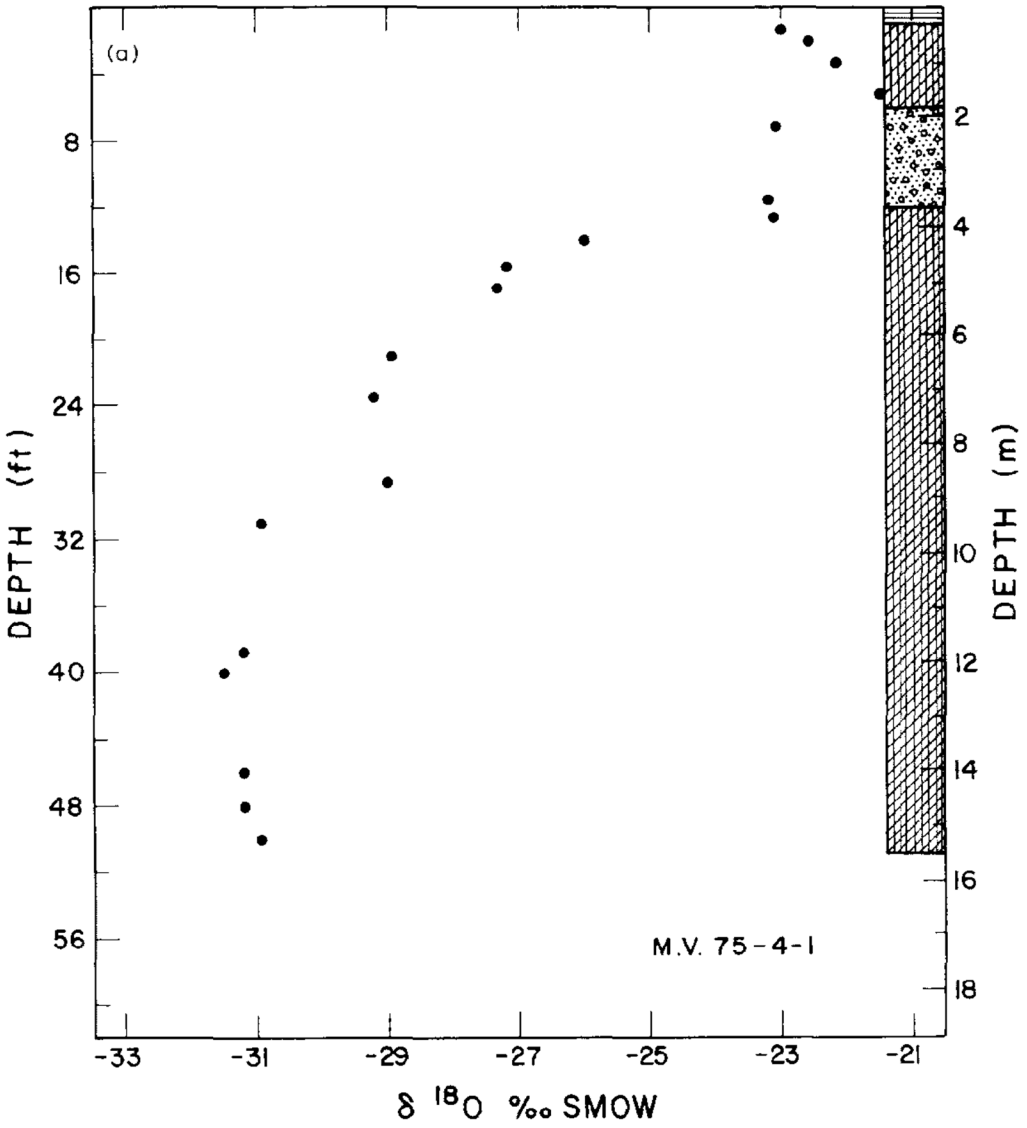


Fig. 5. Variation in ^{18}O content with depth for cores 75-4-1 (a), 75-8-2 (b), 75-13-2 (c), and 75-19-3 (d). (Horizontal bars = peat; solid dots = sand; vertical bars = silt; cross-hatched = clay; and open circles = stony material.)

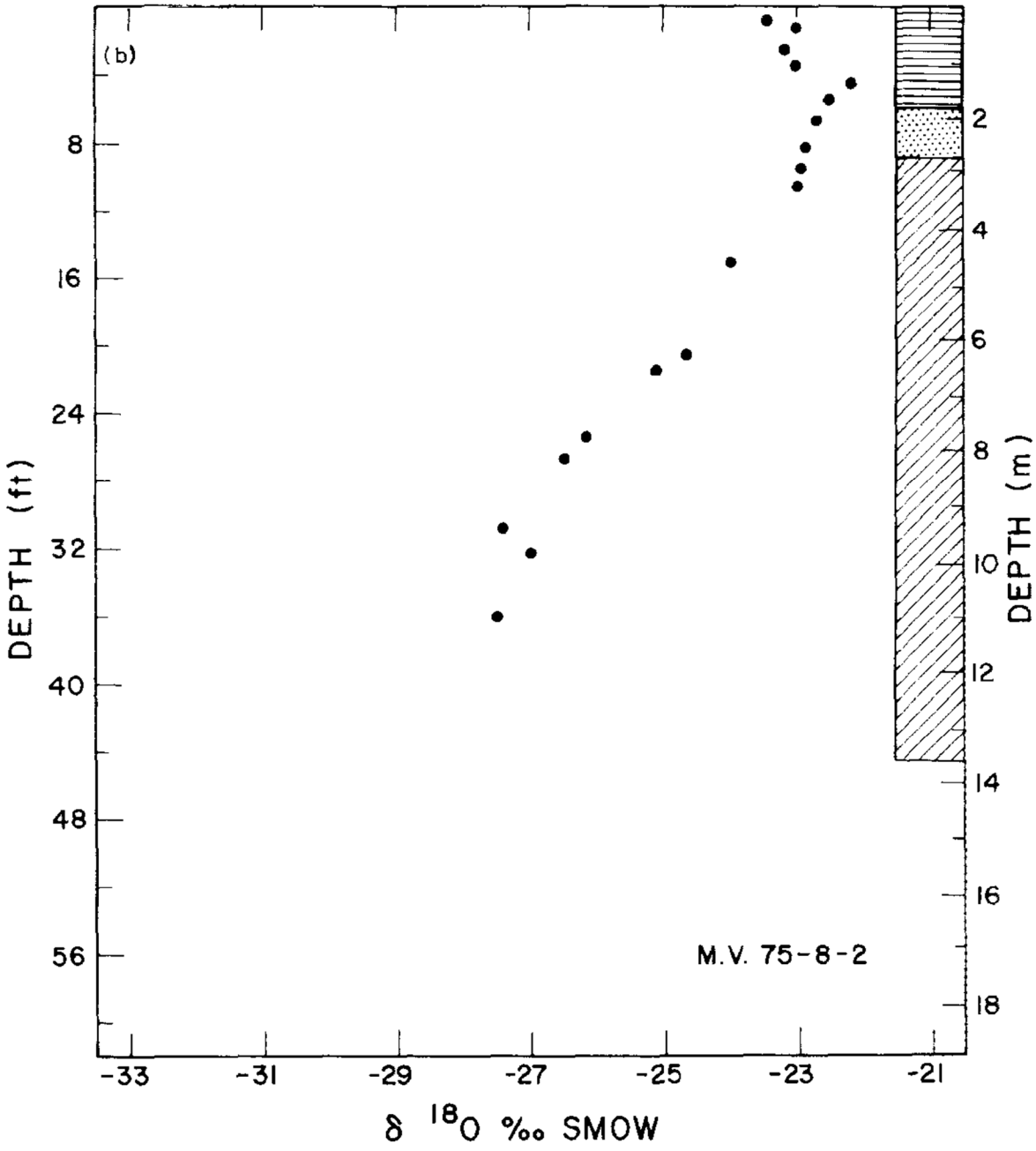


Fig. 5b (see p. 389 for caption)

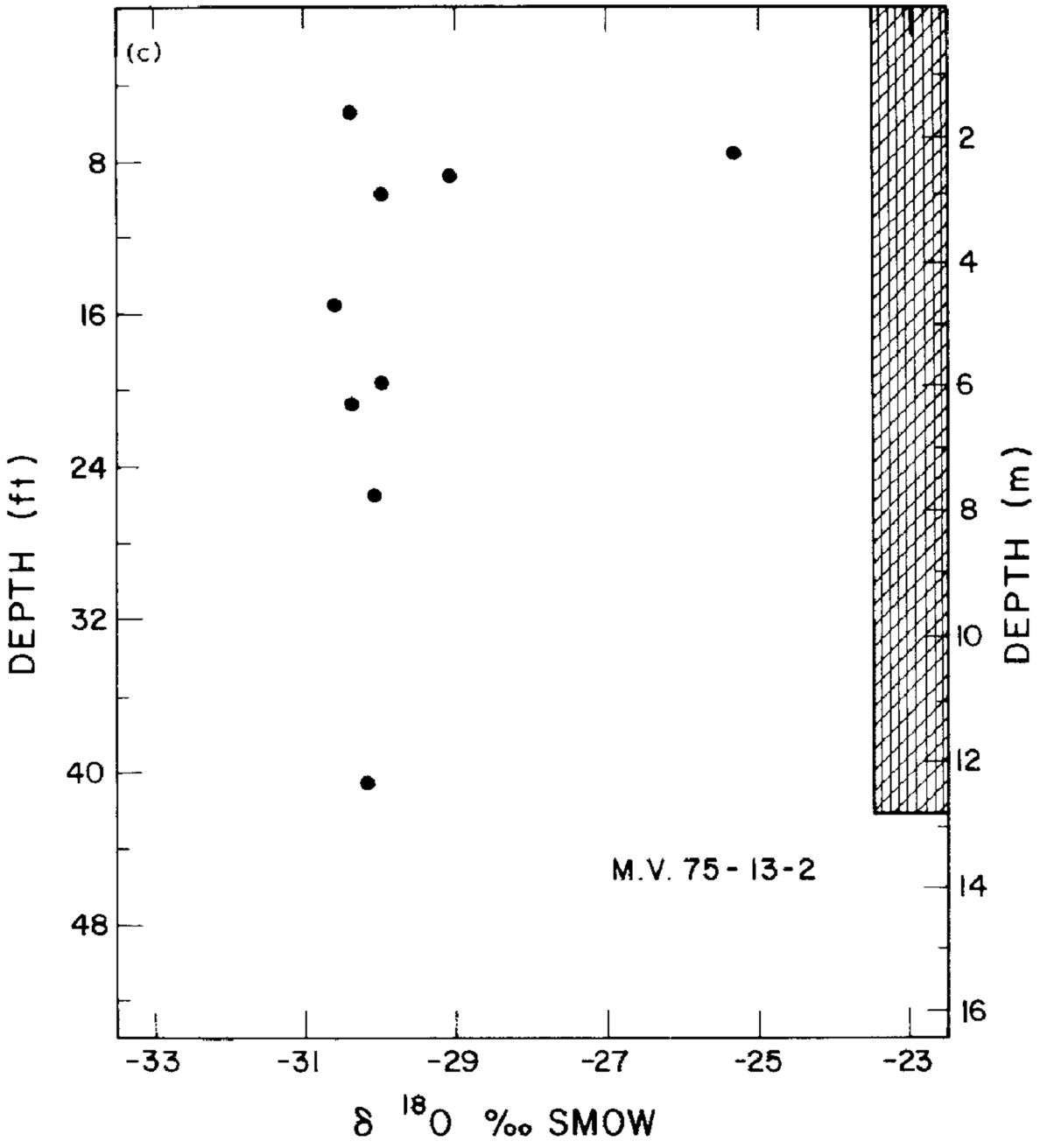


Fig. 5c (see p. 389 for caption)

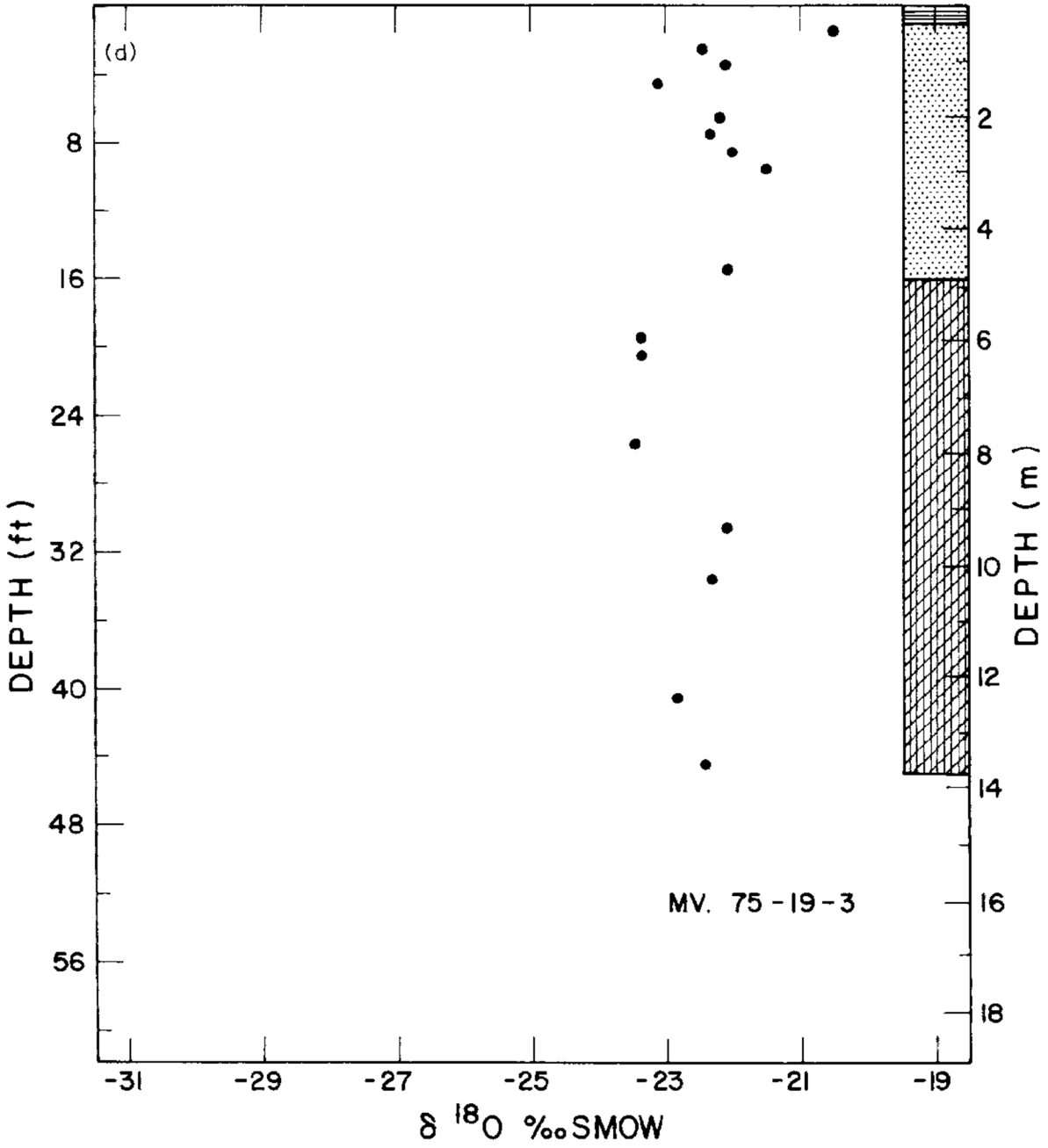
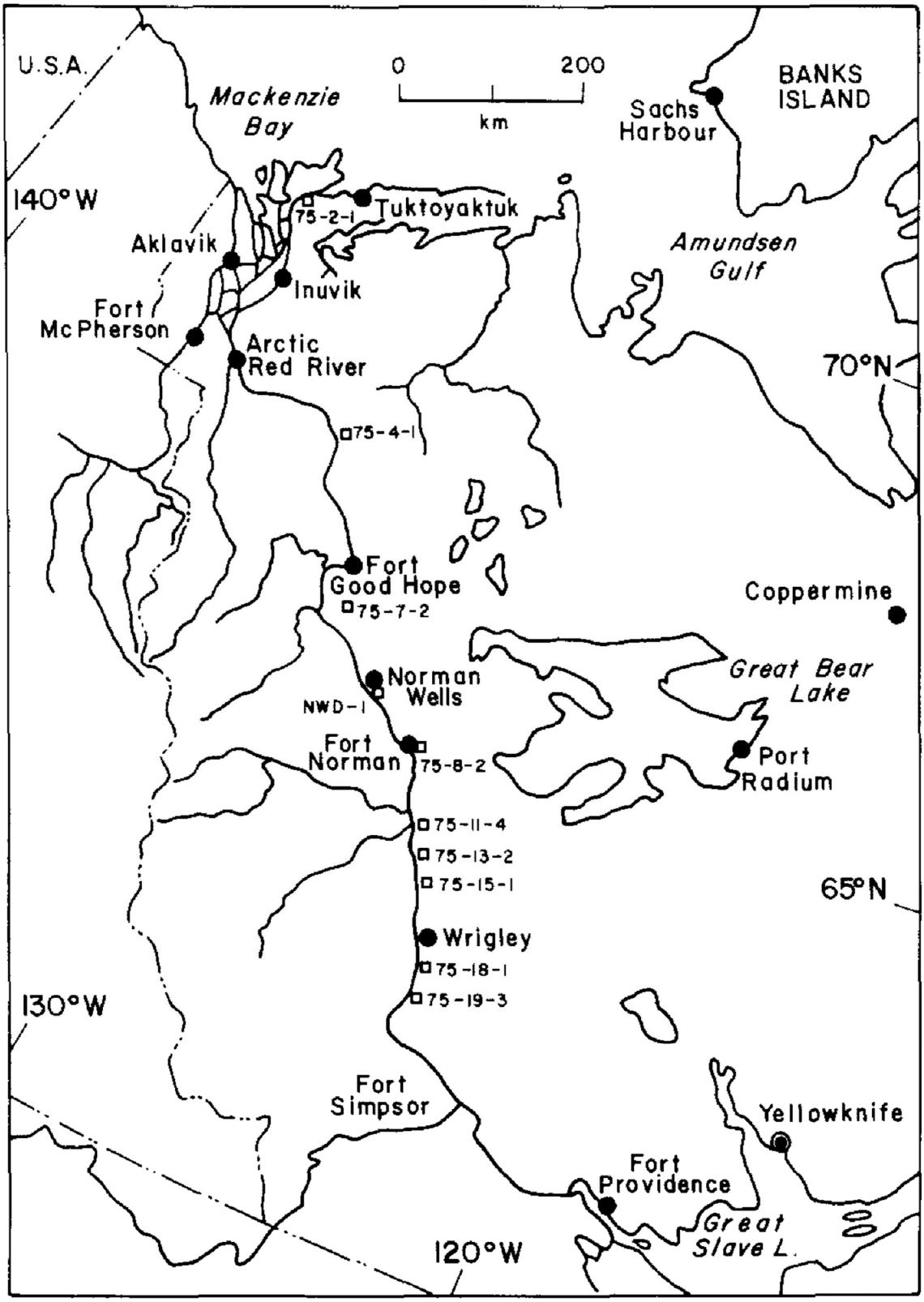


Fig. 5d (see p. 389 for caption)


U.S.A.
Mackenzie Bay
0
200
km
BANKS ISLAND
Sachs Harbour
140°W
75-2-1
Tuktoyaktuk
Aklavik
Inuvik
Amundsen Gulf
Fort McPherson
Arctic Red River
70°N
75-4-1
Fort Good Hope
75-7-2
Coppermine
Great Bear Lake
Norman Wells
NWD-1
Fort Norman
75-8-2
Port Radium
75-11-4
75-13-2
75-15-1
65°N
Wrigley
75-18-1
75-19-3
130°W
Fort Simpsor
Yellowknife
Fort Providence
Great Slave L.
120°W

D3 IORVL (2004) Seep Information and Sample Location Maps

Table D3.1 Characteristics of Seep Discharge Described in IORVL (2004)

Associated Stream	Spring ID	IORVL, 2004 Comment	Discharge Rate (L/s)[1]	TDS (mg/L)[1]
Hodgson Creek	A02-55, 56, 57, 58	calcium-bicarbonate water type	-[3]	Moderately low
Hodgson Creek	M31	M series spring samples collected by Michel (1977)	3	320
Ochre River	n/a[2]	No springs identified from the air during the survey		-
White Sand Creek	n/a	No springs identified from the air during the survey	-	-
Blackwater River	A52	Sodium-chloride, sodium-sulfate water type	100	Twice A51 TDS
Blackwater River	A51	Calcium-magnesium bicarbonate water type	100	-
Steep Creek	A24, A24b, A24c	Larger perennial springs near creek-level; calcium-carbonate water type	-	452 to 472
Little Smith Creek Tributary	n/a	Spring appeared representative of other discharge along the bank; possible flow from active layer	0.25	276
Little Smith Creek	M57	M series spring samples collected by Michel (1977)	93	365 to 476
Vermilion Creek North	A27 and A27b	Calcium-sulfate water type; higher than normal water temperature	180 (combined)	2,324
Helava Creek	Helava Creek Spring	Calcium-carbonate water type	-	315
Christina Creek	Christina Creek Spring	Calcium-carbonate water type	-	292
Prohibition Creek	A28	Calcium-sulfate water type	2.2	1,712
Bosworth Creek	A22b	Higher mineralization than Bosworth Creek	-	-
Bosworth Creek	A22	Higher mineralization than Bosworth Creek	-	-

Notes:

1. “L/s” is litres per second; “mg/L” is milligrams per litre.
2. “n/a” is not available.
3. “-“ is not provided by IORVL, 2004.
4. Spring locations provided on figures from IORVL (2004) in Appendix D3, pages D3-3 to D3-13.

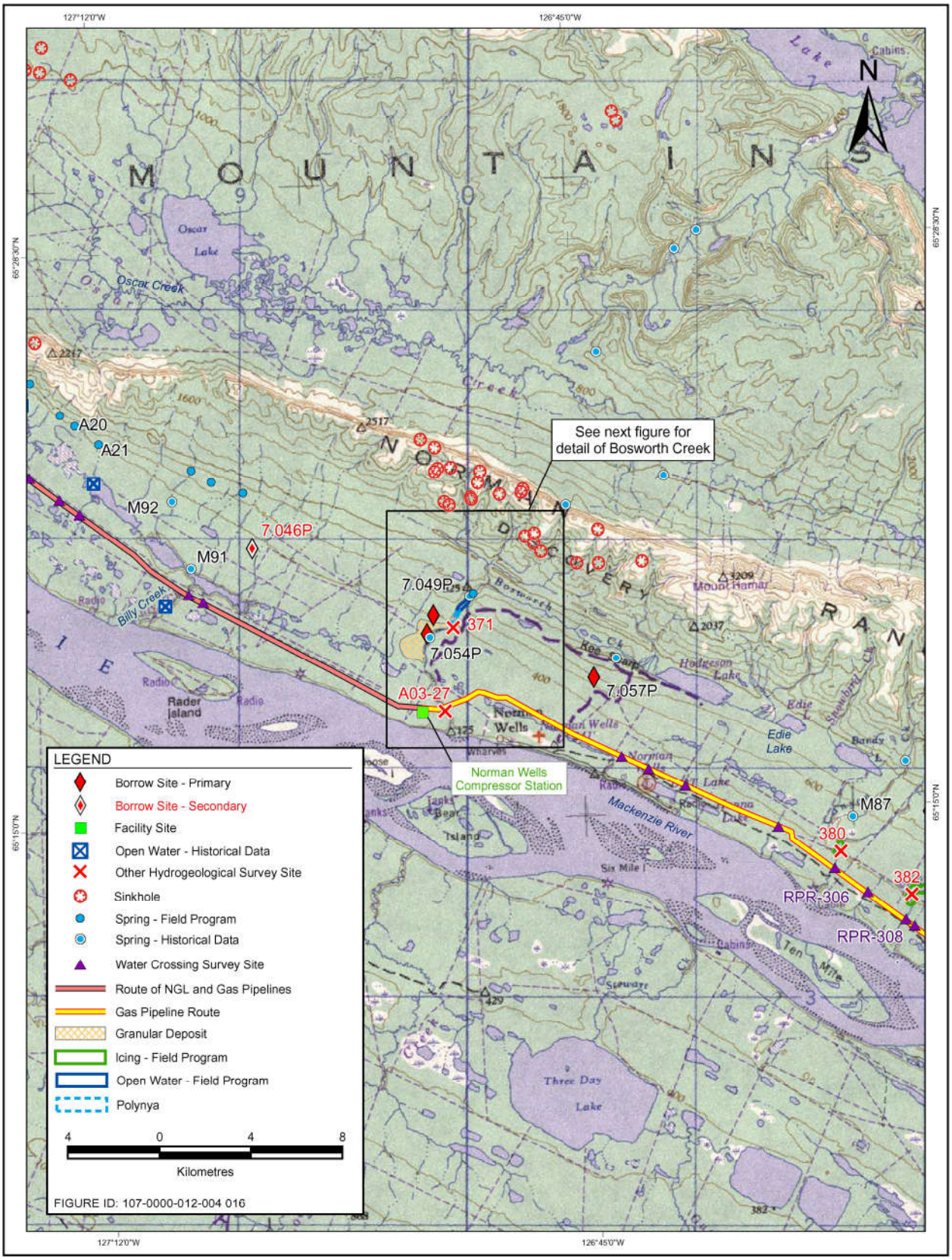


Figure 4-33: Hydrogeological Features – Oscar Creek to Edie Lake

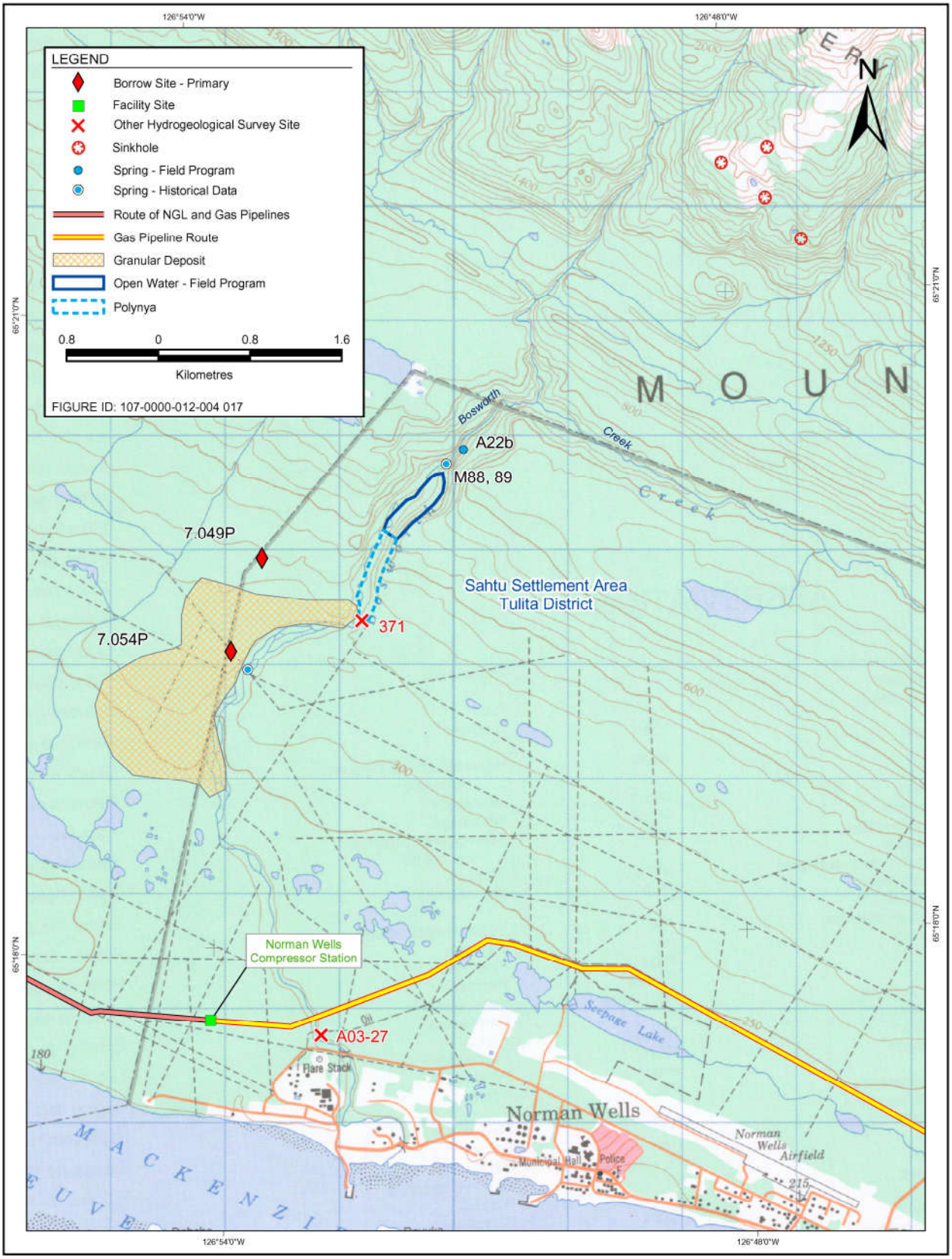


Figure 4-34: Hydrogeological Features – Bosworth Creek – Site 371

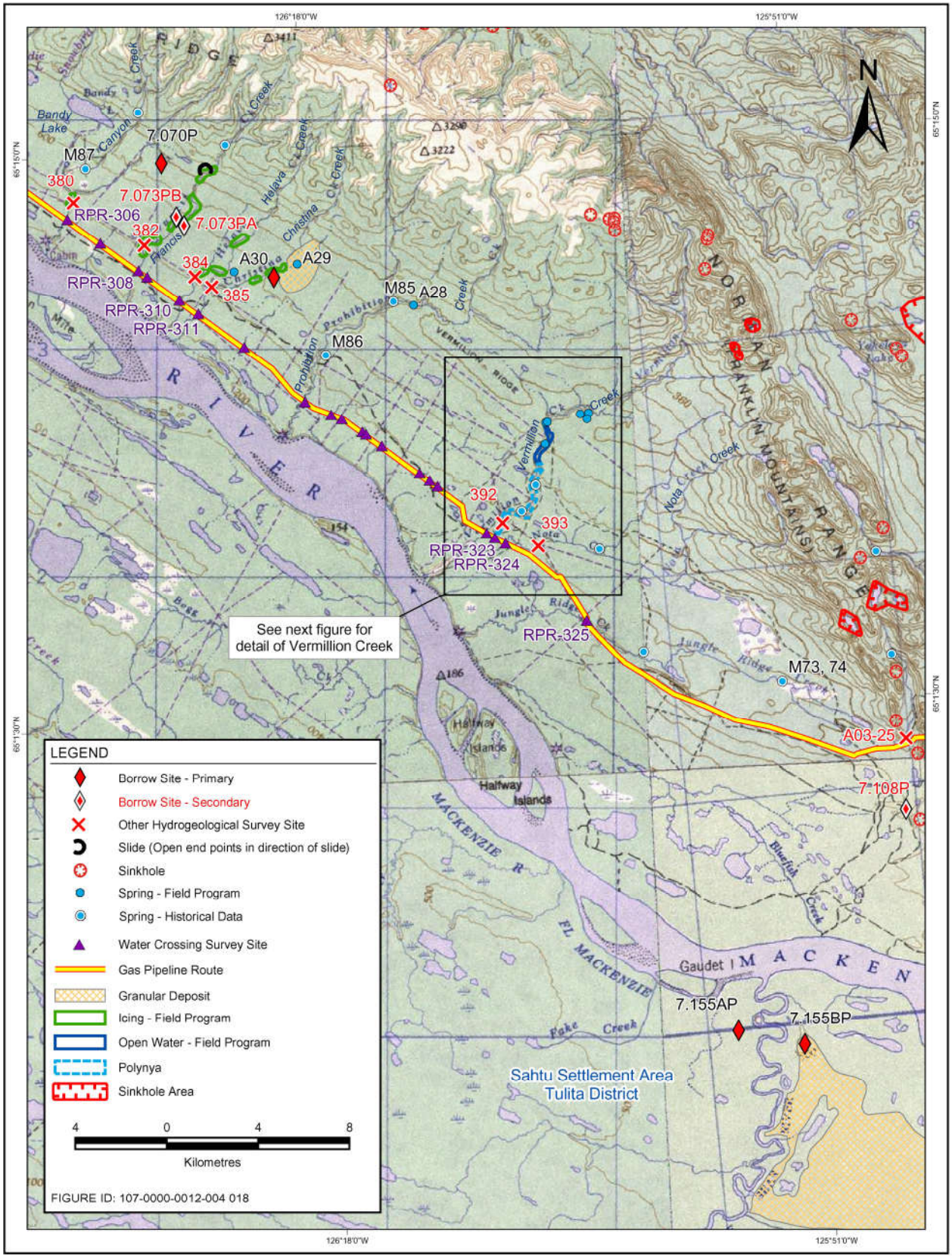


Figure 4-35: Hydrogeological Features – Bandy Lake to Bluefish Creek

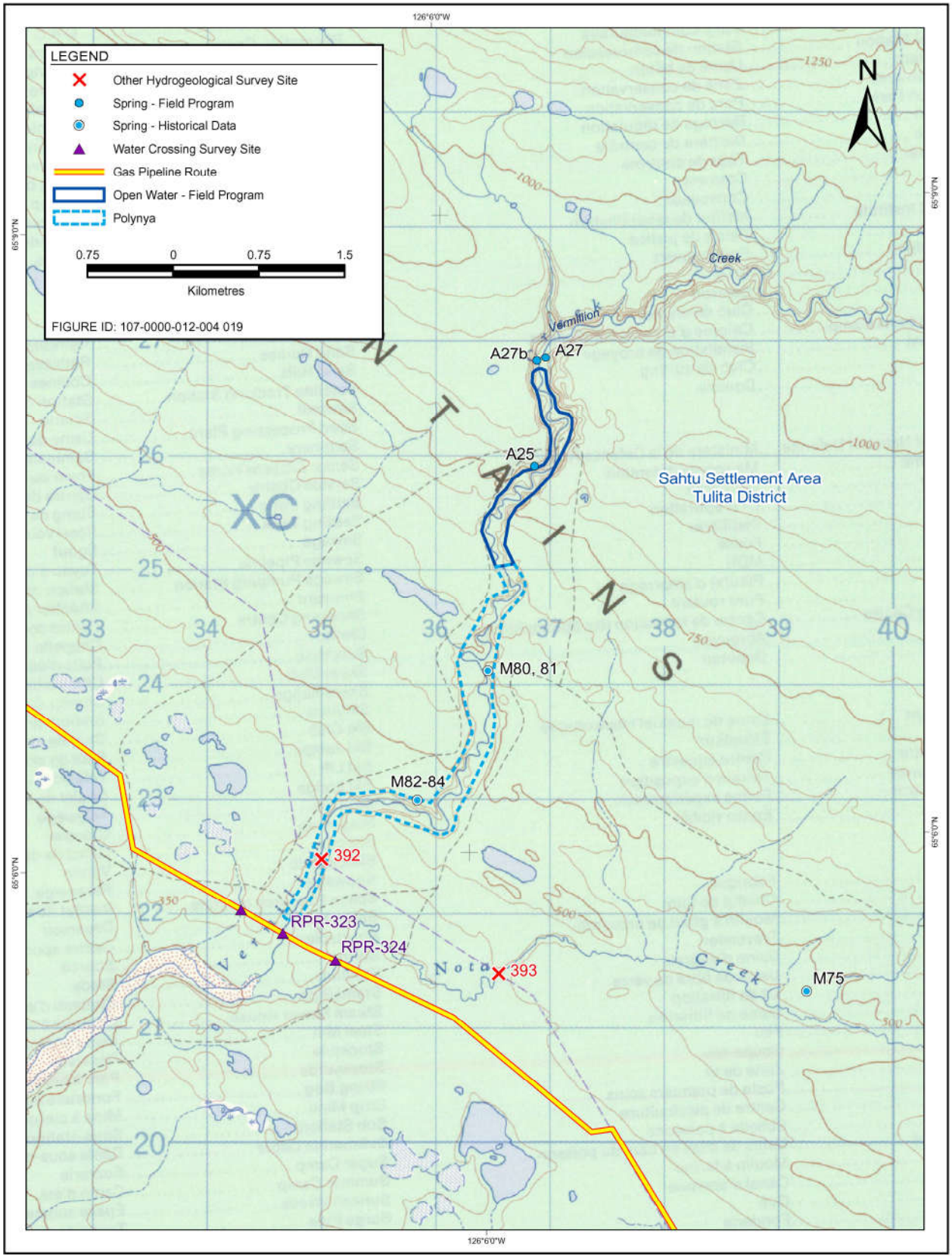


Figure 4-36: Hydrogeological Features – Vermilion Creek – Site 392

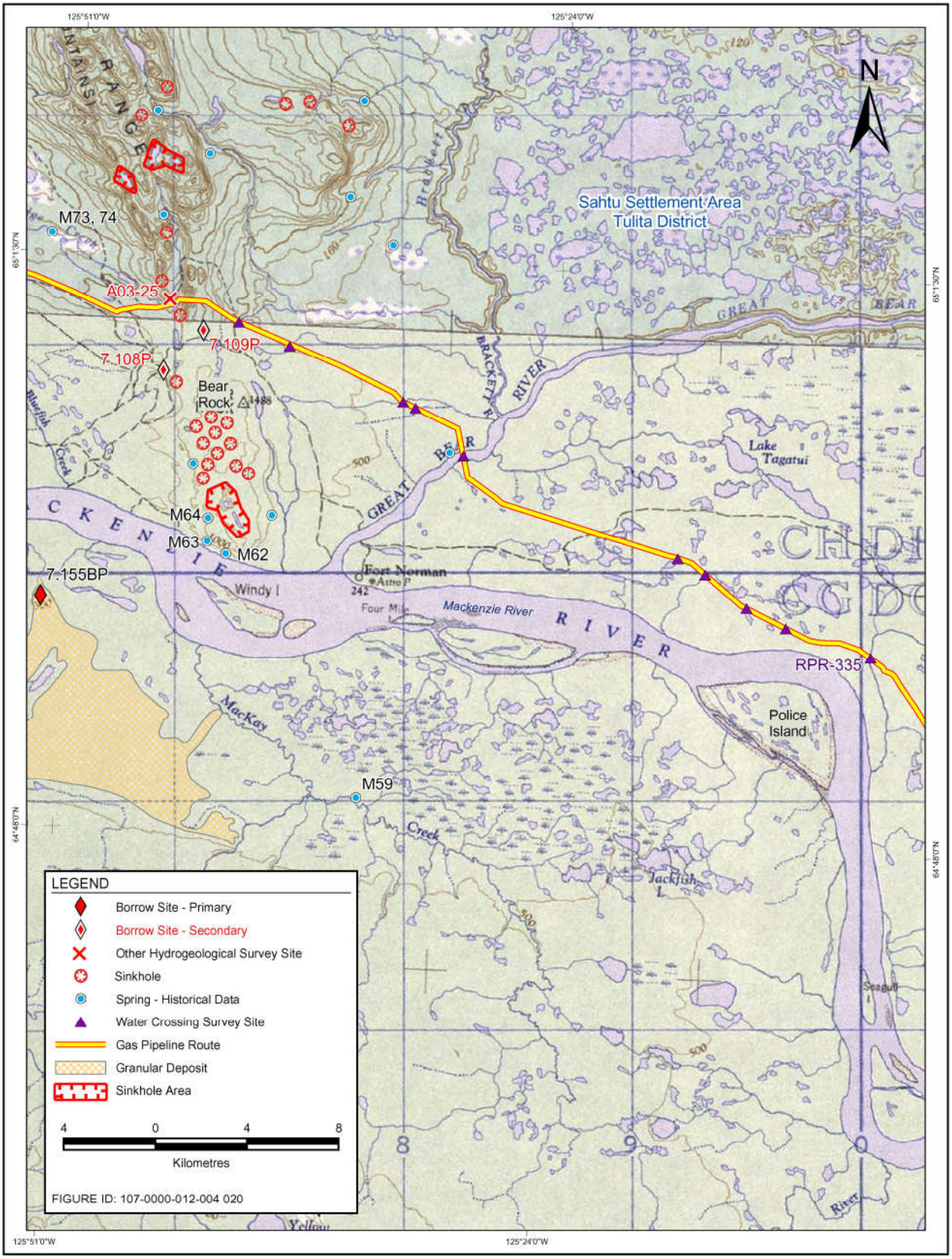


Figure 4-37: Hydrogeological Features – Bear Rock to Police Island

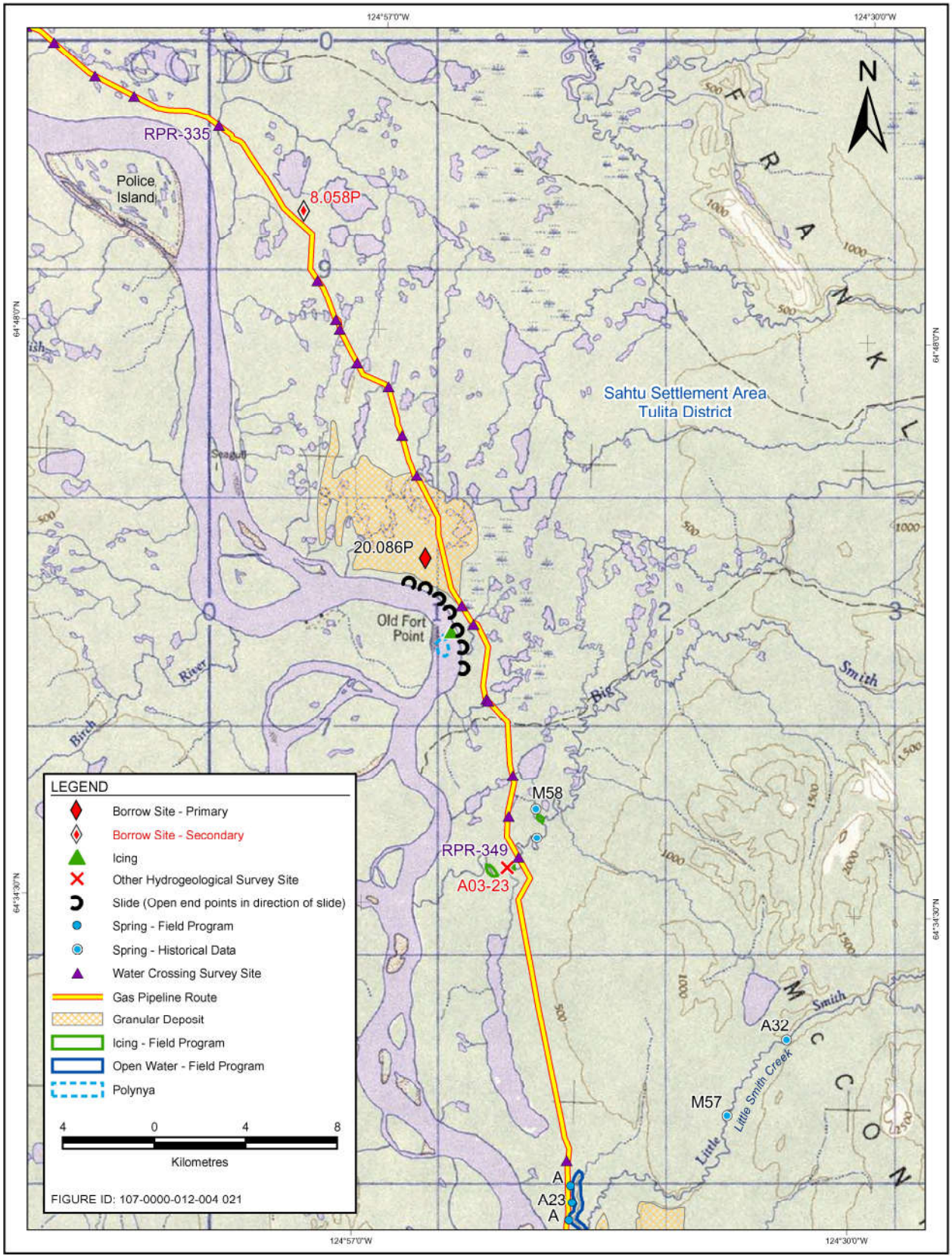


Figure 4-38: Hydrogeological Features – Police Island to Little Smith Creek

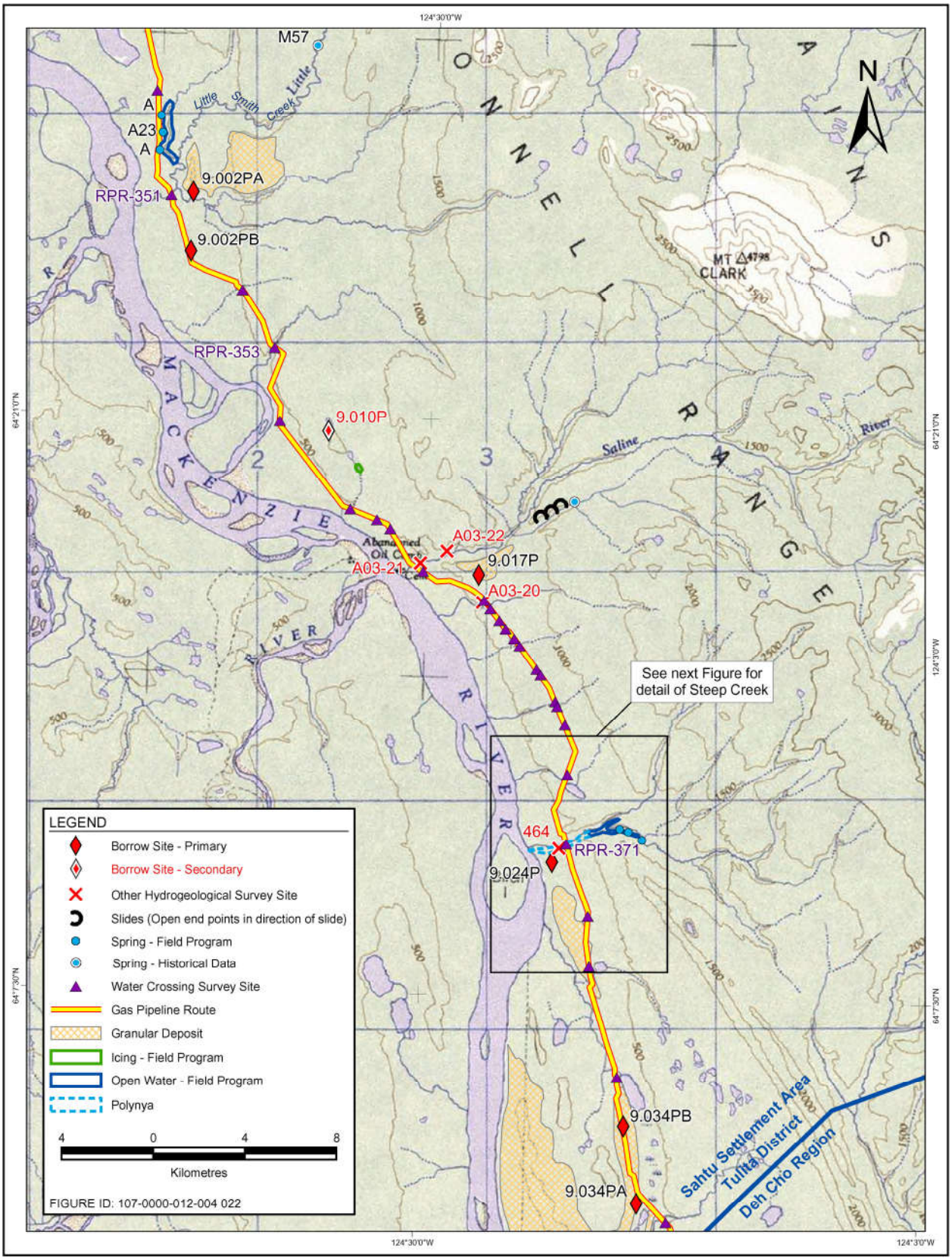


Figure 4-39: Hydrogeological Features – Little Smith Creek to the Sahtu–Deh Cho Boundary

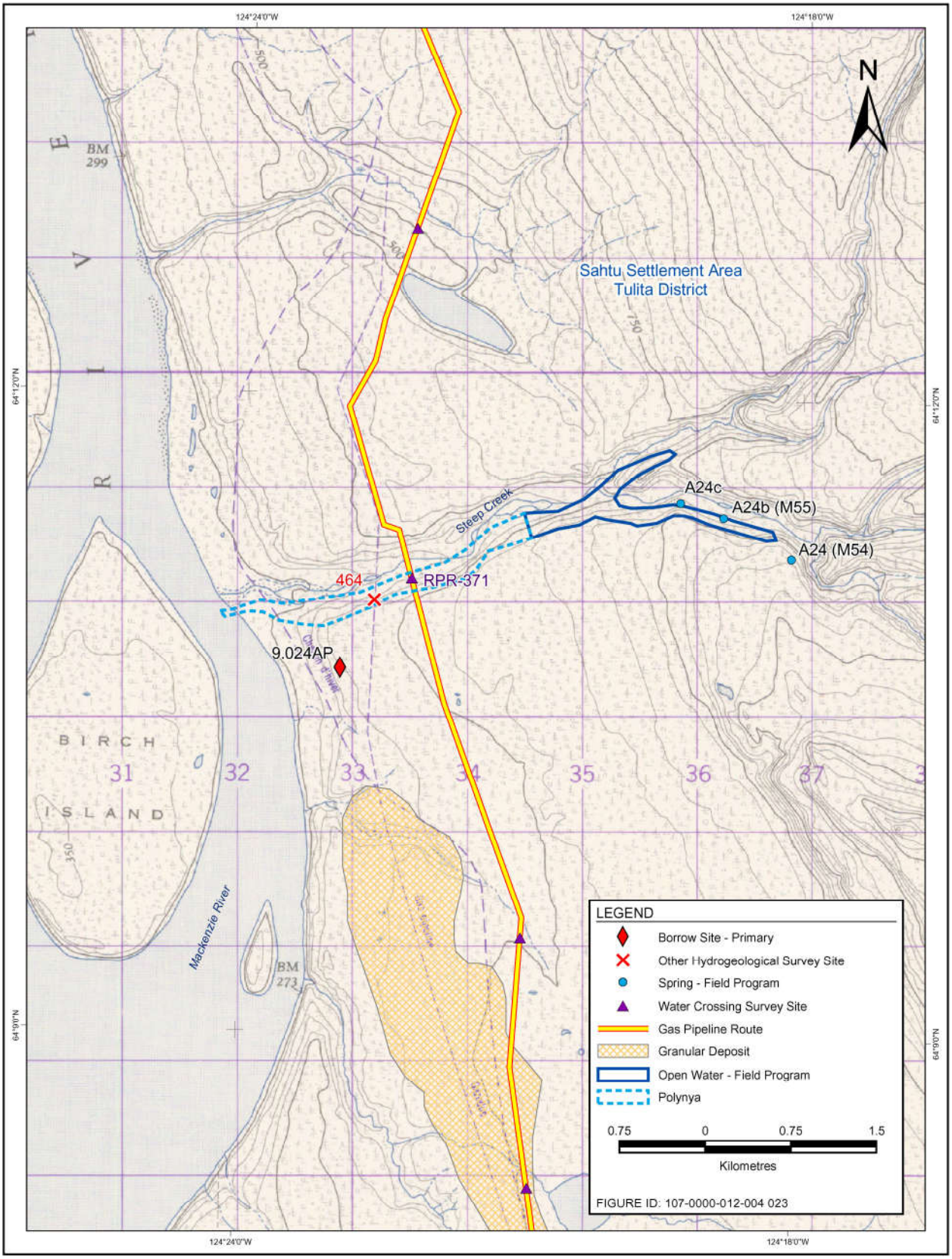


Figure 4-40: Hydrogeological Features – Steep Creek – Site 464

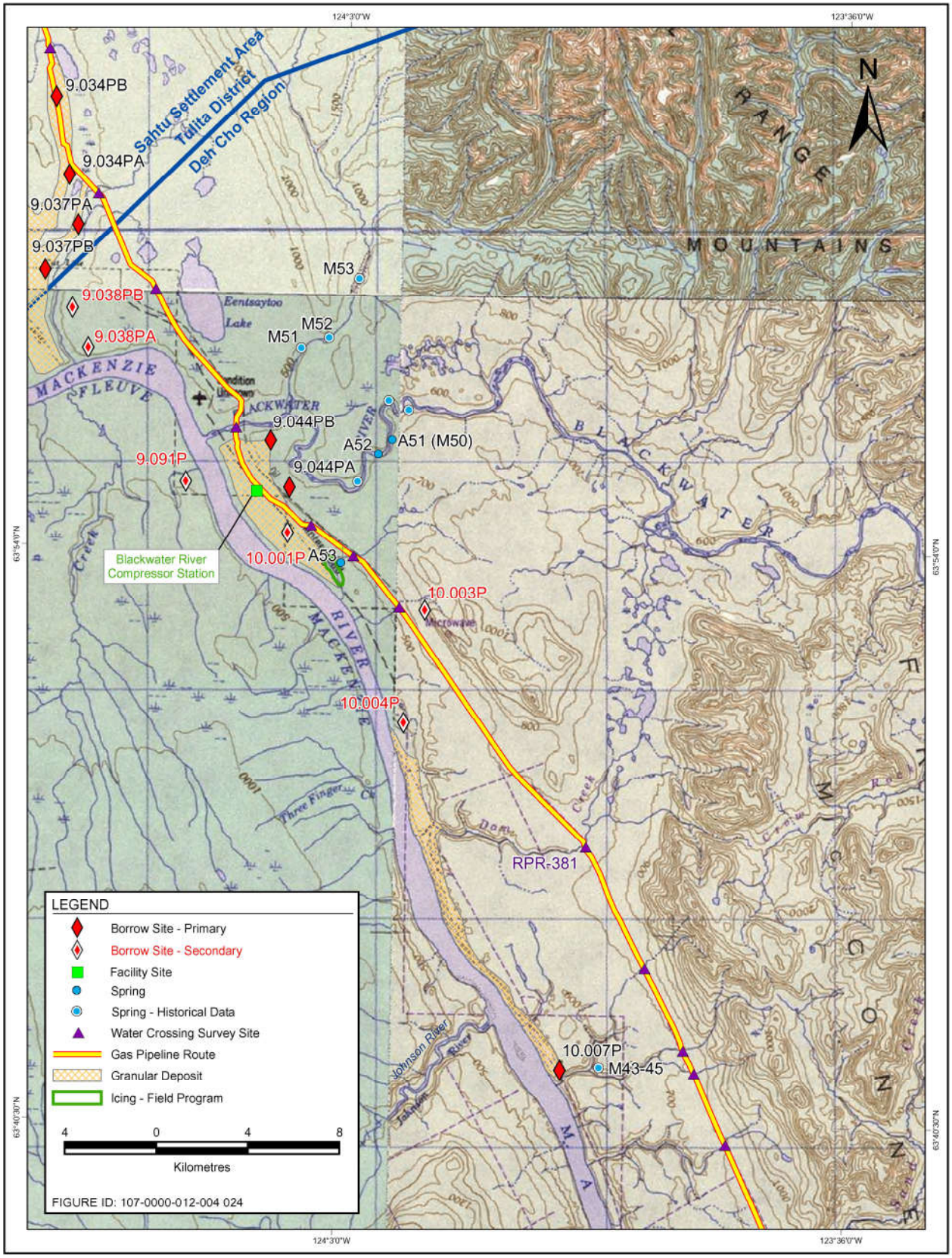


Figure 4-41: Hydrogeological Features – Sahtu-Deh Cho Boundary to Johnson River

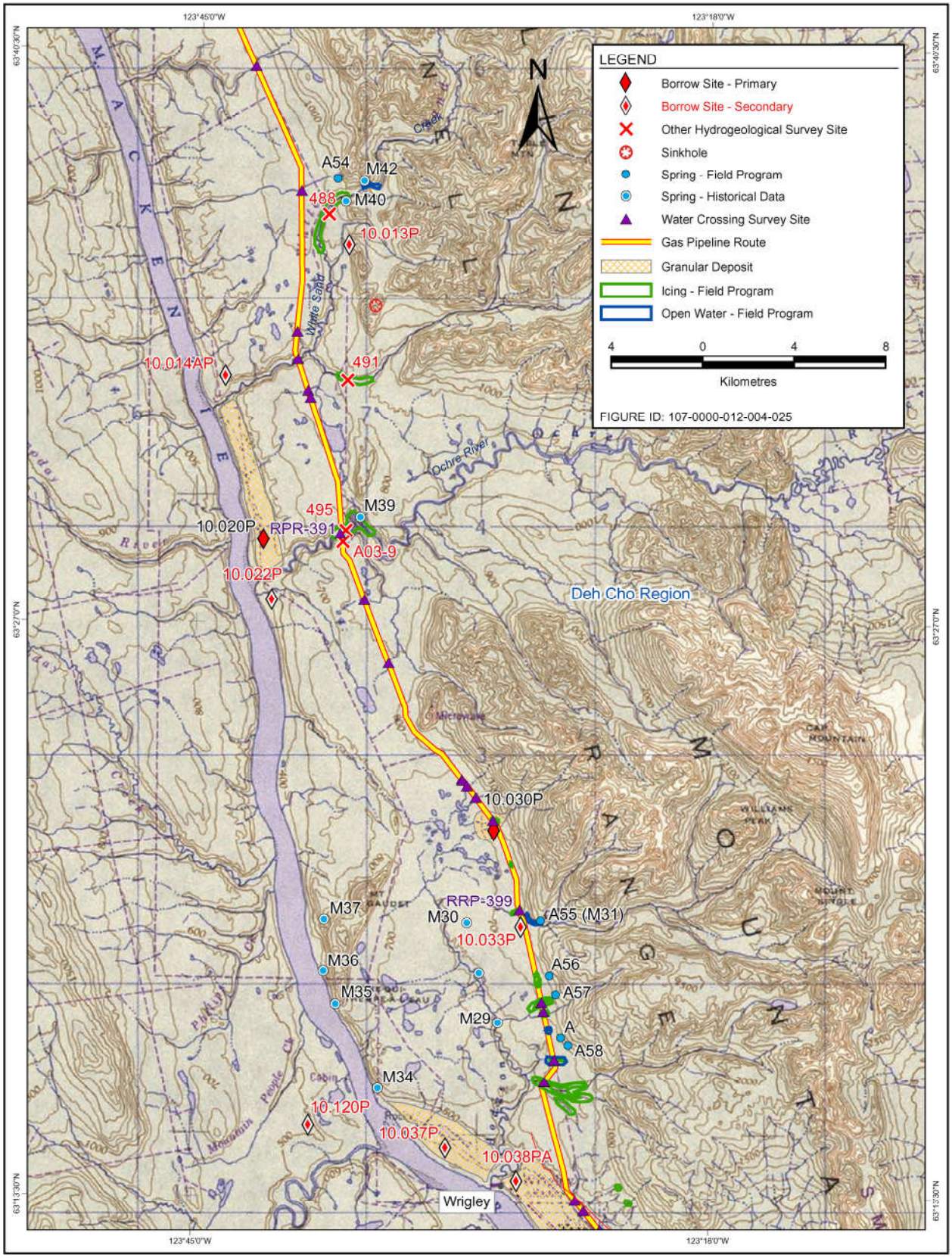


Figure 4-42: Hydrogeological Features – White Sand Creek to Wrigley

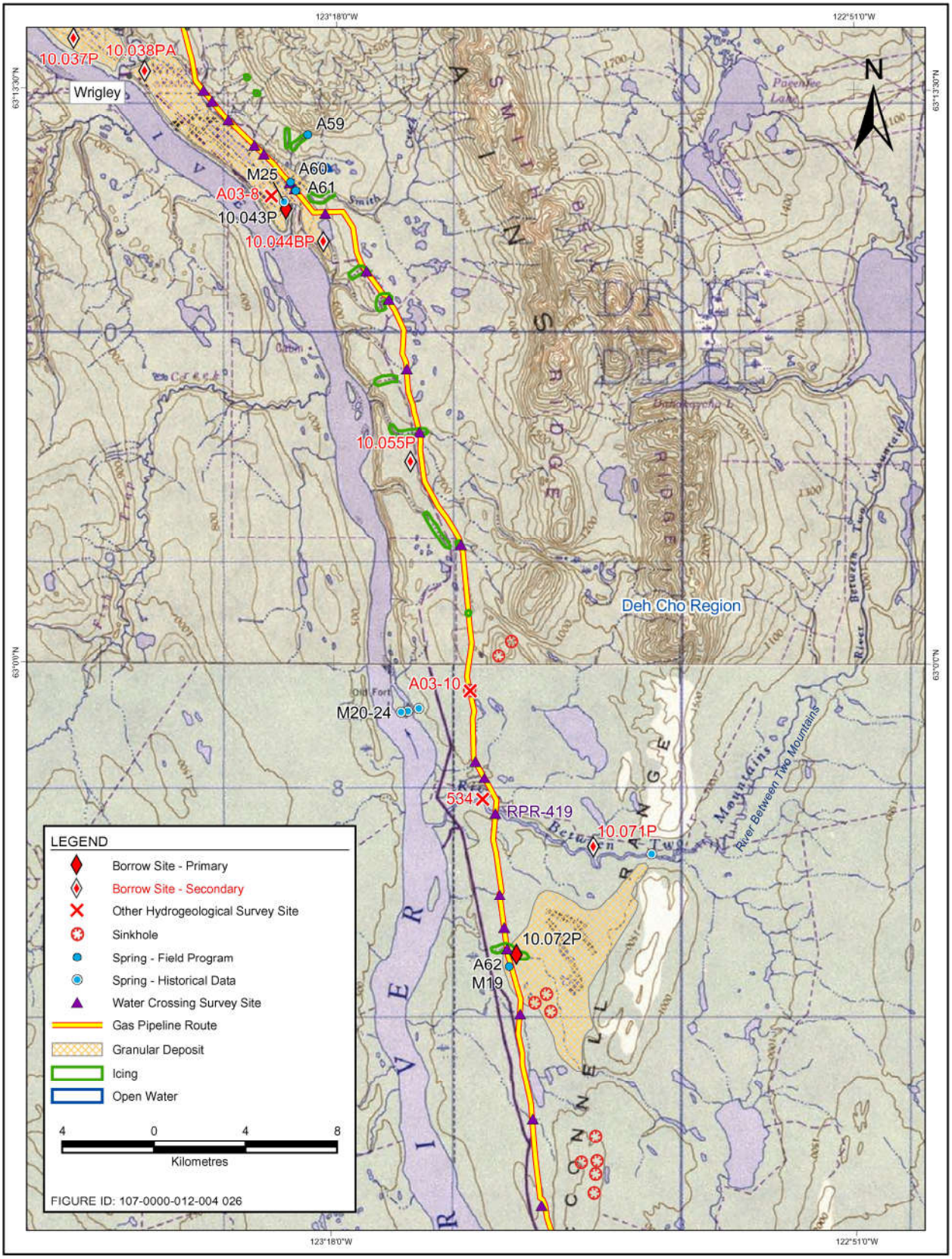


Figure 4-43: Hydrogeological Features – Wrigley to South of River Between Two Mountains

D4 AMEC (2014) Groundwater Sample Chemistry

Table D4.1 Groundwater Results Analytical Summary from AMEC (2014)

Parameter	Units	CCME-PAL	GW001		GW002		GW003		
			22-Jan-13	8-Mar-13	22-Jan-13	7-Mar-13	22-Jan-13	2-Feb-13	8-Mar-13
Physical Tests									
Total Suspended Solids	mg/L		19	2	70	200	14	-	<2
Turbidity	NTU		34.6	7.46	79.3	50.1	14.8	-	23.9
Anions and Nutrients									
p-Alkalinity (as $CaCO_3$)	mg/L		26	29	25	25	8	-	28
Alkalinity, Total (as $CaCO_3$)	mg/L		282	290	312	295	290	283	296
Bicarbonate ($HCO_{3)}$	mg/L		280	284	320	300	336	310	293
Carbonate (CO_3)	mg/L		31	34	30	30	9	17.2	34
Chloride (Cl)	mg/L	120	6	2	2	1	3	0.91	1
Conductivity (EC)	µS/cm		574	572	589	576	648	578	579
Fluoride	mg/L	0.12	**0.31**	**0.23**	**0.21**	**0.18**	**0.21**	**-**	**0.27**
Hardness (as $CaCO_3$)	mg/L	-	10	5	8	5	12	6.5	5
Hydroxide (OH)	mg/L		<5	<5	<5	<5	<5	<5	<5
Nitrate and Nitrate (as N)	mg/L	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate (as N)	mg/L	13	<0.113	<0.113	<0.113	<0.113	<0.113	<0.050	<0.113
Nitrite (as N)	mg/L	0.197	<0.015	<0.015	<0.015	<0.015	<0.015	<0.050	<0.015
Total Kjeldahl Nitrogen	mg/L	-	0.21	0.10	0.24	0.24	0.22	-	<0.05
pH	pH	6.5-9	**9.23**	**9.25**	**9.14**	**9.23**	8.94	8.82	**9.24**
TDS	mg/L	-	360	345	355	370	320	360	330
TDS (Calculated)	mg/L	-	348	340	357	338	342	331	339
Sulphate (SO4)	mg/L	-	36	26	23	24	25	19.6	22
Nitrite	mg.L	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Parameter	Units	CCME-PAL	GW001		GW002		GW003		
			22-Jan-13	8-Mar-13	22-Jan-13	7-Mar-13	22-Jan-13	2-Feb-13	8-Mar-13
Dissolved Metals									
Aluminum (Al)- Dissolved	mg/L	0.1	**0.208**	0.011	**0.581**	0.016	0.021	<0.0050	0.033
Antimony (Sb) – Dissolved	mg/L	-	0.002	0.001	0.001	<0.001	0.002	<0.00040	<0.001
Arsenic (As) – Dissolved	mg/L	0.005	**0.005**	0.004	0.004	0.002	**0.006**	<0.00040	<0.001
Barium (Ba) -Dissolved	mg/L	-	<0.05	<0.05	<0.05	<0.05	<0.05	0.0084	<0.05
Boron (B)	mg/L	-	0.03	0.07	0.07	0.07	0.07	0.056	0.07
Cadmium (Cd) – Dissolved	mg/L	0.00001	**0.000074**	**0.000025**	**0.000018**	<0.000016	**0.000026**	<0.00010	<0.000016
Calcium (Ca) – Dissolved	mg/L	-	3.4	2.2	2.8	2.1	4	2.38	2.1
Chromium (Cr) – Dissolved	mg/L	0.0089	0.002	0.002	0.002	0.001	<0.001	<0.0050	0.003
Copper (Cu) – Dissolved	mg/L	0.002	**0.018**	<0.002	**0.003**	<0.002	**0.002**	<0.00010	<0.002
Iron (Fe) – Dissolved	mg/L	0.3	**0.3**	<0.1	**0.3**	<0.1	<0.1	<0.010	<0.1
Lead (Pb) – Dissolved	mg/L	-	0.002	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.001
Magnesium (Mg) – Dissolved	mg/L	-	0.4	<0.2	0.3	<0.2	0.5	0.13	<0.2
Manganese (Mn) – Dissolved	mg/L	-	0.014	0.005	0.015	<0.005	0.006	0.0038	<0.005
Mercury (Hg) – Dissolved	mg/L	0.000026	<0.000025	<0.000025	<0.000025	<0.000025	<0.000025	<0.000025	<0.000025
Molybdenum (Mo) – dissolved	mg/L	0.073	0.004	0.005	0.004	0.004	0.006	-	0.003
Nickel (Ni) – Dissolved	mg/L	0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.0020	<0.01
Potassium (K) -Dissolved	mg/L	-	<0.6	<0.6	<0.6	<0.6	0.6	0.2	<0.6
Selenium (Se) – Dissolved	mg/L	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.00040	<0.001
Silver (Ag) – Dissolved	mg/L	0.001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Sodium (Na) – Dissolved	mg/L	-	133	136	141	134	135	138	136
Strontium (Sr) - Dissolved	mg/L	-	-	0.016	-	-	-	-	0.014
Thallium (Tl) – Dissolved	mg/L	0.0008	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-	<0.0005

Parameter	Units	CCME-PAL	GW001		GW002		GW003		
			22-Jan-13	8-Mar-13	22-Jan-13	7-Mar-13	22-Jan-13	2-Feb-13	8-Mar-13
Uranium (U) – Dissolved	mg/L	0.015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.00010	<0.001
Zinc (Zn) – Dissolved	mg/L	0.03	**0.038**	0.003	0.005	0.001	0.002	<0.0030	0.004
Speciated Metals									
Hexavalent Chromium	mg/L	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	-	<0.0010
Methyl Mercury – Dissolved	µg/L		<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	-	<0.000050
Methyl Mercury – Total	µg/L		<0.0000025	<0.0000025	<0.0000025	<0.0000025	<0.0000025	-	<0.0000025
Volatile Organic Compounds									
Benzene	mg/L	0.37	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Ethylbenzene	mg/L	0.09	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Toluene	mg/L	-	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Xylenes	mg/L	-	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
F1 (>C10-16)	mg/L	-	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
F1-BTEX	mg/L	-	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Hydrocarbons									
F2 (>C10-C16)	mg/L	-	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
F3 (C16-C34)	mg/L	-	0.1	0.2	<0.1	<0.1	0.2	<0.1	<0.1
F4 (C34-C50)	mg/L	-	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Polycyclic Aromatic Hydrocarbons									
Acenaphthylene	mg/L	0.0058	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	-	<0.00001
Acenaphthylene	mg/L	-	0.00003	<0.00001	<0.00001	<0.00001	<0.00001	-	<0.00001
Acridine	mg/L	0.0044	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		<0.0001
Benzo(a)anthracene	mg/L	0.000018	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	-	<0.00001
Benzo(a)pyrene	mg/L	0.000015	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	-	<0.00001
Benzo(b&j)fluoranthene	mg/L	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	-	<0.00001
Benzo(g,h,i)perylene	mg/L	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	-	<0.00001

Parameter	Units	CCME-PAL	GW001		GW002		GW003		
			22-Jan-13	8-Mar-13	22-Jan-13	7-Mar-13	22-Jan-13	2-Feb-13	8-Mar-13
Benzofluoranthene	mg/L	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	-	<0.00001
Chrysene	mg/L	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	-	<0.00001
Dibenzo(a,h)anthracene	mg/L	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	-	<0.00001
Fluorene	mg/L	0.003	0.00009	<0.00001	<0.00001	<0.00001	<0.00001	-	<0.00001
Indeno(1,2,3-cd_pyrene	mg/L	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	-	<0.00001

Notes:
Table adapted from AMEC (2014)
CCME-PAL is Canadian Council for Ministers of the Environment and Water Quality Guidelines for Protection of Aquatic Life
Red bold indicates the results exceed the CCME guidelines

The groundwater from GW001 and GW002 was tested in January and March of 2013 and GW003 was tested in January, February, and March of 2013 and provide a sample of groundwater within the Summit Formation. The results are summarized in Table D4.1. The results were compared to the Canadian Council for Ministers of the Environment Water Quality Guidelines for Protection- " of Aquatic Life (CCME, 2012). Some dissolved metals were found to be in exceedance of the guidelines in GW001 – GW003 including aluminum, arsenic, cadmium, copper, iron and zinc. These are possibly from natural sources such as the bedrock. There was also exceedances in the pH and fluoride in these wells (AMEC, 2014). These are thought to be from natural sources as well. Inorganic fluoride is often found in the bedrock in fluoride containing minerals that are leached by groundwater (CCME, 2002).

APPENDIX 15C

Mackenzie Valley Highway:
Desktop-based Assessment of Water Availability

Mackenzie Valley Highway: Desktop-based Assessment of Water Availability

Prepared for:

Department of Infrastructure, Government of the Northwest Territories
Yellowknife, NT

Prepared by:

K'alo-Stantec Limited
P.O. Box 176
Tulita, NT

Janaury 26, 2023

Project No.: 144903284

K'alo-Stantec

Executive Summary

Water volumes available for withdrawal have been assessed for 22 watercourses and 24 waterbodies along the proposed Mackenzie Valley Highway (MVH) alignment, spanning roughly from Wrigley, Northwest Territories (NT) to Norman Wells.

For the purposes of this document, a watercourse is defined as surface water that flows in a natural defined channel (e.g., creeks, streams, and rivers), and a waterbody is "*any water-filled basin that is potential fish habitat. A waterbody is defined by the ordinary high water mark of the basin, and excludes connecting watercourses*" (DFO 2010).

Water will be used for construction-related activities, compaction, and dust control in winter and non-winter periods. The amount and timing of water withdrawals are not yet known; however, the majority is anticipated to be needed in early winter (November-December) for winter road construction.

General findings are summarized in the summary figure and summary tables below.

For watercourses, water available for withdrawal was calculated as 10% of monthly flow in months where discharge is greater than 30% of mean annual discharge (MAD) (DFO 2013) Monthly flows were sourced using regional analysis (n=16), monitored flows (n=5), or reproduced from previously published reports (n=1; Great Bear River near the Mackenzie River).

For watercourses:

- water is likely typically available for withdrawal from approximately from April to October, and not available for withdrawal over winter due to low flows in winter (Summary Table 1).
- the main exception is Great Bear River near the Mackenzie River, where extremely large volumes of water are available year-round due to winter outflow from Great Bear Lake.
- volumes available for withdrawal are likely to be large compared to waterbodies (Summary Figure).
- not all the annual volume available for withdrawal may be useful. Much of this water is available in May when there may be limited water demand and accessibility (Summary Table 1).
- potential sources are relatively spatially extensive. For example, the largest gap between watercourses is about 41 km (Gotcha to Big Smith creeks; Summary Table 1).
- water availability generally scales with upstream watershed area and varies by orders of magnitude.

For waterbodies, water available for withdrawal in ice covered periods ('winter') was evaluated using criteria intended to protect oxygen levels under ice for fish (DFO 2010) and littoral habitat (MVLWB 2021a; MVLWB 2021b). Conservative potential withdrawals in ice covered periods are calculated for lakes with maximum depths greater than 3.0 m as the *lesser of* (1) 10% of the under ice water volume (DFO 2010) and (2) the volume equivalent of 0.1 m of drawdown based on the lake surface area (MVLWB 2021a; MVLWB 2021b). The MVLWB protocol is considered here because it provides guidance for preservation of littoral habitat and because it is regionally applicable; however, its intended use is for small projects.

Water withdrawals in the open water period ('non-winter') are evaluated here using the MVLWB method, since it is intended to preserve littoral zone habitat. The DFO (2010) method is not applied in the open water period since lakes typically experience wind-generated mixing and seasonal overturn which oxygenates the water column.

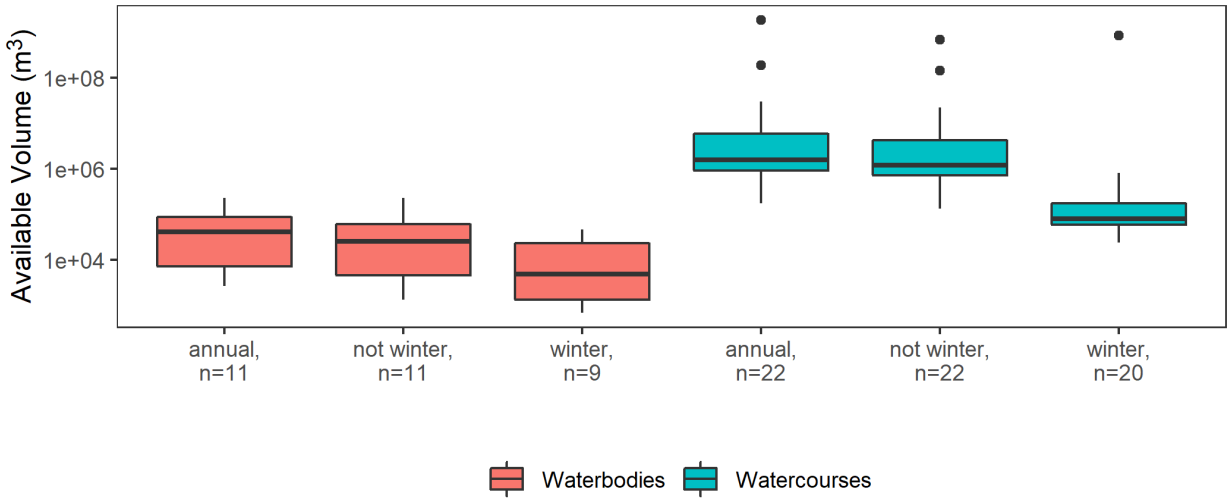
For waterbodies:

- in the ice-covered period there are nine lakes where data are available that meet criteria for winter withdrawals. In the open water period, there are eleven lakes (Summary Table 2).
- volumes available for withdrawal from waterbodies are small compared to watercourses (Summary Figure).
- there are long distances between lakes that meet assessment criteria and where data are available (Summary Table 2).
- additional lakes have been identified as candidates for future bathymetric surveys based on their surface area and depth (where known). However, even if the bathymetry of these lakes is surveyed and the lakes are found to meet withdrawal criteria, large gaps between lakes will remain along the proposed MVH alignment.

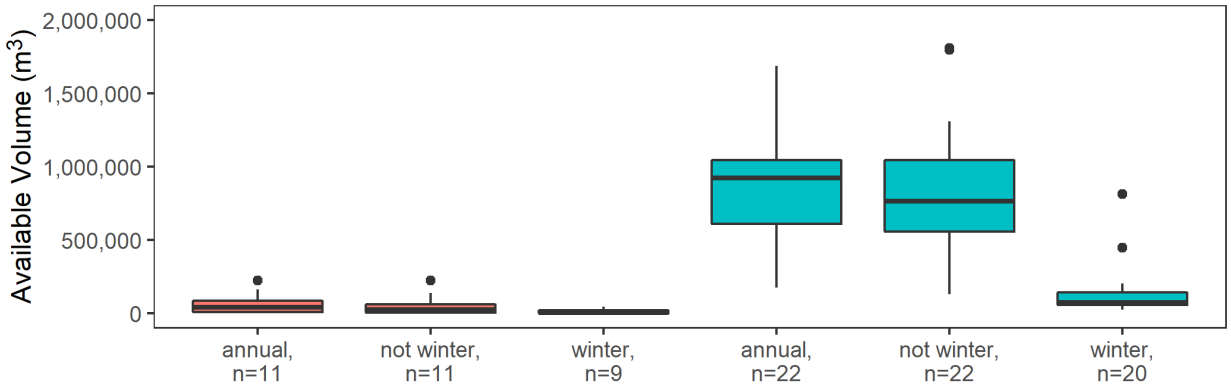
The provided volumes are estimates based on desktop studies. Additional data on a site-specific basis may be required by regulators in support of authorizations. Additional limitations are described in Section 2.

Summary Figure: Summary of Available Water for Withdrawal for Waterbodies and Watercourses

(a) all waterbodies and watercourses (log_{10} y-axis)



(b) waterbodies and watercourses, excluding the largest ten watercourses (linear y-axis)



NOTES:

- Boxplots summarize distributions of available water volumes for all waterbodies or watercourses annually and by season. They show the median (heavy line inside box) and interquartile range (IQR; spanning from 25th to 75th percentiles). The upper whisker extends from the top of the box to the largest value no further than 1.5 * IQR from the lower and upper edges of the box (the 'hinge'). The lower whisker extends from the bottom of the box to the smallest value at most 1.5 * IQR of the hinge. Data beyond the end of the whiskers are outliers and are plotted individually where present (Wickham 2016).
- 'Winter' as used here is November through April and 'not winter' is May through October, which aligns with approximate freeze up and breakup dates for waterbodies in the region.
- Positive outliers in panel A are the Great Bear and Blackwater rivers.
- n = sample size.
- A total of 24 waterbodies were assessed. Results shown here are for those waterbodies where sufficient data were available to calculate water availability or where waterbodies passed withdrawal criteria.
- Except for Great Bear River, watercourses do not have water available for withdrawal over most of the winter (Summary Table 1). However, most smaller watercourses have some water availability in April. One watercourse other than Great Bear River has availability in November (Hodgson Creek).

Summary Table 1: Calculated Water Availability at Assessed Watercourses Along the Proposed Mackenzie Valley Alignment

Watercourse Location	MVH Alignment (km)	Watershed Area (km^2)	Monthly Water Availability (m^3)												Annual Water Availability (m^3)
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Hodgson Creek Bridge	695.6	358	0	0	0	253,860	2,561,344	745,800	781,913	700,817	576,570	386,663	193,710	0	6,200,677
Ochre River Bridge	725.7	1,207	0	0	0	813,120	13,287,561	3,524,820	3,443,046	3,780,326	3,758,520	1,439,857	0	0	30,047,250
Whitesand Creek Bridge	733.8	346	0	0	0	179,340	2,346,545	788,370	524,396	490,668	426,300	313,658	0	0	5,069,277
Big Strawberry Creek Culvert	748.5	59	0	0	0	67,140	511,097	98,280	67,146	73,005	63,240	59,458	0	0	939,366
Small Strawberry Creek Culvert	748.6	49	0	0	0	60,570	435,705	79,050	54,157	59,799	51,780	49,941	0	0	791,002
Vermillion Creek South Bridge	752.3	68	0	0	0	72,630	577,592	116,160	79,174	85,064	73,710	67,952	0	0	1,072,282
Bob's Canyon Creek Culvert	755.3	9	0	0	0	23,880	102,765	10,980	7,719	9,827	8,490	10,323	0	0	173,984
Dam Creek Bridge	764.8	110	0	0	0	94,890	874,200	204,630	138,477	142,786	123,840	106,795	0	0	1,685,618
Blackwater Bridge	785.3	10,716	0	0	0	0	57,512,502	59,656,980	31,846,269	15,246,389	13,791,420	10,055,470	0	0	188,109,030
Steep Creek Bridge	816.5	154	0	0	0	114,390	1,168,204	304,050	204,724	205,158	178,020	146,537	0	0	2,321,083
Devil's Canyon Bridge	828.4	21	0	0	0	37,800	209,870	29,130	20,212	23,994	20,760	22,506	0	0	364,272
Saline River Bridge	831.9	317	0	0	0	170,850	2,176,076	711,180	473,680	446,524	387,900	288,858	0	0	4,655,068
Seagrams Creek Bridge	844.3	57	0	0	0	65,850	496,124	94,380	64,511	70,339	60,930	57,567	0	0	909,701
Little Smith Creek Bridge	852.3	439	0	0	0	204,720	2,880,799	1,043,340	691,486	634,105	551,130	392,336	0	0	6,397,916
Big Smith Creek Bridge	872.1	1,076	0	0	0	0	9,012,816	4,527,960	1,438,524	1,730,141	1,973,850	827,545	0	0	19,510,836
Gotcha Creek Bridge	912.7	155	0	0	0	114,810	1,174,745	306,360	206,274	206,615	179,280	147,436	0	0	2,335,520
Twelve Mile Creek Bridge	922.0	42	0	0	0	55,830	384,028	66,510	45,663	51,057	44,220	43,524	0	0	690,832
Four Mile Creek Culvert	931.5	17	0	0	0	33,630	174,933	22,710	15,810	19,096	16,530	18,445	0	0	301,154
Great Bear River Bridge	937.2	158,400	141,955,200	126,524,160	139,276,800	132,710,400	182,666,880	169,257,600	168,739,200	169,810,560	162,000,000	160,704,000	144,892,800	145,972,800	1,844,510,400
Jungle Ridge Creek Bridge	967.8	60	0	0	0	39,960	550,219	168,660	60,419	78,864	88,890	48,701	0	0	1,035,713
Notta Creek Bridge	971.5	65	0	0	0	70,830	555,582	110,160	75,144	81,034	70,200	65,131	0	0	1,028,081
Vermillion Creek North Bridge	973.4	92	0	0	0	85,920	749,456	165,810	112,530	117,800	102,120	90,272	0	0	1,423,908

NOTES:
Watercourses are sorted from south to north along the proposed MVH alignment.
Zero water availability indicates that discharge in that month is less than 30% of mean annual discharge (DFO 2013).

Summary Table 2: Calculated Water Availability at Waterbodies Along the Proposed MVH Alignment

Waterbody	Alignment (km)	Surface Area (m^2)	Available Volume (m^3)		
			Winter	Not winter	Annual
WR2	702.2	364,955	4,277	36,496	40,773
WR6	804.0	796,473	682	79,647	80,330
WR8	820.0	251,743	25,174	25,174	50,349
WR10	835.0	13,160	1,316	1,316	2,632
WR16	882.5	56,631	4,899	5,663	10,562
WR18	892.0	1,385,441	22,937	138,544	161,481
WR19	903.0	35,950	1,181	3,595	4,776
WR22	916.0	2,254,359	0	225,436	225,436
WR21	921.3	30,606	0	3,061	3,061
WR25	944.6	461,128	46,113	46,113	92,226
WR28	950.4	204,493	20,449	20,449	40,899

NOTES:

- A total of 24 waterbodies were assessed. Results shown here are for those waterbodies where sufficient data were available to calculate water availability or where waterbodies passed withdrawal criteria.
- 'Winter' as used here is November through April and 'not winter' is May through October, which aligns with approximate freeze up and breakup dates for waterbodies in the region.
- There is zero reported water availability for WR21 and WR22 in winter because volume data are not available for these waterbodies.

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Abbreviations

A.	watershed area
b.	regression line intercept
BCOGC.	British Columbia Oil and Gas Commission
e.g.	example
DFO	Fisheries and Oceans Canada
EFN	Environmental Flow Needs
ENV	Ministry of Environment and Climate Change Strategy
FLNRORD	Ministry of Forests, Lands, Natural Resource Operations and Rural Development
GBR	Great Bear River
i.e.	that is to say
IQR	Inter Quartile Range
m	regression line slope
MAD	Mean Annual Discharge
masl	Metres Above Sea Level
MVH	Mackenzie Valley Highway
MVLWB	Mackenzie Valley Land and Water Board
MVWR	Mackenzie Valley Winter Road
n	sample size
NHC	Northwest Hydraulic Consultants
NT	Northwest Territories
PCAR	Prohibition Creek Access Road
Q	Discharge
QAQC	Quality Assurance/Quality Control
TOR	Terms of Reference
WSC	Water Survey of Canada

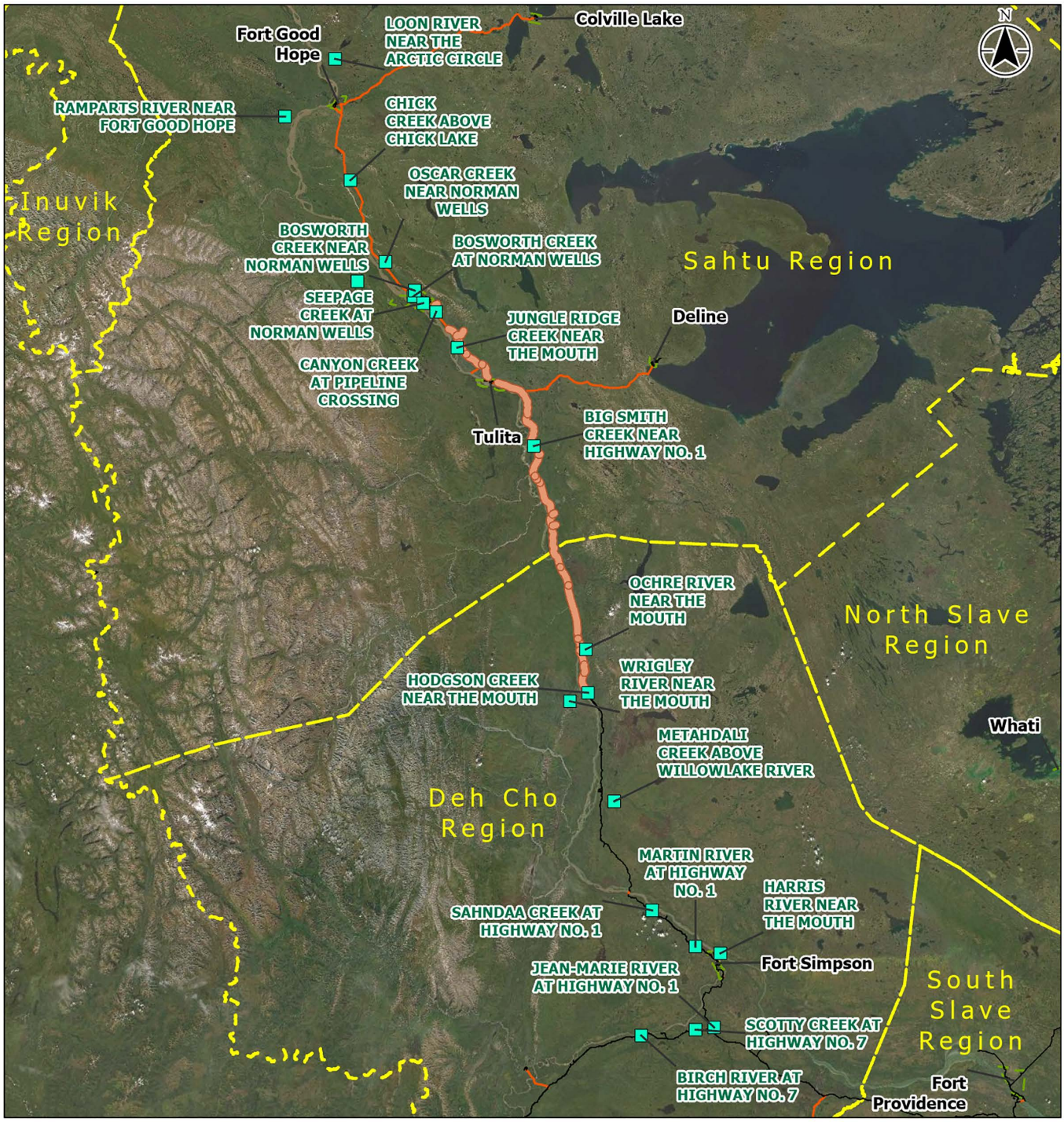
1 Introduction

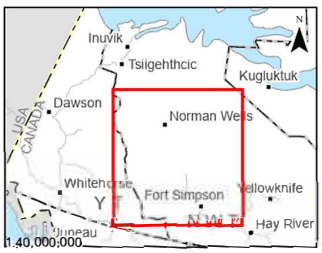
This document provides flow and water withdrawal volume estimates for watercourses and waterbodies near the proposed Mackenzie Valley Highway alignment (MVH; Figure 1.1) identified for assessment as potential water sources for construction and operations of the MVH. The assessed area spans roughly from Wrigley, Northwest Territories (NT) in the south to Prohibition Creek, 18 kilometres (km) south of Norman Wells, NT in the north (an approximately 260 km straight line distance). The proposed MVH alignment distance between the southernmost and northernmost assessed sites is about 275 km (the 'Study Area'). The proposed alignment typically parallels the east bank of the Mackenzie River, mostly along the alignment of the Mackenzie Valley Winter Road (MVWR). Watercourse crossings and water availability between Prohibition Creek and Norman Wells are published elsewhere (K'alo-Stantec 2022a). Twenty-two watercourses and twenty-four waterbodies were evaluated for potential future water withdrawals within approximately 500 m of the proposed MVH alignment between Wrigley and Prohibition Creek (Figure 1.2, Figure 1.3). These sources were identified based on their size and proximity to the alignment. Larger waterbodies and all watercourses with existing bridge crossings were included in the study.

The objectives and scope of the study are to:

- Review potential water withdrawal sources along the proposed MVH alignment.
- Review existing available data to identify sources that are likely to support water withdrawal (based on watershed, flow data, hydrographs, etc.) during certain times of the year.
- Identify monthly and/or seasonal withdrawal magnitudes that are likely to meet environmental flow needs (EFN); i.e., the volume and timing of water flow required for proper functioning of the aquatic ecosystem. EFN criteria were assessed and applied from the Mackenzie Valley Land and Water Board (MVLWB), Fisheries and Oceans Canada (DFO), Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD), and the Ministry of Environment and Climate Change Strategy (ENV) (FLNRORD and ENV 2022; DFO 2013; DFO 2010).
- Identify additional studies required to verify the findings of this desktop study (Section 7) and to support environmental assessment and licensing of water withdrawal.

During construction and operation of the MVH, water will be used for winter road construction, compaction, and dust control. The amount and timing of water withdrawals are not yet known. This document aims to research potential water withdrawal sources that could support withdrawals throughout the year while meeting EFN, and therefore could be supported by regulators for purpose of licensing. It is understood that the majority of water for winter road construction is needed in early winter (November–December); whereas water is used for compaction and dust control from June to September (Stevens, pers. comm., 2022).





Notes
1. Coordinate System: NAD83 Northwest Territories Lambert
2. Data Sources: Government of Northwest Territories, Open Data Canada, Government of Canada, ESRI Base Layers

- Water Survey of Canada Hydrometric Station
- Winter Road
- All Weather Road
- Project Alignment
- Region Boundary
- Community Boundary

0 40 80 120 160 km

1:3,847,888 (at original document size of 8.5x11)

Stantec

Project Location: Northwest Territories, Canada

Project Number: <144903284>
Prepared by EHERTZMAN on 20220908
Requested by TLEWIS on 20220908

Client/Project/Report
Mackenzie Valley Highway
Mackenzie Valley Highway: Desktop Based Assessment of Water Availability

Figure No.
1.1

Title
Mackenzie Valley Highway Proposed Alignment: Regional Map and Selected Water Survey of Canada Stations

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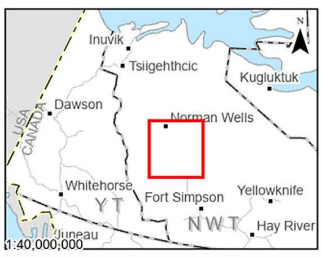

Notes
1. Coordinate System: NAD83 Northwest Territories Lambert
2. Data Sources: Government of Northwest Territories, Open Data Canada, Government of Canada, ESRI Base Layers

Prediction Type
- Regional Analysis (MVH)
- Regional Analysis (PCAR)
- WSC Scaling
- NHC
- Winter Road
- All Weather Road
- Project Alignment
- Region Boundary
- Community Boundary

0 10 20 30 40 km
1:1,600,000 (at original document size of 8.5x11)

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Project Location:
Northwest Territories, Canada

Project Number: <144903284>
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Mackenzie Valley Highway
Mackenzie Valley Highway: Desktop Based Assessment of Water Availability

Figure No.
1.2

Title
Potential Watercourse Water Sources along the Mackenzie Valley Highway Proposed Alignment

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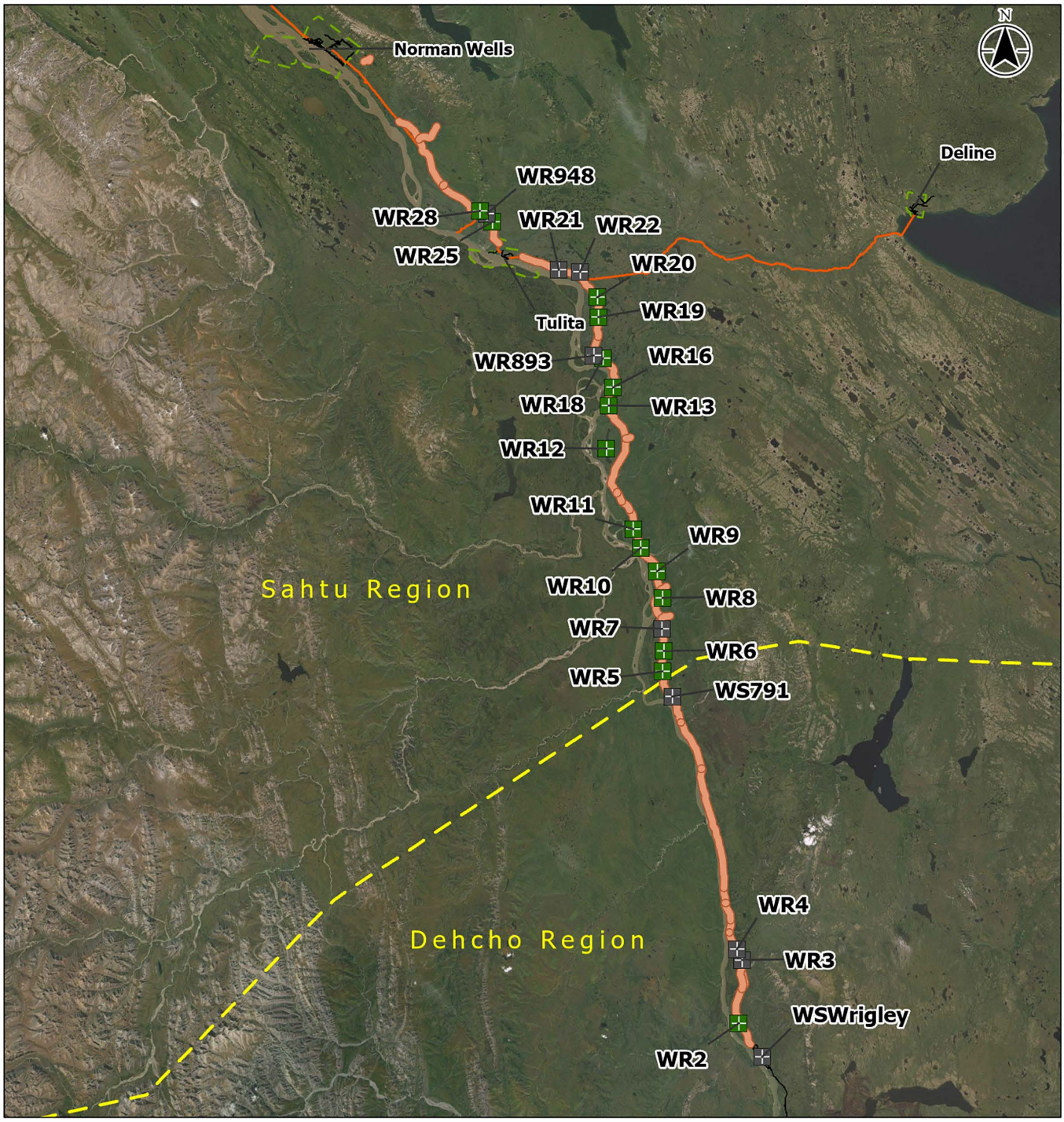

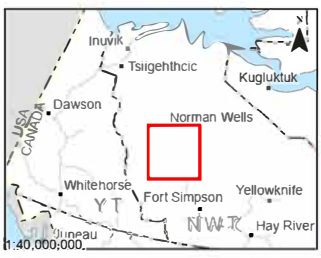

Notes
1. Coordinate System: NAD83 Northwest Territories Lambert
2. Data Sources: Government of Northwest Territories, Open Data Canada, Government of Canada, ESRI Base Layers

Potential Waterbody Water Sources

- Bathymetry Data Available
- No Bathymetry Data Available
- Winter Road
- All Weather Road
- Project Alignment
- Region Boundary
- Community Boundary

0 10 20 30 40 km
1:1,525,000 (at original document size of 8.5x11)

Stantec

Project Location: Northwest Territories, Canada
Project Number: <144903284>
Prepared by EHERTZMAN on 20220908
Requested by TLEWIS on 20220908

Client/Project/Report
Mackenzie Valley Highway
Mackenzie Valley Highway: Desktop Based Assessment of Water Availability

Figure No.
1.3

Title
Potential Waterbody Water Sources near the Mackenzie Valley Highway Proposed Alignment

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For watercourses, this document provides average monthly and annual volumes available for withdrawal designed to meet EFN and Fisheries and Oceans Canada (DFO) protocols (DFO 2013). This requires flows to be known. Of the 22 studied watercourses:

- Five are gauged by the WSC and these gauged data are appropriate for deriving flows at ungauged MVH crossings.
- One is gauged by the WSC, but the gauge is far upstream of the proposed bridge crossing, and several large tributaries contribute to flows between the gauge and the crossing. This site is the proposed bridge over the Great Bear River (GBR) near Tulita and the Mackenzie River. Flow data at this crossing were obtained from previous studies (NHC 2006; NHC 2018).
- Flows at the remaining 16 proposed MVH crossings were calculated using a regional analysis approach based on the principle that streamflow from ungauged basins can be reasonably estimated from gauged basins of similar physiographic, geologic, or climatic factors (MOE 1991). Regional flow analysis was conducted by compiling flow data from 21 regional WSC stations and relating monthly flows to watershed size. Regression equations were then used to predict flows using the watershed area of each ungauged catchment.

For waterbodies, this document provides estimates of water volumes that will protect littoral habitat and oxygenated water for fish in winter, and follows protocols developed by DFO (DFO 2010) and the Mackenzie Valley Land and Water Board (MVLWB; called the 'MVLWB method' here) (MVLWB 2021a; MVLWB 2021b). Recommendations are made for withdrawal protocols from waterbodies that could protect flows in downstream watercourses (Section 6.3, Section 7).

2 Limitations

Flows, water volumes, and water withdrawals provided here are estimates. Most studied withdrawal sources are ungauged, and bathymetric surveys have not yet been conducted at many waterbodies. Results are approximations and are intended to focus efforts on watercourses, waterbodies, and seasons where withdrawals will have the least ecological impacts. Limitations include:

- Flows and water volumes provided here are not precise assessments of water availability in a given year. Flow predictions are reflective of average conditions in the years regional data were collected.
- Flows during floods and changes in flow due to climate change have been evaluated elsewhere (Tetra Tech 2021; Tetra Tech 2022; Tetra Tech 2020; K'alo-Stantec 2021).
- Results presented here should not be used for purposes other than those stated. For example, data presented here do not provide engineering design parameters. Engineering design and analysis of crossings (e.g., conveyance capacity and channel stability) would require a separate study tailored for such purposes.
- Analysis and recommendations are based on data available at the time of the report and rely on data provided by others which we assume to be correct but were not verified as part of this study.
- Cumulative withdrawals are not accounted for here.
- Results provided here do not consider potential effects on specific species of interest, cultural values, or on downstream flows (Section 6.3 and Section 7).
- Further site-specific study or evaluation may be required to support regulatory approval for water withdrawal.
- Changes in flows and water availability due to backwatering have not been considered. Backwatering causes river levels to rise independently from discharge, often in response to a downstream obstruction (e.g., ice, beaver dams), or a downstream waterbody or watercourse.

Recommendations for refining estimates provided here are presented in Section 6.3 and Section 7.

3 Regional Hydroclimatic Context

The watercourses and waterbodies evaluated in this study are located between approximately Wrigley, NT in the south to Prohibition Creek in the north (Figure 1.1) and are within about 500 m of the proposed MVH alignment. Climate at the northern and southern ends of the alignment is summarized in Table 3.1. Overall, climatic normal conditions (1991-2020) are similar at the southern and northern ends of the Study Area (Table 3.1). Air temperatures cool slightly from south to north. Annual total precipitation decreases slightly, i.e., by about 2%. Potential evapotranspiration (ET) increases by about 3%. These north-south differences are negligible from a hydrologic perspective. At both locations. ET exceeds precipitation (Wang 2022; Wang et al. 2012; K'alo-Stantec 2022a); i.e., there is a potential annual moisture deficit in the region.

Table 3.1 Summary Climate Data from Norman Wells and Wrigley, NT

Community	Elevation (masl)	Air Temperature (°C)			Annual Total Precipitation (MAP, mm)	Annual Total Potential Evapotranspiration (ET, mm)	MAP-ET (mm)
		Mean Annual	Maximum	Minimum			
Norman Wells	72	-4.5	16.4	-24.3	323	389	-66
Wrigley	150	-3.6	17.1	-25.4	316	401	-85
Difference (Wrigley-Norman Wells)	**78**	**0.9**	**0.7**	**-1.1**	**-7**	**12**	**-19**
Difference (%; Wrigley-Norman Wells)	**n/a**	**n/a**	**n/a**	**n/a**	**-2**	**3**	**n/a**

NOTES:
Elevations in metres above sea level (masl) are at the airstrip in both communities.
Climate data are interpolated 1991 to 2020 climate normals from ClimateNA (Wang 2022).
Evapotranspiration (ET) is Hargreaves reference potential ET.
Maximum and minimum air temperatures are monthly averages for the warmest and coolest months.
n/a = not applicable.

Climate normal data used here are from ClimateNA, which uses peer-reviewed gridded climate data (Wang 2022; Wang et al. 2012). This data source was selected over station data (ECCC 2022a) because (a) climate normal data are available from Wrigley which allowed assessment of north-south climate trends along the proposed alignment, and (b) because it provides evapotranspiration data from land surfaces, while climate normal data from stations do not. There are therefore slight differences between climate normal data presented here from gridded datasets, and climate normal data presented elsewhere based on station data (K'alo-Stantec 2022b).

The Study Area is within the 'extensive discontinuous' (50-90%) permafrost zone (GNWT 2022a). Most of the Study Area falls within the 'Taiga Plains, Norman Range LS Ecoregion'; vegetation is a "*complex of mixed-wood forests on westerly slopes and lacustrine deposits, mixed spruce stands on the interior plateau and slopes, and extensively burned areas*" (GNWT 2009). The entirety of the Study Area is south of the tree line (GNWT 2022b).

Elevations in the Study Area decrease generally from south to north (Table 3.1), and close to the Mackenzie River. Watercourses generally drain westward from highlands to the east towards the Mackenzie River.

The Study Area is part of the Dehcho and Sahtu regions. Runoff patterns in both regions are similar and are classified as nival, i.e., a "*large portion of the annual precipitation is stored for several months in the form of snow and therefore snowmelt runoff in spring is a dominant feature of regional stream hydrographs*" (Kokelj 2001). The period of snowmelt runoff in spring is called freshet, and typically starts in May. Flows decline after freshet, with occasional increases in response to rainfall, then decline through winter (October to April). The ability of a watercourse in the region to sustain flows over winter depends watershed area as well as "*watershed-specific factors including precipitation, channel slope, upland storage and particularly the presence of springs*" (Golder Associates 2006). Watersheds larger than 50-100 km^2 may be perennial (MGP 2004; K'alo-Stantec 2021).

Annual runoff changes outside of the Study Area. For example, runoff increases to the west of the Mackenzie River in the Mackenzie Mountains, decreases to the east towards Great Bear Lake, and north towards the Arctic Ocean (Cole 2013).

Precipitation and ET are similar at the northern and southern ends of the Study Area (Table 3.1). This helps explain the north-south similarity of runoff noted above.

Gauged runoff in the Sahtu region spans from 60 to about 330 mm/year, not including stations in the Mackenzie Mountains (Kokelj 2001). In the Dehcho region, the Study Area falls within the 'Interior plains' regime, where annual runoff at gauging stations spans from 55 to almost 200 mm (Faria 2002). Mean annual runoff in the Study Area was found to range between 151 and 220 mm (K'alo-Stantec 2021). Differences among published ranges may be more reflective of local site conditions and the relatively sparse gauging network than general spatial hydroclimatic trends (e.g., storage in muskeg and lakes that locally affects the timing and magnitude of flows).

4 Methods

Methods are described below for watercourses and waterbodies. Each section begins by presenting regionally applicable criteria for water withdrawals, then provides the methodologies used to assess these criteria at candidate withdrawal sites.

The MVH alignment used here is the IFAE21 alignment, and KPs cited here are relative to this. Data were collected, filtered, analyzed, and plotted using R (R Core Team 2022).

4.1 Watercourses

For the purposes of water availability calculations, all watercourses are conservatively considered to be potential fish habitat.

4.1.1 Criteria for Assessment of Environmental Flow Needs in Watercourses

For watercourses, DFO guidance (DFO 2013) is:

- "*cumulative flow alterations of less than +/- 10% of the magnitude of actual (instantaneous) flow in the river relative to a "natural flow regime" have a low probability of detectable negative impacts to ecosystems*"; and
- "*cumulative flow alterations that result in instantaneous flows less than 30% of the Mean Annual Discharge (MAD) have a heightened risk of impacts to ecosystems that support fisheries*". Periods below 30% MAD were identified as 'highest risk'.

Mean monthly flows are predicted here in place of instantaneous flows as a desktop-based means of estimating monthly and annual low risk withdrawals. MAD is calculated from mean monthly flows to identify the months with the 'highest risk'. This approach allows for: (a) an assessment of which months are likely candidates for low-risk water withdrawal; and (b) an estimation of water available for withdrawal during low-risk conditions.

Flow data are required to apply these criteria and calculate water availability. Flow and water availability methodologies are described below.

4.1.2 Calculation of Volumes Available for Withdrawal in Watercourses

Volumes of water potentially available for withdrawal were calculated using criteria described above (DFO 2013). Application of these criteria require flow data. Methodologies for compiling and calculating flow data are described below.

Table 4.1 Mackenzie Valley Highway Watercourse Crossings where Water Availability was Assessed

Watercourse Location	MVH Alignment (km)	UTM			Region	Watershed Area (km^2)	Watershed Area Source	Prediction Type
		Easting (m)	Northing (m)	Zone				
Hodgson Creek Bridge	695.6	475,755	7,011,710	10	Dehcho	358	(K'alo-Stantec 2021)	WSC Scaling
Ochre River Bridge	725.7	465,971	7,038,047	10	Dehcho	1,207	(K'alo-Stantec 2021)	WSC Scaling
Whitesand Creek Bridge	733.8	463,508	7,045,441	10	Dehcho	346	(K'alo-Stantec 2021)	Regional Analysis
Big Strawberry Creek Culvert	748.5	459,694	7,059,416	10	Dehcho	59	(K'alo-Stantec 2021)	Regional Analysis
Small Strawberry Creek Culvert	748.6	459,640	7,059,510	10	Dehcho	49	herein	Regional Analysis
Vermillion Creek South Bridge	752.3	457,967	7,062,906	10	Dehcho	68	(K'alo-Stantec 2021)	Regional Analysis
Bob's Canyon Creek Culvert	755.3	456,550	7,065,460	10	Dehcho	9	(Tetra Tech 2020)	Regional Analysis
Dam Creek Bridge	764.8	452,501	7,074,004	10	Dehcho	110	(K'alo-Stantec 2021)	Regional Analysis
Blackwater Bridge	785.3	443,181	7,091,526	10	Dehcho	10,716	(K'alo-Stantec 2021)	WSC Scaling
Steep Creek Bridge	816.5	432,421	7,118,214	10	Sahtu	154	(K'alo-Stantec 2021)	Regional Analysis
Devil's Canyon Bridge	828.4	430,299	7,128,819	10	Sahtu	21	(K'alo-Stantec 2021)	Regional Analysis
Saline River Bridge	831.9	427,270	7,130,500	10	Sahtu	317	(K'alo-Stantec 2021)	Regional Analysis
Seagrams Creek Bridge	844.3	421,623	7,141,075	10	Sahtu	57	(K'alo-Stantec 2021)	Regional Analysis
Little Smith Creek Bridge	852.3	416,273	7,146,420	10	Sahtu	439	(K'alo-Stantec 2021)	Regional Analysis
Big Smith Creek Bridge	872.1	413,214	7,163,972	10	Sahtu	1,076	(K'alo-Stantec 2021)	WSC Scaling
Gotcha Creek Bridge	912.7	400,354	7,196,273	10	Sahtu	155	(K'alo-Stantec 2021)	Regional Analysis
Twelve Mile Creek Bridge	922.0	392,054	7,198,761	10	Sahtu	42	herein	Regional Analysis
Four Mile Creek Culvert	931.5	382,829	7,200,812	10	Sahtu	17	(K'alo-Stantec 2021)	Regional Analysis
Great Bear River	937.2	377,381	7,201,412	10	Sahtu	158,400	(NHC 2006; NHC 2018)	NHC
Jungle Ridge Creek Bridge	967.8	638,257	7,218,483	9	Sahtu	60	(K'alo-Stantec 2021)	WSC Scaling
Notta Creek Bridge	971.5	636,476	7,221,655	9	Sahtu	65	(K'alo-Stantec 2021)	Regional Analysis
Vermillion Creek North Bridge	973.4	634,748	7,222,289	9	Sahtu	92	(K'alo-Stantec 2021)	Regional Analysis

NOTES:
UTM coordinates use the WGS84 datum and are approximate.
Watercourses are sorted from south to north.
Watershed delineation methodologies for this document are described in Section 4.1.2.2. 'Watershed Area Sources' noted as 'herein' were calculated as part of this study.
'Prediction types' are described in the text.

4.1.2.1 Flow Estimation for Gauged Basins: WSC Scaling

Five candidate watercourses are gauged by the WSC (Table 4.2), not including Great Bear River (Section 4.1.2.3). Where gauged data are available, they were used to assess water availability, rather than deriving them using regional analyses.

WSC stations and studied withdrawal locations are often not at the same location. Scaling factors were produced that relate the watershed area at each WSC station to the watershed area at each bridge crossing (Table 4.2). Monthly average flows from WSC stations were modified by multiplying by scaling factors.

Table 4.2 Gauged Watercourses along the Proposed Mackenzie Valley Highway Alignment

Water Survey of Canada				Existing Bridge Crossing			
Station Name	Station Number	Watershed Area (km^2)	Delineation Source	Crossing Name	Watershed Area (km^2)	Delineation Source	Scaling Factor
HODGSON CREEK NEAR THE MOUTH	10HC007	303	K'alo-Stantec (this document)	Hodgson Creek Bridge	358	K'alo-Stantec (2022)	1.18
OCHRE RIVER NEAR THE MOUTH	10HC008	1,031	K'alo-Stantec (this document)	Ochre River Bridge	1,207	K'alo-Stantec (2022)	1.17
BLACKWATER RIVER AT OUTLET OF BLACKWATER LAKE	10HC006	7,850	ECCC (2022b)	Blackwater Bridge	10,716	K'alo-Stantec (2021)	1.37
BIG SMITH CREEK NEAR HIGHWAY NO. 1	10HC003	980	ECCC (2022b)	Big Smith Creek Bridge	1,076	K'alo-Stantec (2021)	1.10
JUNGLE RIDGE CREEK NEAR THE MOUTH	10KA006	60	ECCC (2022b)	Jungle Ridge Creek Bridge	47	BP-TEC (2002)	0.78

NOTES:
Stations are sorted from south to north.
'Scaling factor' is the watershed area at each crossing divided by watershed area at each WSC station.
Coordinates for each site are provided in Table 4.1 and Table 4.3.

4.1.2.2 Flow Estimation at Ungauged Basins: Regional Analysis

Monthly average flows and water availability were calculated using linear regressions between monthly average flow and watershed area using flow data from regional WSC stations. Regression equations were then used to calculate monthly flows at proposed crossing locations using the upstream watershed areas for these locations.

Daily flow data from WSC stations were compiled with the R library 'Tidyhydat' (Goetz, Albers and Pike 2018). Tidyhydat uses the WSC database 'Hydat' (ECCC 2022b). The Hydat version used here was published on 2022-04-18 and is the most recent database at the time of writing. The most recent finalized data for regional stations is from 2020. Provisional real-time data that have not yet undergone full quality assurance/quality control (QA/QC) were not used here.

Station Selection Methodologies

To develop an applicable dataset for regional analyses and flow predictions of watercourses in the Study Area, a set of selection criteria were developed and applied to regional WSC stations. Hydrometric data were compiled for all WSC stations in the NT, then filtered to include only:

- Stations falling within a 300 km buffer of the proposed MVH alignment. The start and end points of the buffer are Norman Wells in the north and Wrigley in the south.
- Stations with watershed areas up to 7,400 km^2 (set to include WSC stations 10KB001 and 10KD004; Table 4.3). This is larger than the threshold used in a recent water availability study for the Prohibition Creek Access Road (PCAR), where a ~1,000 km^2 upper limit was applied (K'alo-Stantec 2022a). The larger threshold was applied to: (a) provide more applicable predictions for MVH watercourses with larger watersheds (up to about 440 km^2; Table 4.1) compared to PCAR crossings (up to about 86 km^2), and (b) increase the number of regional WSC stations used in analyses in this data-sparse region. Effects of increasing this threshold are assessed in Section 6.2.1. For reference, proposed PCAR crossings are mapped in Figure 1.2.
- Stations with watersheds that do not drain the Mackenzie Mountains, due to the different hydrologic regime there (Golder Associates 2015) (Section 3).
- Stations where discharge is unlikely to be affected by drainage of large upstream lakes or muskeg, potentially causing delays between snowmelt and rainfall, and runoff (Section 3).
- Months (regardless of the year) with greater than or equal to 92 daily observations (i.e., greater than about three years of data per month; Figure 4.1). The statistical validity of using relatively small sample sizes was explored in the PCAR water availability study (K'alo-Stantec 2022a) and is discussed below for the MVH.

WSC stations remaining after applying the filtering process are summarized in Table 4.3, mapped in Figure 1.1, and monthly data availability at each station is presented in Figure 4.1.

Annual runoff is generally relatively uniform in the Study Area (Section 3). However, regional WSC stations that remain following the filtering process described above extend north and south of the Study Area (Figure 1.1). The relatively invariant north-south trends in runoff described in Section 3 also generally apply to these spatial limits. In the south, runoff decreases eastwards along the Mackenzie River between Fort Simpson and Great Slave Lake. In the north, runoff decreases north of Tsiigehtchic (Figure 1.1) (Cole 2013).

Data from three WSC stations[1] were frequently anomalous when flagged as backwatered and were removed from analyses.

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[1] 10KA005 (SEEPAGE CREEK AT NORMAN WELLS), 10LA004 (WELDON CREEK NEAR THE MOUTH), and 10GB005 (METAHDALI CREEK ABOVE WILLOWLAKE RIVER).

Table 4.3 Regional Water Survey of Canada Stations Used for Flow Predictions in the Study Area along the Proposed Mackenzie Valley Highway Alignment

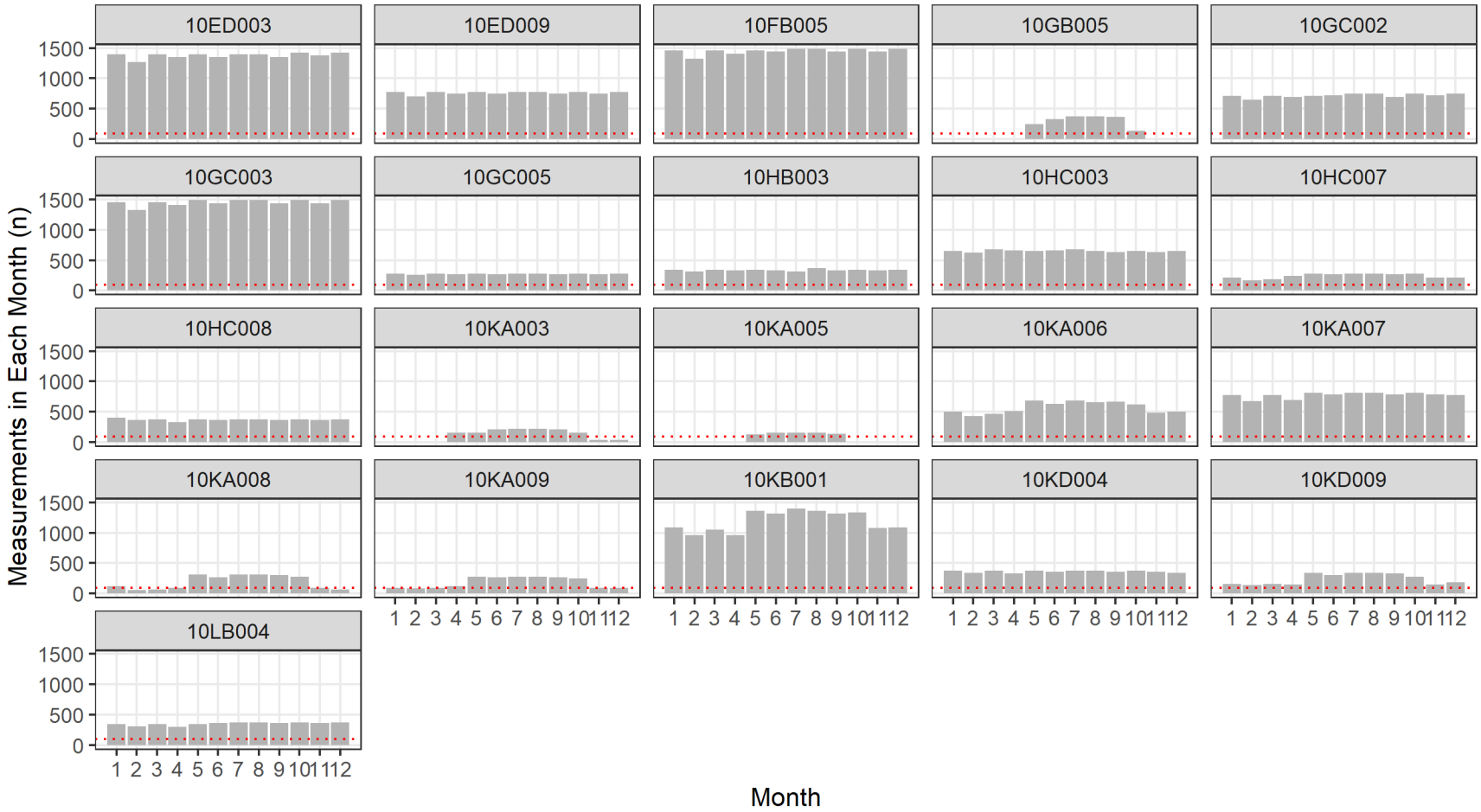
Station Number	Station Name	UTM Easting (m)	UTM Northing (m)	UTM Zone	Drainage Area (km^2)	Location[a] Dist. (km)	Location[a] Bearing (deg)[b]	Monitoring Period Begins	Monitoring Period Ends	Data Points (n)[c]
10ED003	BIRCH RIVER AT HIGHWAY NO. 7	548,472	6,800,280	10	542	434	155	1974	2019	16,528
10ED009	SCOTTY CREEK AT HIGHWAY NO. 7	582,393	6,810,134	10	202	440	150	1995	2019	9,131
10FB005	JEAN-MARIE RIVER AT HIGHWAY NO. 1	593,943	6,813,683	10	1,310	442	148	1972	2019	17,380
10GB005	METAHDALI CREEK ABOVE WILLOWLAKE RIVER	504,798	6,946,566	10	344	283	151	1976	1987	4,201
10GC002	HARRIS RIVER NEAR THE MOUTH	589,613	6,861,617	10	701	399	146	1972	1995	8,584
10GC003	MARTIN RIVER AT HIGHWAY NO. 1	572,957	6,863,145	10	2,050	389	148	1972	2019	17,411
10GC005	SAHNDAA CREEK AT HIGHWAY NO. 1	541,293	6,881,332	10	251	358	151	1982	1990	3,287
10HB003	WRIGLEY RIVER NEAR THE MOUTH	465,247	7,005,398	10	1,230	213	154	1977	1988	4,018
10HC003	BIG SMITH CREEK NEAR HIGHWAY NO. 1	413,224	7,164,281	10	980	50	133	1973	1994	7,820
10HC007	HODGSON CREEK NEAR THE MOUTH	475,833	7,012,887	10	**303**	211	150	2006	2014	2,896
10HC008	OCHRE RIVER NEAR THE MOUTH	469,488	7,040,295	10	**1,031**	184	148	2006	2019	4,412
10KA003	BOSWORTH CREEK AT NORMAN WELLS	599,129	7,242,508	9	122	75	-54	1973	1979	1,375
10KA005	SEEPAGE CREEK AT NORMAN WELLS	606,333	7,239,786	9	31	68	-53	1974	1978	1,614
10KA006	JUNGLE RIDGE CREEK NEAR THE MOUTH	635,408	7,217,955	9	60	31	-56	1980	2018	6,796
10KA007	BOSWORTH CREEK NEAR NORMAN WELLS	598,863	7,246,213	9	125	77	-52	1980	2018	9,256
10KA008	OSCAR CREEK NEAR NORMAN WELLS	575,639	7,259,095	9	638	104	-53	2009	2018	2,264
10KA009	CANYON CREEK AT PIPELINE CROSSING	615,995	7,236,583	9	*68*	58	-50	2009	2018	2,199
10KB001	CARCAJOU RIVER BELOW IMPERIAL RIVER	561,399	7,242,010	9	7,400	108	-65	1976	2020	14,321

Table 4.3 Regional Water Survey of Canada Stations Used for Flow Predictions in the Study Area along the Proposed Mackenzie Valley Highway Alignment

Station Number	Station Name	UTM Easting (m)	UTM Northing (m)	UTM Zone	Drainage Area (km^2)	Location[a] Dist. (km)	Location[a] Bearing (deg)[b]	Monitoring Period Begins	Monitoring Period Ends	Data Points (n)[c]
10KD004	RAMPARTS RIVER NEAR FORT GOOD HOPE	487,561	7,332,446	9	7,300	218	-50	1985	1996	4,322
10KD009	CHICK CREEK ABOVE CHICK LAKE	539,521	7,304,005	9	**16**	160	-47	2008	2018	2,870
10LB004	LOON RIVER NEAR THE ARCTIC CIRCLE	508,817	7,377,239	9	2,745	233	-38	2009	2020	4,202

NOTES:
Stations are sorted by station number.
[a] Relative to Tulita, NT.
[b] Bearing is degrees clockwise (+) or counterclockwise (-) from Tulita, NT to the WSC station.
[c] Number of daily observations of flow.
Bolded watershed areas were calculated herein by K'alo-Stantec (see text for methods). The watershed area for Canyon Creek was obtained from hydrotechnical assessment and design documents (Tetra Tech 2021; Tetra Tech 2022).
Coordinates use the WGS84 datum.

Figure 4.1 Histograms for Selected Water Survey of Canada Stations, Showing the Number of Observations in Each Month for the Period of Record



NOTES:
(1) the red horizontal line is at n=92. Months where n<92 at each station were excluded from regression modelling.
(2) Month=1 represents January; Month=12 represents December

Watershed Delineation Methodologies

The regional flow analysis method requires watershed areas for regional WSC stations and for target watercourses. For WSC stations, most watershed areas are available from HYDAT (ECCC 2022b) (Table 4.3). For target crossings, most watershed areas have been published in previous studies (Table 4.1).

Where watershed areas were missing, they were calculated by K'alo-Stantec in ArcGIS. The watershed areas for these stations were calculated using ArcGIS software. National Hydrographic Network basins (Natural Resources Canada 2022) were segmented along topographic ridgelines and flow patterns.

Flow and Water Availability Calculation

Flows were calculated using linear regressions between watershed area and mean monthly discharge for selected regional WSC stations (Table 4.3; Figure 1.2). Discharge and watershed area were log-transformed and regressions were conducted for each month. Watershed area is the predictor and mean monthly flow is the predictand.

Flow data were grouped by station and month, and average flows were retained if at least 92 daily data points remained in each group (Figure 4.1; horizontal red lines). This represents about three years of monitoring in each month if monitoring was continuous. This small sample size threshold may not capture the full range of hydroclimatic variability. Effects of sample size on flow statistics were assessed in the PCAR water availably report; stations with small monthly sample sizes were found to have similar variability as stations with larger samples sizes (K'alo-Stantec 2022a). An assessment of the relationships between sample size and flow variability was also conducted for WSC stations selected here (Table 4.3); variability was also found to be more controlled by site-specific factors than by sample size.

4.1.2.3 Flow Estimation at the Great Bear River near the Mackenzie River: 'NHC' Method

The proposed MVH alignment crosses the GBR near Tulita and the Mackenzie River (Figure 1.2). A WSC gauging station is located on the GBR about 100 km^2 upstream of the proposed crossing, near the outlet of Great Bear Lake (GREAT BEAR RIVER AT OUTLET OF GREAT BEAR LAKE, station number 10JC003). The WSC Scaling approach was not used at this crossing because several large tributaries enter the GBR between the WSC gauge and Tulita, potentially altering the timing and magnitude of flows (NHC 2006; NHC 2018).

The upstream watershed area at the outlet of Great Bear Lake is 145,400 km^2 (ECCC 2022b), and downstream tributaries contribute an additional 12,000 km^2 (NHC 2006; NHC 2018), so the total watershed area at the proposed crossing is about 158,400 km^2. The regional analysis approach used here is also not appropriate for estimating GBR flows because of the extremely large watershed area of both the lake and downstream tributaries.

Monthly flow statistics for the GBR at Tulita have been published (NHC 2006; NHC 2018). These were calculated by combining gauged flows at the WSC station with flows from downstream tributaries estimated using a regional analysis deemed to be appropriate for the scale of the downstream tributaries.

The 50th percentile (median) monthly flow data from this analysis are used here (NHC 2018). Other methodologies used here present monthly mean rather than median flow statistics. Water available from the GBR is likely more constrained by pump capacity than by river flow rates; therefore, this decision is not expected to impact water availability for the Project.

It should also be noted that the Mackenzie River seasonally backwaters into the GBR near the proposed crossing (NHC 2006; NHC 2018). When backwatering occurs, water availability would not be directly related to flows in the GBR. Water availability would increase at these times due to contributions from the Mackenzie River

4.2 Waterbodies

4.2.1 Criteria for Assessment of Environmental Flow Needs in Waterbodies

For the purposes of water availability calculations, all waterbodies with open water maximum depths greater than 1.5 m (the maximum ice depth in the region; DFO, 2010) are potential fish habitat. Lakes shallower than this would freeze to ground in winter.

Criteria for withdrawals vary depending on when lakes are ice covered or ice-free. The ice-covered period for lakes in the region spans from approximately November to April (Bigras 1990), though this period has been shortening (Duguay et al. 2006), and larger lakes would be expected to freeze and break up later than smaller lakes due to their larger thermal inertia. Methods for ice-covered periods are applied for November to April, and methods for open water periods are applied for May through October, with the caveat that these should be adjusted where site-specific information is available.

4.2.1.1 Criteria During Periods of Ice-Cover

DFO (2010) Criteria

The proposed alignment is located south of the tree line, but north of Fort Simpson, NT. Maximum ice thickness is expected to be about 1.5 m (DFO 2010). Given this expected maximum thickness, DFO winter withdrawal guidance is summarized in Table 4.4. To apply these criteria, maximum lake depth and lake volume are needed.

Table 4.4 Fisheries and Oceans Canada (DFO) Winter Water Withdrawal Guidance for Ice-Covered Waterbodies, Applicable to Lakes Located South of the Tree Line but North of Fort Simpson, Northwest Territories

Maximum Open Water Depth	DFO Protocol Guidance (applies to ice-covered waterbodies)
Shallower than 1.5 m	"*exempt from 10% maximum withdrawal limit*". Interpreted as withdrawals cannot occur when ice is at its maximum thickness, and may occur based on site-specific conditions when ice thickness is less than its annual maximum.
Deeper than 1.5 m, and shallower than 3.0 m	waterbodies are "*particularly vulnerable to the effects of water withdrawal*" Interpreted as withdrawals should not occur.
Deeper than 3.0 m	"*total water withdrawal… is not to exceed 10% of the available water volume*"

NOTE:
Guidance is from DFO 2010.

Importantly, these criteria are not applicable if less than 100 m^3 is to be withdrawn over the course of one ice-covered period, or if the waterbody is not potential fish habitat (DFO 2010).

Mackenzie Valley Land and Water Boards Method

The above (DFO) criteria were developed for winter water withdrawals as a means of preserving oxygenated water for overwintering fish (Cott et al. 2008); however, protocols for withdrawal from waterbodies often also include consideration of littoral habitat (BCOGC 2022; Hatfield Consultants 2016).

The Land and Water Boards of the Mackenzie Valley (MVLWB) developed a simple methodology for determining winter water use capacity for small-scale projects in the NT that explicitly considers changes to littoral habitat (MVLWB 2021b; MVLWB 2021a) (called 'MVLWB method' here). The MVLWB method may not be directly applicable to the MVH due to the large size of the MVH project and potential multi-year use of water sources; however, it is considered here because it provides guidance for preservation of littoral habitat and because it is regionally applicable.

Where waterbodies have under-ice water depth of at least 1.5 m and a minimum total (open water) depth of at least 3 m, the MVLWB method defines total available water in winter as (MVLWB 2021b; MVLWB 2021a):

$$\text{Total Available Water Use Capacity } (m^3) = \text{Total Surface Area } (m^2) * 0.10 \text{ m}$$

The MVLWB method has the advantage of not requiring detailed bathymetric surveys to determine water availability, unlike the DFO (2010) protocol.

Where this method is used, seasonal field verification of water depth is recommended, with at least three depth measurements >20 m from shore and approximately 20 m apart recommended (MVLWB 2021b; MVLWB 2021a).

4.2.1.2 Criteria During Periods of Open-Water

Criteria for open water withdrawals from lakes have not been published for the NT. The DFO (2010) method is not directly pertinent since lakes typically experience wind-generated mixing and seasonal overturn which oxygenates the water column (Wetzel 2001). The MVLWB criterion (volume equivalent of 0.1 m of drawdown) is ecologically relevant during periods of open water from the perspective of preserving littoral habitat. This is also a criterion adopted by the British Columbia Oil and Gas Commission (BCOGC)(BCOGC 2022). Therefore, the MVLWB method is applied here for periods of open water.

Lakes with maximum open water depths of less than 1.5 m would freeze to bottom in winter. These are not considered waterbodies by the definition in DFO (2010) and would not be expected to support fish. Therefore, it is proposed that these lakes may be considered for withdrawal in periods of open water. This is supported by discussions with MVLWB. However, MVLWB also noted that these lakes may contain environmental values other than fish; therefore, for these instances MVLWB encourage submission of information demonstrating how impacts would be minimized (Potten, pers. comm., 2022).

Withdrawals from lakes with maximum open water depths between 1.5 and 3.0 m are not allowed during periods of ice cover and were identified as "*particularly vulnerable to the effects of water withdrawal*" (DFO 2010)(Table 4.4). This vulnerability is considered here to extend into the open water period, given that residence time could be low in some lakes and in some months where throughflow is low. This is a conservative assumption that could be refined on a site-specific basis and/or with additional study (Section 6.3).

The criterion used here during periods of open water only requires surface area, not volume from bathymetric surveys. Therefore, a larger set of lakes are available for open water withdrawal calculations (Section 4.2.2).

The criterion applied here for open water withdrawals is intended for the preservation of littoral habitat only. Volumes provided here are coarse estimates for environmental assessment. For the purposes of licensing, other environmental values may need to be considered, for example EFN in watercourses downstream of where withdrawals occur. A potential water balance methodology based on methodologies in British Columbia and Alberta is described in Section 6.3.

4.2.2 Calculation of Volumes Available for Withdrawal in Waterbodies

Waterbodies for consideration for withdrawal were selected based on their previous use by the GNWT for winter road construction and/or proximity to the MVH alignment and are summarized in Table 4.5. Bathymetry, volume, surface area, lake depth, and long axis length for these waterbodies were compiled from previous studies (Golder Associates 2008; Golder Associates 2006; AAR 2003; K'alo-Stantec 2021). Where surface area and long axis length were not available, they were calculated by K'alo Stantec using remotely sensed imagery.

To summarize the criteria for calculating withdrawals from waterbodies used here:

- In periods of ice-cover (November to April), the *minimum* of the DFO (10% of under ice volume) and MVLWB methods (volume equivalent of a 0.1 m drawdown).
- In periods of open-water (May to October), the MVLWB method only (volume equivalent of a 0.1 m drawdown).

For evaluation of DFO criteria, volumes available for withdrawal were calculated at 10% of winter lake volume where available (DFO 2010). For evaluation using MVLWB methods, lake surface areas (units = m^2) were multiplied by 0.1 m (units = m^3) to approximate available under-ice volume (MVLWB 2021b; MVLWB 2021a).

Table 4.5 Waterbodies Considered for Withdrawals Near the Proposed Mackenzie Valley Highway

Waterbody Name			UTM[b]						Depth (m)		Volume (m^3)			Data Sources			
Used Here	Other	MVH Alignment (km)[a]	Easting (m)	Northing (m)	Zone	Region	Long Axis Length (m)	Surface Area (m^2)	Max.	Max. (coarse)[d]	Mean	Non-Winter	Winter[c]	Long Axis	Area	Depth	Bathymetry and Volume
WSWrigley	Lake 686.5	686.5	479,403	7,008,904	10	Dehcho	2,700	902,073						herein	herein		
WR2	DCN3	702.2	472,036	7,016,389	10	Dehcho	800	364,955	5.1		1.1	296,193	42,770	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)	(AAR 2003)
WR3		718.8	470,063	7,032,542	10	Dehcho	1,235	533,832		2.9				herein	herein	(Golder Associates 2006)	
WR4		721.8	468,228	7,035,063	10	Dehcho	290	36,400		2.9				herein	herein	(Golder Associates 2006)	
WS791		791.0	440,446	7,096,280	10	Dehcho	215	36,388						herein	herein		
WR5	ST24	798.8	436,935	7,102,044	10	Dehcho	1,100	200,168	2.1		0.8	107,350	729	herein	(Golder Associates 2006)	(Golder Associates 2006)	(AAR 2003)
WR6	ST23	804	436,369	7,107,258	10	Sahtu	1,780	796,473	3.4		0.9	743,539	6,823	herein	herein	(Golder Associates 2006)	(AAR 2003)
WR7		810.1	434,895	7,112,780	10	Sahtu	498	207,259		1.5				herein	herein	(Golder Associates 2006)	
WR8		820.0	433,668	7,120,640	10	Sahtu	1,005	251,743	15.2		6.2	1,604,238	1,265,534	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)
WR9	ST21	826.6	431,087	7,127,153	10	Sahtu	195	19,617	2.2		1.1	14,646	1,159	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)
WR10		835.0	425,896	7,132,328	10	Sahtu	200	13,160	15.1		3.3	44,488	30,844	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)
WR11	ST20	839.5	423,158	7,136,740	10	Sahtu	450	43,646	1.9		1.0	29,979	1,492	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)
WR12	Mio Lake	863	412,714	7,155,905	10	Sahtu	8,931	7,432,430	2.3			9,144,746	987,269	herein	herein	(Golder Associates 2006)	(Golder Associates 2008)
WR13	ST18	876.3	411,369	7,166,920	10	Sahtu	1,100	714,769	1.7		0.9	464,479	6,061	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)
WR16		882.5	411,677	7,171,746	10	Sahtu	300	56,631	4.9		2.1	120,505	48,991	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)
WR18		892.0	407,963	7,179,438	10	Sahtu	1,010	1,385,441	9.3		2.8	400,864	229,369	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)
WR893		893	405,318	7,178,932	10	Sahtu	823	190,086						herein	herein		
WR19		903.0	404,789	7,188,754	10	Sahtu	870	35,950	3.8		1.4	51,306	11,811	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)
WR20	ST14	908.9	403,623	7,193,829	10	Sahtu	1,780	3,595,971	2.6		1.1	2,400,015	114,579	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)
WR22		916	398,118	7,199,490	10	Sahtu	2,455	2,254,359		3.4				herein	herein	(Golder Associates 2006)	
WR21		921.3	392,634	7,199,056	10	Sahtu	262	30,606		5.2				herein	herein	(Golder Associates 2006)	
WR948		948.4	371,930	7,210,050	10	Sahtu	163	16,463						herein	herein		
WR25	ST12x	944.6	373,663	7,208,213	10	Sahtu	1,700	461,128	21.7		8.2	3,804,074	3,163,813	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)
WR28	ST11	950.4	370,015	7,210,416	10	Sahtu	800	204,493	14.8		6.6	941,140	746,860	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)

NOTES:
Waterbodies are sorted from south to north.
[a] 'Alignment (km)' is the approximate mid-point of each lake along the proposed MVH alignment.
[b] UTM coordinates use the WGS84 datum.
[c] the liquid water volume is calculated assuming 1.5 m thick ice.
[d] From Table 8.1 in Golder (2006). These are lakes where full bathymetric surveys have not been conducted and may not represent the true maximum lake depth.
Data are not available when cells are blank.
Lake metric sources noted as 'herein' were calculated as part of this study.

5 Results

5.1 Watercourses

5.1.1 Flows Estimation and Water Availability for Gauged Basins: WSC Scaling

Results are provided here for each of the watercourses (at the noted location) analyzed for potential water withdrawals as calculated directly from WSC stations (Figure 1.2, Appendix A). This includes Big Smith Creek, Blackwater River, Hodgson Creek, Jungle Ridge Creek, and Ochre River (Table 4.2). Flows from these sites were obtained from WSC stations, then adjusted according to 'scaling factors': the watershed area at each crossing divided by the watershed area at each WSC station (Section 4.1.2.1).

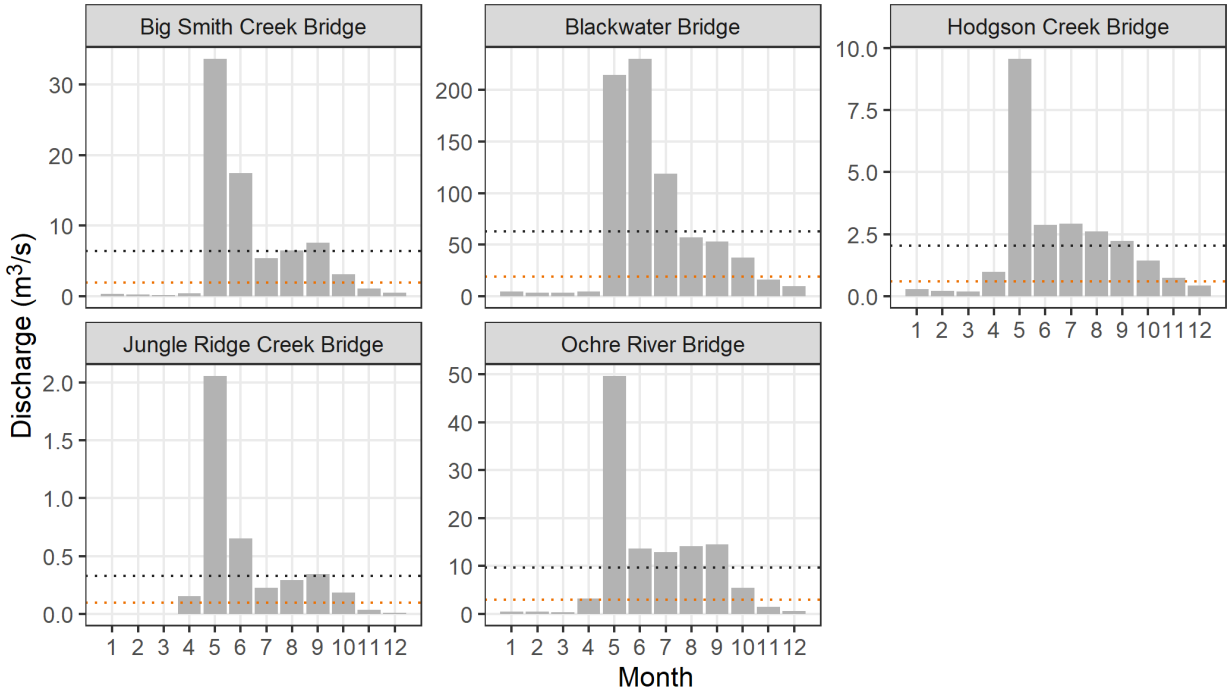
Where WSC stations exist on the same watercourse, scaling factors are typically within ±20% (Table 4.2) indicating that watershed areas are relatively similar.

The exception is Blackwater River (Figure 1.1, Table 4.2). The WSC station 10HC006 (BLACKWATER RIVER AT OUTLET OF BLACKWATER LAKE) is about 55 km upstream of the Blackwater River bridge. In addition, 10HC006 is located at the outlet of Blackwater Lake. Between these two sites, the Blackwater River watershed area increases from 7,850 km^2 to 10,716 km^2 (Table 4.2). Flows from 10HC006 would be expected to be highly influenced by the upstream lake. For example, all other sites analyzed here experience peak flow in May, while peak flow at Blackwater River occurs in June. This delay is likely a result of slow release of water from Blackwater Lake (Faria 2002). Flows at Blackwater River bridge are also likely influenced from the almost 3,000 km^2 of land area downstream of 10HC006.

Flows at Blackwater River bridge were calculated using the 'scaling factor' approach rather than the regression-based approach because of the large watershed size at Blackwater River. The largest target watershed area used in the regression approach was about 440 km^2: about 24 times smaller than the Blackwater River watershed area at the bridge (Table 4.1). Given the large size of the Blackwater River, flows there may have very different timing and magnitudes compared to smaller watersheds; therefore. regional analysis was not used at this site. However, this site was used to evaluate differences between the regional analysis and WSC scaling approaches; results are presented in Section 6.2.1.

Notably, a WSC station briefly operated on the Blackwater River, much closer to the bridge crossing: 10HC005: BLACKWATER RIVER NEAR THE MOUTH. However, this station only operated from 1983 to 1985. Its period of operation did not overlap with 10HC006, preventing comparison of flows at both sites.

Figure 5.1 Monthly Average Discharge at Potential Water Withdrawal Locations Along the Proposed Mackenzie Valley Highway Alignment, Derived Directly from Water Survey of Canada Stations (WSC Scaling Approach)



NOTES:

The upper dark horizontal lines are MAD at each location calculated using the 'scaling factor'. The lower orange lines are 30% of MAD. Month=1 represents January; Month=12 represents December.

5.1.2 Flows and Water Availability at Ungauged Basins Derived Using Regional Analyses

Regressions developed for ungauged watercourses along the proposed MVH alignment are presented in Figure 5.2 and statistics are provided in Table 5.1.

Table 5.1 Regional Analysis Regression Coefficients and Statistics

Month	Slope (m)	Intercept (b)	r^2	p-value	n
Jan	1.352	-4.651	0.60	<0.001	16
Feb	1.918	-6.603	0.68	<0.001	15
Mar	1.439	-5.155	0.59	0.001	14
Apr	0.556	-1.571	0.65	<0.001	16
May	0.862	-1.245	0.91	<0.001	21
Jun	1.177	-2.505	0.96	<0.001	21
Jul	1.162	-2.658	0.92	<0.001	21
Aug	1.077	-2.472	0.90	<0.001	21
Sep	1.079	-2.523	0.85	<0.001	21
Oct	0.940	-2.319	0.93	<0.001	19
Nov	1.104	-3.282	0.90	<0.001	16
Dec	1.101	-3.607	0.74	<0.001	17

NOTES:
Regressions equations are solved using $\log_{10}$-transformed drainage area (see text below). r^2 is a measure of the regression's overall 'goodness of fit' and a p-value >0.05 indicates that a regression is not statistically significant. n = sample size, i.e., the number of flow-area pairs in each regression.

Monthly average discharge (Q) is calculated as follows:

$$\log_{10}Q = m*\log_{10}A + b$$

where '$\log_{10}Q$' is $\log_{10}$ transformed monthly average discharge, 'm' and 'b' are regression coefficient slopes and intercepts (Table 5.1), and '$\log_{10}A$' is the $\log_{10}$ transformed watershed area (*A*, km^2) for the location of interest.

Q in metres cubed per second (m^3/s) is calculated as:

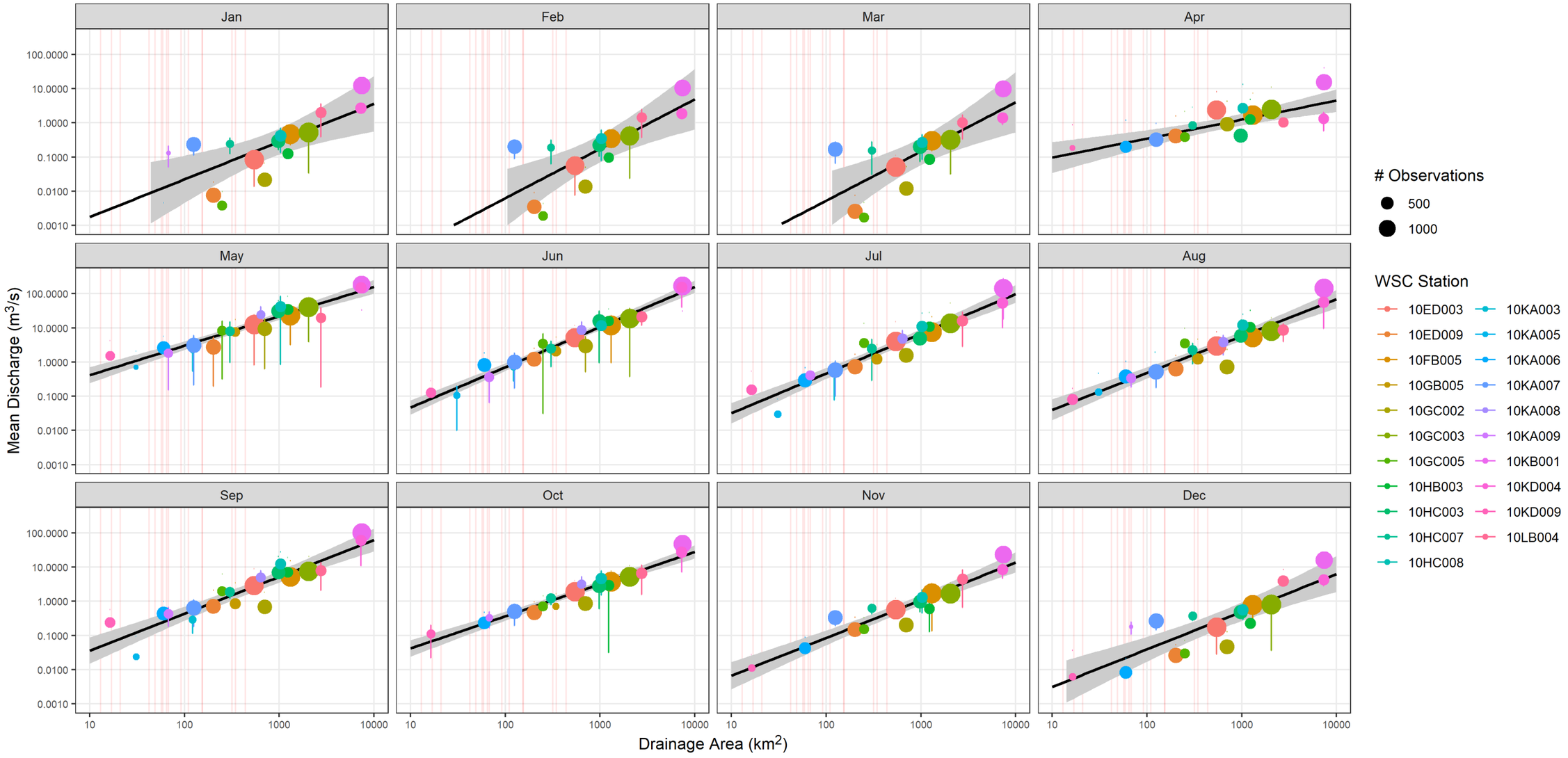
$$Q = 10^{\log_{10}Q}$$

All monthly regressions are statistically significant (p-value less than or equal to 0.05; Figure 5.2; Table 5.1). Correlation coefficients are high (>0.85) from May to November, and lower (but >0.59) from December through April. Correlation coefficients are highest from spring through to early fall when snowmelt and rainfall feed watercourses and flow magnitudes scale with the land area over which water collects (watershed area). This is the period when flows are highest and most of the annual runoff occurs.

In winter months, regressions remain statistically significant (p-value >0.05), but correlation coefficients are lower (Figure 5.2; Table 5.1), meaning that discharge is less directly related to watershed area compared to other months. Discharge is low in these months and is a small fraction of MAD. Discharge in winter is likely mainly fed by site-specific occurrence of groundwater seeps (Section 3). Seasonal operation of regional WSC stations also leads to smaller sample sizes for regressions in these winter months, which likely negatively affects regression results in these months (Figure 4.1).

Watersheds where regional analyses were applied span a large range of areas (9 to 440 km^2; Table 4.1). From April to December, regional WSC data exist from stations with watershed areas in the range of those of target watersheds (Table 4.3; vertical lines on Figure 5.2). From January through March, there are fewer data from WSC stations with small watersheds, which contributes to uncertainty in flow predictions in these months.

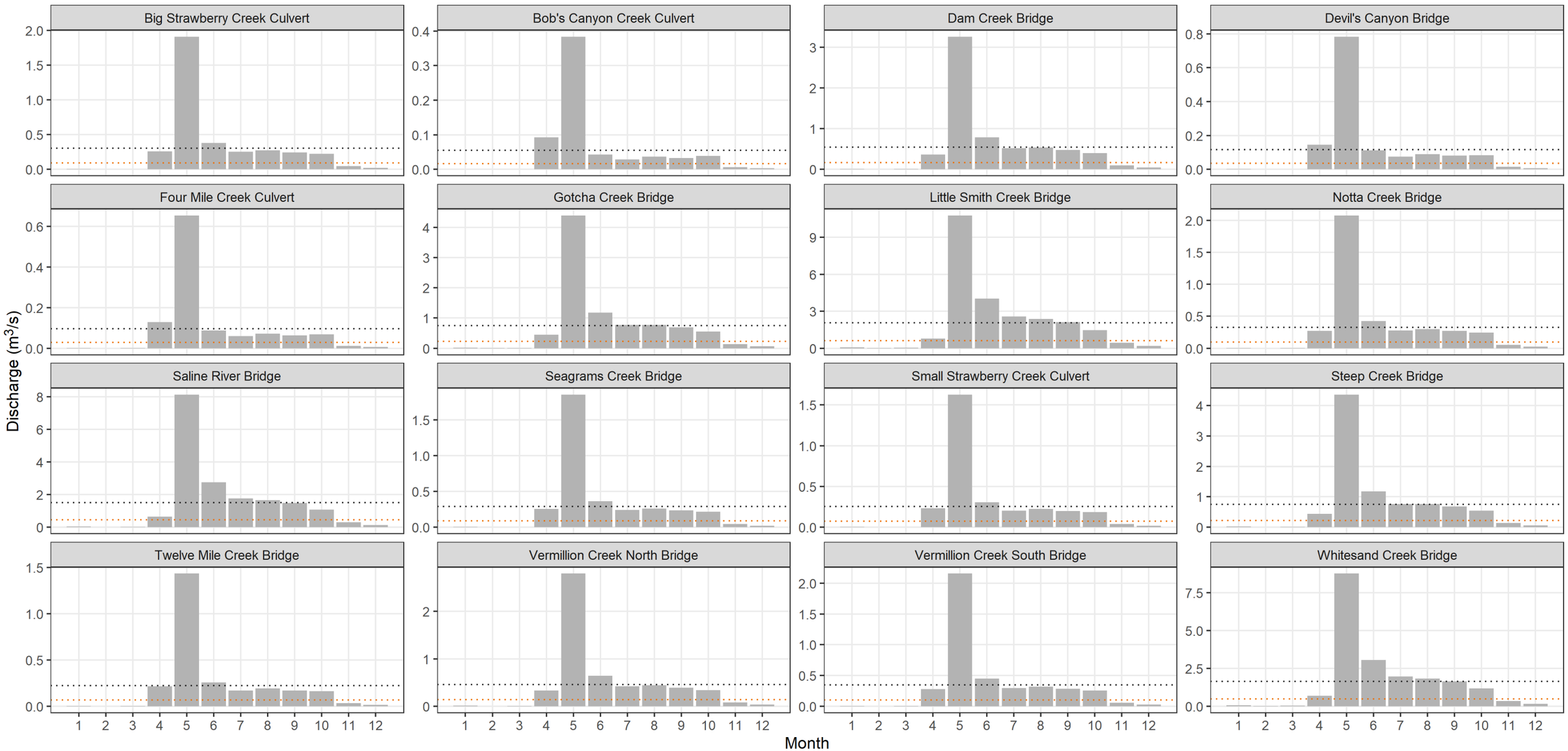
Figure 5.2 Relationships Between Watershed Area and Mean Monthly Discharge at Selected Regional Water Survey of Canada Stations



NOTES:
Vertical red lines are the watershed areas of potential withdrawal sites (not including sites where WSC stations exist and the 'WSC scaling' flow prediction approach was used). Black lines are best-fit linear regressions and grey envelopes represent 95% confidence intervals. Confidence intervals are outside y-axis limits for small watersheds in January, February, and March. Vertical error bars on points are +/- one standard deviation and the size of each point is scaled to the number of daily observations. Regression statistics are provided in Table 5.1.

Results are provided for each of the watercourses analyzed for potential water withdrawals predicted with regression-based techniques in Figure 5.3 and Appendix B. Predicted flows follow the nival hydrologic regime of the region, i.e., typically a snowmelt dominated freshet in May, declining flows from June through to early fall, and a small increase in flows due to rainfall runoff in October (Section 3).

Figure 5.3 Monthly Average Discharge at Potential Water Withdrawal Locations Along the Proposed Mackenzie Valley Highway Alignment, Predicted by Regression



NOTES:
The upper dark horizontal lines are MAD at each crossing. The lower orange lines are 30% of MAD. Month=1 represents January; Month=12 represents December. Watercourses are sorted alphabetically.

5.1.3 Flows and Water Availability at the Great Bear River near the Mackenzie River

Flows and water availability at the GBR near the Mackenzie River are summarized in Table 5.2. Unlike all other rivers analyzed here, the GBR has large amounts of flow over winter (*cf.* Appendices A and B). No months have flows that are less than 30% of MAD. Therefore, according to DFO (2013) criteria, water is available for withdrawal in all months. Due to the large size of the GBR, large volumes are available for withdrawal in all months.

Table 5.2 Great Bear River Near the Mackenzie River: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)		
Month	Median (m^3/s)	% of Annual Discharge[a]	10% Median (m^3/s)	Median	10% Median	Median	10% Median	Available[b]
Jan	530	91	53	4.58E+07	4.58E+06	1.42E+09	1.42E+08	1.42E+08
Feb	523	89	52	4.52E+07	4.52E+06	1.27E+09	1.27E+08	1.27E+08
Mar	520	89	52	4.49E+07	4.49E+06	1.39E+09	1.39E+08	1.39E+08
Apr	512	88	51	4.42E+07	4.42E+06	1.33E+09	1.33E+08	1.33E+08
May	682	117	68	5.89E+07	5.89E+06	1.83E+09	1.83E+08	1.83E+08
Jun	653	112	65	5.64E+07	5.64E+06	1.69E+09	1.69E+08	1.69E+08
Jul	630	108	63	5.44E+07	5.44E+06	1.69E+09	1.69E+08	1.69E+08
Aug	634	108	63	5.48E+07	5.48E+06	1.70E+09	1.70E+08	1.70E+08
Sep	625	107	63	5.40E+07	5.40E+06	1.62E+09	1.62E+08	1.62E+08
Oct	600	103	60	5.18E+07	5.18E+06	1.61E+09	1.61E+08	1.61E+08
Nov	559	96	56	4.83E+07	4.83E+06	1.45E+09	1.45E+08	1.45E+08
Dec	545	93	55	4.71E+07	4.71E+06	1.46E+09	1.46E+08	1.46E+08
Annual Mean	**584**	**n/a**	**58**	**5.05E+07**	**5.05E+06**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**1.84E+10**	**1.84E+09**	**1.84E+09**

NOTES:

Flow data source is NHC (2018); described in Section 4.1.2.3.

No months have less than 30% of mean annual discharge (175 m^2/s).

[a] Calculated as monthly discharge divided by MAD x100.

[b] 'Available' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).

n/a: not applicable.

5.1.4 Summary of Flow Predictions and Water Availability at all Studied Locations

Detailed month-by-month flow and water availability predictions are provided in Appendices A and B. Key statistics are summarized and visualized in Table 5.3 and Figure 5.4.

In Table 5.3, the '*Annual Available Withdrawal Volume*' is the water volume available for low-risk withdrawal, using criteria from DFO (2013); i.e., 10% of monthly average flow in months where discharge is greater than 30% of MAD. These volumes are useful as a basis for water license applications and will need to be verified by monitoring/measuring flows in the field (Section 7).

Not all the annual volume available for withdrawal may be useful. Much of this water is available in May when there may be limited water demand and accessibility. Please refer to Appendices A and B for monthly water availability data.

The GBR and Blackwater River are much larger than the other studied watercourses, and water availability is correspondingly high.

At the proposed GBR crossing, water is available for withdrawal year-round according to criteria applied here. Volumes available are extremely large compared to other assessed sources. Water available from this source represents 87% of all water availability from all assessed watercourses.

At the Blackwater River bridge, the watershed area of the river is 10,716 km^2, about 24 times larger than the next largest watershed area where regional analysis was conducted. Excluding the GBR, the annual available withdrawal volume there (~1.9 x 10^8 m^3) is more than twice what is available at all other studied locations combined (~8.7 x 10^7 m^3; Table 5.3).

Note that according to DFO protocols (DFO 2013), water is likely to be available for withdrawal from most watercourses from approximately from April to October[2]. Flows in these months are greater than 30% of MAD. In addition, about half of the annual water volume available for low-risk withdrawal occurs in May (Figure 5.4). See Appendices A and B for monthly flow data and volumes.

As described above, the availability of water from watercourses is highly seasonal (Figure 5.4); however, waterbodies provide additional potential water sources in winter. This is assessed in the next section.

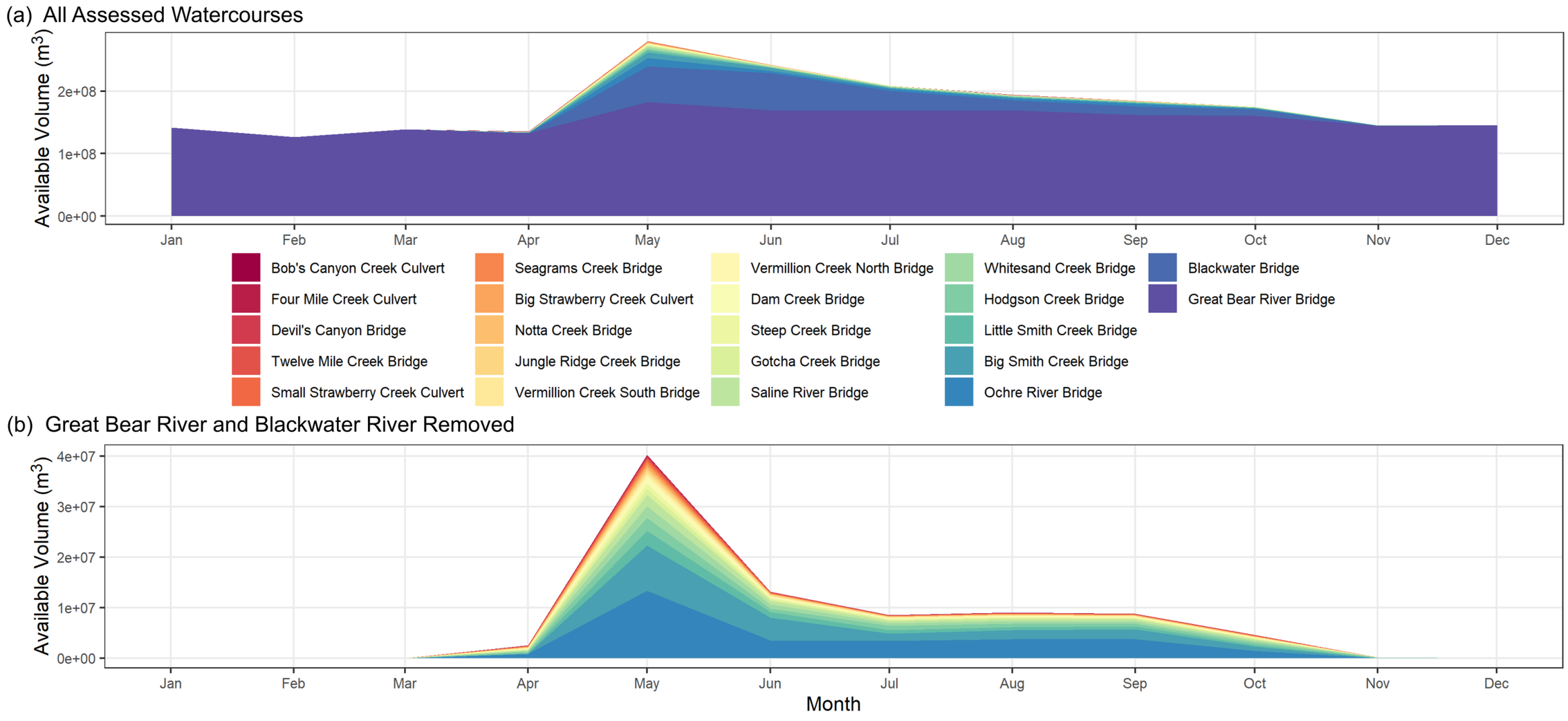
[2] Exceptions are flows at Blackwater River bridge (allowed from May to October) and Hodgson Creek bridge (allowed from April to November).

Table 5.3 Flow Summary Statistics for Flow and Water Availability at Potential Water Withdrawal Locations Along the Proposed Mackenzie Valley Highway Alignment

Watercourse Location	MVH Alignment (km)	Watershed Area (km^2)	MAD (m^3/s)	30%MAD (m^3/s)	Max Discharge (m^3/s)	Potential Annual Available Withdrawal Volume (m^3)[a]	Flow Prediction Type
Hodgson Creek Bridge	695.6	358	2.04	0.613	9.6	6,200,677	WSC Scaling
Ochre River Bridge	725.7	1,207	9.71	2.91	49.6	30,047,250	WSC Scaling
Whitesand Creek Bridge	733.8	346	1.64	0.492	8.8	5,069,277	Regional Analysis
Big Strawberry Creek Culvert	748.5	59	0.30	0.090	1.9	939,366	Regional Analysis
Small Strawberry Creek Culvert	748.6	49	0.25	0.076	1.6	791,002	Regional Analysis
Vermillion Creek South Bridge	752.3	68	0.34	0.103	2.2	1,072,282	Regional Analysis
Bob's Canyon Creek Culvert	755.3	9	0.06	0.017	0.4	173,984	Regional Analysis
Dam Creek Bridge	764.8	110	0.54	0.163	3.3	1,685,618	Regional Analysis
Blackwater Bridge	785.3	10,716	62.8	18.9	230	188,109,030	WSC Scaling
Steep Creek Bridge	816.5	154	0.75	0.224	4.4	2,321,083	Regional Analysis
Devil's Canyon Bridge	828.4	21	0.12	0.035	0.8	364,272	Regional Analysis
Saline River Bridge	831.9	317	1.51	0.452	8.1	4,655,068	Regional Analysis
Seagrams Creek Bridge	844.3	57	0.29	0.087	1.9	909,701	Regional Analysis
Little Smith Creek Bridge	852.3	439	2.08	0.623	10.8	6,397,916	Regional Analysis
Big Smith Creek Bridge	872.1	1,076	6.38	1.91	33.7	19,510,836	WSC Scaling
Gotcha Creek Bridge	912.7	155	0.75	0.226	4.4	2,335,520	Regional Analysis
Twelve Mile Creek Bridge	922.0	42	0.22	0.066	1.4	690,832	Regional Analysis
Four Mile Creek Culvert	931.5	17	0.10	0.029	0.7	301,154	Regional Analysis
Great Bear River Bridge	937.2	158,400	584	175	682	1,844,510,400	NHC[b]
Jungle Ridge Creek Bridge	967.8	60	0.33	0.099	2.1	1,035,713	WSC Scaling
Notta Creek Bridge	971.5	65	0.33	0.099	2.1	1,028,081	Regional Analysis
Vermillion Creek North Bridge	973.4	92	0.46	0.137	2.8	1,423,908	Regional Analysis

NOTES:
Watercourse crossings are sorted from south to north.
'Max Discharge' is the maximum monthly average flow, which typically occurs in May (the exception is Blackwater River, where maximum annual discharge occurs in June).
Flow prediction types are described in Section 4.1.
Please refer to Appendices A and B for the full monthly set of flow and water availability statistics.
[a] calculated as 10% of volumetric flow in months where discharge is more than 30%MAD (DFO 2013).
[b] Flows for the GBR near the Mackenzie River are from the hydrotechnical design document for the proposed GBR bridge (NHC 2018).

Figure 5.4 Area Charts of Monthly Water Availability from Studied Watercourses



NOTE:
Watercourses are sorted in order of increasing annual water availability. Plots are stacked, i.e., the uppermost line represents cumulative monthly total withdrawal volumes from considered watercourses.

5.2 Waterbodies

Potential withdrawal volumes for studied lakes along the proposed MVH alignment are presented in Table 5.5 using criteria presented in Section 4.2.1.1.

5.2.1 Withdrawals During Periods of Ice-Cover

Waterbodies that are too shallow (DFO 2010) for winter withdrawals are first removed from analyses; i.e., lakes with open water maximum depths between 1.5 and 3.0 m. None of the considered lakes have maximum open water depths of less than 1.5 m. A total of 11 lakes are likely sufficiently deep (Table 5.5; '*Max Depth (m)*' columns).

DFO (2010) criteria require lake volume to be known. Volumes are unknown in two of the eleven remaining lakes because bathymetric survey data are not available (WR21 and WR22), leaving nine lakes for consideration (Table 5.5; '*Volume (DFO 2010)*' columns).

Volumes potentially available for winter withdrawal using DFO (2010) criteria were calculated as 10% of the under-ice water volume, assuming a 1.5 m thick ice cover. To assess these volumes relative to MVLWB criteria, depth equivalents were calculated by dividing by lake surface area (Table 5.5, column '*Depth Equivalent of Winter Volume (m)*'). Where this depth equivalent is greater than 0.1 m, the withdrawal volume exceeds that recommended by MVLWB (MVLWB 2021b; MVLWB 2021a). These are flagged as 'littoral zone loss' (Table 5.5; column '*Winter Volume Comments*').

Next, the MVLWB method was applied using lake surface area (i.e., the volume of the lake surface area multiplied by 0.1 m)(MVLWB 2021b; MVLWB 2021a). Lake surface area is available from all considered lakes, so MVLWB method can be applied for all lakes. These volume estimates are cross-checked against volumes calculated using DFO (2010) criteria (Table 5.5, column '*Volume (%)*'). In five out of nine lakes where this is possible to assess, the volume of under ice water lost by solely applying the MVLWB method would exceed 10% (Table 5.5, column '*Surface Area Notes*', flagged as 'Volume Loss').

From the perspective of preserving environmental values, DFO (2010) criteria are explicitly intended to preserve oxygen under ice, while MVLWB method is explicitly intended to preserve littoral habitat. Neither set of protocols are consistently limiting for lakes along the proposed MVH alignment. It is therefore not considered appropriate to only apply one set of criteria. Choosing the *minimum* volume predicted by both sets of criteria is intended to preserve both littoral habitat and under ice oxygen (Table 5.5, column '*Conservative Withdrawal (m^3)*').

Application of both protocols limits assessments to lakes where bathymetric surveys have been conducted (this would also be true if only DFO (2010) criteria were applied). After filtering lakes that are too shallow to support withdrawals, this leaves nine lakes where conservative withdrawal volumes can be provided (Table 5.5, column '*Conservative Withdrawal (m^3)*').

Again, 'conservative' potential winter withdrawal volumes are provided here (Table 5.5) that consider the environmental values of littoral zone habitat and overwinter oxygen levels. Results provided here do not consider other potential environmental values, such as potential effects on specific species of interest, cultural values, or on downstream flows (Section 6.3 and Section 7).

Table 5.4 Potential Withdrawal Limits for Waterbodies Along the Proposed Mackenzie Valley Highway Alignment during Periods of Ice Cover

		Max Depth (m)			Under Ice Volume (DFO 2010)[c]			Surface Area (MVLWB 2021)					Recommended Withdrawals		Candidate for Future Bathymetric Surveys?	
Name	MVH Alignment (km)[a]	Surveyed	Coarse[b]	Too Shallow?	10% of Under Ice Volume (m^3)	Depth Equivalent of Volume (m)	Volume Comments	Surface Area (m^2)	Volume from Surface Area (m^3)[d]	Volume (%)	Surface Area Notes	Conservative Withdrawal (m^3)	Limiting Criterion	Notes	Assessment	Comment
WSWrigley	686.5			UNKNOWN			Volume unknown	902,073	90,207		Volume unknown			Volume unknown	Yes	
WR2	702.2	5.1		NO	4,277	0.01	PASSES CRITERIA	364,955	36,496	85	Volume loss	4,277	DFO (2013)	Conservative volume available	n/a	n/a survey already conducted
WR3	718.8		2.9	YES (Potentially)			Volume unknown	533,832	53,383		Volume unknown			Volume unknown	Yes	If max. depth >3.0 m
WR4	721.8		2.9	YES (Potentially)			Volume unknown	36,400	3,640		Volume unknown			Volume unknown	Yes	If max. depth >3.0 m
WS791	791			UNKNOWN			Volume unknown	36,388	3,639		Volume unknown			Volume unknown	Maybe	Given small surface area, may be shallow
WR5	798.8	2.1		YES			Too shallow to withdraw	200,168	20,017		Too shallow to withdraw			Too shallow to withdraw	No	Too shallow
WR6	804	3.4		NO	682	0.00	PASSES CRITERIA	796,473	79,647	1167	Volume loss	682	DFO (2013)	Conservative volume available. volume anomalously low?	n/a	n/a survey already conducted
WR7	810.1		1.5	YES (Potentially)			Volume unknown	207,259	20,726		Volume unknown			Too shallow to withdraw (based on coarse max depth)	No	Too shallow to withdraw
WR8	820	15.2		NO	126,553	0.50	Littoral zone loss	251,743	25,174	2	PASSES CRITERIA	25,174	MVLWB (2021)	Conservative volume available	n/a	n/a survey already conducted
WR9	826.6	2.2		YES			Too shallow to withdraw	19,617	1,962		Too shallow to withdraw			Too shallow to withdraw	No	Too shallow
WR10	835	15.1		NO	3,084	0.23	Littoral zone loss	13,160	1,316	4	PASSES CRITERIA	1,316	MVLWB (2021)	Conservative volume available	n/a	n/a survey already conducted
WR11	839.5	1.9		YES			Too shallow to withdraw	43,646	4,365		Too shallow to withdraw			Too shallow to withdraw	No	Too shallow
WR12	863	2.3		YES			Too shallow to withdraw	7,432,430	743,243		Too shallow to withdraw			Too shallow to withdraw	No	Too shallow to withdraw (based on coarse max depth)
WR13	876.3	1.7		YES			Too shallow to withdraw	714,769	71,477		Too shallow to withdraw			Too shallow to withdraw	No	Too shallow
WR16	882.5	4.9		NO	4,899	0.09	PASSES CRITERIA	56,631	5,663	12	Volume loss	4,899	DFO (2013)	Conservative volume available	n/a	n/a survey already conducted
WR18	892	9.3		NO	22,937	0.02	PASSES CRITERIA	1,385,441	138,544	60	Volume loss	22,937	DFO (2013)	Conservative volume available	n/a	n/a survey already conducted
WR893	893			UNKNOWN			Volume unknown	190,086	19,009		Volume unknown			Volume unknown	Yes	
WR19	903	3.8		NO	1,181	0.03	PASSES CRITERIA	35,950	3,595	30	Volume loss	1,181	DFO (2013)	Conservative volume available	n/a	n/a survey already conducted
WR20	908.9	2.6		YES			Too shallow to withdraw	3,595,971	359,597		Too shallow to withdraw			Too shallow to withdraw	No	Too shallow

Table 5.4 Potential Withdrawal Limits for Waterbodies Along the Proposed Mackenzie Valley Highway Alignment during Periods of Ice Cover

		Max Depth (m)			Under Ice Volume (DFO 2010)[c]			Surface Area (MVLWB 2021)					Recommended Withdrawals			Candidate for Future Bathymetric Surveys?	
Name	MVH Alignment (km)[a]	Surveyed	Coarse[b]	Too Shallow?	10% of Under Ice Volume (m^3)	Depth Equivalent of Volume (m)	Volume Comments	Surface Area (m^2)	Volume from Surface Area (m^3)[d]	Volume (%)	Surface Area Notes	Conservative Withdrawal (m^3)	Limiting Criterion	Notes	Assessment	Comment
WR22	916		3.4	NO			Volume unknown	2,254,359	225,436		Volume unknown			Volume unknown	Yes	
WR21	921.3		5.2	NO			Volume unknown	30,606	3,061		Volume unknown			Volume unknown	Yes	
WR948	948.4			UNKNOWN			Volume unknown	16,463	1,646		Volume unknown			Volume unknown	Maybe	Given small surface area, may be shallow
WR25	944.6	21.7		NO	316,381	0.69	Littoral zone loss	461,128	46,113	1	PASSES CRITERIA	46,113	MVLWB (2021)	Conservative volume available	n/a	n/a survey already conducted
WR28	950.4	14.8		NO	74,686	0.37	Littoral zone loss	204,493	20,449	3	PASSES CRITERIA	20,449	MVLWB (2021)	Conservative volume available	n/a	n/a survey already conducted

NOTES:
Waterbodies are sorted from south to north.
[a] 'Alignment (km)' is the approximate mid-point of each lake along the proposed MVH alignment.
[b] From Table 8.1 in Golder (2006). These are lakes where full bathymetric surveys have not been conducted and may not represent the true maximum lake depth.
[c] under ice water volume is calculated assuming 1.5 m thick ice.
[d] Waterbody surface area (units = m^2) multiplied by 0.1 m.
Data are not available when cells are blank.
Please refer to Table 4.5 for waterbody metadata.

Candidate Lakes for Future Bathymetric Surveys

The number of lakes assessed for withdrawals during periods of ice cover could be increased by conducting additional bathymetric surveys (Section 7). Bathymetry has not been conducted at nine lakes. The 'Candidate for Future Bathymetric Surveys' columns (Table 5.5) identify:

- six lakes (WSWrigley, WR3, WR4, WR893, WR21, WR22) where bathymetric surveys have not been conducted and are potentially deeper than 3.0 m and may support withdrawals. These are primary candidates for future bathymetric surveys. Note that if surveys determined maximum depth to be between 1.5 and 3.0 m, then DFO (2010) criteria would not be met.
- two lakes (WS791, WR948) where bathymetric surveys have not been conducted; however, these lakes have small surface areas and/or long axis lengths. If maximum open water depth were less than 1.5 m or greater than 3.0, then withdrawals may be allowed. These are secondary candidates for future bathymetric surveys.
- one lake (WR7) that has a (coarsely determined) maximum depths of 1.5 m. This lake is not recommended for future bathymetric surveys.

Lakes with larger surface areas and long axes would have a greater chance of being sufficiently deep to support withdrawals, and more water would be available for withdrawal from more voluminous lakes. For (e.g., WSWrigley and WR893). The above assessments could be refined by statistically relating surface area, long axis length, and other morphology indicators to maximum depth and lake volume using regional datasets of lakes where bathymetry is known (AEP 2019; Islam et al. 2018).

5.2.2 Withdrawals During Periods of Open-Water

Volumes of water potentially available for withdrawal using the MVLWB criterion are presented in Table 5.5. Lakes with open water maximum depths less than 1.5 m might be considered for licensing (Section 4.2.1.2), but no candidate lakes have been identified as being this shallow (Table 5.5). Lakes with maximum open water depths between 1.5 and 3.0 m are excluded given their potential sensitivity to withdrawal.

Lakes were categorized based on available maximum depth data (Table 5.6). Lakes that are either known to be too shallow to support open water withdrawals, or where maximum depth is not confidently known, were not carried forward. Eleven lakes remained (Table 5.5; Table 5.6).

In Section 5.2.1, candidate lakes were identified for additional bathymetric surveys to assess winter withdrawal volumes. This would also be beneficial for lakes identified in Table 5.6. However, note that MVLWB may allow maximum depth to be coarsely determined by measuring lake depth "*prior to each season of use, avoiding freshet. This must be measured in at least three locations >20 m from shore and approximately 20 m apart.*" (MVLWB 2021a). This is applicable only in the open water period because under ice volume is required in the ice-covered period.

Neither the DFO nor MVLWB methods are explicitly intended to preserve downstream flows for EFN. Impacts to downstream flows caused by withdrawals in upstream lakes are important to assess both in summer and potentially in winter, given that some of the larger watercourses in the Study Area flow in winter (Section 5.1.1) (K'alo-Stantec 2022a). Please refer to Section 6.3 for potential methods to estimate EFN in watercourses downstream of waterbodies.

Table 5.5 Potential Withdrawal Limits for Waterbodies Along the Proposed Mackenzie Valley Highway Alignment during Periods of Open Water

Name	MVH Alignment (km)[a]	Max Depth (m) Surveyed	Max Depth (m) Coarse[b]	Too Shallow?	Surface Area (MVLWB 2021) Surface Area (m^2)	Surface Area (MVLWB 2021) Volume from Surface Area (m^3)[c]	Surface Area Notes
WSWrigley	686.5			UNKNOWN	902,073		Unknown if too shallow to withdraw
WR2	702.2	5.1		NO	364,955	36,496	Sufficiently deep
WR3	718.8		2.9	YES (Potentially)	533,832		Potentially too shallow to withdraw
WR4	721.8		2.9	YES (Potentially)	36,400		Potentially too shallow to withdraw
WS791	791			UNKNOWN	36,388		Unknown if too shallow to withdraw
WR5	798.8	2.1		YES	200,168		Too shallow to withdraw
WR6	804	3.4		NO	796,473	79,647	Sufficiently deep
WR7	810.1		1.5	YES (Potentially)	207,259		Potentially too shallow to withdraw
WR8	820	15.2		NO	251,743	25,174	Sufficiently deep
WR9	826.6	2.2		YES	19,617		Too shallow to withdraw
WR10	835	15.1		NO	13,160	1,316	Sufficiently deep
WR11	839.5	1.9		YES	43,646		Too shallow to withdraw
WR12	863	2.3		YES	7,432,430		Too shallow to withdraw
WR13	876.3	1.7		YES	714,769		Too shallow to withdraw
WR16	882.5	4.9		NO	56,631	5,663	Sufficiently deep
WR18	892	9.3		NO	1,385,441	138,544	Sufficiently deep
WR893	893			UNKNOWN	190,086		Unknown if too shallow to withdraw
WR19	903	3.8		NO	35,950	3,595	Sufficiently deep
WR20	908.9	2.6		YES	3,595,971		Too shallow to withdraw
WR22	916		3.4	NO	2,254,359	225,436	Sufficiently deep
WR21	921.3		5.2	NO	30,606	3,061	Sufficiently deep
WR948	948.4			UNKNOWN	16,463		Unknown if too shallow to withdraw
WR25	944.6	21.7		NO	461,128	46,113	Sufficiently deep
WR28	950.4	14.8		NO	204,493	20,449	Sufficiently deep

NOTES:
Waterbodies are sorted from south to north.
[a] 'Alignment (km)' is the approximate mid-point of each lake along the proposed MVH alignment.
[b] From Table 8.1 in Golder (2006). These are lakes where full bathymetric surveys have not been conducted and may not represent the true maximum lake depth.
[d] Waterbody surface area (units = m^2) multiplied by 0.1 m.
Data are not available when cells are blank.
Please refer to Table 4.5 for waterbody metadata.

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Table 5.6 Open Water Withdrawal Categories based on Maximum Open Water Depth

Category	Category Description	Applies to	Action	Recommendation
Sufficiently deep	Either bathymetric surveys or coarse measurements of depth indicate that open water maximum depth is greater than 3.0 m	WR2, WR6, WR8, WR10, WR16, WR18, WR19, WR21, WR22, WR25, WR28	Calculate open water withdrawal volumes	None
Unknown if too shallow to withdraw	No bathymetric surveys have been conducted and no coarse measurements of maximum depth are available	WSWrigley, WS791, WR893, WR948	Exclude from open water withdrawal volume calculations	Conduct additional measurements* where morphology suggests lakes may be sufficiently deep.
Potentially too shallow to withdraw	No bathymetric surveys have been conducted. However, limited depth measurements indicate that the open water maximum depth may be between 1.5 and 3.0 m, and hence withdrawals may not be permissible.	WR3, WR4, WR7	Exclude from open water withdrawal volume calculations	These are lower priority for additional measurements* surveys given preliminary indications of their maximum depth.
Too shallow to withdraw	Either bathymetric surveys or coarse measurements of depth indicate that open water maximum depth is shallower than 3.0 m and not shallower than 1.5 m	WR5, WR9, WR11, WR12, WR13, WR20	Exclude from open water withdrawal volume calculations	None

NOTE:
*Bathymetry or coarse measurements of depth, see text.

5.2.3 Summary of Water Availability from Waterbodies in the Ice-Covered and Ice-Free Periods

Please refer to Summary Table 2 in the executive summary for a compilation of water availability from watercourses in open-water periods, ice-covered periods, and annually.

6 Discussion

6.1 Licensing Considerations

For 'miscellaneous' projects, the *Northwest Territories Waters Act* and Regulations permit water to be withdrawn from watercourses[3] without a licence for uses less than 100 m^3 *per day* (GNWT 2014; Schedule H). This equates to 36,400 m^3 annually, or about 18,000 m^3 in both the ice covered and open water periods. This implies that:

- if required water volumes from watercourses and waterbodies are less than identified maximums in Table 5.3, Table 5.4, and Table 5.5, then water licenses may not be required.
- if regulators only consider the *Waters Act* criterion, then more water may be available for waterbodies than identified in Table 5.4 and Table 5.5.

In contrast to the *Waters Act*, the MVLWB method and DFO protocols both stipulate non-application below 100 m^3 withdrawal *in a single ice-covered season.* The application of these protocols is preferred for environmental assessment despite being more limiting and more conservative. The *Waters Act* criterion is discussed here only because of its implications for when licensing is —and is not— required.

Note that if desired withdrawals do not meet limits calculated using protocols (e.g., DFO 2010, DFO 2013), a Request for Review could be submitted to DFO.

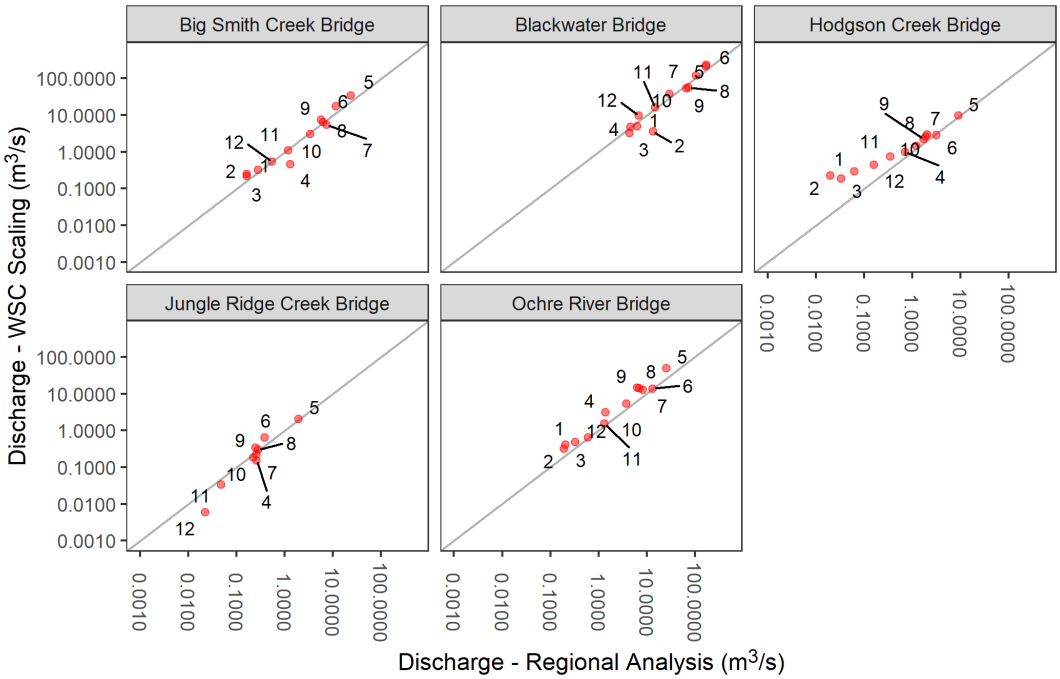
6.2 Assessment of Methods for Determination of Streamflow In Ungauged Catchments

6.2.1 Comparison Results from Regional Analysis and 'WSC Scaling' Methods

Figure 6.1 compares monthly average flows calculated using the WSC scaling approach and the regional regression approach. Results appear similar for both approaches except for Hodson Creek Bridge, where the WSC scaling approach suggests higher flows in winter. Hodgson Creek is the southernmost studied watercourse, and its watershed area is relatively large (Figure 1.1; Table 4.1); winter flows may be higher here than suggested by regional analyses. Monitored flows from Hodson Creek are relatively recent and the period of record is relatively short (2006 to 2014; Table 4.3). Available flow data from this site may not be representative of the full range of hydroclimatic variability, or winter flows may be affected by recent climate change.

[3] The definition of 'watercourse' differs here compared to the Waters Act. The Waters Act defines a watercourse as "a natural watercourse, body of water or water supply, whether usually containing water or not, and includes groundwater, springs, swamps and gulches.", i.e., it includes waterbodies.

Figure 6.1 Comparison of Monthly Flows Predicted using the 'WSC Scaling' Technique and the Regional Analysis Technique



NOTES:

Labeled numbers are months (1=January, 12=December).

Grey lines are 1:1 lines (i.e., have slopes of one and intercepts of zero). Monthly predictions (red dots) falling exactly on the 1:1 line are identical.

Flows from the regional analysis method were predicted using regression equations provided in Table 5.1.

'WSC scaling' flows were scaled directly from WSC stations on the same watercourse as the proposed crossing.

Table 6.1 compares annual water availability per DFO criteria calculated using the WSC scaling approach and the MVH regional regression approach. Except for the Ochre River, water availability calculated from both approaches is within about 22%. For all five gauged crossings, the MVH regression approach is conservative, as it predicts that less water is available for withdrawal than the WSC scaling approach.

Table 6.1 Comparison of Annual Water Availability per DFO Criteria Predicted Using the 'WSC Scaling' Technique and the Regional Analysis (MVH) Technique

Watercourse	Crossing Watershed Area (km^2)	Availability (m^3/yr)[a]		Difference	
		WSC Scaling	Regional Analysis	m^3	%
Big Smith Creek	1,076	19,510,836	15,220,279	4,290,557	22
Blackwater River	10,716	188,109,030	163,361,027	24,748,003	13
Hodgson Creek	358	6,200,677	5,240,689	959,988	15
Jungle Ridge Creek	60	1,035,713	954,213	81,500	8
Ochre River	1,207	30,047,250	17,097,693	12,949,557	43

NOTE:
[a] calculated as 10% of volumetric flow in months where discharge is more than 30%MAD (DFO 2013).

For the Ochre River, the difference between approaches in annual water availability is 43% (Table 6.1). This is not apparent in the comparison of monthly discharge (Figure 6.1), partly because of the use of log-log axes. The WSC scaling approach predicts about 1.3 x 10^7 m^3 of water available for withdrawal in May, while the regional analysis approach predicts about half this volume: 6.9 x10^6 m^3. This is a large difference in the month with peak annual flows. In addition, the WSC scaling approach suggests that withdrawals are likely permissible in April, while the MVH approach suggests that no water is available for withdrawal in this month due to flows being <30%MAD (DFO 2013). Similar to Hodgson Creek, Ochre River is located far south along the proposed MVH alignment and has a relatively large watershed area (Figure 1.1; Table 4.1), which could affect the accuracy of regional regression-based flow predictions. Also similar to Hodson Creek, the Ochre River monitoring period is relatively short and recent (2006 to 2019). Available flow data from this site may not be representative of the full range of hydroclimatic variability, or winter flows may be affected by recent climate change.

At Blackwater River, flows and water availability calculated using both approaches are relatively similar. This is surprising given the large size of the Blackwater River watershed area and given that its flows are likely influenced by discharge from Blackwater Lake (Faria 2002) (Section 4.1.2.1).

Overall, the regional analysis approach appears to provide conservative estimates of water availability. The WSC scaling approach uses site-specific data where available. These data are preferable over regionally based flow predictions, but results can be susceptible to influences from short records and potentially, climate change.

6.2.2 Comparison of Flows Predicted Using Differing Regression Equations

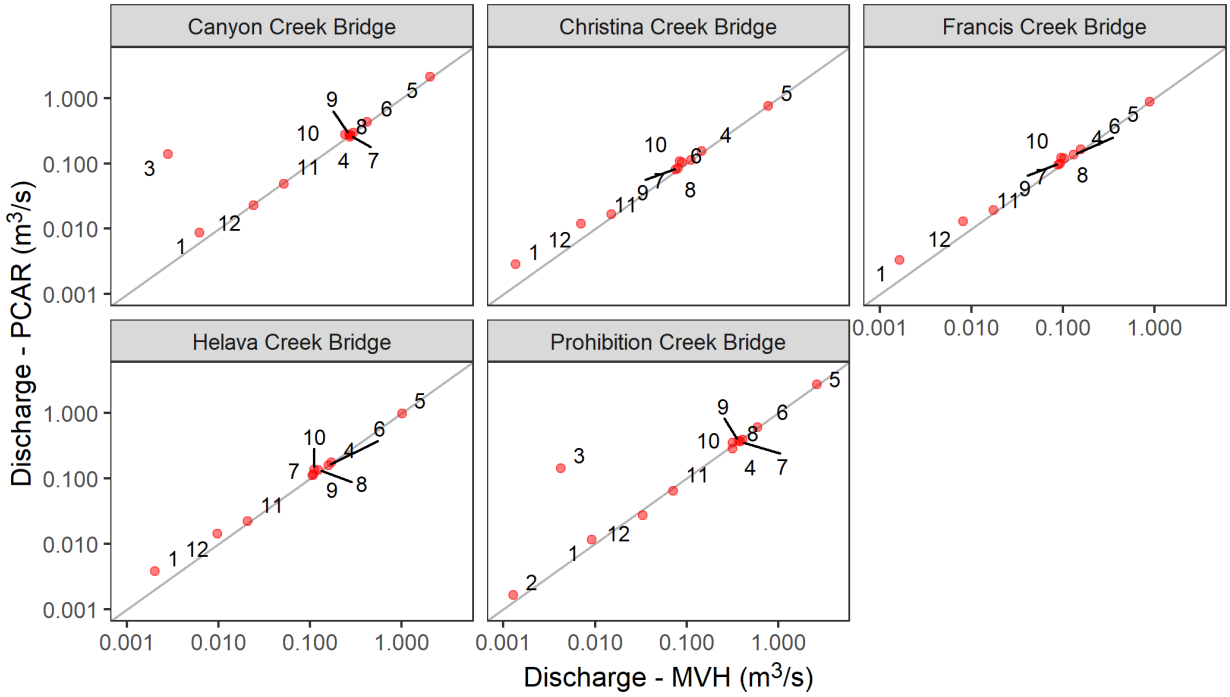
Flow estimates and water availability were recently assessed for five watercourses along the proposed Prohibition Creek Access Road (PCAR) alignment (K'alo-Stantec 2022a) (Figure 1.2). A similar regional analysis methodology was used for flow predictions for both MVH and PCAR. However, regional station selection criteria were tailored to crossings along each alignment. Differences include:

- WSC stations were selected based on a point for the PCAR study rather than a buffered linear feature used here (Section 4.1.2.2). The difference occurs because the proposed PCAR alignment spans only about 14 km while watercourse crossings along the proposed MVH alignment span about 275 km.
- The maximum considered watershed area for regional WSC stations in the PCAR study was about 1,000 km^2, compared to about 7,400 km^2 for the MVH study. WSC stations were chosen to best represent the range of target watershed areas for each study. For example, target watersheds for the PCAR study spanned from 21 to 86 km^2 but reach about 440 km^2 for this study.

Differing station selection criteria produced differing regression coefficients and flow predictions. The PCAR alignment immediately north of the proposed MVH alignment, and the watershed areas of some MVH crossings are smaller than those of PCAR crossings (as small as about 9 km^2; Table 4.1). Therefore, it could be argued that the same regional station selection criteria should be applied to both MVH and PCAR crossings.

To evaluate the effects of differing regional station selection criteria on flow predictions and water availability, flows were predicted for the five previously studied PCAR watercourses using regression coefficients derived in this study and in the PCAR study, and results are compared in Figure 6.2. Flows are similar for both approaches in most months. The exception is March. Regionally, flows are variable in March: flows begin to increase at some sites, while flow is delayed at other sites. March regression equations were not statistically significant in the PCAR study.

Figure 6.2 Comparison of Monthly Flows Predicted Using Differing Sets of Regional Stations



NOTES:
Labeled numbers are months (1=January, 12=December).
Grey lines are 1:1 lines (i.e., have slopes of one and intercepts of zero). Monthly predictions (red dots) falling exactly on the 1:1 line are identical.
MVH flows were predicted using regression equations provided in Table 5.1.
PCAR flows were predicted using regression equations provided in the PCAR water availability study (K'alo-Stantec 2022a) and Appendix B.
Flow predictions from March for Christina, Francis, and Helava creeks are lower than axes limits.

The PCAR water availability study found that withdrawals may be permitted in March, since predicted flows were >30%MAD. However, it was noted that uncertainty was high in spring. This study finds that withdrawals may be permissible at some MVH crossings in March, but uncertainty is high, and site-specific field investigations would be required to assess this possibility.

On an annual basis, the impact of differing methodologies on predicted water availability is small, i.e., less than 11% at PCAR crossings (Table 6.2). Differences are larger for smaller watersheds, reflecting greater uncertainty in predictions from smaller watersheds (Figure 5.2).

Table 6.2 Comparison of Annual Water Availability Predicted Using Differing Sets of Regional Stations

Creek	Watershed Area (km^2)	Availability (m^3/yr)[a]		Difference	
		PCAR	MVH	m^3	%
Canyon	64	1,079,056	1,013,325	65,731	6
Christina	21	402,695	364,272	38,423	10
Francis	24	460,297	411,145	49,152	11
Helava	28	518,448	472,932	45,516	9
Prohibition	86	1,408,600	1,336,324	72,276	5

NOTE:
[a] calculated as 10% of volumetric flow in months where discharge is more than 30%MAD (DFO 2013).

6.3 Approaches for Assessment of Withdrawals from Waterbodies Appropriate for Preserving Downstream Environmental Flow Needs

Withdrawal volumes provided here for waterbodies follow guidelines intended to preserve littoral habitat and under-ice oxygen for aquatic life (MVLWB 2021b; MVLWB 2021a; DFO 2010). However, these guidelines do not explicitly consider impacts to downstream flows from upstream waterbody withdrawals. If this environmental value were to be considered, then appropriate withdrawal volumes in non-winter periods could be assessed as best practice. This may also be important to assess in winter at sites with large upstream lakes or with large watersheds, where flow continues over winter. It is possible in some cases, and at some times, that this environmental value may not be limiting. For example, at lakes with short residence times and during periods of high throughflow, i.e., when and where inflow is much greater than proposed withdrawals.

Impacts to downstream EFN from upstream lake withdrawals are explicitly considered in protocols from neighbouring jurisdictions. For short-term water withdrawals from lakes in the open water period, the British Columbia Oil and Gas Commission (BCOGC) guidance is:

> *"the water availability as calculated by NEWT, NWWT or OWT*[4]*, and limited to the 10 centimetre maximum drawdown limit from the HWL [High Water Level] mark. An estimate of the available water must be provided for the lake based on a 10 centimetre drawdown, and other authorizations"* (BCOGC 2022)

[4] Online water tools that produce discharge and water availability estimates for watercourses for regions in British Columbia.

Similar online water tools do not exist in NT. In Alberta, allocation criteria for lakes also consider downstream flows, but do not rely on data from online water tools. Instead, allocation limits in the open water period are calculated using a site-specific water balance approach. In particular:

- "The cumulative annual allocation limit is ≤12% of the mean annual outflow"; and
- To protect downstream EFN over shorter periods of time "*Mean annual outflow divided equally across April to October. Monthly cumulative limit ≤ 15% of monthly apportioned outflow*".

Withdrawals from Alberta Lakes in winter follow a similar approach, but also consider volumetric equivalents of lake surface area, modified from DFO (2010).

Application of a similar water balance approach to preserving flows downstream of waterbodies in NT would be possible using publicly available data sources or can be readily calculated. Required data include lake area, watershed area, average annual evaporation and precipitation, average annual runoff, and groundwater flux (where relevant). Lake area has been provided here, watershed area can be readily calculated, site-specific precipitation is readily available (Wang et al. 2012; Wang 2022), and runoff can be calculated with the regional analysis approach presented here (Section 4.1). Site-specific evaporation from lakes requires calculation (McMahon et al. 2013), but may be negligible relative to other water balance components in lakes with small surface areas and/or high throughflow.

The water balance approach described above may help satisfy the MVH environmental assessment Terms of Reference (TOR) request to "*describe the recharge ability of lakes that will be used for winter road watering or ice mining*" (MVEIRB 2015).

7 Conclusions and Recommendations

Water volumes available for withdrawal have been assessed for 22 watercourses and 24 waterbodies along the proposed Mackenzie Valley Highway (MVH) alignment, spanning roughly from Wrigley to Norman Wells, NT.

Conclusions for watercourses include:

- For all watercourses except the GBR, water is typically available for withdrawal from approximately April to October, and not available for withdrawal over winter. Over winter, withdrawals are unlikely to be classified as 'low-risk' because flows are likely to be less than 30% of mean annual discharge (DFO 2013). Large volumes of water are expected to be available for withdrawal from the GBR year-round.
- On an annual basis, volumes available for withdrawal are likely to be large compared to waterbodies.
- There are numerous (22) potential watercourse water sources.
- No long gaps exist between candidate watercourses along the proposed MVH alignment ('long' relative to gaps between waterbodies).

Conclusions for waterbodies include:

- Conservative, low-risk, regionally appropriate potential withdrawal volumes have been provided here in ice covered and ice-free periods.
  - In ice covered periods, volumes provided here are the *minimum* of criteria designed to protect littoral habitat (MVLWB 2021a; MVLWB 2021b) and oxygen levels under ice (DFO 2010).
  - In ice-free periods, volumes provided here align with criteria designed to protect littoral habitat (MVLWB 2021a; MVLWB 2021b).
- Volumes available for withdrawal from waterbodies are likely to be small compared to watercourses.
- In ice covered periods, there are nine waterbodies with sufficient data to assess relative to withdrawal criteria. In ice-free periods there are eleven waterbodies.
- There are long distances between lakes that meet assessment criteria and where data are available.

Recommendations related to watercourses include:

- Withdrawal from a watercourse —whether under licence or not— should include a requirement for measurements of instantaneous flow at the time of withdrawal. These flow measurements should be compared to mean annual discharge for each creek to ensure flows are >30%MAD at the time of withdrawal and that withdrawals are <10% of instantaneous flow.
- If water is required in spring and to a lesser extent autumn, then additional site-specific flow measurements would be beneficial, given (a) uncertainties in flow predictions in spring, (b) the months where discharge is greater than 30% of MAD varies regionally, (c) monthly averages have been provided here, and flows will vary within each month and year, and (d) months in spring and autumn where flows pass DFO criteria sometimes vary between the WSC scaling approach and the regional analysis approach.
- Flow measurements over winter would help define the timing and magnitudes of flows. This is recommended since the MVH TOR request a description of watercourses that have year-round flow (MVEIRB 2015), and in the event that over winter withdrawals from watercourses are sought.
- Pertinent supplemental information for winter MVH withdrawals would be defined by DFO and/or MVLWB. Where not already available, this could take the form of a fish periodicity table, baseline hydrological data, detailed fish habitat modelling, reconnaissance-level fish and fish habitat impact assessment, withdrawal rate limits, limited licence terms, and/or requirements to monitor water use (FLNRORD and ENV 2022).

Recommendations related to waterbodies include:

- Candidate lakes where bathymetric data are not available but may have maximum depths greater than 3.0 m were selected based on their surface areas and long axis lengths. The list could be refined by statistically relating surface area, maximum length, and other morphology indicators to maximum depth and lake volume using regional datasets of lakes where bathymetry is known (AEP 2019; Islam et al. 2018).
- Given the absence of published regional protocols for withdrawals from the open water period, discussions should occur with decision makers to identify data requirements for the Project. A potential water balance approach that aligns with EFN methodologies in neighbouring jurisdictions has been described in Section 6.3. This approach could be applied to watercourses and waterbodies in the non-winter period and may also be applicable in the winter period at watercourses that are downstream of large waterbodies and continue to flow through winter. This approach could be combined with targeted flow measurements in the winter and non-winter periods.

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9 Closure

If you have any questions, please do not hesitate to contact the undersigned.

Respectfully Submitted,

K'ALO-STANTEC LIMITED

Original signed by

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Appendix A Average Flows and Statistics for Gauged Crossings ('WSC Scaling' Method)

This Appendix provides flow and water availability statistics at proposed MVH crossings that were compiled from WSC stations on the same watercourse. Monitored flows have been scaled to flows at each crossing using scaling factors that scale crossing watershed area to the watershed area at each crossing (Section 4.1.2.1)

Predicted monthly average discharge is provided (units = m^3/s), along with mean daily and monthly flows (units = m^3/d, m^3/m).

Ten percent of these discharge and flow estimates are provided to indicate the maximum of cumulative withdrawals for a "low probability of detectable impacts to ecosystems" (DFO 2013). Water availability is set to zero in months where flow is <30% of MAD. Although DFO guidelines are for instantaneous rather than monthly average flows, monthly average flows are useful for initial assessment of typical flow magnitudes and water availability.

Table A.1 Big Smith Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)		
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]
Jan	0.33	5	0.033	28182	2818	873,642	87,358	0
Feb	0.25	4	0.025	21646	2165	606,088	60,620	0
Mar	0.22	3	0.022	18,996	1,900	588,876	58,900	0
Apr	0.46	7	0.046	40,090	4,009	1,202,700	120,270	0
May	33.65	528	3.365	2,907,361	290,736	90,128,191	9,012,816	9,012,816
Jun	17.47	274	1.747	1,509,325	150,932	45,279,750	4,527,960	4,527,960
Jul	5.37	84	0.537	464,036	46,404	14,385,116	1,438,524	1,438,524
Aug	6.46	101	0.646	558,106	55,811	17,301,286	1,730,141	1,730,141
Sep	7.62	119	0.762	657,949	65,795	19,738,470	1,973,850	1,973,850
Oct	3.09	48	0.309	266,952	26,695	8,275,512	827,545	827,545
Nov	1.08	17	0.108	92,877	9,288	2,786,310	278,640	0
Dec	0.53	8	0.053	46,002	4,600	1,426,062	142,600	0
Annual Mean	**6.38**	**n/a**	**0.638**	**550,960**	**55,096**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**202,592,003**	**20,259,224**	**19,510,836**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (1.913 m^2/s).

[a] Calculated as monthly discharge divided by MAD x100.

[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).

n/a: not applicable.

Table A.2 Blackwater Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)		
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]
Jan	4.92	8	0.492	425188	42519	13,180,828	1,318,089	0
Feb	3.53	6	0.353	305301	30530	8,548,428	854,840	0
Mar	3.27	5	0.327	282,201	28,220	8,748,231	874,820	0
Apr	4.81	8	0.480	415,112	41,511	12,453,360	1,245,330	0
May	214.73	342	21.473	18,552,418	1,855,242	575,124,958	57,512,502	57,512,502
Jun	230.16	366	23.016	19,885,663	1,988,566	596,569,890	59,656,980	59,656,980
Jul	118.90	189	11.890	10,272,987	1,027,299	318,462,597	31,846,269	31,846,269
Aug	56.92	91	5.692	4,918,191	491,819	152,463,921	15,246,389	15,246,389
Sep	53.21	85	5.321	4,597,143	459,714	137,914,290	13,791,420	13,791,420
Oct	37.54	60	3.754	3,243,695	324,370	100,554,545	10,055,470	10,055,470
Nov	16.45	26	1.645	1,421,513	142,151	42,645,390	4,264,530	0
Dec	9.63	15	0.963	832,168	83,217	25,797,208	2,579,727	0
Annual Mean	**62.84**	**n/a**	**6.284**	**5,429,298**	**542,930**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**1,992,463,646**	**199,246,366**	**188,109,030**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (18.852 m^2/s).

[a] Calculated as monthly discharge divided by MAD x100.

[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).

n/a: not applicable.

Table A.3 Hodgson Creek Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)		
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]
Jan	0.29	14	0.029	25180	2518	780,580	78,058	0
Feb	0.22	11	0.022	19358	1936	542,024	54,208	0
Mar	0.19	9	0.019	16,054	1,605	497,674	49,755	0
Apr	0.98	48	0.098	84,620	8,462	2,538,600	253,860	253,860
May	9.56	468	0.956	826,238	82,624	25,613,378	2,561,344	2,561,344
Jun	2.88	141	0.288	248,600	24,860	7,458,000	745,800	745,800
Jul	2.92	143	0.292	252,228	25,223	7,819,068	781,913	781,913
Aug	2.62	128	0.262	226,072	22,607	7,008,232	700,817	700,817
Sep	2.22	109	0.222	192,193	19,219	5,765,790	576,570	576,570
Oct	1.44	71	0.144	124,731	12,473	3,866,661	386,663	386,663
Nov	0.75	37	0.075	64,569	6,457	1,937,070	193,710	193,710
Dec	0.44	22	0.044	38,297	3,830	1,187,207	118,730	0
Annual Mean	**2.04**	**n/a**	**0.204**	**176,512**	**17,651**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**65,014,284**	**6,501,428**	**6,200,677**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.613 m^2/s).

[a] Calculated as monthly discharge divided by MAD x100.

[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).

n/a: not applicable.

Table A.4 Jungle Ridge Creek Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)		
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]
Jan	0.00	0	0.000	29	3	899	93	0
Feb	0.00	0	0.000	1	0	28	0	0
Mar	0.00	0	0.000	0	0	0	0	0
Apr	0.15	47	0.015	13,321	1,332	399,630	39,960	39,960
May	2.05	625	0.205	177,491	17,749	5,502,221	550,219	550,219
Jun	0.65	198	0.065	56,225	5,622	1,686,750	168,660	168,660
Jul	0.23	69	0.023	19,492	1,949	604,252	60,419	60,419
Aug	0.29	89	0.029	25,438	2,544	788,578	78,864	78,864
Sep	0.34	104	0.034	29,627	2,963	888,810	88,890	88,890
Oct	0.18	55	0.018	15,713	1,571	487,103	48,701	48,701
Nov	0.03	10	0.003	2,880	288	86,400	8,640	0
Dec	0.01	2	0.001	555	56	17,205	1,736	0
Annual Mean	**0.33**	**n/a**	**0.033**	**28,398**	**2,840**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**10,461,876**	**1,046,182**	**1,035,713**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.099 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
n/a: not applicable.

Table A.5 Ochre River Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)		
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]
Jan	0.49	5	0.049	42240	4224	1,309,440	130,944	0
Feb	0.41	4	0.041	34981	3498	979,468	97,944	0
Mar	0.32	3	0.032	27,318	2,732	846,858	84,692	0
Apr	3.14	32	0.314	271,037	27,104	8,131,110	813,120	813,120
May	49.61	511	4.961	4,286,306	428,631	132,875,486	13,287,561	13,287,561
Jun	13.60	140	1.360	1,174,935	117,494	35,248,050	3,524,820	3,524,820
Jul	12.86	132	1.286	1,110,656	111,066	34,430,336	3,443,046	3,443,046
Aug	14.11	145	1.411	1,219,460	121,946	37,803,260	3,780,326	3,780,326
Sep	14.50	149	1.450	1,252,839	125,284	37,585,170	3,758,520	3,758,520
Oct	5.38	55	0.538	464,469	46,447	14,398,539	1,439,857	1,439,857
Nov	1.51	16	0.151	130,695	13,070	3,920,850	392,100	0
Dec	0.65	7	0.065	56,139	5,614	1,740,309	174,034	0
Annual Mean	**9.71**	**n/a**	**0.972**	**839,256**	**83,926**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**309,268,876**	**30,926,964**	**30,047,250**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (2.914 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
n/a: not applicable.

Appendix B Average Flows and Statistics for Ungauged Crossings Derived Using Regional Analyses

This Appendix provides flow and water availability statistics at proposed MVH crossings that were predicted with regression-based techniques.

Predicted monthly average discharge is provided (units = m^3/s), along with mean daily and monthly flows (units = m^3/d, m^3/m).

Ten percent of these discharge and flow estimates are provided to indicate the maximum of cumulative withdrawals for a “low probability of detectable impacts to ecosystems” (DFO 2013). Water availability is set to zero in months where flow is <30% of MAD. Although DFO guidelines are for instantaneous rather than monthly average flows, monthly average flows are useful for initial assessment of typical flow magnitudes and water availability.

Table B.1 Big Strawberry Creek Culvert: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.01	2	0.001	478	48	14,818	1,488	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	54	5	1,512	140	0	0.00	0.00	0.68	0.000	15
Mar	0.00	1	0.000	214	21	6,634	651	0	0.00	0.00	0.59	0.001	14
Apr	0.26	86	0.026	22,376	2,238	671,280	67,140	67,140	0.10	0.50	0.65	0.000	16
May	1.91	634	0.191	164,871	16,487	5,111,001	511,097	511,097	1.40	2.70	0.91	0.000	21
Jun	0.38	126	0.038	32,764	3,276	982,920	98,280	98,280	0.30	0.50	0.96	0.000	21
Jul	0.25	83	0.025	21,660	2,166	671,460	67,146	67,146	0.20	0.40	0.92	0.000	21
Aug	0.27	91	0.027	23,547	2,355	729,957	73,005	73,005	0.20	0.40	0.90	0.000	21
Sep	0.24	81	0.024	21,082	2,108	632,460	63,240	63,240	0.10	0.40	0.85	0.000	21
Oct	0.22	74	0.022	19,179	1,918	594,549	59,458	59,458	0.20	0.30	0.93	0.000	19
Nov	0.05	16	0.005	4,079	408	122,370	12,240	0	0.00	0.10	0.90	0.000	16
Dec	0.02	7	0.002	1,900	190	58,900	5,890	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.30**	**n/a**	**0.030**	**26,017**	**2,602**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**9,597,861**	**959,775**	**939,366**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.09 m²/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.2 Bob's Canyon Creek Culvert: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.00	0	0.000	39	4	1,209	124	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	2	0	56	0	0	0.00	0.00	0.68	0.000	15
Mar	0.00	0	0.000	15	2	465	62	0	0.00	0.00	0.59	0.001	14
Apr	0.09	166	0.009	7,955	796	238,650	23,880	23,880	0.00	0.30	0.65	0.000	16
May	0.38	693	0.038	33,154	3,315	1,027,774	102,765	102,765	0.20	0.70	0.91	0.000	21
Jun	0.04	76	0.004	3,663	366	109,890	10,980	10,980	0.00	0.10	0.96	0.000	21
Jul	0.03	52	0.003	2,490	249	77,190	7,719	7,719	0.00	0.10	0.92	0.000	21
Aug	0.04	67	0.004	3,170	317	98,270	9,827	9,827	0.00	0.10	0.90	0.000	21
Sep	0.03	60	0.003	2,830	283	84,900	8,490	8,490	0.00	0.10	0.85	0.000	21
Oct	0.04	70	0.004	3,332	333	103,292	10,323	10,323	0.00	0.10	0.93	0.000	19
Nov	0.01	11	0.001	522	52	15,660	1,560	0	0.00	0.00	0.90	0.000	16
Dec	0.00	5	0.000	245	24	7,595	744	0	0.00	0.00	0.74	0.000	17
Annual Mean	**0.06**	**n/a**	**0.006**	**4,785**	**478**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**1,764,951**	**176,474**	**173,984**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.017 m²/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.3 Dam Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.01	2	0.001	1109	111	34,379	3,441	0	0.00	0.10	0.6	0.000	16
Feb	0.00	0	0.000	177	18	4,956	504	0	0.00	0.00	0.68	0.000	15
Mar	0.01	1	0.001	525	52	16,275	1,612	0	0.00	0.00	0.59	0.001	14
Apr	0.37	68	0.037	31,630	3,163	948,900	94,890	94,890	0.20	0.60	0.65	0.000	16
May	3.26	602	0.326	282,001	28,200	8,742,031	874,200	874,200	2.50	4.30	0.91	0.000	21
Jun	0.79	146	0.079	68,207	6,821	2,046,210	204,630	204,630	0.60	1.00	0.96	0.000	21
Jul	0.52	95	0.052	44,670	4,467	1,384,770	138,477	138,477	0.40	0.70	0.92	0.000	21
Aug	0.53	98	0.053	46,063	4,606	1,427,953	142,786	142,786	0.40	0.80	0.90	0.000	21
Sep	0.48	88	0.048	41,280	4,128	1,238,400	123,840	123,840	0.30	0.80	0.85	0.000	21
Oct	0.40	74	0.040	34,449	3,445	1,067,919	106,795	106,795	0.30	0.50	0.93	0.000	19
Nov	0.09	17	0.009	8,116	812	243,480	24,360	0	0.10	0.20	0.90	0.000	16
Dec	0.04	8	0.004	3,771	377	116,901	11,687	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.54**	**n/a**	**0.054**	**46,833**	**4,683**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**17,272,174**	**1,727,222**	**1,685,618**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.163 m²/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.4 Devil's Canyon Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.00	1	0.000	118	12	3,658	372	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	7	1	196	28	0	0.00	0.00	0.68	0.000	15
Mar	0.00	1	0.000	48	5	1,488	155	0	0.00	0.00	0.59	0.001	14
Apr	0.15	126	0.015	12,605	1,260	378,150	37,800	37,800	0.10	0.40	0.65	0.000	16
May	0.78	674	0.078	67,700	6,770	2,098,700	209,870	209,870	0.50	1.20	0.91	0.000	21
Jun	0.11	96	0.011	9,713	971	291,390	29,130	29,130	0.10	0.20	0.96	0.000	21
Jul	0.08	65	0.008	6,522	652	202,182	20,212	20,212	0.00	0.10	0.92	0.000	21
Aug	0.09	77	0.009	7,739	774	239,909	23,994	23,994	0.00	0.20	0.90	0.000	21
Sep	0.08	69	0.008	6,918	692	207,540	20,760	20,760	0.00	0.20	0.85	0.000	21
Oct	0.08	72	0.008	7,262	726	225,122	22,506	22,506	0.10	0.10	0.93	0.000	19
Nov	0.02	13	0.002	1,303	130	39,090	3,900	0	0.00	0.00	0.90	0.000	16
Dec	0.01	6	0.001	609	61	18,879	1,891	0	0.00	0.00	0.74	0.000	17
Annual Mean	**0.12**	**n/a**	**0.012**	**10,045**	**1,005**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**3,706,304**	**370,618**	**364,272**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.035 m²/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.5 Four Mile Creek Culvert: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.00	1	0.000	89	9	2,759	279	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	5	0	140	0	0	0.00	0.00	0.68	0.000	15
Mar	0.00	0	0.000	36	4	1,116	124	0	0.00	0.00	0.59	0.001	14
Apr	0.13	135	0.013	11,209	1,121	336,270	33,630	33,630	0.10	0.30	0.65	0.000	16
May	0.65	680	0.065	56,431	5,643	1,749,361	174,933	174,933	0.40	1.10	0.91	0.000	21
Jun	0.09	92	0.009	7,574	757	227,220	22,710	22,710	0.10	0.10	0.96	0.000	21
Jul	0.06	61	0.006	5,102	510	158,162	15,810	15,810	0.00	0.10	0.92	0.000	21
Aug	0.07	74	0.007	6,163	616	191,053	19,096	19,096	0.00	0.10	0.90	0.000	21
Sep	0.06	67	0.006	5,508	551	165,240	16,530	16,530	0.00	0.10	0.85	0.000	21
Oct	0.07	72	0.007	5,953	595	184,543	18,445	18,445	0.00	0.10	0.93	0.000	19
Nov	0.01	13	0.001	1,032	103	30,960	3,090	0	0.00	0.00	0.90	0.000	16
Dec	0.01	6	0.001	483	48	14,973	1,488	0	0.00	0.00	0.74	0.000	17
Annual Mean	**0.10**	**n/a**	**0.010**	**8,299**	**830**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**3,061,797**	**306,135**	**301,154**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.029 m²/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.6 Gotcha Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.02	3	0.002	1762	176	54,622	5,456	0	0.00	0.10	0.6	0.000	16
Feb	0.00	1	0.000	342	34	9,576	952	0	0.00	0.00	0.68	0.000	15
Mar	0.01	1	0.001	860	86	26,660	2,666	0	0.00	0.10	0.59	0.001	14
Apr	0.44	59	0.044	38,268	3,827	1,148,040	114,810	114,810	0.30	0.70	0.65	0.000	16
May	4.39	583	0.439	378,949	37,895	11,747,419	1,174,745	1,174,745	3.40	5.70	0.91	0.000	21
Jun	1.18	157	0.118	102,125	10,212	3,063,750	306,360	306,360	0.90	1.50	0.96	0.000	21
Jul	0.77	102	0.077	66,538	6,654	2,062,678	206,274	206,274	0.60	1.10	0.92	0.000	21
Aug	0.77	103	0.077	66,647	6,665	2,066,057	206,615	206,615	0.60	1.10	0.90	0.000	21
Sep	0.69	92	0.069	59,759	5,976	1,792,770	179,280	179,280	0.50	1.00	0.85	0.000	21
Oct	0.55	73	0.055	47,555	4,756	1,474,205	147,436	147,436	0.40	0.70	0.93	0.000	19
Nov	0.14	18	0.014	11,853	1,185	355,590	35,550	0	0.10	0.20	0.90	0.000	16
Dec	0.06	9	0.006	5,501	550	170,531	17,050	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.75**	**n/a**	**0.075**	**65,013**	**6,501**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**23,971,898**	**2,397,194**	**2,335,520**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.226 m²/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.7 Little Smith Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.08	4	0.008	7198	720	223,138	22,320	0	0.00	0.20	0.6	0.000	16
Feb	0.03	1	0.003	2521	252	70,588	7,056	0	0.00	0.10	0.68	0.000	15
Mar	0.05	2	0.005	3,847	385	119,257	11,935	0	0.00	0.10	0.59	0.001	14
Apr	0.79	38	0.079	68,238	6,824	2,047,140	204,720	204,720	0.50	1.20	0.65	0.000	16
May	10.76	518	1.076	929,289	92,929	28,807,959	2,880,799	2,880,799	8.70	13.30	0.91	0.000	21
Jun	4.03	194	0.403	347,775	34,778	10,433,250	1,043,340	1,043,340	3.30	4.90	0.96	0.000	21
Jul	2.58	124	0.258	223,058	22,306	6,914,798	691,486	691,486	2.00	3.40	0.92	0.000	21
Aug	2.37	114	0.237	204,554	20,455	6,341,174	634,105	634,105	1.80	3.10	0.90	0.000	21
Sep	2.13	102	0.213	183,707	18,371	5,511,210	551,130	551,130	1.50	3.00	0.85	0.000	21
Oct	1.47	71	0.147	126,556	12,656	3,923,236	392,336	392,336	1.20	1.80	0.93	0.000	19
Nov	0.43	21	0.043	37,429	3,743	1,122,870	112,290	0	0.30	0.60	0.90	0.000	16
Dec	0.20	10	0.020	17,305	1,730	536,455	53,630	0	0.10	0.40	0.74	0.000	17
Annual Mean	**2.08**	**n/a**	**0.208**	**179,290**	**17,929**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**66,051,075**	**6,605,147**	**6,397,916**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.623 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.8 Notta Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.01	2	0.001	544	54	16,864	1,674	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	65	6	1,820	168	0	0.00	0.00	0.68	0.000	15
Mar	0.00	1	0.000	246	25	7,626	775	0	0.00	0.00	0.59	0.001	14
Apr	0.27	83	0.027	23,613	2,361	708,390	70,830	70,830	0.10	0.50	0.65	0.000	16
May	2.07	629	0.207	179,220	17,922	5,555,820	555,582	555,582	1.50	2.90	0.91	0.000	21
Jun	0.43	129	0.043	36,720	3,672	1,101,600	110,160	110,160	0.30	0.60	0.96	0.000	21
Jul	0.28	85	0.028	24,240	2,424	751,440	75,144	75,144	0.20	0.40	0.92	0.000	21
Aug	0.30	92	0.030	26,136	2,614	810,216	81,034	81,034	0.20	0.50	0.90	0.000	21
Sep	0.27	82	0.027	23,403	2,340	702,090	70,200	70,200	0.20	0.50	0.85	0.000	21
Oct	0.24	74	0.024	21,007	2,101	651,217	65,131	65,131	0.20	0.30	0.93	0.000	19
Nov	0.05	16	0.005	4,539	454	136,170	13,620	0	0.00	0.10	0.90	0.000	16
Dec	0.02	7	0.002	2,113	211	65,503	6,541	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.33**	**n/a**	**0.033**	**28,487**	**2,849**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**10,508,756**	**1,050,859**	**1,028,081**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.099 m²/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.9 Saline River Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.05	4	0.005	4635	464	143,685	14,384	0	0.00	0.10	0.6	0.000	16
Feb	0.02	1	0.002	1350	135	37,800	3,780	0	0.00	0.10	0.68	0.000	15
Mar	0.03	2	0.003	2,407	241	74,617	7,471	0	0.00	0.10	0.59	0.001	14
Apr	0.66	44	0.066	56,947	5,695	1,708,410	170,850	170,850	0.40	1.00	0.65	0.000	16
May	8.13	539	0.813	701,959	70,196	21,760,729	2,176,076	2,176,076	6.50	10.10	0.91	0.000	21
Jun	2.74	182	0.274	237,062	23,706	7,111,860	711,180	711,180	2.30	3.30	0.96	0.000	21
Jul	1.77	117	0.177	152,797	15,280	4,736,707	473,680	473,680	1.30	2.30	0.92	0.000	21
Aug	1.67	111	0.167	144,042	14,404	4,465,302	446,524	446,524	1.30	2.20	0.90	0.000	21
Sep	1.50	99	0.150	129,297	12,930	3,878,910	387,900	387,900	1.00	2.10	0.85	0.000	21
Oct	1.08	72	0.108	93,183	9,318	2,888,673	288,858	288,858	0.90	1.30	0.93	0.000	19
Nov	0.30	20	0.030	26,123	2,612	783,690	78,360	0	0.20	0.40	0.90	0.000	16
Dec	0.14	9	0.014	12,092	1,209	374,852	37,479	0	0.10	0.30	0.74	0.000	17
Annual Mean	**1.51**	**n/a**	**0.151**	**130,158**	**13,016**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**47,965,235**	**4,796,542**	**4,655,068**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.452 m²/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.10 Seagrams Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.01	2	0.001	456	46	14,136	1,426	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	50	5	1,400	140	0	0.00	0.00	0.68	0.000	15
Mar	0.00	1	0.000	204	20	6,324	620	0	0.00	0.00	0.59	0.001	14
Apr	0.25	87	0.025	21,952	2,195	658,560	65,850	65,850	0.10	0.50	0.65	0.000	16
May	1.85	635	0.185	160,044	16,004	4,961,364	496,124	496,124	1.30	2.60	0.91	0.000	21
Jun	0.36	125	0.036	31,461	3,146	943,830	94,380	94,380	0.30	0.50	0.96	0.000	21
Jul	0.24	83	0.024	20,810	2,081	645,110	64,511	64,511	0.20	0.40	0.92	0.000	21
Aug	0.26	90	0.026	22,688	2,269	703,328	70,339	70,339	0.20	0.40	0.90	0.000	21
Sep	0.24	81	0.024	20,312	2,031	609,360	60,930	60,930	0.10	0.40	0.85	0.000	21
Oct	0.22	74	0.022	18,567	1,857	575,577	57,567	57,567	0.20	0.30	0.93	0.000	19
Nov	0.05	15	0.005	3,926	393	117,780	11,790	0	0.00	0.10	0.90	0.000	16
Dec	0.02	7	0.002	1,829	183	56,699	5,673	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.29**	**n/a**	**0.029**	**25,192**	**2,519**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**9,293,468**	**929,350**	**909,701**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.087 m²/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.11 Small Strawberry Creek Culvert: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.00	2	0.000	372	37	11,532	1,147	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	38	4	1,064	112	0	0.00	0.00	0.68	0.000	15
Mar	0.00	1	0.000	164	16	5,084	496	0	0.00	0.00	0.59	0.001	14
Apr	0.23	92	0.023	20,189	2,019	605,670	60,570	60,570	0.10	0.50	0.65	0.000	16
May	1.63	642	0.163	140,553	14,055	4,357,143	435,705	435,705	1.10	2.30	0.91	0.000	21
Jun	0.31	120	0.031	26,347	2,635	790,410	79,050	79,050	0.20	0.40	0.96	0.000	21
Jul	0.20	80	0.020	17,467	1,747	541,477	54,157	54,157	0.10	0.30	0.92	0.000	21
Aug	0.22	88	0.022	19,288	1,929	597,928	59,799	59,799	0.10	0.40	0.90	0.000	21
Sep	0.20	79	0.020	17,264	1,726	517,920	51,780	51,780	0.10	0.40	0.85	0.000	21
Oct	0.19	74	0.019	16,114	1,611	499,534	49,941	49,941	0.10	0.30	0.93	0.000	19
Nov	0.04	15	0.004	3,324	332	99,720	9,960	0	0.00	0.10	0.90	0.000	16
Dec	0.02	7	0.002	1,549	155	48,019	4,805	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.25**	**n/a**	**0.025**	**21,889**	**2,189**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**8,075,501**	**807,522**	**791,002**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.076 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.12 Steep Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.02	3	0.002	1747	175	54,157	5,425	0	0.00	0.10	0.6	0.000	16
Feb	0.00	1	0.000	338	34	9,464	952	0	0.00	0.00	0.68	0.000	15
Mar	0.01	1	0.001	852	85	26,412	2,635	0	0.00	0.10	0.59	0.001	14
Apr	0.44	59	0.044	38,131	3,813	1,143,930	114,390	114,390	0.30	0.70	0.65	0.000	16
May	4.36	583	0.436	376,841	37,684	11,682,071	1,168,204	1,168,204	3.40	5.60	0.91	0.000	21
Jun	1.17	157	0.117	101,350	10,135	3,040,500	304,050	304,050	0.90	1.50	0.96	0.000	21
Jul	0.76	102	0.076	66,040	6,604	2,047,240	204,724	204,724	0.60	1.10	0.92	0.000	21
Aug	0.77	102	0.077	66,184	6,618	2,051,704	205,158	205,158	0.60	1.10	0.90	0.000	21
Sep	0.69	92	0.069	59,343	5,934	1,780,290	178,020	178,020	0.50	1.00	0.85	0.000	21
Oct	0.55	73	0.055	47,267	4,727	1,465,277	146,537	146,537	0.40	0.70	0.93	0.000	19
Nov	0.14	18	0.014	11,769	1,177	353,070	35,310	0	0.10	0.20	0.90	0.000	16
Dec	0.06	8	0.006	5,462	546	169,322	16,926	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.75**	**n/a**	**0.075**	**64,610**	**6,461**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**23,823,437**	**2,382,331**	**2,321,083**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.224 m²/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.13 Twelve Mile Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.00	2	0.000	305	30	9,455	930	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	28	3	784	84	0	0.00	0.00	0.68	0.000	15
Mar	0.00	1	0.000	133	13	4,123	403	0	0.00	0.00	0.59	0.001	14
Apr	0.22	97	0.022	18,610	1,861	558,300	55,830	55,830	0.10	0.40	0.65	0.000	16
May	1.43	648	0.143	123,885	12,388	3,840,435	384,028	384,028	1.00	2.10	0.91	0.000	21
Jun	0.26	116	0.026	22,174	2,217	665,220	66,510	66,510	0.20	0.40	0.96	0.000	21
Jul	0.17	77	0.017	14,733	1,473	456,723	45,663	45,663	0.10	0.30	0.92	0.000	21
Aug	0.19	86	0.019	16,472	1,647	510,632	51,057	51,057	0.10	0.30	0.90	0.000	21
Sep	0.17	77	0.017	14,740	1,474	442,200	44,220	44,220	0.10	0.30	0.85	0.000	21
Oct	0.16	74	0.016	14,040	1,404	435,240	43,524	43,524	0.10	0.20	0.93	0.000	19
Nov	0.03	15	0.003	2,828	283	84,840	8,490	0	0.00	0.10	0.90	0.000	16
Dec	0.02	7	0.002	1,319	132	40,889	4,092	0	0.00	0.00	0.74	0.000	17
Annual Mean	**0.22**	**n/a**	**0.022**	**19,106**	**1,910**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**7,048,841**	**704,831**	**690,832**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.066 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.14 Vermillion Creek North Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.01	2	0.001	871	87	27,001	2,697	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	126	13	3,528	364	0	0.00	0.00	0.68	0.000	15
Mar	0.01	1	0.001	406	41	12,586	1,271	0	0.00	0.00	0.59	0.001	14
Apr	0.33	72	0.033	28,640	2,864	859,200	85,920	85,920	0.20	0.60	0.65	0.000	16
May	2.80	612	0.280	241,760	24,176	7,494,560	749,456	749,456	2.10	3.80	0.91	0.000	21
Jun	0.64	140	0.064	55,269	5,527	1,658,070	165,810	165,810	0.50	0.80	0.96	0.000	21
Jul	0.42	92	0.042	36,295	3,630	1,125,145	112,530	112,530	0.30	0.60	0.92	0.000	21
Aug	0.44	96	0.044	37,998	3,800	1,177,938	117,800	117,800	0.30	0.60	0.90	0.000	21
Sep	0.39	86	0.039	34,043	3,404	1,021,290	102,120	102,120	0.20	0.60	0.85	0.000	21
Oct	0.34	74	0.034	29,121	2,912	902,751	90,272	90,272	0.20	0.50	0.93	0.000	19
Nov	0.08	17	0.008	6,662	666	199,860	19,980	0	0.00	0.10	0.90	0.000	16
Dec	0.04	8	0.004	3,098	310	96,038	9,610	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.46**	**n/a**	**0.046**	**39,524**	**3,953**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**14,577,967**	**1,457,830**	**1,423,908**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.137 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.15 Vermillion Creek South Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.01	2	0.001	579	58	17,949	1,798	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	70	7	1,960	196	0	0.00	0.00	0.68	0.000	15
Mar	0.00	1	0.000	263	26	8,153	806	0	0.00	0.00	0.59	0.001	14
Apr	0.28	81	0.028	24,213	2,421	726,390	72,630	72,630	0.10	0.50	0.65	0.000	16
May	2.16	627	0.216	186,325	18,632	5,776,075	577,592	577,592	1.60	3.00	0.91	0.000	21
Jun	0.45	130	0.045	38,723	3,872	1,161,690	116,160	116,160	0.30	0.60	0.96	0.000	21
Jul	0.30	86	0.030	25,545	2,554	791,895	79,174	79,174	0.20	0.40	0.92	0.000	21
Aug	0.32	92	0.032	27,438	2,744	850,578	85,064	85,064	0.20	0.50	0.90	0.000	21
Sep	0.28	83	0.028	24,571	2,457	737,130	73,710	73,710	0.20	0.50	0.85	0.000	21
Oct	0.25	74	0.025	21,917	2,192	679,427	67,952	67,952	0.20	0.40	0.93	0.000	19
Nov	0.06	16	0.006	4,771	477	143,130	14,310	0	0.00	0.10	0.90	0.000	16
Dec	0.03	8	0.003	2,221	222	68,851	6,882	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.34**	**n/a**	**0.034**	**29,720**	**2,972**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**10,963,228**	**1,096,274**	**1,072,282**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.103 m²/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.16 Whitesand Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.06	4	0.006	5217	522	161,727	16,182	0	0.00	0.20	0.6	0.000	16
Feb	0.02	1	0.002	1597	160	44,716	4,480	0	0.00	0.10	0.68	0.000	15
Mar	0.03	2	0.003	2,731	273	84,661	8,463	0	0.00	0.10	0.59	0.001	14
Apr	0.69	42	0.069	59,785	5,978	1,793,550	179,340	179,340	0.50	1.00	0.65	0.000	16
May	8.76	534	0.876	756,952	75,695	23,465,512	2,346,545	2,346,545	7.10	10.90	0.91	0.000	21
Jun	3.04	185	0.304	262,790	26,279	7,883,700	788,370	788,370	2.50	3.70	0.96	0.000	21
Jul	1.96	119	0.196	169,156	16,916	5,243,836	524,396	524,396	1.50	2.60	0.92	0.000	21
Aug	1.83	112	0.183	158,285	15,828	4,906,835	490,668	490,668	1.40	2.40	0.90	0.000	21
Sep	1.65	100	0.165	142,102	14,210	4,263,060	426,300	426,300	1.20	2.30	0.85	0.000	21
Oct	1.17	71	0.117	101,176	10,118	3,136,456	313,658	313,658	0.90	1.40	0.93	0.000	19
Nov	0.33	20	0.033	28,775	2,878	863,250	86,340	0	0.20	0.50	0.90	0.000	16
Dec	0.15	9	0.015	13,315	1,332	412,765	41,292	0	0.10	0.30	0.74	0.000	17
Annual Mean	**1.64**	**n/a**	**0.164**	**141,823**	**14,182**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**52,260,068**	**5,226,034**	**5,069,277**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.492 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

APPENDIX 15D

Prohibition Creek Access Road: Desktop-based Assessment of Water Availability

Prohibition Creek Access Road: Desktop-Based Assessment of Water Availability

Prepared for:

Department of Infrastructure, Government of the Northwest Territories
Yellowknife, NT

Prepared by:

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September 16, 2022

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Executive Summary

Monthly average discharge, mean annual discharge, and water volumes available for withdrawal have been calculated for four ungauged—and one gauged—creeks along the proposed Prohibition Creek Access Road (PCAR) alignment (the Study Area), near Norman Wells, Northwest Territories. Selected results are summarized in the summary table below.

Summary Table: Selected Statistics and Observations for Predicted Discharge and Water Availability for Potential Water Sources Along the Proposed Prohibition Creek Access Road Alignment

Creek[a]	Watershed Area (km^2)	May Mean Discharge (m^3/s)	Mean Annual Discharge (m^3/s)	30% of Mean Annual Discharge (m^3/s)[b]	Annual Volume Available (m^3)[c]	Flows Likely in Winter?	Winter Observation Data Source
Canyon	64	2.12	0.35	0.104	1,079,056	y	Water Survey of Canada gauge 10KA009
Francis	24	0.88	0.15	0.044	460,297	n	Limited qualitative observations
Helava	28	1.00	0.17	0.050	518,448	n	Limited qualitative observations
Christina	21	0.76	0.13	0.039	402,695	n	Limited qualitative observations
Prohibition	86	2.76	0.45	0.135	1,408,600	y	One manual discharge measurement in April 1973

NOTES:

[a] At bridge crossings.

[b] The criterion used to define periods of 'low' risk withdrawals (months with greater than 30% of mean annual discharge (MAD) vs. 'high' risk withdrawals (months with less than 30% of MAD

[c] *Annual Water Available'* is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD)

Criteria described above follow: Fisheries and Oceans Canada. 2013. Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada. Canadian Science Advisory Secretariat Science Advisory Report 2013/017

Water will be used for winter and summer construction related activities, compaction, and dust control. The amount and timing of water withdrawals are not yet known; however, the majority is anticipated to be needed in early winter (November-December) for winter road construction.

Flows were predicted with a regional analysis of data from Water Survey of Canada (WSC) stations. Predictions are statistically significant from May to November. Winter flows in regional creeks are conditioned by site specific groundwater inputs as well as watershed size. Therefore, WSC data and historic literature from the area were reviewed for information pertinent to winter flows. The two largest creeks, Canyon and Prohibition, flow in winter. Limited available data suggest that the smaller creeks (Francis, Helava, and Christina) do not flow in winter.

"Cumulative flow alterations that result in instantaneous flows less than 30% of the Mean Annual Discharge (MAD) have a heightened risk of impacts to ecosystems that support fisheries". Periods of heightened risk were assessed (1) locally, using the results of flow predictions calculated here, and (2) regionally, using WSC data. By this definition, periods of heightened risk consistently occur over winter (November through February) both locally and regionally. Regionally, the only exception is a creek that drains several upstream ponds.

Monthly and annual average water volumes potentially available for withdrawal were calculated using DFO's criteria and 'desktop-based' flow estimates produced here. Annual volumes range from about 403,000 m^3 from Christina Creek to about 1,409,000 m^3 from Prohibition Creek (Summary Table). About half of this annual flow volume is in May. No water is predicted to be available using this 'desktop-based' methodology for withdrawal in November through February. Withdrawals during this overwinter period will likely require "*a more rigorous level of assessment… to evaluate potential impacts on ecosystem functions which support fisheries*" as required by DFO.

The region is sparsely gauged. Existing datasets are sometimes short and limited over winter. Stations with the shortest records are located close to the proposed PCAR alignment. Data from these stations were used in analyses because of their proximity to the Project. However, the variability of flows from these stations is similar to that of more distant stations with longer records, suggesting that the limited data available from these local sites adequately capture flow variability.

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Abbreviations

e.g.	example
DFO	Fisheries and Oceans Canada
EFN	Environmental Flow Needs
i.e.	that is to say
MAD	Mean Annual Discharge
masl	Metres Above Sea Level
PCAR	Prohibition Creek Access Road
QAQC	Quality Assurance/Quality Control
WSC	Water Survey of Canada

1 Introduction

This document provides monthly and annual flow estimates for candidate water withdrawal locations on streams crossing the proposed Prohibition Creek Access Road (PCAR) based on a desktop study of historic flows and literature in the region. The PCAR is proposed to be located about 16 to 30 km southeast of Norman Wells, Northwest Territories (NT), about 1.5 km from the north (right) bank of the Mackenzie River (Figure 1.1; Figure 1.2). The existing PCAR water licence authorizes water withdrawal from the Mackenzie River only (water license S20L8-002); this work investigates water availability in creeks along the PCAR alignment for potential future withdrawals.

The objectives and scope of the study are summarized below:

- Review potential water withdrawal sources along the proposed PCAR alignment. The five potential withdrawal sources are all moving waterbodies at existing bridges (Tetra Tech 2021; Tetra Tech 2022) (Table 1.1). An additional 39 proposed culvert crossings were identified that drain relatively small upstream catchments (<8.8 km^2) (Tetra Tech 2021; Tetra Tech 2022). Discharge is not predicted for these small creeks but can be calculated using equations presented here. No lakes or ponds were identified within 500 m of the PCAR alignment to be used as potential water withdrawal sources.
- Review existing available data to identify sources that are likely to support water withdrawal (based on watershed, flow data, hydrographs, etc.) during certain times of the year (Sections 4.1 and 5.2).
- Identify monthly discharge magnitudes and volumes potentially able to be withdrawn while meeting environmental flow needs (EFN; i.e. the volume and timing of water flow required for proper functioning of the aquatic ecosystem (FLNRORD 2022); Section 5.2). Criteria for low-risk withdrawals follow the '*Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada*' (DFO 2013) and are described in Section 4.4.
- Identify additional studies required to verify the findings of this desktop study (Section 7) and to support licensing of water withdrawal.

Table 1.1 Potential Water Withdrawal Sources at Creek Crossings Along the Proposed Prohibition Creek Access Road Alignment

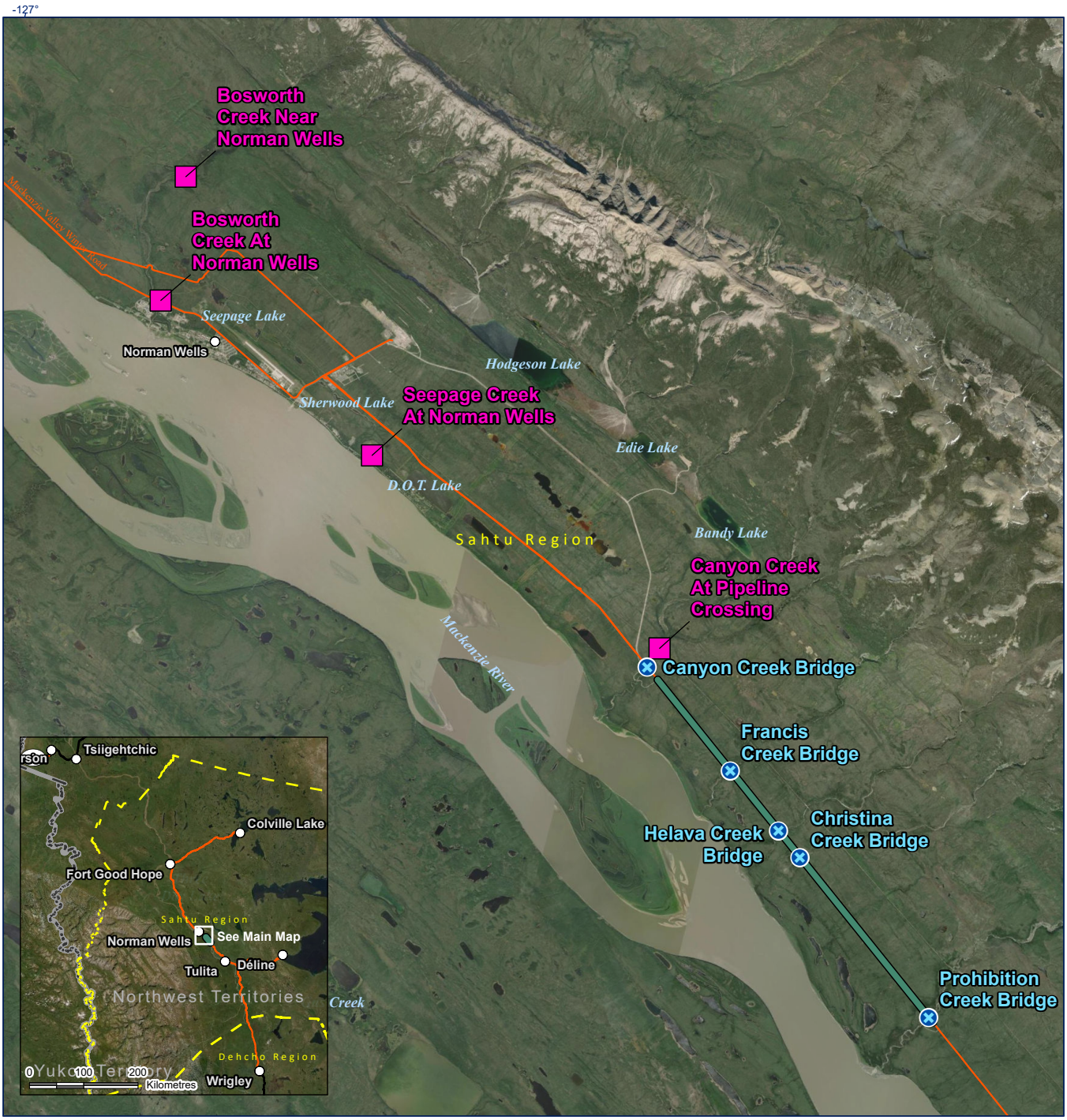
Crossing	UTM Easting (m)	UTM Northing (m)	Watershed Area (km^2)
Canyon Creek	615,829	7,235,942	64
Christina Creek	621,630	7,231,762	21
Francis Creek	618,988	7,233,671	24
Helava Creek	620,808	7,232,368	28
Prohibition Creek	626,507	7,228,256	86

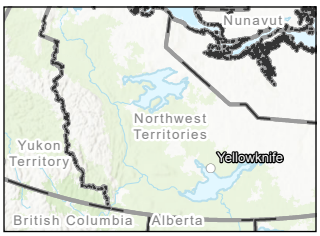
NOTE:
Coordinates are UTM Zone 9, WGS84 Datum. Watershed areas are from hydrotechnical assessments and design documents (Tetra Tech 2021; Tetra Tech 2022).

Fish habitat assessments have been conducted at each of the creeks near the crossings summarized in Table 1.1 (K'alo-Stantec Limited 2020). All creeks are classified as having the potential for fish habitat.

During construction and operation of the PCAR, water will be used for winter road construction, compaction and dust control. The amount and timing of water withdrawals are not yet known. This document aims to research potential water withdrawal sources that could support withdrawals throughout the year while meeting the DFO guidelines, and therefore could be supported by regulators for purpose of licensing. It is understood that the majority of water for winter road construction is needed in early winter (November-December) (Stevens 2022); whereas water is used for compaction and dust control from June to September.

This document provides average volumes available for withdrawal. Previous studies have provided discharges during floods and changes in flow due to climate change (Tetra Tech 2021; Tetra Tech 2022).





Water Survey of Canada Hydrometric Station
Existing Bridge
Prohibition Creek Access Road Proposed Alignment
Community
All-Season Road
Winter Road
Region Boundary

0 1.5 3 Kilometres
(At original document size of 8.5x11)
1:175,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by DS on 9/1/2022
TR by CES on 9/1/2022

Client/Project
144903025-0156

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
1.1

Title
Prohibition Creek Access Road Proposed Alignment, Potential Water Sources, and Analyzed Water Survey of Canada Stations

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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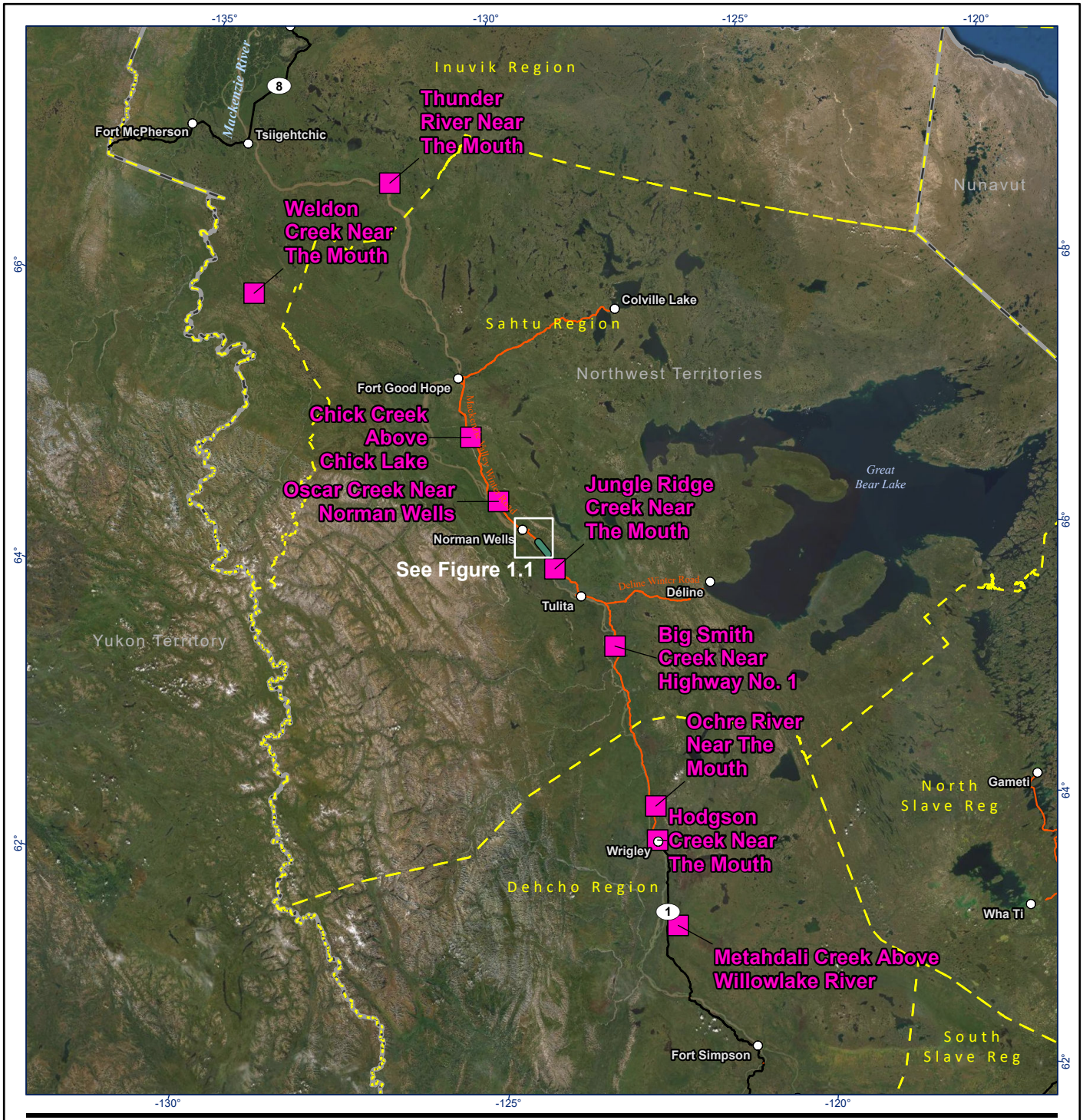

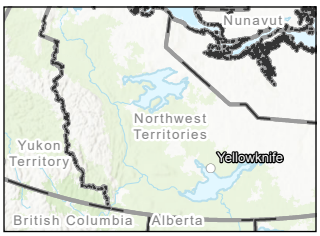

Water Survey of Canada Hydrometric Station
Prohibition Creek Access Road Proposed Alignment
Community
All-Season Road
Winter Road
Region Boundary

0 50 100 Kilometres
(At original document size of 8.5x11)
1:4,781,845

N

Kálo-Stantec

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

Project Location
Wrigley to Norman Wells, NWT

Prepared by DS on 9/6/2022
TR by CES on 9/6/2022

Client/Project
144903025-0158

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
1.2

Title
Regional Water Survey of Canada Stations Selected for Analyses

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2 Limitations

Flows and water volumes provided here are estimates for ungauged creeks in a sparsely monitored region (sparse both spatially and temporally). Results are approximations and are intended to focus efforts on creeks and time periods where the ecological impacts of withdrawals will be low. Limitations include:

- Flows and water volumes provided here are not prescriptive assessments of water availability in a given year. Flow predictions are reflective of average conditions in the years regional data were collected.
- Flows during floods and changes in flow due to climate change have been evaluated elsewhere (Tetra Tech 2021; Tetra Tech 2022).
- Results presented here should not be used for purposes other than those stated. For example, data presented here do not provide engineering design parameters. Engineering design and analysis of crossings (e.g., conveyance capacity and channel stability) would require a separate study tailored for such purposes.
- Analysis and recommendations are based on data available at the time of the report and rely on data provided by others which we assume to be correct but were not verified as part of this study.

Recommendations for refining estimates provided here are presented in Section 7.

3 Regional Hydroclimate

The proposed PCAR alignment is within the Mackenzie River Valley, about 30 km southeast of Norman Wells. A long-term climate station operates at Norman Wells (Station 'Norman Wells A', 73 masl). Average annual 30-year normal (1981-2010) air temperature is -5.1°C (ECCC 2022a). Average air temperatures dip below freezing in October and rise above freezing in May. Maximum monthly average air temperature occurs in July (17.1°C). The Mackenzie Valley itself has a somewhat milder climate than adjacent areas to the east and west (Kokelj 2001). Norman Wells receives 294 mm of precipitation annually, about 55% of which falls as snow. Daily rainfall amounts approaching 50 mm have historically occurred. Climate normal Hargreaves reference annual evapotranspiration is 389 mm (Wang et al. 2012); i.e., there is a potential annual moisture deficit in the region.

The proposed PCAR alignment is within the 'extensive discontinuous' (50-90%) permafrost zone (GNWT 2022). Norman Wells falls within the 'Taiga Plains, Norman Range LS Ecoregion'; vegetation is a "*complex of mixed-wood forests on westerly slopes and lacustrine deposits, mixed spruce stands on the interior plateau and slopes, and extensively burned areas*" (GNWT 2009).

The proposed PCAR alignment spans elevations from about 90 to 100 metres above sea level (masl). Creeks drain the Norman Range and Discovery Ridge to the east, with elevations up to about 1,500 masl.

The Sahtu Region has been classified into Arctic, East Mackenzie, Great Bear, and West Mackenzie hydrologic zones; the proposed PCAR alignment falls within the East Mackenzie zone (Golder Associates 2015). Regionally, a "*large portion of the annual precipitation is stored for several months in the form of snow and therefore snowmelt runoff in spring is a dominant feature of regional stream hydrographs*" (Kokelj 2001). Annual runoff for regional watersheds that drain into the Mackenzie River's east bank spans from about 60 mm (Seepage Creek at Norman Wells) to 327 mm (Jungle Ridge Creek near the Mouth)(Kokelj 2001). This is generally lower than runoff in the adjacent West Mackenzie zone.

Flows decline after freshet in May, with occasional increases in response to rainfall, then decline through winter. The ability of a watercourse to sustain flows over winter depends on "*watershed-specific factors including precipitation, channel slope, upland storage and particularly the presence of springs*" (Golder Associates 2006). Watercourses in the Sahtu Region have been described as:

> *"highly influenced by groundwater inflow… where streams with drainage areas larger than 50 km^2 likely maintain some flow over the winter because of groundwater contribution…Depending on local groundwater conditions, stream drainages smaller than 25 km^2 might also exhibit stream flow over the winter, whereas others with less groundwater inflow might freeze completely to the streambed."* (MGP 2004)

4 Methods

The main deliverables of this report are modelled predictions of mean monthly discharge, MAD, and ecologically 'low-risk' water withdrawal volumes at potential PCAR water sources. This was accomplished by conducting regression analyses of monthly mean flow for regional WSC stations and watershed area.

This section begins by describing available data, then describes the flow prediction methodology and criteria used for the assessment of low-risk water withdrawal volumes.

Data were collected, filtered, and analyzed in (R Core Team 2022). All regressions, statistics, and plotting were also conducted in R.

4.1 Data Sources

Daily flow data from WSC stations were compiled with the R library 'Tidyhydat' (Goetz, Albers and Pike 2018). Tidyhydat uses the WSC database 'Hydat' (ECCC 2022b). The Hydat version used here was published on 2022-04-18 and is the most recent database at the time of writing. The most recent finalized data for regional stations is from 2019 Provisional real-time data that have not yet undergone full quality assurance/quality control (QAQC) were not used here.

Hydrometric data were compiled for the WSC stations in the NT, then filtered to include only:

- Stations within 400 km of the Helava Creek crossing (a central point in the Study Area; Figure 1.2)
- Stations with watersheds that do not drain the Mackenzie Mountains, due to the different hydrologic regime there (Golder Associates 2015)(Section 3)
- Stations with relatively small to medium-sized watersheds, i.e., <~1000 km^2 [1]
- Stations whose discharge is unlikely to be affected by drainage of large upstream lakes, potentially causing delays between snowmelt and rainfall, and runoff[2]
- Months with greater than or equal to 92 daily observations (i.e., greater than about 3-years of data; Section 4.3; Section 6.2)

WSC stations included in the analysis after applying the filtering process are summarized in Table 4.1 and mapped in Figure 1.1 and Figure 1.2. Some stations in Table 4.1 have short periods of record, and/or have not recently operated. Several stations also have limited datasets over winter due to seasonal operation (Figure 4.1). Implications for use of relatively small sample sizes are explored in Section 6.2. Data from two stations[3] were frequently anomalous when flagged as backwatered. Backwatering causes river levels to rise independently from discharge, often in response to a downstream obstruction (e.g., ice, beaver dams), or a downstream waterbody or watercourse. These data were removed.

[1] 1,031 km^2. Set to include 10HC008, Oche River Near the Mouth.
[2] 10LB007 TIEDA RIVER NEAR THE MOUTH and 10LD002 JACKFISH CREEK NEAR FORT GOOD HOPE were excluded.
[3] 10KA005 SEEPAGE CREEK AT NORMAN WELLS and 10LA004, WELDON CREEK NEAR THE MOUTH.

4.2 Watershed Delineation

The WSC publish watershed areas for most stations in the NT (ECCC 2022b); however, watershed areas were missing for several stations that remained following the filtering process described above (station numbers 10KD009, 10HC007, 10HC008, and 10LB006; Table 4.1). The watershed areas for these stations were calculated using ArcGIS software. National Hydrographic Network basins (Natural Resources Canada 2022) were segmented along topographic ridgelines and flow patterns. Where watershed areas were available from the '*Prohibition Creek Access Road Hydrotechnical Assessments*' report, they were preferentially used here, since these watersheds were delineated using high-resolution LiDAR data (Tetra Tech 2021). The watershed area at the WSC station at Canyon Creek (10KA009) is about 3% smaller than 0.7 km downstream at the bridge crossing; for the purposes of these analyses, 64 km^2 (Tetra Tech 2021; Tetra Tech 2022) was used for both catchment areas.

Table 4.1 Regional Water Survey of Canada Stations Used for Flow Predictions along the Proposed Prohibition Creek Access Road Alignment

Station Number	Station Name	UTM Easting (m)	UTM Northing (m)	UTM Zone	Drainage Area (km^2)	Location[a] Dist. (km)	Location[a] Bearing (deg)[b]	Monitoring Period Begins	Monitoring Period Ends	Data Points (n)[c]
10KA009	CANYON CREEK AT PIPELINE CROSSING	615,995	7,236,583	9	*64*	6	-46	2009	2018	2,199
10KA005	SEEPAGE CREEK AT NORMAN WELLS	606,333	7,239,786	9	31	16	-60	1974	1978	1,614
10KA006	JUNGLE RIDGE CREEK NEAR THE MOUTH	635,408	7,217,955	9	60	21	137	1980	2018	6,796
10KA003	BOSWORTH CREEK AT NORMAN WELLS	599,129	7,242,508	9	122	24	-63	1973	1979	1,375
10KA007	BOSWORTH CREEK NEAR NORMAN WELLS	598,863	7,246,213	9	125	26	-55	1980	2018	9,256
10KA008	OSCAR CREEK NEAR NORMAN WELLS	575,639	7,259,095	9	638	53	-57	2009	2018	2,264
10HC003	BIG SMITH CREEK NEAR HIGHWAY NO. 1	413,224	7,164,281	10	980	101	131	1973	1994	7,820
10KD009	CHICK CREEK ABOVE CHICK LAKE	539,521	7,304,005	9	**16**	108	-46	2008	2018	2,870
10HC008	OCHRE RIVER NEAR THE MOUTH	469,488	7,040,295	10	**1,031**	233	143	2006	2019	4,412
10HC007	HODGSON CREEK NEAR THE MOUTH	475,833	7,012,887	10	**303**	260	145	2006	2014	2,896
10LA004	WELDON CREEK NEAR THE MOUTH	602,944	7,367,726	8	852	318	-62	1978	1990	4,748
10LB006	THUNDER RIVER NEAR THE MOUTH	418,760	7,488,203	9	**441**	326	-36	2006	2017	3,867
10GB005	METAHDALI CREEK ABOVE WILLOWLAKE RIVER	504,798	6,946,566	10	344	332	147	1976	1987	4,201

NOTES:

Stations are sorted by distance from Helava Creek bridge, a central point along the PCAR proposed alignment.

[a] Relative to the Helava Creek bridge.

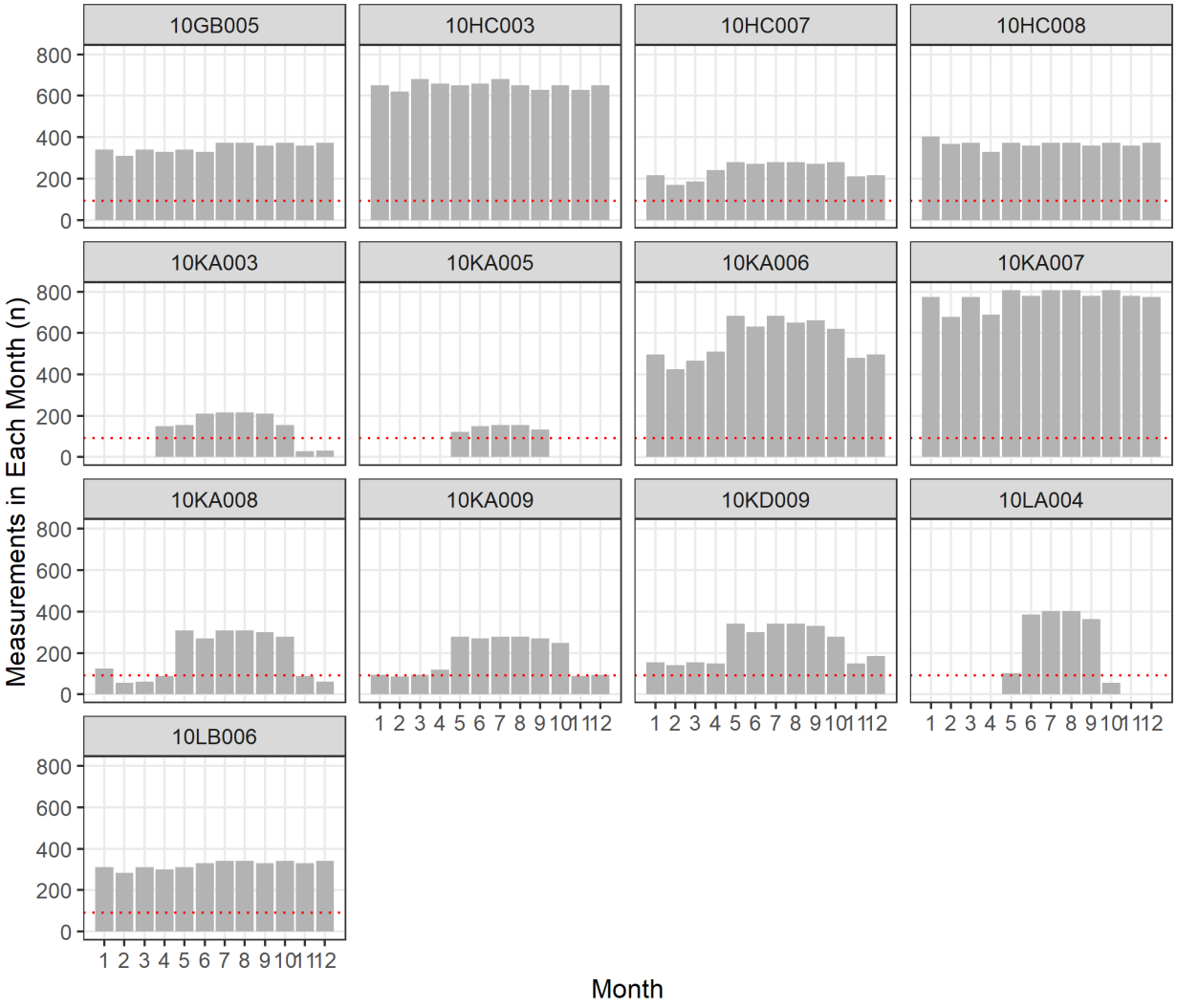
[b] Bearing is degrees clockwise (+) or counterclockwise (-) bearing from the Helava Creek bridge to the WSC station.

[c] Number of daily observations of flow.

*Bolded watershed areas were calculated by K'alo-Stantec (see text for methods). Watershed area for Canyon Creek was obtained from hydrotechnical assessment and design documents (Tetra Tech 2021; Tetra Tech 2022).

Coordinates use the WGS84 datum.

Figure 4.1 Histograms for Selected Water Survey of Canada Stations, Showing the Number of Observations in Each Month for the Period of Record



NOTES:

(1) the red horizontal line is at n=92. Months where n<92 at each station were excluded from regression modelling (Section 4.3).

(2) Month=1 represents January; Month=12 represents December

4.3 Flow Predictions

Monthly mean discharge was modelled for each of the five potential PCAR water withdrawal sources (Table 1.1). Modelling consisted of linear regressions between watershed area and mean monthly discharge for selected regional WSC stations (Table 4.1; Figure 1.2). Discharge and watershed area were log-transformed and regressions were conducted for each month. Watershed area is the predictor and mean monthly flow is the predictand.

Several WSC stations have operated very close to the Study Area (Table 4.1; Figure 1.1) and these stations have watershed areas that are relatively close to those of the potential water source creeks (Table 1.1). For example, 'Canyon Creek at Pipeline Crossing' (station 10KA009) was monitored by the WSC from 2009 to 2018 about 700 m upstream from the Canyon Creek bridge. 'Seepage Creek at Norman Wells' (station 10KA005) has a very small watershed area and is close to the Study Area; however, it only operated between 1974 and 1978. Given their watershed areas and proximity to the Study Area, data from these stations are valuable and were included in analyses whenever possible despite their relatively short period of operation.

It was therefore decided to include these local stations with short records in analyses while acknowledging that flow statistics from these stations may not characterize the full range of hydroclimatic variability. Flow data were grouped by station and month, and average flows were retained if at least 92 daily data points remained in each group (Figure 4.1; horizontal red lines). This would represent about three years of monitoring in each month if monitoring had been continuous. Implications for the use of relatively small sample sizes are discussed in Section 6.2.

An alternative to the methods described above would be to relax the filtering criteria, for example by increasing the maximum distance from PCAR where data should be collected. The disadvantage of relaxing filtering criteria is that distant or hydrologically different sites would be included in analyses. This is sometimes mitigated by incorporating additional predictors such as watershed elevation, air temperature and/or precipitation (Zhang, Balay and Liu 2020).

4.4 Criteria for Assessment of Environmental Flow Needs

For flowing waterbodies, DFO guidance (DFO 2013) is:

- "*cumulative flow alterations of less than +/- 10% of the magnitude of actual (instantaneous) flow in the river relative to a "natural flow regime" have a low probability of detectable negative impacts to ecosystems*"; and
- "*cumulative flow alterations that result in instantaneous flows less than 30% of MAD have a heightened risk of impacts to ecosystems that support fisheries*". Periods below 30% MAD were identified as 'highest risk'.

Mean monthly flows are predicted here in place of instantaneous flows as a desktop-based means of estimating monthly and annual low-risk withdrawals. MAD is calculated from mean monthly flows to identify the months with the 'highest risk'. This approach allows for (a) an assessment of which months are likely candidates for low-risk water withdrawal, and (b) an estimation of water available for withdrawal.

5 Results

Regression model results are first presented below. Next, flow predictions for each water withdrawal candidate are described. Reports describing hydrologic conditions near withdrawal candidate sites were reviewed and are summarized in each section below.

5.1 Regression Model Results

Regressions between watershed area and mean monthly discharge are presented in Figure 5.1 and statistics are provided in Table 5.1.

Table 5.1 Regression Coefficients and Statistics

Month	Slope (m)	Intercept (b)	r^2	p-value	n
Jan	0.997	-3.861	0.11	0.461	7
Feb	2.480	-7.576	0.55	0.153	5
Mar	0.181	-1.188	0.58	0.238	4
Apr	0.444	-1.397	0.47	0.089	7
May	0.913	-1.326	0.86	<0.001	13
Jun	1.202	-2.538	0.95	<0.001	13
Jul	1.068	-2.502	0.83	<0.001	13
Aug	0.942	-2.231	0.78	<0.001	13
Sep	1.060	-2.472	0.77	<0.001	13
Oct	0.835	-2.068	0.86	<0.001	10
Nov	0.959	-3.045	0.61	0.022	8
Dec	0.583	-2.692	0.10	0.400	9

NOTE:
Regressions equations are solved using $\log_{10}$-transformed drainage area (see text below). r^2 is a measure of the regression's overall 'goodness of fit' and a p-value >0.05 (underlined) indicates that a regression is not statistically significant. n = sample size, i.e., the number of flow-area pairs in each regression.

Monthly average discharge (Q) is calculated as follows:

$$\log_{10}Q = m*\log_{10}A + b$$

where '$\log_{10}Q$' is $\log_{10}$ transformed monthly average discharge, 'm' and 'b' are regression coefficient slopes and intercepts (Table 5.1), and '$\log_{10}A$' is the $\log_{10}$ transformed watershed area for the location of interest.

Q in metres cubed per second (m^3/s) is calculated as:

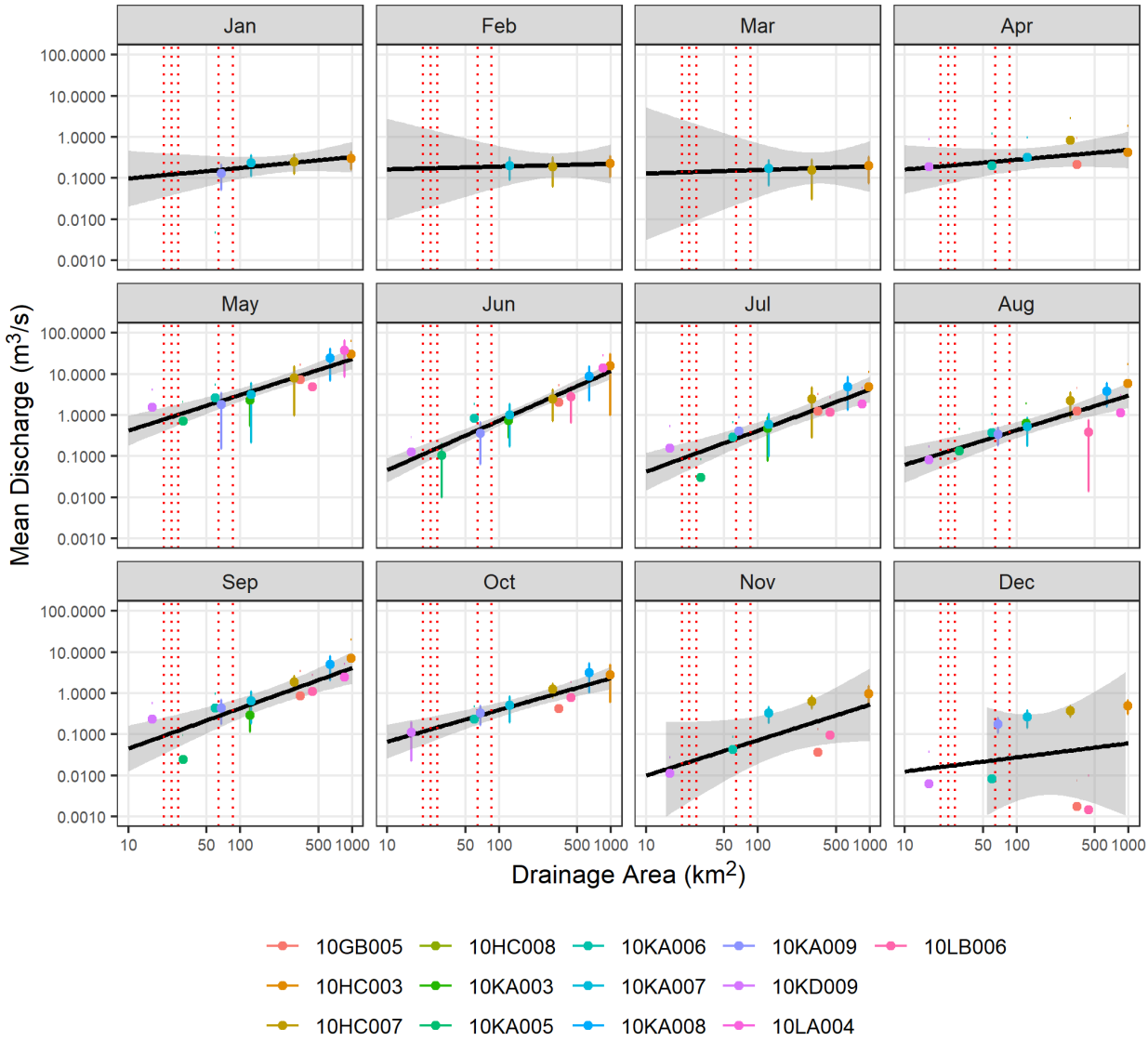
$$Q = 10^{\log_{10}Q}$$

In the ‘thaw period’ and early winter (May to November), monthly regressions are statistically significant (p-value less than or equal to 0.05) and correlation coefficients are generally high (Figure 5.1; Table 5.1). This is the period where snowmelt and rainfall produce the highest flows and most runoff of the year. Snowmelt and precipitation feed watercourses during these months, and the magnitude of discharge is proportional to watershed area.

In the ‘frozen’ period from December to April, regressions are generally not statistically significant (p-value >0.05; and/or low r^2; Figure 5.1; Table 5.1), meaning that discharge in these months is not strongly proportional to watershed area. Discharge is low in these months and is a small fraction of MAD. Discharge in winter is likely mainly fed by groundwater (Section 3). Seasonal operation of regional WSC stations also leads to small sample sizes for regressions in these winter months (Figure 4.1), making it difficult to establish regional relationships.

PCAR target watershed areas are relatively small (21 to 86 km^2; Table 1.1). However, regional WSC data exist from stations with watershed areas in the range of those of target watersheds (Table 4.1; vertical lines on Figure 5.1).

Figure 5.1 Relationships between Watershed Area and Mean Monthly Discharge at Selected Regional Water Survey of Canada Stations



NOTE:
Vertical red lines are the watershed areas of the five considered PCAR withdrawal sites. Vertical error bars on points are +/- one standard deviation. Grey shaded envelopes represent 95% confidence intervals. Where confidence intervals are missing, they are outside the y-axis limits. Regression statistics are provided in Table 5.1.

5.2 Flow Predictions and Historic Observations Pertinent to Flow for Potential PCAR Water Sources

Sections are presented below for each of the five PCAR crossings that were analyzed for potential water withdrawals. Predicted monthly average discharge is provided (units = m^3/s), along with mean daily and monthly flows (units = m^3/d, m^3/m). Results are tabulated in Table 5.2 through Table 5.6.

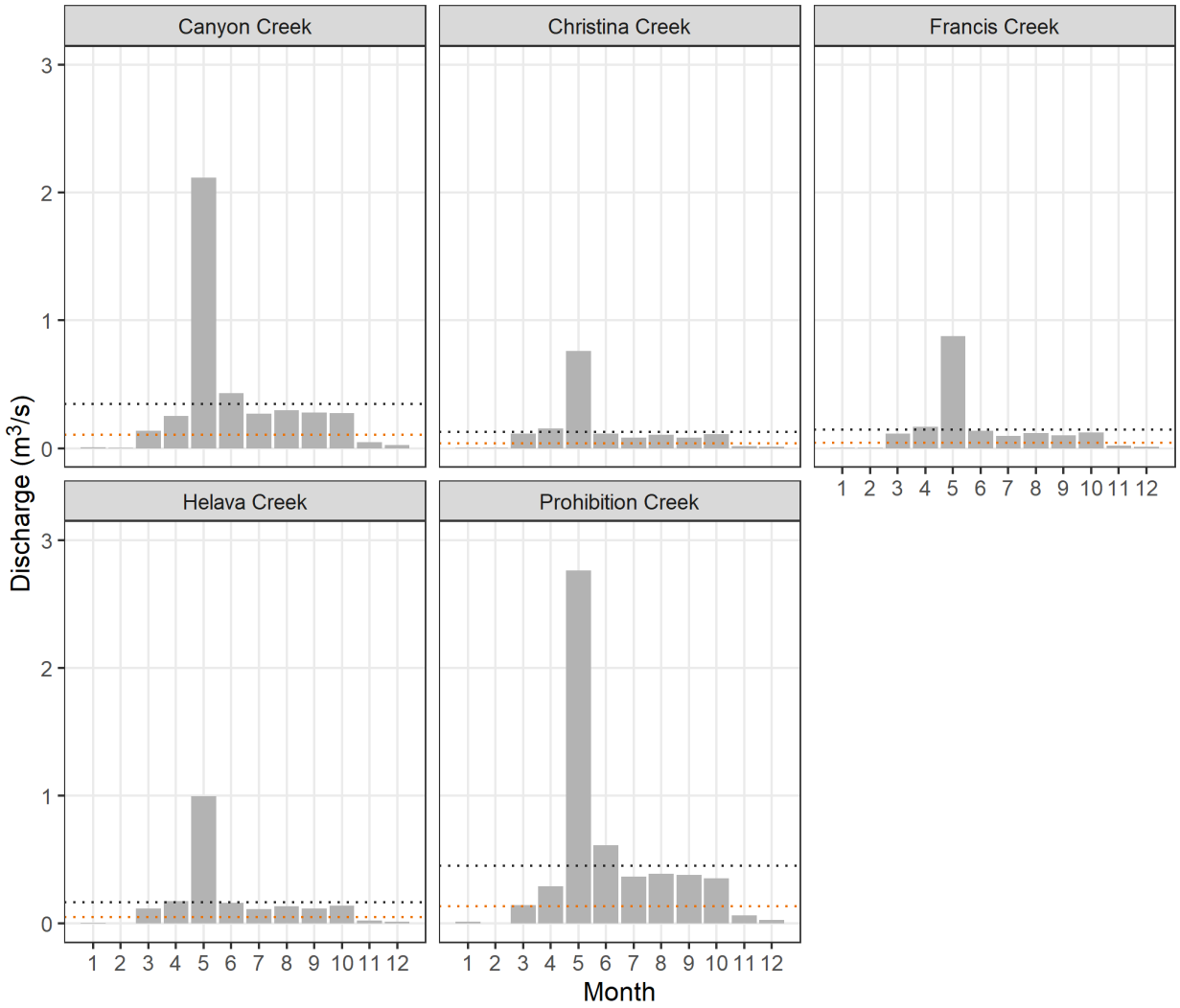
Ten percent of these discharge and flow estimates are provided to indicate the maximum of cumulative withdrawals for a "low probability of detectable impacts to ecosystems" (DFO 2013). Although DFO guidelines are for instantaneous rather than monthly average flows, monthly average flows are useful for initial assessment of typical flow magnitudes and water availability.

Predicted monthly average flows for all candidate water sources are presented in Figure 5.2. Predicted flows follow the nival hydrologic regime of the region, i.e., typically a snowmelt dominated freshet in May, declining flows from June through to early fall, and a small increase in flows due to rainfall runoff in October (Section 3). Flows from December through April are presented in Figure 5.2 but were derived from regressions that are not statistically significant and are not likely to be representative of local flows in these months (see Section 6.2 for a discussion).

Historic reports and datasets pertinent to flow at these crossings were also reviewed and are summarized below. Historic observations of flow in winter were of particular interest given the difficulty of predicting winter flows in ungauged catchments in the region.

Cross sections of creeks at proposed water crossings along with summer and flood water levels have been compiled (Tetra Tech 2022). Depth to bed appears to be sufficiently shallow in all candidate creeks that they could freeze to bottom in the absence of winter groundwater discharge.

Figure 5.2 Predicted Monthly Average Discharge for Potential Water Withdrawal Locations Along the Proposed Prohibition Creek Access Road Alignment



NOTES:
(1) The upper dark horizontal lines are MAD for each creek. The lower orange lines are 30% of MAD;
(2) Month=1 represents January; Month=12 represents December.

Table 5.2 Canyon Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value	n[d]
Jan	0.01	3	0.001	756	76	23,436	2,356	0	0.00	2.20	0.11	0.461	7
Feb	0.00	0	0.000	70	7	1,960	196	0	0.00	2.10	0.55	0.153	5
Mar	0.14	40	0.014	11,879	1,188	368,249	36,828	36,828	0.10	0.40	0.58	0.238	4
Apr	0.25	74	0.025	21,930	2,193	657,900	65,790	65,790	0.10	0.70	0.47	0.089	7
May	2.12	614	0.212	182,924	18,292	5,670,644	567,052	567,052	1.40	3.20	0.86	0.000	13
Jun	0.43	125	0.043	37,348	3,735	1,120,440	112,050	112,050	0.30	0.60	0.95	0.000	13
Jul	0.27	78	0.027	23,208	2,321	719,448	71,951	71,951	0.20	0.50	0.83	0.000	13
Aug	0.30	86	0.030	25,572	2,557	792,732	79,267	79,267	0.20	0.50	0.78	0.000	13
Sep	0.28	81	0.028	24,026	2,403	720,780	72,090	72,090	0.10	0.50	0.77	0.000	13
Oct	0.28	80	0.028	23,878	2,388	740,218	74,028	74,028	0.20	0.50	0.86	0.000	10
Nov	0.05	14	0.005	4,223	422	126,690	12,660	0	0.00	0.20	0.61	0.022	8
Dec	0.02	7	0.002	1,988	199	61,628	6,169	0	0.00	0.30	0.10	0.400	9
Annual Mean	**0.35**	**n/a**	**0.035**	**29,817**	**2,982**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**11,004,125**	**1,100,437**	**1,079,056**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.104 m^3/s).
Underlined values indicate months where regressions are not statistically significant (p-value >0.05).

[a] Calculated as monthly discharge divided by MAD x100.

[b] *Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD)
(DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

n/a: not applicable.

Table 5.3 Francis Creek Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value	N[d]
Jan	0.00	2	0.000	289	29	8,959	899	0	0.00	11.90	0.11	0.461	7
Feb	0.00	0	0.000	6	1	168	28	0	0.00	6.20	0.55	0.153	5
Mar	0.12	78	0.012	9,979	998	309,349	30,938	30,938	0.00	0.50	0.58	0.238	4
Apr	0.17	112	0.017	14,292	1,429	428,760	42,870	42,870	0.00	0.60	0.47	0.089	7
May	0.88	596	0.088	75,744	7,574	2,348,064	234,794	234,794	0.50	1.60	0.86	0.000	13
Jun	0.14	92	0.014	11,703	1,170	351,090	35,100	35,100	0.10	0.20	0.95	0.000	13
Jul	0.10	65	0.010	8,277	828	256,587	25,668	25,668	0.00	0.20	0.83	0.000	13
Aug	0.12	81	0.012	10,302	1,030	319,362	31,930	31,930	0.10	0.30	0.78	0.000	13
Sep	0.10	68	0.010	8,638	864	259,140	25,920	25,920	0.00	0.30	0.77	0.000	13
Oct	0.12	84	0.012	10,667	1,067	330,677	33,077	33,077	0.10	0.20	0.86	0.000	10
Nov	0.02	13	0.002	1,673	167	50,190	5,010	0	0.00	0.10	0.61	0.022	8
Dec	0.01	9	0.001	1,133	113	35,123	3,503	0	0.00	0.60	0.10	0.400	9
Annual Mean	**0.15**	**n/a**	**0.015**	**12,725**	**1,273**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**4,697,469**	**469,737**	**460,297**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.044 m^3/s).
Underlined values indicate months where regressions are not statistically significant (p-value > 0.05).

[a] Calculated as monthly discharge divided by MAD x100.

[b] *Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD) (DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

n/a: not applicable

Table 5.4 Helava Creek Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value	n[d]
Jan	0.00	2	0.000	332	33	10,292	1,023	0	0.00	9.20	0.11	0.461	7
Feb	0.00	0	0.000	9	1	252	28	0	0.00	5.20	0.55	0.153	5
Mar	0.12	71	0.012	10,231	1,023	317,161	31,713	31,713	0.00	0.50	0.58	0.238	4
Apr	0.18	106	0.018	15,196	1,520	455,880	45,600	45,600	0.00	0.60	0.47	0.089	7
May	1.00	600	0.100	85,944	8,594	2,664,264	266,414	266,414	0.60	1.80	0.86	0.000	13
Jun	0.16	96	0.016	13,820	1,382	414,600	41,460	41,460	0.10	0.30	0.95	0.000	13
Jul	0.11	67	0.011	9,595	960	297,445	29,760	29,760	0.10	0.20	0.83	0.000	13
Aug	0.14	82	0.014	11,736	1,174	363,816	36,394	36,394	0.10	0.30	0.78	0.000	13
Sep	0.12	70	0.012	10,002	1,000	300,060	30,000	30,000	0.00	0.30	0.77	0.000	13
Oct	0.14	84	0.014	11,973	1,197	371,163	37,107	37,107	0.10	0.30	0.86	0.000	10
Nov	0.02	13	0.002	1,910	191	57,300	5,730	0	0.00	0.10	0.61	0.022	8
Dec	0.01	8	0.001	1,228	123	38,068	3,813	0	0.00	0.50	0.10	0.400	9
Annual Mean	**0.17**	**n/a**	**0.017**	**14,331**	**1,433**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**5,290,301**	**529,042**	**518,448**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.050 m^3/s).

Underlined values indicate months where regressions are not statistically significant (p-value > 0.05).

[a] Calculated as monthly discharge divided by MAD x100.

[b] *Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD) (DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

n/a: not applicable.

Table 5.5 Christina Creek Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value	n[d]
Jan	0.00	2	0.000	247	25	7,657	775	0	0.00	16.10	0.11	0.461	7
Feb	0.00	0	0.000	4	0	112	0	0	0.00	7.70	0.55	0.153	5
Mar	0.11	87	0.011	9,700	970	300,700	30,070	30,070	0.00	0.50	0.58	0.238	4
Apr	0.15	120	0.015	13,329	1,333	399,870	39,990	39,990	0.00	0.60	0.47	0.089	7
May	0.76	589	0.076	65,612	6,561	2,033,972	203,391	203,391	0.40	1.40	0.86	0.000	13
Jun	0.11	87	0.011	9,687	969	290,610	29,070	29,070	0.10	0.20	0.95	0.000	13
Jul	0.08	63	0.008	6,998	700	216,938	21,700	21,700	0.00	0.20	0.83	0.000	13
Aug	0.10	80	0.010	8,884	888	275,404	27,528	27,528	0.00	0.20	0.78	0.000	13
Sep	0.09	66	0.009	7,313	731	219,390	21,930	21,930	0.00	0.20	0.77	0.000	13
Oct	0.11	84	0.011	9,355	936	290,005	29,016	29,016	0.10	0.20	0.86	0.000	10
Nov	0.02	13	0.002	1,438	144	43,140	4,320	0	0.00	0.10	0.61	0.022	8
Dec	0.01	9	0.001	1,033	103	32,023	3,193	0	0.00	0.60	0.10	0.400	9
Annual Mean	**0.13**	**n/a**	**0.013**	**11,133**	**1,113**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**4,109,821**	**410,983**	**402,695**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.039 m^3/s).

Underlined values indicate months where regressions are not statistically significant (p-value > 0.05).

[a] Calculated as monthly discharge divided by MAD x100.

[b] *Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD) (DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

n/a: not applicable.

Table 5.6 Prohibition Creek Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value	n[d]
Jan	0.01	3	0.001	1012	101	31,372	3,131	0	0.00	1.50	0.11	0.461	7
Feb	0.00	0	0.000	144	14	4,032	392	0	0.00	1.70	0.55	0.153	5
Mar	0.15	32	0.015	12,522	1,252	388,182	38,812	38,812	0.10	0.30	0.58	0.238	4
Apr	0.29	64	0.029	24,963	2,496	748,890	74,880	74,880	0.10	0.70	0.47	0.089	7
May	2.76	613	0.276	238,844	23,884	7,404,164	740,404	740,404	1.90	4.00	0.86	0.000	13
Jun	0.61	136	0.061	53,055	5,306	1,591,650	159,180	159,180	0.50	0.80	0.95	0.000	13
Jul	0.37	81	0.037	31,703	3,170	982,793	98,270	98,270	0.20	0.60	0.83	0.000	13
Aug	0.39	87	0.039	33,668	3,367	1,043,708	104,377	104,377	0.20	0.70	0.78	0.000	13
Sep	0.38	84	0.038	32,740	3,274	982,200	98,220	98,220	0.20	0.70	0.77	0.000	13
Oct	0.35	78	0.035	30,470	3,047	944,570	94,457	94,457	0.20	0.50	0.86	0.000	10
Nov	0.07	14	0.007	5,588	559	167,640	16,770	0	0.00	0.20	0.61	0.022	8
Dec	0.03	6	0.003	2,358	236	73,098	7,316	0	0.00	0.30	0.10	0.400	9
Annual Mean	**0.45**	**n/a**	**0.045**	**38,922**	**3,892**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**14,362,299**	**1,436,209**	**1,408,600**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.135 m^3/s).
Underlined values indicate months where regressions are not statistically significant (p-value > 0.05).

[a] Calculated as monthly discharge divided by MAD x100.

[b] *Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD) (DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

n/a: not applicable.

5.2.1 Canyon Creek

At 64 km^2, the watershed area upstream of the Canyon Creek bridge is the second largest of those assessed. Canyon Creek is unique in that a WSC station operated about 0.7 km upstream of the bridge crossing beginning in 2009, with data available until 2018 (Figure 1.1, Table 4.1).

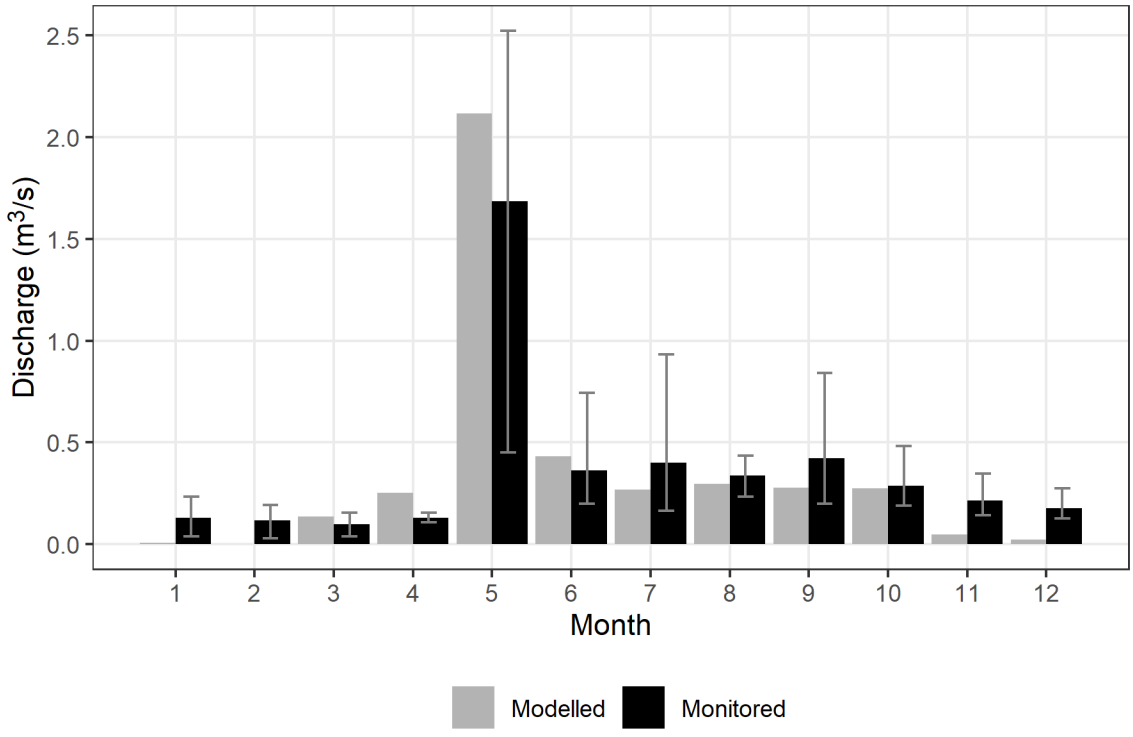
5.2.1.1 Flow Predictions

Flows and water availability predictions for Canyon Creek are presented in Table 5.2.

5.2.1.2 Historic Observations Pertinent to Flow

The Canyon Creek WSC data are highly valuable; therefore, these data are presented, described, and compared to modelled results (Figure 5.3). Flow predictions overlap with monitored flows in all months except in winter when regressions are not statistically significant (Section 5.1). Note that sample sizes for each month of monitored flows range from two in winter to eight to nine for June through to September, and therefore may not represent 'typical' hydrologic conditions, especially in winter.

Figure 5.3 Canyon Creek: Comparison of Monitored to Modelled Discharge (Monthly Averages)



NOTE:
Max/min error bars are presented rather than standard deviation due to low sample sizes in winter.

Predicted flows are lower than monitored flows in winter (Figure 5.3), reflecting the likely presence of groundwater discharge at Canyon Creek. This is supported by field studies on Canyon Creek, for example "*springs that flow year-round have been investigated here*" (Golder Associates 2006), and:

> *"Canyon Creek was noted as having "*open water in winter and a small aufeis area*". On 13-Apr-73, open water and a temperature of 0.5°C was noted, but discharge was not measured. It was noted that "there are several small springs located in the canyon about 3 miles upstream of the [pipeline corridor]."*

5.2.2 Francis Creek

At 24.5 km^2, the Francis Creek catchment has the second smallest of the assessed watersheds (Table 1.1).

5.2.2.1 Flow Predictions

Flows and water availability predictions for Francis Creek are presented in Table 5.3.

5.2.2.2 Historic Observations Pertinent to Flow

Limited historic observations suggest that there is no flow in winter at Francis Creek:

> *"Francis Creek had no winter observations and it was noted that "there are no winter data. It is frozen over in winter and is a doubtful overwintering area." There was no note of springs feeding the creek" (Golder Associates 2006)*

5.2.3 Helava Creek

At 28 km^2, the Helava Creek catchment is the median of those assessed (Table 1.1).

5.2.3.1 Flow Predictions

Flows and water availability predictions for Helava Creek are presented in

Table 5.4.

5.2.3.2 Historic Observations Pertinent to Flow

The same winter observations are available for Helava Creek ad Francis Creek (Golder Associates 2006); winter flow is unlikely.

5.2.4 Christina Creek

At 21 km^2, the Christina Creek catchment is the smallest of those assessed (Table 1.1).

5.2.4.1 Flow Predictions

Flows and water availability predictions for Christina Creek are presented in Table 5.5.

5.2.4.2 Historic Observations Pertinent to Flow

Available manual flow measurements for Christina Creek are summarized in Table 5.7.

Table 5.7 Summary of Historic Instantaneous Discharge Measurements on Christina Creek

Date (dd-mmm-yy)	Instantaneous Discharge (m^3/s)
04-Jun-02	0.04
17-Aug-02	0.1
28-Sep-02	0.07
12-Jul-03	0.01
10-Apr-04	Frozen to bottom

NOTE:
Data were published in Golder Associates (2006), originally from MGP 2004.

In April 2004, the creek was noted to be "*frozen to bottom at location 1.3 km upstream; likely frozen to bottom in winter*". Other assessments also suggest there is little or no flow in winter (Golder Associates 2006):

> "*March 2006, late winter assessments found no water under 0.55 m of ice. Similar, late winter field assessments by McCart and McCart (1982) and MGP (2004) in 1981 and 2002, respectively, also both found the stream frozen to the bed of the watercourse*"
>
> *"Christina Creek has none-to-low storage and a watershed area small enough that if it was solely fed by surface runoff, it would likely freeze to the bottom in winter. Winter observations in 1981, 2002 and 2006 noted the stream was frozen to bottom (McCart and McCart 1982; MGP 2004). There is some evidence of springs on adjacent creeks, but these are small and have not been noted as sufficient to sustain flows during the winter. Although this stream does not appear to provide overwintering fish habitat, because of low water levels it is an unlikely to be a candidate for winter water supply. If under-ice water is present during early winter months, its use for the construction and maintenance of the winter road would have negligible affects* [sic] *on fish habitat. The road crossing is only 0.4 km from the confluence with the Mackenzie River and no fish were recorded in the vicinity of the road crossing during winter months. Therefore, if under-ice water is present, its use for winter road construction and maintenance, should not adversely affect fish habitat at the site or in downstream environments."*

5.2.5 Prohibition Creek

At 86 km^2, the Prohibition Creek catchment is the largest of those assessed (Table 1.1).

5.2.5.1 Flow Predictions

Flows and water availability predictions for Prohibition Creek are presented in Table 5.6.

5.2.5.2 Historic Observations Pertinent to Flow

Limited observations suggest that there is flow in Prohibition Creek in winter:

> *Prohibition Creek was noted as "no overwintering likely". At the winter road, on 10-Apr-73 open water was noted "in patches" with an ice depth of 1.0 m. Approximately 6 km upstream of the winter road, open-water conditions were observed with a water temperature of 7.5°C and a measured discharge of 0.003 m^3/s."* (Golder Associates 2006)

6 Discussion

6.1 Will winter withdrawals be 'low-risk'?

Flow predictions for potential water sources in the PCAR region are statistically significant and relatively well constrained from May to November.

Flow predictions in winter are not statistically significant and winter flow appears to be controlled more by the occurrence of groundwater discharge than strictly by watershed area. Flow predictions for December through April should therefore not be considered accurate.

DFO identifies periods when flows are less than 30% of MAD as periods of 'highest risk' to river ecosystems (Section 4.4) (DFO 2013). Given that winter flow predictions presented here are uncertain and given the potential for water needs in winter for PCAR, a regional assessment of flows in winter was conducted.

Monthly average flows were calculated at regional WSC stations that operate year-round, and %MAD was calculated for each month. Results are presented in Table 6.1.

Regionally, monthly average flows at stations that operate year-round are consistently less than 30% MAD through winter (i.e., November through March-April) (Table 6.1). In addition, low flows at WSC stations that operate seasonally were summarized in Golder (2006) and found to be zero (at stations 10KA005, 10KA006, and 10LD002).

The notable exception is 10KA007, Bosworth Creek near Norman Wells, where monthly discharges are >30% MAD in all months except March (Table 6.1). Bosworth Creek is fed by a series of upstream lakes, including Hodgson (Jackfish) Lake, Edie Lake, and Bandy Lake (Figure 1.1). Winter flows may be fed by these lakes and/or groundwater discharge. The only other exception is 10HC007, Hodson Creek Near the Mouth in November.

Despite these exceptions, it can be said that regionally the winter period is typically a period of 'highest risk' following DFO guidelines. Guidelines state that "*for instances where the cumulative water use reduces the river flow below the level of 30% of the MAD, a rigorous level of assessment should be required to evaluate potential impacts on ecosystem functions that sustain fisheries, including identification of mitigation measures*" (DFO 2013). This rigorous level of assessment (e.g., fish habitat modelling) may be required if winter withdrawals are to be considered along the PCAR alignment (Section 7).

Table 6.1 Monthly Mean Discharge and Percent of Mean Annual Discharge at Regional Water Survey of Canada Stations That Routinely Operate Year Round

	Mean Discharge (m^3/s)									Percent of MAD								
Month	10GB005 (344 km^2)	10HC003 (980 km^2)	10HC007 (303 km^2)	10HC008 (1030 km^2)	10KA006 (60 km^2)	10KA007 (125 km^2)	10KD009 (64 km^2)	10LA004 (852 km^2)	10LB006 (441 km^2)	10GB005 (344 km^2)	10HC003 (980 km^2)	10HC007 (303 km^2)	10HC008 (1030 km^2)	10KA006 (60 km^2)	10KA007 (125 km^2)	10KD009 (64 km^2)	10LA004 (852 km^2)	10LB006 (441 km^2)
Jan	0.000	0.297	0.247	0.418	0.000	0.236	0.000	0.001	0.000	0	5	14	5	0	36	0	0	0
Feb	0.000	0.228	0.190	0.346	0.000	0.201	0.000	0.000	0.000	0	4	11	4	0	31	0	0	0
Mar	0.000	0.200	0.157	0.270	0.000	0.169	0.000	0.000	0.000	0	3	9	3	0	26	0	0	0
Apr	0.210	0.423	0.829	2.680	0.197	0.321	0.186	0.022	0.000	19	7	48	32	47	49	91	1	0
May	7.192	30.648	8.094	42.376	2.623	3.125	1.529	19.515	4.865	651	528	468	511	625	475	752	571	523
Jun	2.058	15.910	2.435	11.616	0.831	1.002	0.127	14.201	2.762	186	274	141	140	198	152	63	416	297
Jul	1.232	4.892	2.471	10.980	0.288	0.581	0.155	1.831	1.180	112	84	143	132	69	88	76	54	127
Aug	1.243	5.883	2.215	12.056	0.376	0.514	0.080	1.120	0.388	113	101	128	145	90	78	40	33	42
Sep	0.861	6.936	1.883	12.386	0.438	0.640	0.235	2.377	1.079	78	119	109	149	104	97	116	70	116
Oct	0.424	2.814	1.222	4.592	0.232	0.509	0.111	1.752	0.789	38	49	71	55	55	77	55	51	85
Nov	0.036	0.979	0.633	1.292	0.043	0.328	0.011	0.172	0.094	3	17	37	16	10	50	6	5	10
Dec	0.002	0.485	0.375	0.555	0.008	0.264	0.006	0.008	0.001	0	8	22	7	2	40	3	0	0
MAD	**1.105**	**5.808**	**1.729**	**8.297**	**0.420**	**0.658**	**0.203**	**3.417**	**0.930**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTE:
Cells are shaded grey where monthly discharge is less than 30% of MAD. Regional stations where winter flows were not routinely monitored year-round have been excluded (10KA003, 10KA005, 10KA008, 10KA009).

6.2 What volumes of water are available for withdrawal?

Table 5.2 through Table 5.6 present monthly and annual water volumes available for low-risk withdrawal, using criteria from DFO (2013); i.e., 10% of monthly average flow in months where discharge is greater than 30% of MAD. This is an estimate of the maximum monthly and annual volumes of water available for low-risk withdrawal. On average, annual water available for low-risk withdrawal ranges from a low of 402,695 m^3 at Christina Creek (Table 5.5) to 1,408,600 m^3 at Prohibition Creek (Table 5.6) during the months of May to October only. These volumes are useful as a basis for water license applications and will need to be verified by monitoring/measuring flows in the field (Section 7). Note that about half of the annual water volume available for low-risk withdrawal occurs in only one month: May. Monthly volumes available for low-risk withdrawal are presented in tables Table 5.2 through Table 5.6.

6.3 Is it justifiable to include Water Survey of Canada stations with relatively small datasets for flow predictions?

Several stations local to the PCAR proposed alignment have relatively small datasets due to limited periods of operation and/or seasonal operation (i.e., 10KA003, 10KA005, 10KA008, and 10KA009; Figure 4.1). It was decided to include months with greater than 92 measurements for each station given their proximity to the proposed alignment and the paucity of long-term regional flow data. Statistics derived from small populations might not be indicative of typical conditions, e.g., average flows calculated here might not be indicative of overall average conditions at these sites. For example, a minimum of 20 years of data are recommended for instream flow analyses (DFO 2013).

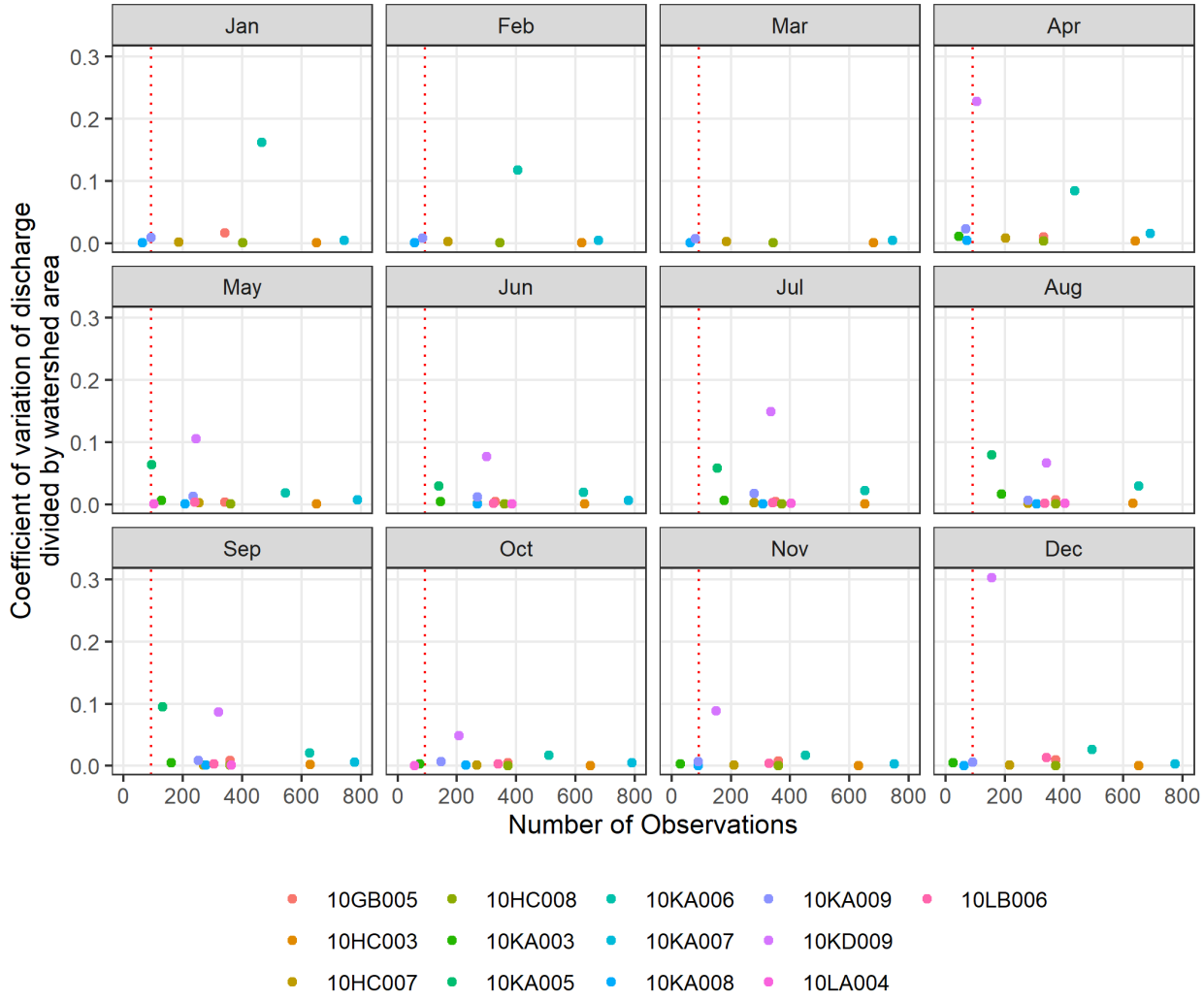
To assess whether stations with small numbers of observations in each month are statistically anomalous relative to stations with large numbers of observations, the monthly coefficient of variation of average flow was divided by basin area. The coefficient of variation is the standard deviation (68% of a normal distribution fall within +/- 1 standard deviation) divided by the mean and was chosen because it normalizes the effects of basin size on discharge. The statistic was further normalized by dividing by basin area.

Stations with small sample sizes might be expected to have smaller variability of flows than stations with larger sample sizes, but this does not consistently occur (Figure 5.1). This shows that the variability of flow in each month is typically not affected by relatively small sample sizes. Instead, Figure 5.1 shows that flow variability is more controlled at the station/site level (e.g., 10KD009 in most months, 10KA006 in January and February).

While the minimum number of observations in a month was set to 92, most months have many more observations than this. For example, the 25th percentile of sample size is a minimum of 120 in November and greater than or equal to 270 for 6 months of the year. Most data points on the left-hand sides of the vertical red lines in Figure 6.1 are in winter months. Any effects of small sample size would be greatest in winter when regressions are not statistically significant.

Given the value of data from stations proximal to PCAR, the methods described above are considered appropriate with the caveat that flow predictions provided here are representative of flows at the times where WSC monitoring occurred.

Figure 6.1 Effects of Sample Size on Flow Variability



NOTE:
Vertical dashed lines are at n=92, the minimum number of observations allowed in each month.

7 Conclusions and Recommendations

Measurements of instantaneous discharge should occur at the time of withdrawal. These flow measurements should be compared to mean annual discharge for each creek to ensure instantaneous flows are <10% of MAD.

Annual volumes of water predicted to be available for withdrawal within DFO's (2013) criteria range from about 403,000 m^3 for Christina Creek to about 1,409,000 m^3 for Prohibition Creek. About half of this annual flow volume is in May. No water is predicted to be available using this 'desktop-based' methodology for withdrawal in November through February.

This assessment has shown that the three creeks along the proposed PCAR alignment with the smallest watersheds (Francis, Helava, and Christina) are unlikely to flow for at least part of the winter. Furthermore, creeks that do flow over winter (Canyon and Prohibition) are unlikely to be classified as 'low-risk' at these times, i.e. flows are likely to be less than 30% of mean annual discharge (DFO 2013).

The 'low' risk period varies regionally. Regression modelling suggests this period is approximately March to October along the PCAR alignment, but uncertainties are high in predicted flows over winter. Regionally, this "low-risk" period spans about April or May to October.

If water is required over winter, potential solutions include (a) withdrawal outside of these periods and storing water for winter, (b) supplying supplemental information/studies (see below), and/or (c) offsetting withdrawals.

Pertinent supplemental information for winter PCAR withdrawals would be defined by DFO but could take the form of the creation of a fish periodicity table, establishment of baseline hydrological data, preparation of a detailed fish habitat modelling, preparation of a reconnaissance-level fish and fish habitat impact assessment, issuance of withdrawal rate limits, issuance of limited licence terms, and/or requirement to monitor water use (FLNRORD 2022).

The rigor of additional studies required depends on the timing and volume of water required. If water is required in spring and to a lesser extent autumn, then additional site-specific flow measurements would be beneficial, given (a) flow predictions are not statistically significant in these months, (b) the months where discharge is greater than 30% varies regionally, and (c) monthly averages have been provided here, and flows will vary within each month and year.

If withdrawals over winter are required, additional flow measurements on Prohibition creek could help define the timing and magnitudes of flows over winter. Additional winter investigations at Francis, Helava, and Christina Creeks would help confirm previous assessments that these creeks freeze to bottom in winter.

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9 Closure

If you have any questions, please do not hesitate to contact the undersigned.

Respectfully Submitted,

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APPENDIX 16A

Surface Water and Sediment Quality Technical Data Report

Mackenzie Valley Highway Project
Technical Data Report—Surface Water and Sediment Quality

Prepared for:

Government of the Northwest Territories

Prepared by:

K'alo-Stantec Limited

December 2022

Project No.: 144903025

K'alo-Stantec

Limitations and Sign-off

This document entitled Mackenzie Valley Highway Project Technical Data Report—Surface Water and Sediment Quality was prepared by K'alo-Stantec Limited ("K'alo-Stantec") for the account of Government of the Northwest Territories (the "Client") to support the regulatory review process for its Developer's Assessment Report (the "DAR") for the Mackenzie Valley Highway Project (the "Project"). In connection therewith, this document may be reviewed and used by the Government of the Northwest Territories Department of Infrastructure participating in the review process in the normal course of its duties. Except as set forth in the previous sentence, any reliance on this document by any other party or use of it for any other purpose is strictly prohibited. The material in it reflects K'alo-Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between K'alo-Stantec and the Client. The information and conclusions in the document are based on the conditions existing at the time the document was published and does not consider any subsequent changes. In preparing the document, K'alo-Stantec did not verify information supplied to it by the Client or others, unless expressly stated otherwise in the document. Any use which another party makes of this document is the responsibility and risk of such party. Such party agrees that K'alo-Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other party as a result of decisions made or actions taken based on this document.

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Executive Summary

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells to replace the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT).

The Project subject to Part 5 of *the Mackenzie Valley Resource Management Act*. As part of the environmental assessment process, the Developer's Assessment Report (DAR) will assess how development of the proposed Project could affect surface water and sediment quality. The purpose of the technical data report (TDR) is to characterize baseline (i.e., existing) surface water quality conditions within local and regional study areas to support the environmental assessment of the Project presented in the DAR.

The main anthropogenic influences on water quality in the Mackenzie River Basin include historical and existing mines, municipal sewage, oil and gas exploration activities, pulp mills and land disturbances, and climate change. Natural influences include soils, bedrock, and forest fires from which naturally occurring constituents can be released.

This TDR presents a summary of the surface water and sediment data collected over the last 20 years within the Regional Study Area (RSA) and Local Study Area (LSA). These data sources can be used to help characterize existing conditions and to support the DAR, as required by the DAR Terms of Reference.

Surface water quality data was reviewed from various government and industry reports. Collectively, sampling programs have acquired surface water quality data for *in situ* parameters (e.g., pH, turbidity, temperature, conductivity, and dissolved oxygen) and laboratory-analyzed parameters (e.g., metals and nutrients) within the RSA at numerous locations and periods over the last few decades. A source of sediment quality data in the RSA was the baseline sampling results for the Mackenzie Gas Project Environmental Impact Statement conducted in 2002 and 2003. Sediment sampling included metals analyses for sediments collected in nine watersheds within the RSA: Prohibition Creek, Nota Creek, Great Bear River, Big Smith Creek, and Saline Creek in the Sahtu Region, and Blackwater River, Strawberry Creek, White Sand Creek, and Hodgson Creek in the Dehcho Region.

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Abbreviations

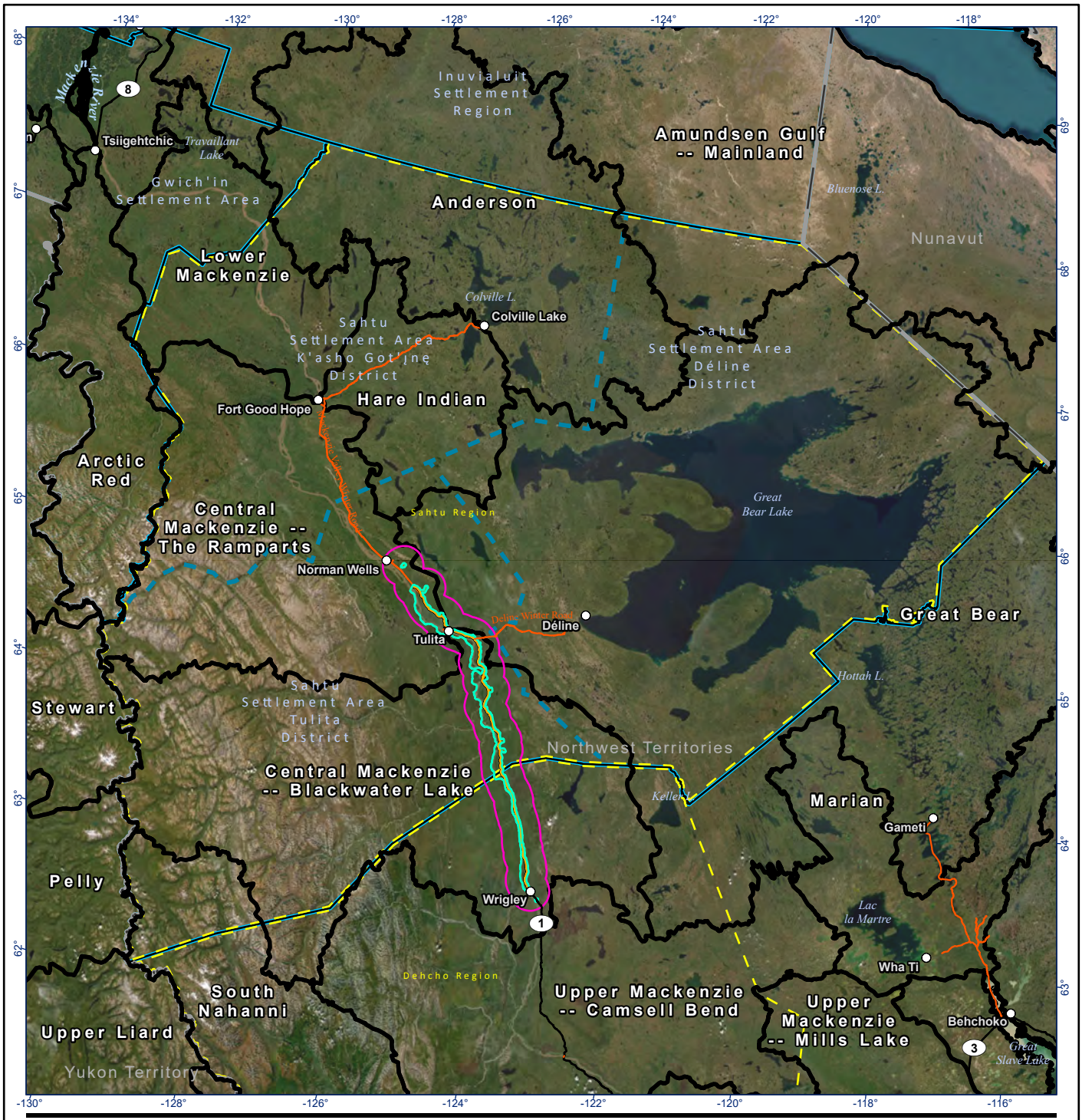
ARD/ML	acid rock drainage and metal leaching
DAR	Developer's Assessment Report
ECCC	Environment and Climate Change Canada
EIS	environmental impact statement
GNWT	Government of the Northwest Territories
HCO_3^-	bicarbonate ion
INAC	Indigenous and Northern Affairs Canada
INF	Department of Infrastructure
km	kilometre
km^2	square kilometre
LSA	Local Study Area
m	metre
mg/L	milligram per litre
MVEIRB	Mackenzie Valley Environmental Impact Review Board
MVLWB	Mackenzie Valley Land and Water Board
MVWR	Mackenzie Valley Winter Road
NT	Northwest Territories
PKFN	Pehdzeh Ki First Nation
RSA	Regional Study Area
TDR	technical data report
the Project	Mackenzie Valley Highway Project
TK	traditional knowledge
TLRU	Traditional Land and Resource Use
TOR	terms of reference

1 Introduction

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells to replace the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT) (Figure 1.1).

The Project is subject to an environmental assessment and the requirements of Part 5 of *the Mackenzie Valley Resource Management Act*. This technical data report (TDR) presents the existing conditions for surface water quality to support preparation of the Developer's Assessment Report (DAR), as required by the Terms of Reference (MVEIRB, 2015). This TDR presents a summary of the sampling locations within regional and local study areas for which baseline surface water and sediment data have been collected over the last 20 years.

The study areas are described in Section 2 and the summary of existing data is provided in Section 3.



- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Sub-Basin
- Territorial Boundary

0 40 80 Kilometres

(At original document size of 8.5x11)
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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0063 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
1.1

Title
MVH Project Overview

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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2 Study Areas

The Project is in the Mackenzie Valley region of the NT between the current terminus of the existing all-weather highway in Wrigley (Highway #1, km 690) and Prohibition Creek (located approximately 28 km southeast of Norman Wells). The project highway alignment parallels the Mackenzie River, which is to the west, and is in the Mackenzie River basin within the Central Mackenzie-Blackwater Lake, Central Mackenzie-the Ramparts, and Great Bear sub-basins as defined by the Standard Drainage Area Classification (NRCan, 2003; Figure 1.1 and Figure 2.1).

2.1 Project Development Area

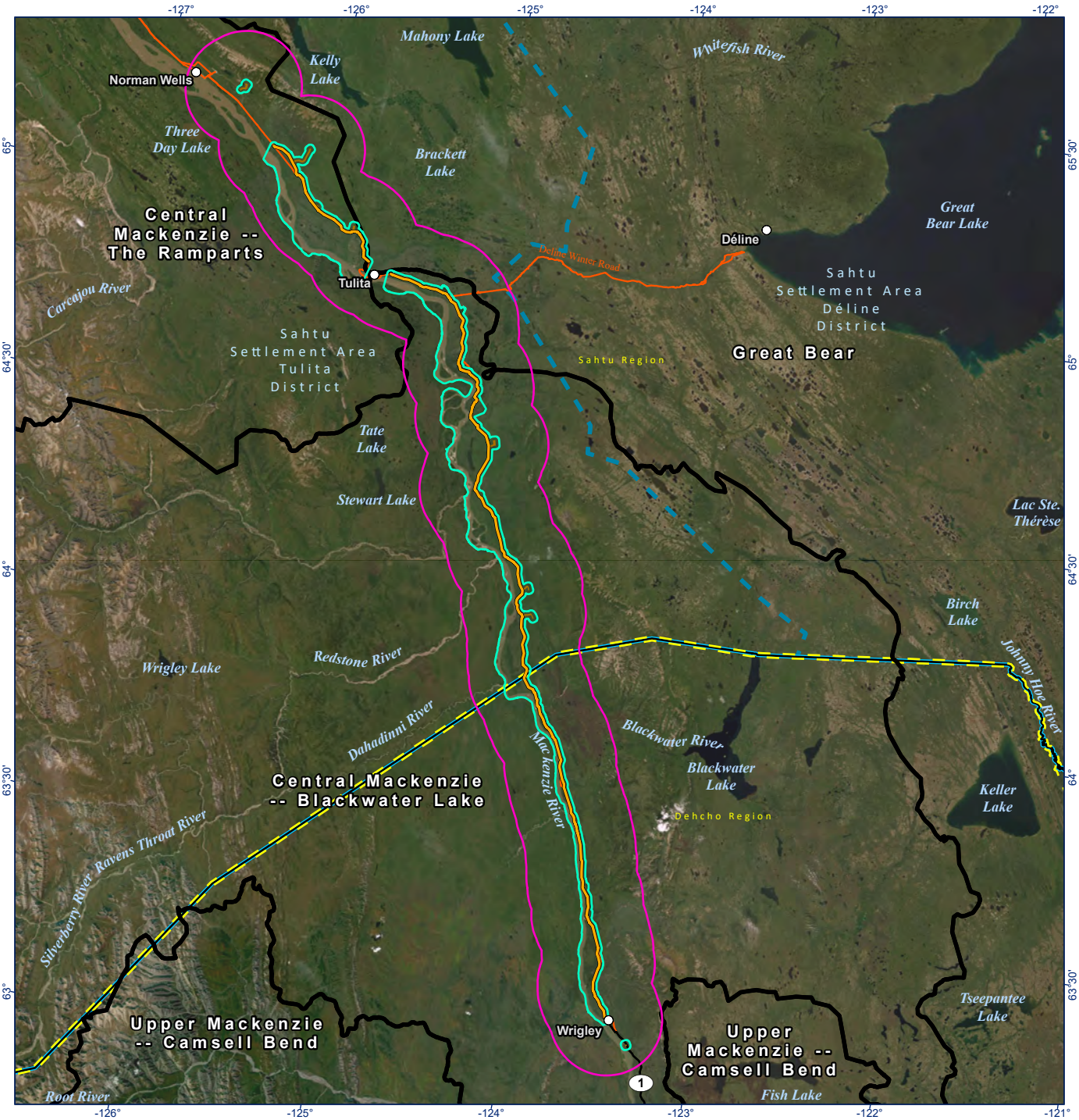
The Project Development Area (PDA) is the area of direct Project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 m wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps and quarry/borrow sites with access roads on a 30 m ROW. The PDA is defined as the area to be used by the Project from Wrigley to approximately 25 km Southeast of Norman Wells. The PDA does not include a section of Project (less than 10 km in length) that passes through the hamlet of Tulita.

The local and regional study areas presented in this TDR are the areas where compiled data were collected to allow for an understanding of the environment in support of the Project-specific effects assessment and the cumulative effects assessment.

2.2 Local Study Area

For consistency with the surface water quantity TDR (DAR Volume 4, Appendix 15A, K'alo-Stantec, 2022a), the surface water and sediment quality Local Study Area (LSA) is a 1 km buffer around the alignment, and it is extended to include the mainstem of Mackenzie River and potential water sources for construction of the MVH, so as to encompass the anticipated extent of Project-related direct and indirect effects on surface water quantity (Figure 2.1).

Granular and rock materials for the construction and maintenance of the Project will be sourced from local material sources (quarries and borrow sources). The LSA includes a 1 km buffer around the quarry and borrow source footprints and associated access roads.



- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
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- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Sub-Basin

0 10 20 Kilometres
(At original document size of 8.5x11)
1:1,600,000

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Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2023-03-07
TR by CS on 2023-03-07

Client/Project
144903025-0064 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
2.1

Title
Water and Sediment Quality Assessment Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
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2.3 Regional Study Area

For consistency with the surface water quantity TDR (DAR Volume 4, Appendix 15A, K'alo-Stantec, 2022a), the surface water quality Regional Study Area (RSA) is a 15 km buffer around the PDA. The RSA includes surface water quality-related features that could be affected by the cumulative effects of Project activities interacting with the effects of other existing, past or reasonably foreseeable projects in the area. The RSA does not include the entire Central Mackenzie-Blackwater Lake, Central Mackenzie-the Ramparts, and Great Bear sub-basins because:

- the majority of the Central Mackenzie-Blackwater Lake and Central Mackenzie-the Ramparts sub-basins are to the west of the Mackenzie River, which are not affected by the Project.
- the majority of the Great Bear sub-basin is upstream of the Project and, therefore, not likely to be affected by the Project.

3 Review of Existing Data

3.1 Traditional Knowledge and Traditional Use

Traditional knowledge (TK) and traditional land and resource use (TLRU) information and supporting literature were reviewed for the characterization of the existing surface water quality conditions, as summarized below.

3.1.1 Sahtu Region

Golder (2015) provides TK and TLRU information about surface water quality in the Sahtu Region. Golder (2015) states that in the Sahtu Region:

- *Water quality is of the utmost importance to the Dene and Métis in the Sahtu [and] access to clean water is needed for the maintenance of healthy populations of people, fish, and animals.*
- *The Dene have relied on and lived off the clean waters of the Sahtu for many generations, and insist that all water bodies should be kept clean throughout the course of development.*
- *Water quality monitoring should be carried out for developments, even on the smallest of streams, to preserve the integrity of the water quality over the entire area…[these monitoring programs] should be carried out from within communities.*
- *Wastewater associated with developments be removed from site, and that the footprint of [the Project] be limited and work areas be kept clean to minimize runoff and contamination*
- *Shore and wetland vegetation should be kept in place to act as a filter and to provide bank stability*
- *The quality of most waterbodies in the Sahtu is considered by community consultation participants to be good and suitable for drinking*
- *Community participants indicated that when the waterfowl are plentiful and appear healthy, the water must be good.*
- *Big Smith Creek was identified as a good source of drinking water and has been used for many years.*
- *Although many small creeks are not actively used by many people, they are of good, drinkable quality and impacts should be minimized*
- *Community elders have seen waters that were once used for cooking and drinking change so that they are no longer good or safe to use (Golder, 2015).*

As stated in Golder (2015), community concerns regarding changes to water quality because of development in the Sahtu Region include:

- increased sedimentation from construction and clearing of vegetation along the edges of water bodies
- impacts of blasting
- impacts of melting permafrost and the resulting land subsidence, erosion, flooding, and scouring,
- resulting impacts on fish, wildlife, and habitat

Results from the Project-specific TLRU study developed by the Tulita Renewable Resources Council (TRRC, 2022) indicates that:

- Overflows have resulted from previous road construction and operation and has affected valued resources.
- Overflow within the LSA and along existing portions of the MVWR has affected undertaking of TLRU.
- There are many beaver dams within the LSA that have caused overflow.
- All the water resources within the LSA are still used (drinking) and accessed for TLRU.
- More water and wildlife monitoring in the LSA should be used to mitigate potential Project effects.
- There are concerns about potential Project effects on water flowing into the Bear River (community drinking water source).
- The sewer lagoon seeps towards the winter road between Tulita and Four Mile Creek, which causes the overflow on winter road access.
- There are concerns about potential Project effects from vehicle breakdown near open-water sources, specifically near Bear Rock, which is of interest to the community, that have potential to contaminate water sources.
- MVWR flooding occurs near Frank Yalle cabin area, and between the community of Tulita and Four Mile Creek.
- Bear River floods in the spring during the Mackenzie River ice breakup.
- Water is collected from any river or lake nearby the construction of the Bear River Bridge Project which has potential to affect community drinking because the community of Tulita requires a water truck to access water intake from Bear River on the other Bear River Bridge (all year round).
- The MVWR is too close to Plane Lake and could lead to contamination of the water.
- Tulita should be given priority (provide feedback and be the lead) when undertaking Project-related TK studies, monitoring and TK-based monitoring for water, land and wildlife to improve TK-based monitoring, avoid/mitigate potential Project effects and improve safety.

3.1.2 Dehcho Region

Dessau (2012) provides TK and TLRU information pertaining to surface water quality in the Dehcho Region. Dessau (2012) reports that in the Dehcho Region:

- Pehdzeh Ki First Nation (PKFN) have identified watercourses and riverbanks as traditional land use areas, and these traditional areas require protection.
- The PKFN have indicated that the rivers, creeks, and forests should be protected for the future generations and moose, caribou, and fish also need to be protected.
- The PKFN indicated Blackwater River, (which is crossed by the Project's proposed alignment) is one of the watercourses that is very important to protect due to its cultural significance as a sacred burial site.
- Several known fish spawning sites are located near the Project in the Dehcho Region (e.g., spawning sites are located near the mouths of the Ochre River and Blackwater River). Fishing is an important sustenance harvesting activity that is tied to traditional use and non-traditional use (e.g., commercial use) throughout the Mackenzie Valley.
- Drainage areas along the Project are considered potential waterfowl habitat. This includes Mackenzie River, Blackwater River and Ochre River, as well as major creeks and other smaller watercourses.

As stated in Dessau (2012), a Wrigley Community consultation meeting regarding the Project (as "MVH Project") (January 25 and 26th, 2012) included the following community comments and questions pertaining to water quality:

- Environment and safety are a priority for the Project.
- What is the effect of the MVH Project on the Mackenzie River? What are the mitigation measures in case of a spill?
- If the MVH Project is built, will natural resources such as water be protected? Is this resource guaranteed to not be contaminated or destroyed by the chemicals and resources that will be transported for the construction of the highway?

3.2 Literature Review

A literature review was completed to understand the extent of available surface water quality data along the project highway alignment (and within the RSA and LSA). Background information on surface water quality for the Sahtu and Dehcho regions was obtained from the following sources:

- GNWT Community-Based Monitoring Program (GNWT, 2020, pers. comm.)
- GNWT Water Quality Monitoring Network Evaluation report (Summit Environmental Ltd., 2014)
- Environment and Climate Change Canada (ECCC), Northern Water Quality Monitoring Network (ECCC, 2021)

- Mackenzie Gas Project Environmental Impact Statement (EIS), Biophysical Baseline Report for Water Quality (EIS Volume 3, Section 6; IORVL, 2004)
- data from Water Resources, Indigenous and Northern Affairs Canada (INAC) for the Mackenzie Valley Pipeline (GNWT, 2021, pers. comm.)
- Rempel and Gill (2011): *Bioassessment of streams along the Mackenzie River Valley, Canada, using the Reference Condition Approach: biological, habitat, landscape, and climate data*
- Golder (2015): *Central Mackenzie Surface Water and Groundwater Baseline Assessment. Report 1: Technical State of Knowledge*
- Mackenzie River Basin Board (MRBB, 2021): *State of the Aquatic Ecosystem Report (SOAER): Mackenzie-Great Bear Sub-Basin.*
- Mackenzie DataStream open access water quality data hub (DataStream, 2022).

Surface water quality information from the above mentioned resources is summarized in the following sections.

3.2.1 Overview of Study Area Surface Water Quality

The Project is located in the Mackenzie-Great Bear Sub-Basin of the Mackenzie Valley Basin (MRBB, 2021). This Sub-Basin spans roughly a third of the NT and extends from Fort Simpson in the south to the Makenzie River delta in the north, and from the Nunavut border in the east to the Yukon border in the west (MRBB, 2021).

Based on the Standard Drainage Area Classification (NRCan, 2003), the project highway alignment crosses through the Central Mackenzie-The Ramparts, Great Bear Lake, and Central Mackenzie-Blackwater Lake sub-basins of the Mackenzie Valley Basin. Between the southern and northern extents of the Project, the project highway alignment will cross over numerous tributaries of varying size to the Makenzie River, including two major tributaries (i.e., the Blackwater River and the Great Bear River).

Although watercourses within the Mackenzie-Great Bear Sub-Basin are generally of good quality, some localized effects on water quality have been observed nearby anthropogenic influences such as wastewater discharges (MRBB, 2003, 2021). In addition, local Indigenous people have expressed concern about water quality and have reported increasing water temperatures and turbidity compared to past years (MRBB, 2021). However, the most recent State of the Aquatic Ecosystem Report (SOAER) for the Mackenzie-Great Bear Sub-Basin (MRBB, 2021) describes that the "*scientific data generally do not show widespread [anthropogenic] impacts on water quality or on fish health, as indicated by the absence of trends from 2000 to 2018 in water quality parameters that have guidelines*".

Natural water quality of the Mackenzie-Great Bear Sub-Basin, including water flowing through the RSA, is generally influenced by water flowing through the Precambrian Shield of the Mackenzie Mountains, as well as mountains surrounding the Liard River, which drains into the Mackenzie River (Golder, 2015). This flowing water causes streambank erosion, which mobilizes metals and nutrient-rich sediment. Consequently, the Mackenzie River is known for naturally elevated suspended sediment and turbidity compared to other rivers in the arctic. Natural turbidity in the Mackenzie River is highest during the spring

snow melt and is often in exceedance of Canadian Water Quality Guidelines (CWQG) for recreation and aesthetics (MRBB, 2003).

Between 2012 and 2018, TSS was measured in the months of July, August, and September in the Mackenzie River at Norman Wells (Figure 3.1), Tulita (Figure 3.2), and Wrigley (Figure 3.3) as part of the NT-wide Community-Based Monitoring Program (data retrieved from DataStream, 2022). Except for a few elevated concentrations, TSS generally remained below 400 mg/L in the Mackenzie River at Norman Wells and Wrigley, and below 200 mg/L at Tulita. In the context of the proposed Project, historical concentrations of TSS in the Mackenzie River are considered background concentrations, regardless of natural or anthropogenic influences. Therefore, the CWQGs generally do not apply to these historical TSS concentrations because the guidelines for TSS are narrative and based on changes relative to background conditions (CCME, 2022).

Overall, the recorded TSS concentrations trended downward at Norman Wells and Wrigley, but generally remained consistent at Tulita (except for one elevated sample in 2017). Summary statistics for TSS at these three locations are provided in Table 3.1.

Figure 3.1 Total Suspended Solids in the Mackenzie River at Norman Wells: 2012 to 2018

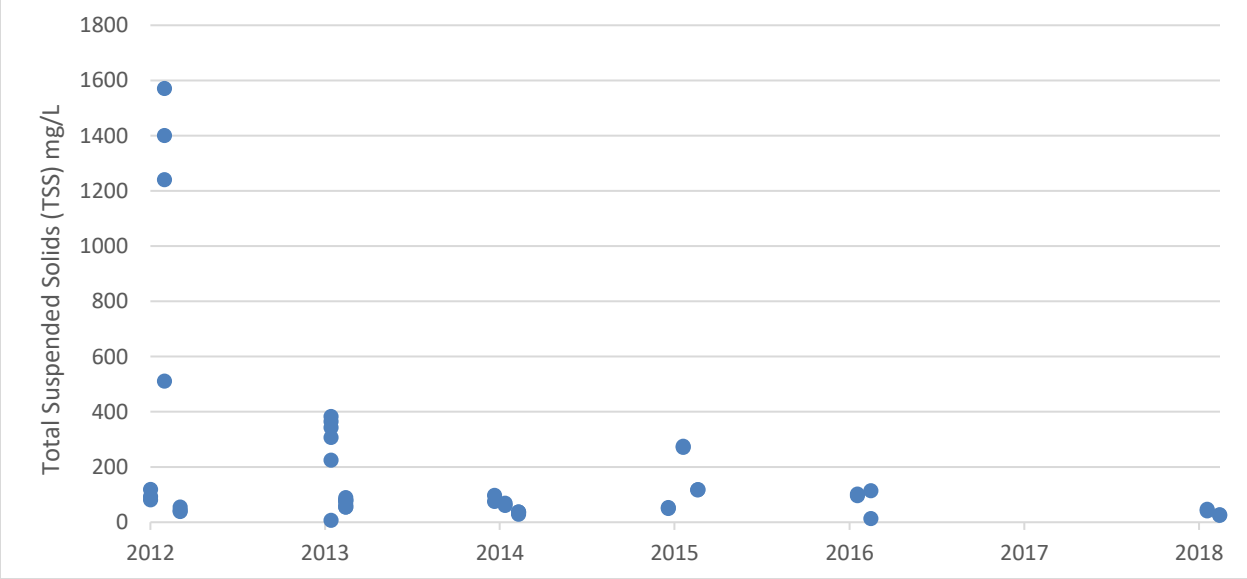


Figure 3.2 Total Suspended Solids in the Mackenzie River at Tulita: 2012 to 2018

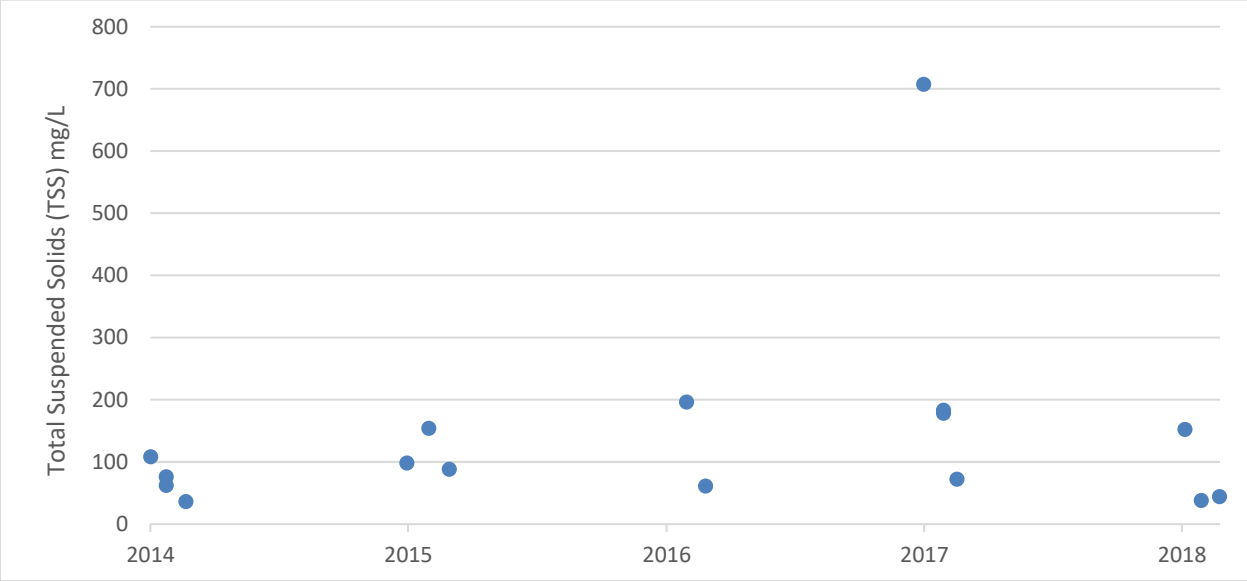


Figure 3.3 Total Suspended Solids in the Mackenzie River at Wrigley: 2013 to 2018

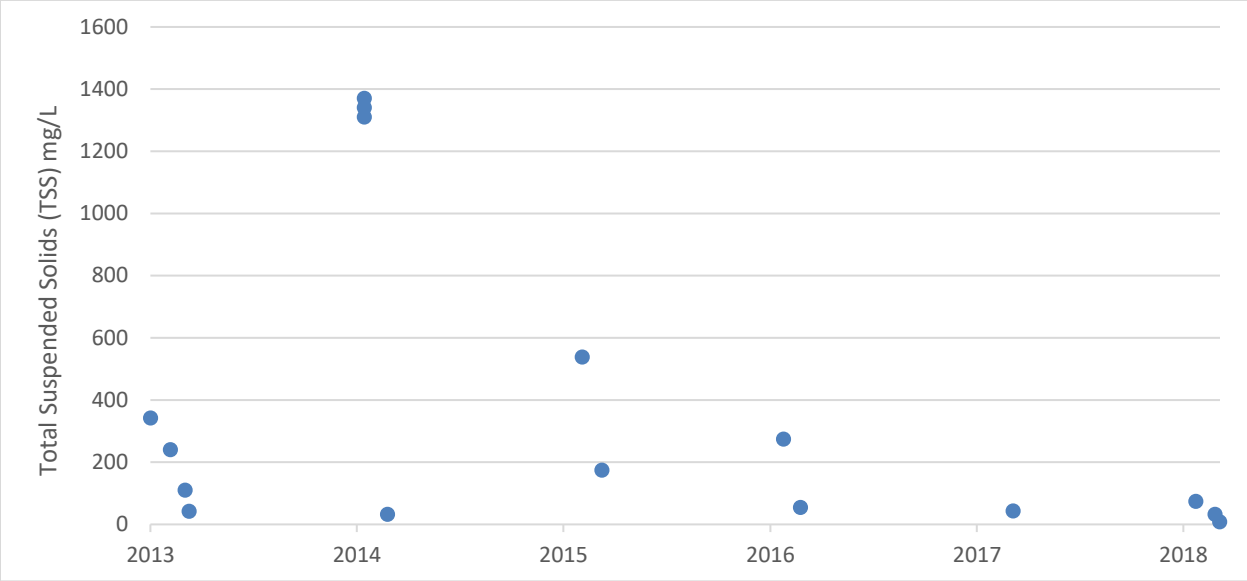


Table 3.1 Total Suspended Solids (TSS) at Different Sites Along the Mackenzie River

Location	Map ID	Date Range	TSS (mg/L)				
			N	Min	Mean	95th P	Max
Norman Wells	1	July 2012 to August 2018	45	6	200	1,352	1,570
Tulita	27	July 2014 to August 2018	16	36	141	324	707
Wrigley	69	June 2013 to August 2018	16	8	374	1,348	1,370

Notes:
TSS = total suspended solids
Map ID = sample site as presented in Figure 3.4 and Figure 3.5;
N = Number of samples collected; 95^{th} P = 95^{th} percentile
Data retrieved from Mackenzie DataStream (https://mackenziedatastream.ca/)

3.2.2 Existing Influences on Surface Water Quality

Surface water quality in the Mackenzie-Great Bear Sub-Basin is influenced by two main sources: local sources and global sources. Local anthropogenic sources (i.e., sources within the Mackenzie-Great Bear Sub-Basin) include historical and existing mines, municipal sewage, oil and gas exploration activities, pulp mills, and other industries (MRBB, 2004, 2021). Local natural sources include soils, bedrock, and forest fires from which naturally occurring constituents can be released. Some water quality parameters observed in the Mackenzie-Great Bear Sub-Basin originate in other parts of the world and travel through the atmosphere before being deposited there (MRBB, 2004, 2021).

In the Mackenzie Valley, uses of water and deposits waste as subject to the *Waters Act* and Waters Regulations. According to the Sahtu Land and Water Board, there are six active water licenses within the RSA as of May 2022:

- The Hamlet of Tulita municipal operations (SI6L8-002)
- Imperial Oil Norman Wells Operations (S13L1-007)
- Town of Norman Wells municipal operations (S18L3-003)
- Geotechnical drilling for the proposed bridge development crossing the Great Bear River at Tulita (S19LI-004) - completed
- Norman Wells Soil Treatment Facility (Sahtu Land and Water Board license S18L1-002)
- Prohibition Creek Access Road (S20L8-002) – not yet constructed

Of these, generally only the Hamlet of Tulita municipal operations has the potential to currently influence water quality in the LSA because the others are either completed or occur at the northern limit of the RSA or downstream of the Project. Other local sources of potential anthropogenic constituents of interest for surface waters within the RSA include land disturbances associated with existing or proposed quarry/borrow in the RSA. Some of these existing borrow sites are proposed to be repurposed for the construction and maintenance of the Project and its associated infrastructure. The twenty primary quarry

and pit locations (and their associated watersheds) selected as candidate borrow sites for the Project are discussed in Section 3.2.3.1.

Climate change also has the potential to influence water quality in the Mackenzie River Basin, including the RSA. Climate change has altered and will continue to alter the cryosphere (e.g., seasonal snow cover, glaciers, ice caps, permafrost, and ice covering surface waters) and the hydrologic cycle in the arctic (MRBB, 2004; Derksen et al., 2019). These effects, including later freeze-ups in the fall and earlier break-ups in the spring, may contribute to increased streambank erosion and increased mobilization of metals and nutrients from the environment to surface waters (MRBB, 2004, 2021).

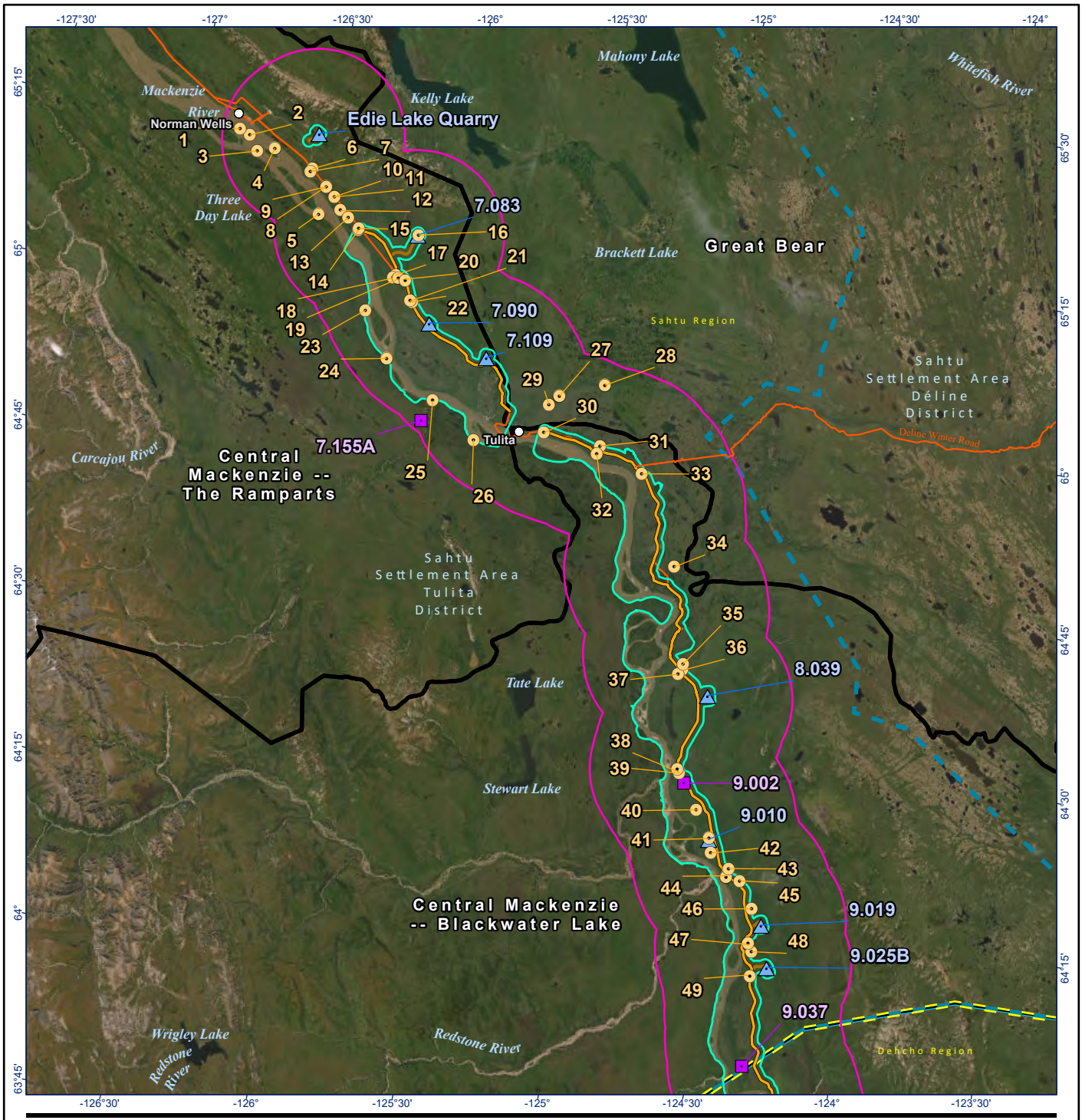
3.2.3 Surface Water Quality Data Sources for the Study Area

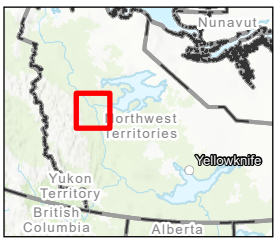
Various surface water quality monitoring programs have been conducted in the Mackenzie River Basin, including long-term monitoring conducted by ECCC, Fisheries and Oceans Canada, community-based monitoring programs supported by GNWT, and monitoring conducted for industrial projects. Collectively, these programs have acquired data for in situ parameters (e.g., pH, turbidity, temperature, conductivity, and dissolved oxygen) and laboratory-analyzed parameters (e.g., metals and nutrients) at different locations and periods over the last few decades.

The search for relevant sources of surface water quality data that could be used to characterize baseline surface water quality for watercourses within the RSA focused primarily on data collected within the last 20 years. Identified surface water quality data includes data for the Mackenzie River and multiple watersheds and tributaries to the Mackenzie River between Wrigley in the Dehcho Region and Norman Wells in the Sahtu Region.

Most of the identified surface water quality monitoring sites in the Dehcho Region are within the RSA but outside the LSA. Watersheds in the RSA for which sources of surface water quality data were not identified include Bob's Canyon in the Dehcho Region, and Bluefish Creek and No Name Creek in the Sahtu Region. Surface water quality downstream of the Project is not consistently represented in each watershed, and seasonal variability in water quality across sites in the RSA is not well characterized with the existing data.

Figure 3.4 and Figure 3.5 show the identified surface water quality monitoring sites in the RSA within the Sahtu Region and Dehcho Region, respectively. Table 3.2, Table 3.3 and Table 3.4 summarize the identified sources of surface water quality data for the RSA watersheds located in the Ramparts sub-basin (Sahtu Region), the Great Bear River and Blackwater Lake sub-basins (Sahtu Region), and the Blackwater Lake sub-basin (Dehcho Region), respectively. The watersheds presented in these tables include the major streams (i.e., tributaries of the Mackenzie River), which the project highway alignment will cross.





- Water Quality Sampling Site

Borrow Source

- Primary - Granular
- Primary - Quarry
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Sub-Basin

0 10 20 Kilometers

(At original document size of 8.5x11)
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N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0070-REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.4

Title
Identified Water Quality Monitoring Sites in the RSA (Sahtu Region)

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Government of Canada
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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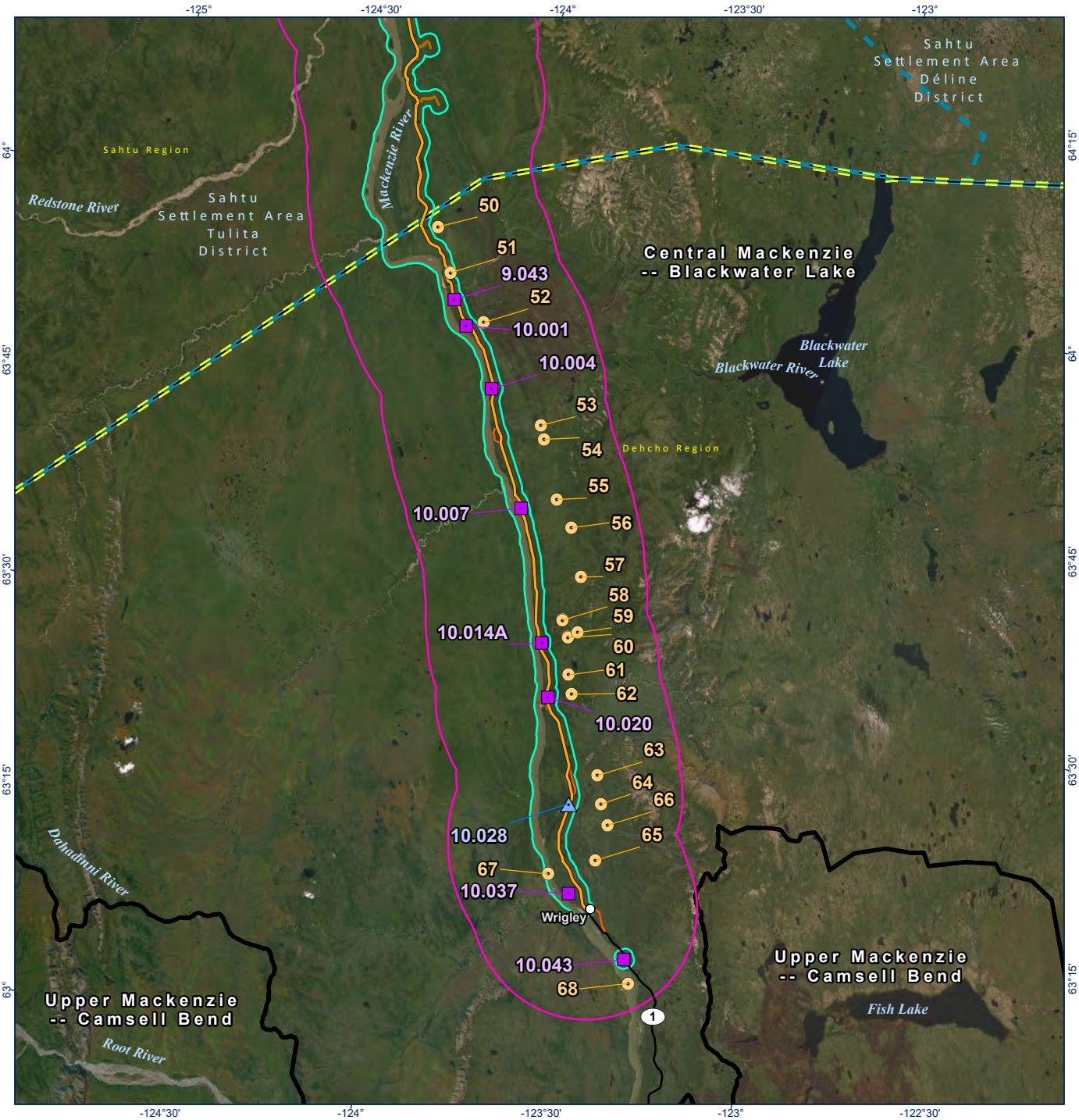

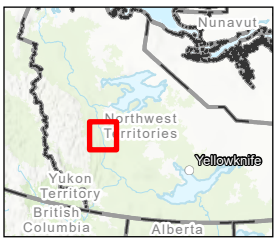

- Water Quality Sampling Site

Borrow Source

- Primary - Granular
- Primary - Quarry
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Sub-Basin

0 7.5 15 Kilometres

(At original document size of 8.5x11)
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N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0069-REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.5

Title
Identified Water Quality Monitoring Sites in the RSA (Dehcho Region)

Notes

1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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Table 3.2 Identified Sources of Surface Water and Sediment Quality Data for RSA and LSA Watersheds Located in The Ramparts Sub-Basin (Sahtu Region)

Watershed/ Watercourse	Map ID[1]	Sampling Site in LSA or RSA	Water Quality Data			Sediment Quality Data	Years of Water Quality Data	UTM Coordinates [2]			Source Site ID or Object ID	Source(s)
			In situ parameters	Metals and Nutrients	Total Suspended Solids			Zone	Easting	Northing		
Mackenzie River at Norman Wells	1	RSA	YES	YES	YES	-	2012	9W	601910	7239319	Mack-NW-02	1
Mackenzie River at Norman Wells	2	RSA	YES	YES	YES	-	2012	9W	603856	7238703	Object ID 427	1
Mackenzie River at Norman Wells	3	RSA	YES	YES	YES	-	2012 to 2018	9W	605801	7236373	Mack-NW-01	1
Mackenzie River at Norman Wells	4	RSA	YES	YES	YES	-	2013	9W	608614	7237661	Object ID 426	1
Mackenzie River at Norman Wells	5	RSA	YES	YES	-	-	2000 to 2019	9W	618938	7228696	NW10KA0001	2
Canyon Creek	6	RSA	YES	YES	YES	-	2002, 2003, 2005, 2006, 2007	9W	615838	7235994	RPR-306	3, 4
Canyon Creek	7	RSA	YES	YES	YES	-	2005	9W	615611	7235425	Canyon Ck	5
Francis Creek	8	RSA	YES	YES	YES	-	2002, 2003, 2005, 2006	9W	618967	7233677	RPR-308	3, 4
Francis Creek	9	RSA	YES	YES	YES	-	2005	9W	618969	7233614	Francis Ck	5
Helava Creek	10	RSA	YES	YES	YES	-	2002, 2003, 2005, 2006	9W	620763	7232296	RPR-310	3, 4
Helava Creek	11	RSA	YES	YES	YES	-	2005	9W	620781	7232324	Heleva Ck	5
Christina Creek	12	RSA	YES	-	YES	-	2002, 2003	9W	**622383**	**7230390**	RPR-311	3
Unnamed Creek	13	RSA	YES	-	YES	-	2002, 2003	9W	**624057**	**7229536**	RPR-312	3
Prohibition Creek	14	LSA	YES	YES	YES	YES	2002, 2003, 2005, 2006	9W	626292	7227921	RPR-313	3, 4
Prohibition Creek	15	LSA	YES	YES	YES	-	2005	9W	626304	7228212	Prohibition Ck	5
Vermillion Creek North	16	LSA	YES	-	-	-	2020	9W	636588	7229804	7.083-SW-1	6
Vermillion Creek North	17	LSA	YES	YES	YES	-	2002, 2003, 2005, 2006	9W	634623	7222098	RPR-323	3, 4
Vermillion Creek North	18	LSA	YES	YES	YES	-	2005	9W	634277	7221560	Vermillion Ck	5
Nota Creek	19	LSA	YES	YES	YES	YES	2002, 2003, 2005, 2006	9W	635169	7221789	RPR-324	3, 4
Nota Creek	20	LSA	YES	YES	YES	-	2005	9W	636476	7221669	Nota Ck	5
Jungle Ridge Creek	21	LSA	YES	YES	YES	-	2002, 2005, 2006	9W	638592	7218394	RPR-325	3, 4
Jungle Ridge Creek	22	LSA	YES	YES	YES	-	2005	9W	638206	7218535	Jungle Ridge Ck	5
Bluefish Creek	-	-	-	-	-	-	-	-	-	-	-	-
No Name Creek	-	-	-	-	-	-	-	-	-	-	-	-
Bog Creek at Mackenzie River	23	RSA	YES	YES	YES	-	2014 to 2016	9W	631206	7214889	Mack Tul-05	1
Slater Creek	24	RSA	YES	YES	YES	-	2014 to 2016	9W	636935	7207841	Mack-Tul-04	1
Little Bear	25	LSA	YES	YES	YES	-	2013 to 2018	10W	**362829**	**7202526**	Mack-Tul-03	1
MacKay Creek	26	RSA	YES	YES	YES	-	2014 to 2016	10W	370992	7197018	Mack-Tul-02	1
Mackenzie River at Tulita	27	RSA	YES	YES	YES		2014 to 2021	10W	376412	7198985	TUL-MR	1

Notes:

[1] Map IDs correspond to Figure 3.4 and Figure 3.5.

[2] Sampling coordinates may differ between years and monitoring programs. In cases where sources 3 and 4 are both cited, the coordinates were obtained from source 4 (source 3 did not report sampling site coordinates). **Bold** coordinates were estimated from source maps because the site coordinates were not reported.

Source: 1 = GNWT Community Based Monitoring; 2 = ECCC Northern Water Quality Monitoring Network; 3 = Mackenzie Gas Project EIS Baseline Report (Volume 3, Section 6); 4 = Mackenzie Valley Pipeline (i.e., Mackenzie Gas Project), raw data from INAC; 5 = Rempel and Gill (2011); 6 = Stantec surface water sampling, October 2020

" – " indicates where monitoring data were not identified

Table 3.3 Identified Sources of Surface Water Quality and Sediment Data for RSA and LSA Watersheds Located in The Great Bear and Blackwater Lake Sub-Basins (Sahtu Region)

Sub-Basin	Watershed/Watercourse	Map ID	Sampling Site in LSA or RSA (outside of LSA)	Water Quality Data			Sediment Quality Data	Years of Water Quality Data	UTM Coordinates [2]			Source Site ID or Object ID	Source(s)
				In situ parameters	Metals and Nutrients	Total Suspended Solids			Zone	Easting	Northing		
Great Bear	Great Bear River	28	RSA	YES	YES	-	-	2000 to 2019	10W	384271	7207108	NW10JC0001	2
Great Bear	Great Bear River	29	RSA	YES	YES	YES	-	2013 to 2018	10W	391699	7210301	GBR-Tul-01	1
Great Bear	Great Bear River	30	RSA	YES	YES	YES	YES	2002, 2003	10W	**382752**	**7205332**	RPR-330	3
Blackwater Lake	Four Mile Creek	31	LSA	YES	-	YES	-	2002	10W	**382747**	**7200398**	Site 404	3
Blackwater Lake	Between Four Mile Creek and Gotcha Creeks	32	LSA	YES	-	YES	-	2002	10W	**392694**	**7199822**	RPR-332	3
Blackwater Lake	Between Four Mile Creek and Gotcha Creeks	33	LSA	YES	-	YES	-	2002	10W	**392406**	**7198380**	Site 406	3
Blackwater Lake	Gotcha Creek	34	LSA	YES	-	YES	-	2002	10W	**400623**	**7196362**	RPR-335	3
Blackwater Lake	Between Gotcha Creek and Big Smith Creek	35	RSA	YES	-	YES	-	2002	10W	**408984**	**7181513**	RPR-342	3
Blackwater Lake	Big Smith Creek	36	LSA	YES	-	YES	-	2002	10W	**413466**	**7164316**	RPR-349	3
Blackwater Lake	Big Smith Creek	37	LSA	YES	YES	YES	-	2006	10W	413453	7165223	Big Smith Ck	5
Blackwater Lake	Big Smith Creek	38	LSA	YES	-	YES	YES	2002	10W	**412876**	**7163349**	Site 435/436	3
Blackwater Lake	Little Smith Creek	39	LSA	YES	-	YES	-	2002	10W	**415616**	**7147203**	RPR-351	3
Blackwater Lake	Little Smith Creek	40	LSA	YES	YES	YES	-	2006	10W	416039	7146590	Little Smith Ck	5
Blackwater Lake	Seagrams Creek	41	LSA	YES	-	YES	-	2002	10W	**420085**	**7140860**	RPR-353	3
Blackwater Lake	Between Seagrams Creek and Saline Creek	42	LSA	YES	YES	-	-	2020	10W	423075	7136476	9.010-SW-1	6
Blackwater Lake	Between Seagrams Creek and Saline Creek	43	LSA	YES	-	YES	YES	2002, 2003	10W	**423833**	**7133940**	RPR-355	3
Blackwater Lake	Saline Creek	44	LSA	YES	YES	YES	YES	2002, 2003	10W	**427363**	**7131821**	RPR-358	3
Blackwater Lake	Saline Creek	45	LSA	YES	YES	YES	-	2006	10W	427168	7130338	Saline Ck	5
Blackwater Lake	Devil's Creek	46	LSA	YES	-	YES	-	2002	10W	**429599**	**7130048**	RPR-359	3
Blackwater Lake	Between Devil's Creek and Steep Creek	47	RSA	YES	-	YES	-	2002	10W	**432482**	**7125723**	RPR-367	3
Blackwater Lake	Steep Creek	48	LSA	YES	-	YES	-	2002, 2003	10W	**432915**	**7119668**	RPR-371	3
Blackwater Lake	Steep Creek	49	RSA	YES	YES	YES	-	2006	10W	433727	7118390	Steep Ck	5
Blackwater Lake	Between Steep Creek and Blackwater Creek	50	LSA	YES	-	YES	-	2002	10W	**434212**	**7114190**	RPR-373	3

Notes:
[1] Map IDs correspond to Figure 3.4 and Figure 3.5.
[2] Sampling coordinates may differ between years and monitoring programs. **Bold** coordinates were estimated from source maps because the site coordinates were not reported.
Source: 1 = GNWT Community Based Monitoring; 2 = ECCC Northern Water Quality Monitoring Network; 3 = Mackenzie Gas Project EIS Baseline Report (Volume 3, Section 6); 5 = Rempel and Gill (2011); 6 = Stantec surface water sampling, October 2020
" – " indicates where monitoring data were not identified

Table 3.4 Identified Sources of Surface Water Quality and Sediment Data for RSA and LSA Watersheds Located in The Blackwater Lake Sub-Basin (Dehcho Region)

Sub-Basin	Watershed/Watercourse	Map ID	Sampling Site in LSA or RSA (outside of LSA)	Water Quality Data			Sediment Quality Data	Years of Water Quality Data	UTM Coordinates 2			Source Station ID or Object ID	Source(s)
				In situ parameters	Metals and Nutrients	Total Suspended Solids			Zone	Easting	Northing		
Blackwater Lake	Between Steep Creek and Blackwater Creek	51	RSA	YES	-	YES	-	2002	10V	**439979**	**7099197**	RPR-376	3
Blackwater Lake	Blackwater River	52	LSA	YES	YES	YES	YES	2002	10V	**442738**	**7093381**	RPR-377	3
Blackwater Lake	Between Blackwater River and Dam Creek	53	RSA	YES	-	YES	-	2002	10V	**448340**	**7087520**	RPR-379	3
Blackwater Lake	Dam Creek	54	RSA	YES	-	YES	-	2002	10V	**458431**	**7075122**	RPR-381	3
Blackwater Lake	Dam Creek	55	RSA	YES	YES	YES	-	2006	10V	459162	7073334	Dam Ck	5
Blackwater Lake	Bob's Canyon	-	-	-	-	-	-	-	10V	-	-	-	-
Blackwater Lake	Vermillion Creek South	56	RSA	YES	-	YES	-	2002	10V	**462324**	**7065608**	RPR-383	3
Blackwater Lake	Strawberry Creek	57	RSA	YES	-	YES	-	2002	10V	**464919**	**7062148**	RPR-385	3
Blackwater Lake	Strawberry Creek	58	RSA	YES	-	YES	YES	2002	10V	**467369**	**7055805**	Site 488	3
Blackwater Lake	Between Strawberry Creek and White Sand Creek	59	RSA	YES	-	YES	-	2002, 2003	10V	**465928**	**7049606**	RPR-388	3
Blackwater Lake	White Sand Creek	60	RSA	YES	-	YES	-	2002	10V	**468234**	**7048309**	Site 491	3
Blackwater Lake	White Sand Creek	61	RSA	YES	YES	YES	-	2007	10V	467066	7047426	White Sand Ck	5
Blackwater Lake	White Sand Creek	62	RSA	YES	YES	YES	YES	2002	10V	**468041**	**7042453**	RPR-391	3
Blackwater Lake	Ochre River	63	RSA	YES	YES	YES	-	2007	10V	468926	7039934	Ochre R	5
Blackwater Lake	Hodgson Creek	64	RSA	YES	-	YES	-	2003	10V	**474289**	**7029712**	RPR-398	3
Blackwater Lake	Hodgson Creek	65	RSA	YES	YES	YES	YES	2002	10V	**475442**	**7025964**	RPR-399	3
Blackwater Lake	Hodgson Creek	66	RSA	YES	-	YES	-	2002, 2003	10V	**476019**	**7018323**	RPR-403	3
Blackwater Lake	Hodgson Creek	67	RSA	YES	YES	YES	-	2006	10V	476802	7023301	Hodgson Ck	5
Blackwater Lake	Mackenzie River at Wrigley	68	LSA	YES	YES	-	-	1969 to 1994	10V	470025	7015379	NW10HC0001	2
Blackwater Lake	Mackenzie River at Wrigley	69	RSA	YES	YES	YES	-	2013 to 2018	10V	483308	7002633	Mack-WRI-01	1

Notes:
[1] Map IDs correspond to Figure 3.4 and Figure 3.5.
[2] Sampling coordinates may differ between years and monitoring programs. **Bold** coordinates were estimated from source maps because the site coordinates were not reported.
Source: 1 = GNWT Community Based Monitoring; 2 = ECCC Northern Water Quality Monitoring Network; 3 = Mackenzie Gas Project EIS Baseline Report (Volume 3, Section 6); 5 = Rempel and Gill (2011); 6 = Stantec surface water sampling, October 2020
" – " indicates where monitoring data were not identified

3.2.3.1 Surface Water Quality Data Sources for Watersheds Associated with Borrow Pits and Rock Quarries

Fifteen material sources have been identified for the Project, with seven of these already existing as sources of gravel or rock for other uses in the Sahtu and Dehcho regions. A preliminary assessment of these sources was completed, as reported in (K'alo-Stantec, 2022b). The potential current or historical uses of these existing borrow sites include bridge construction, road construction, winter road maintenance, pipeline maintenance, and municipal uses. The existing surface water quality data for watercourses located in the same watersheds as the 15 proposed primary material sources are listed in Table 3.5.

Table 3.5 Surface Water Quality Data Sources for Watersheds Associated with Borrow/Quarry Sites

Region	Pit or Quarry	Quarry/ Pit Site ID	Existing /New	Associated Watershed(s)	Map ID of Water Quality Site in Same Watershed as Quarry or Pit
Sahtu	Quarry	Edie Lake	Existing	Bosworth Creek	-
Sahtu	Quarry	7.083*	Existing	Vermillion Creek North	16, 17, 18
Sahtu	Quarry	7.090	New	Jungle Ridge Creek	21, 22
Sahtu	Quarry	7.109	New	Bluefish Creek	-
Sahtu	Quarry	8.039	New	Big Smith Creek	35, 36, 37
Sahtu	Granular Pit	9.002	Existing	Little Smith Creek	38, 39
Sahtu	Quarry	9.019	New	Between Devil's Creek and Steep Creek	46
Sahtu	Quarry	9.025B	New	Steep Creek	47, 48
Dehcho	Granular Pit	9.043	Existing	Between Blackwater River and Dam Creek	52
Dehcho	Granular Pit	10.004	New	Between Blackwater River and Dam Creek	52
Dehcho	Granular Pit	10.007	Existing	Between Bob's Canyon Creek and Vermillion Creek	-
Dehcho	Granular Pit	10.014A	New	Between Strawberry Creek and White Sand Creek	58
Dehcho	Granular Pit	10.020	Existing	Between White Sand Creek and Ochre River	-
Dehcho	Quarry	10.028	New	Hodgson Creek	63 to 66
Dehcho	Granular Pit	10.043	Existing	South of Hodgson Creek	-

Notes:
" – " = indicates no water quality data have been identified for the associated watershed
* = Surface water quality has been sampled at the borrow site (October 2020)
Map IDs correspond to Figure 3.4 and Figure 3.5

In most cases, contact water from a material source (i.e., borrow or rock quarry) does not enter the environment from a single point source. Furthermore, the existing hydraulic connectivity from each of these sites to watercourses in the watershed is not well defined and contact water from a material source does not necessarily flow to the corresponding historical water quality monitoring sites listed for the watersheds in Table 3.5. In addition, the development of material sources may alter hydraulic connectivity to the receiving environment. Therefore, the potential for existing and future material sources to influence surface water quality in the RSA is not well understood.

Prospective material sources were accessed in October 2020 (K'alo-Stantec, 2022b). Eleven granular sources, where clast lithology indicated the possibility of Acid Rock Drainage/Metal Leaching (ARD/ML) potential, were sampled (nine of these eleven sites are identified as primary material sources). Results of the preliminary assessment indicate that the ARD/ML potential of the tested prospective material sources is low and is not expected to adversely affect water quality of the receiving watercourses.

3.2.4 Sediment Quality Data Sources for the Study Area

Sediment quality has been sampled less frequently than surface water quality within the RSA. The only identified source of sediment quality data within the RSA was a baseline characterization study performed for the Mackenzie Gas Project EIS (IORVL, 2004). Sediment sampling for the Mackenzie Gas Project EIS baseline study was conducted in 2002 and 2003 and included metals analyses for sediments collected in nine watersheds within the RSA: Prohibition Creek, Nota Creek, Great Bear River, Big Smith Creek, and Saline Creek in the Sahtu Region; and Blackwater River, Strawberry Creek, White Sand Creek, and Hodgson Creek in the Dehcho Region.

Table 3.2, Table 3.3, and Table 3.4 summarize the identified sediment quality data sources for the RSA watersheds located in the Ramparts sub-basin (Sahtu Region), the Great Bear River and Blackwater Lake sub-basins (Sahtu Region), and the section of the Blackwater Lake sub-basin located in the Dehcho Region, respectively. The watersheds presented in these tables represent the major streams (i.e., tributaries of the Mackenzie River) that the project highway alignment will cross.

3.3 Data Gaps and Future Monitoring

Data gaps for existing conditions were identified for this TDR. These data gaps include, but are not limited to, information requested in the DAR Terms of Reference (TOR; MVEIRB, 2015) and are as follows:

- The TOR requires a description of sediment load (suspended and bed load) for each major drainage or major watercourse (TOR Section 5.1.3; MVEIRB, 2015). Historical concentrations of TSS are summarized for three locations in the Mackenzie River (i.e., Wrigley, Tulita, and Norman Wells) in Section 3.2.1. However, suspended sediments and/or sediment bed loads are not identified for each watercourse that may be affected by the Project. Sites within the RSA and LSA for which historical TSS data are available are summarized in Table 3.3, Table 3.4, and Table 3.5.

- The TOR requires the identification of existing water quality and variations for each area of water use that may be affected by the Project (TOR Section 5.1.3; MVEIRB, 2015). Except for TSS described above, information on the seasonal and/or annual variability of surface water and sediment quality for watercourses that may be affected by Project-related activities (i.e., particularly smaller watercourses that intersect the PDA) is limited and not summarized.
- Detailed information about traditional water-use locations that may be affected by the Project are not identified. Protection of water quality in the Mackenzie Valley is of high cultural importance. Watercourses in the RSA are traditionally used as sources of sustenance, including drinking water and for harvesting of fish. Information on specific water uses and locations, if available, could be incorporated in the design of site-specific monitoring programs that reflect the intended use of a watercourse.

For the Mackenzie Valley Highway Project, management plans and mitigation measures will be implemented to reduce effects to surface water and sediment quality from erosion and sedimentation, ARD/ML, and explosives-related nitrogen loading. As a result, collection of additional site-specific baseline water and sediment quality data is not anticipated for supporting the DAR. Additional water quality data, however, will be required for pre-construction and compliance monitoring and to facilitate adaptive management. Surface water quality data will be collected as part of pre-construction and compliance monitoring program at watercourse crossings and in waterbodies adjacent to borrow sources. Suspended sediments (i.e., total suspended solids; TSS) in surface water will also be monitored during construction at upstream and downstream sites.

In specific cases where historical water/sediment quality data may be appropriate to investigate potential Project-related effects, the available surface water and sediment quality data identified for sites within the RSA and LSA (as identified in Table 3.3, Table 3.4, and Table 3.5) may be used to support future Project-specific monitoring programs. Ongoing consultation and engagement with potentially affected parties will also help inform the design of future monitoring programs to account for specific water uses and water-use locations within the RSA and LSA.

4 Summary

The Project is in the Mackenzie-Great Bear Sub-Basin of the Mackenzie Valley Basin (MRBB, 2021). Although watercourses within the Mackenzie-Great Bear Sub-Basin are generally of good quality, some localized effects to water quality have been observed nearby anthropogenic influences such as wastewater discharges (MRBB, 2003, 2021). In addition, Indigenous people have reported increasing water temperatures and turbidity compared to past years. However, the scientific data generally do not show widespread anthropogenic impacts on water quality or on fish health (MRBB, 2021).

Watercourses that will intersect the PDA drain into the Mackenzie River, which is known for naturally elevated suspended sediment and turbidity compared to other rivers in the arctic (MRBB, 2003). Turbidity in the Mackenzie River is highest during the spring snow melt and is often in exceedance of CWQG for recreation and aesthetics (MRBB, 2003). Between 2012 and 2018, TSS generally remained below 400 mg/L in the Mackenzie River at Norman Wells and Wrigley, and below 200 mg/L at Tulita. However, the CWQGs generally do not apply to these historical TSS concentrations because the guidelines for TSS are narrative and are based on changes relative to background conditions (CCME, 2022).The sources of surface water and sediment quality data identified for monitoring sites specific to sub-basins and watersheds in the RSA include data collected by ECCC (2021), Fisheries and Oceans Canada (Rempel and Gill, 2011), GNWT community-based monitoring (GNWT, 2020, pers. comm.), and industry (IORVL, 2004; GNWT, 2021, pers. comm.).

In addition to the identification of monitoring data for the Mackenzie River, sources of water quality data were identified for most watersheds in the RSA that have major streams (i.e., tributaries of the Mackenzie River) that the Project will cross. Watersheds in the RSA for which sources of surface water quality data were not identified include Bob's Canyon Creek in the Dehcho Region, and Bluefish Creek and No Name Creek in the Sahtu Region. Based on the identified sources of water quality data for the RSA, many monitoring sites in the Sahtu Region ware within the LSA (and, therefore, relatively close to the Project); however, most identified monitoring sites in the Dehcho Region are outside the LSA.

The identified sources of water quality data for the RSA were generally collected within the last 20 years, with some sites having broader temporal coverage than others (e.g., several years vs. a single year of monitoring data). Most sites included both in situ measurements (e.g., pH, turbidity, conductivity, dissolved oxygen) and laboratory analyses for metal concentrations and nutrients; however, several sites were only sampled for in situ parameters. Furthermore, sources of water quality data have not been identified for all watersheds within the RSA where candidate borrow/quarry sources have been proposed.

Sediment quality has been sampled in nine watersheds in the RSA (IORVL, 2004). These sites were also sampled for surface water quality. The watercourses sampled were Prohibition Creek, Nota Creek, Great Bear River, Big Smith Creek, and Saline Creek in the Sahtu Region, and Blackwater River, Strawberry Creek, White Sand Creek, and Hodgson Creek in the Dehcho Region.

Prospective material sources were screened for ARD/ML potential in October 2020 (K'alo-Stantec, 2022b). Eleven granular sources where clast lithology indicated the possibility of ARD/ML potential were sampled (nine of these eleven sites are identified as primary material sources). Results of the preliminary screening indicate that ARD/ML potential of the tested prospective material sources is low and is not expected to adversely affect water quality of the receiving watercourses.

5 Closure

This TDR was prepared for the sole benefit of GNWT to describe existing conditions related to surface water quality within the Project LSA and RSA. If you have any questions, please do not hesitate to contact the undersigned.

Respectfully submitted,

K'alo-Stantec Limited

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APPENDIX 17A

Fish and Fish Habitat Technical Data Report

Mackenzie Valley Highway Project
Technical Data Report—Fish and Fish Habitat

Prepared for:

Government of the Northwest Territories

Prepared by:

K'alo-Stantec Limited

December 2022

Project No.: 144903025

K'alo-Stantec

Limitations and Sign-off

This document entitled Mackenzie Valley Highway Project Technical Data Report— Fish and Fish Habitat was prepared by K'alo-Stantec Limited ("K'alo-Stantec") for the account of Government of the Northwest Territories (the "Client") to support the regulatory review process for its Developers Assessment Report (DAR) (the "Application") for the Mackenzie Valley Highway Project (the "Project"). In connection therewith, this document may be reviewed and used by the Department of Infrastructure (INF) for the Government of the Northwest Territories participating in the review process in the normal course of its duties. Except as set forth in the previous sentence, any reliance on this document by any other party or use of it for any other purpose is strictly prohibited. The material in it reflects K'alo-Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between K'alo-Stantec and the Client. The information and conclusions in the document are based on the conditions existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, K'alo-Stantec did not verify information supplied to it by the Client or others, unless expressly stated otherwise in the document. Any use that another party makes of this document is the responsibility and risk of such party. Such party agrees that K'alo-Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other party as a result of decisions made or actions taken based on this document.

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Principal, Environmental Services

Executive Summary

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the "Project") that will extend the Mackenzie Valley Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells to replace the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment passes through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT).

This technical data report (TDR) presents technical data and analysis of watercourses to be crossed by the highway alignment as well as wetlands and waterbodies immediately adjacent to the highway that may require culvert installations. Watercourses with existing crossing structures (e.g., bridges and culverts) that will become part of the highway are not included in this report. The Great Bear River is also not included because the bridge crossing of this watercourse is undergoing a separate regulatory approvals process.

All watercourses to be crossed by the project highway alignment drain into the Mackenzie River. There are 33 species of fish within the Regional Study Area (RSA); however, not all species found within the RSA would be expected to utilize watercourses to be crossed by the highway (e.g., chum salmon [*Oncorhynchus keta*]). There is a known spawning population of chum salmon in the Liard River, which is a tributary to the Mackenzie River; however, this species is unlikely to use the watercourses expected to be crossed by the highway. Two species, the Western Arctic populations of Bull trout (*Salvelinus confluentus*) and Dolly Varden (*Salvelinus malma*), are listed under Schedule 1 of the *Species at Risk Act* as species of "special concern" and ranked sensitive under the Northwest Territories Species Ranking; however, no additional regulatory restrictions currently apply to these populations.

A desktop assessment was conducted on the 43 watercourses that cross the project highway alignment in the Sahtu Region. This desktop assessment was augmented by 28 field site-assessments within the Sahtu Region portion of the Project. Field assessments were conducted in September and October of 2021. Results indicated that all but 4 of the 43 watercourses assessed provide fish habitat or have the potential to provide fish habitat; most of the watercourses that have the potential to provide fish habitat would likely only support forage fish species.

In the Dehcho Region of the Project, desktop assessments of 49 watercourses or wetlands were augmented by field assessments conducted in September 2020. Field assessments focused on locations where there was not an existing crossing structure. There were 25 watercourses assessed in the field. Of the 49 watercourses and wetlands, 18 were unlikely to provide fish habitat and another 5 are unknown if they provide fish habitat (there was no previous data and could not be assessed in the field at the time). All other watercourses are known to provide fish habitat or have the potential to provide fish habitat. Most of the watercourses that have the potential to provide fish habitat would likely only support forage fish species.

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Abbreviations

%	percent
AT	Alberta Transportation
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DAR	Developer's Assessment Report
DFO	Fisheries and Oceans Canada
GNWT	Government of the Northwest Territories
INF	Department of Infrastructure
IORVL	Imperial Oil Resources Ventures Limited
km	kilometre
KM	kilometre marker
LSA	local study area
m	metre
mg/L	milligrams per litre
MGP	Mackenzie Gas Project
mm	millimetre
MVRMA	*Mackenzie Valley Resource Management Act*
MVWR	Mackenzie Valley Winter Road
NT	Northwest Territories
NTCMA	Northwest Territories Conference of Management Authorities
PDR	Project Description Report
RSA	regional study area
SARA	*Species at Risk Act*
TDR	Technical Data Report
the Project	Mackenzie Valley Highway Project
TK	traditional knowledge
TLRU	traditional land and resource use

Glossary

Centreline	The location where the watercourse crosses the project highway alignment centreline, as currently defined by preliminary-level routing)
Coarse fish	Fish species that are not used for subsistence or recreational fishing such as suckers and Arctic lamprey
Drainage	Ephemeral feature that does not have a defined bed and banks
Feeding habitat	Habitat used by fish primarily for feeding purposes
Forage fish	Minnow-like species which are important food items for larger fish
Migration habitat	Features used by fish to migrate through a watercourse or waterbody to access different habitats to carry out additional life stages
Overwintering habitat	Habitat used by fish during the winter, typically when watercourses and waterbodies are ice-covered
Rearing habitat	Habitat used by larval and juvenile fish for feeding and shelter
Spawning habitat	Habitat used by adult fish to carry out spawning activities
Sport fish	Fish used for subsistence or recreational fishing such as whitefish

1 Introduction

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells to replace the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT; Figure 1.1). Watercourse crossing locations are provided in Appendix A.

The Project is subject to an environmental assessment and the requirements of Part 5 of the *Mackenzie Valley Resource Management Act* (MVRMA). This technical data report (TDR) presents the existing conditions for fish and fish habitat in watercourses, waterbodies, and wetlands crossed by, or adjacent to, the project highway alignment, as based on a preliminary design intended to support development of the Developer's Assessment Report (DAR) as required by the Terms of Reference (Mackenzie Valley Environmental Impact Review Board [MVEIRB], 2015). As per the Terms of Reference (MVEIRB, 2015), a description of existing fish habitat is provided (Table 1.1). As part of the environmental assessment, the DAR will present the GNWT's perspective of how the Project could affect the biophysical and socio-economic environment.

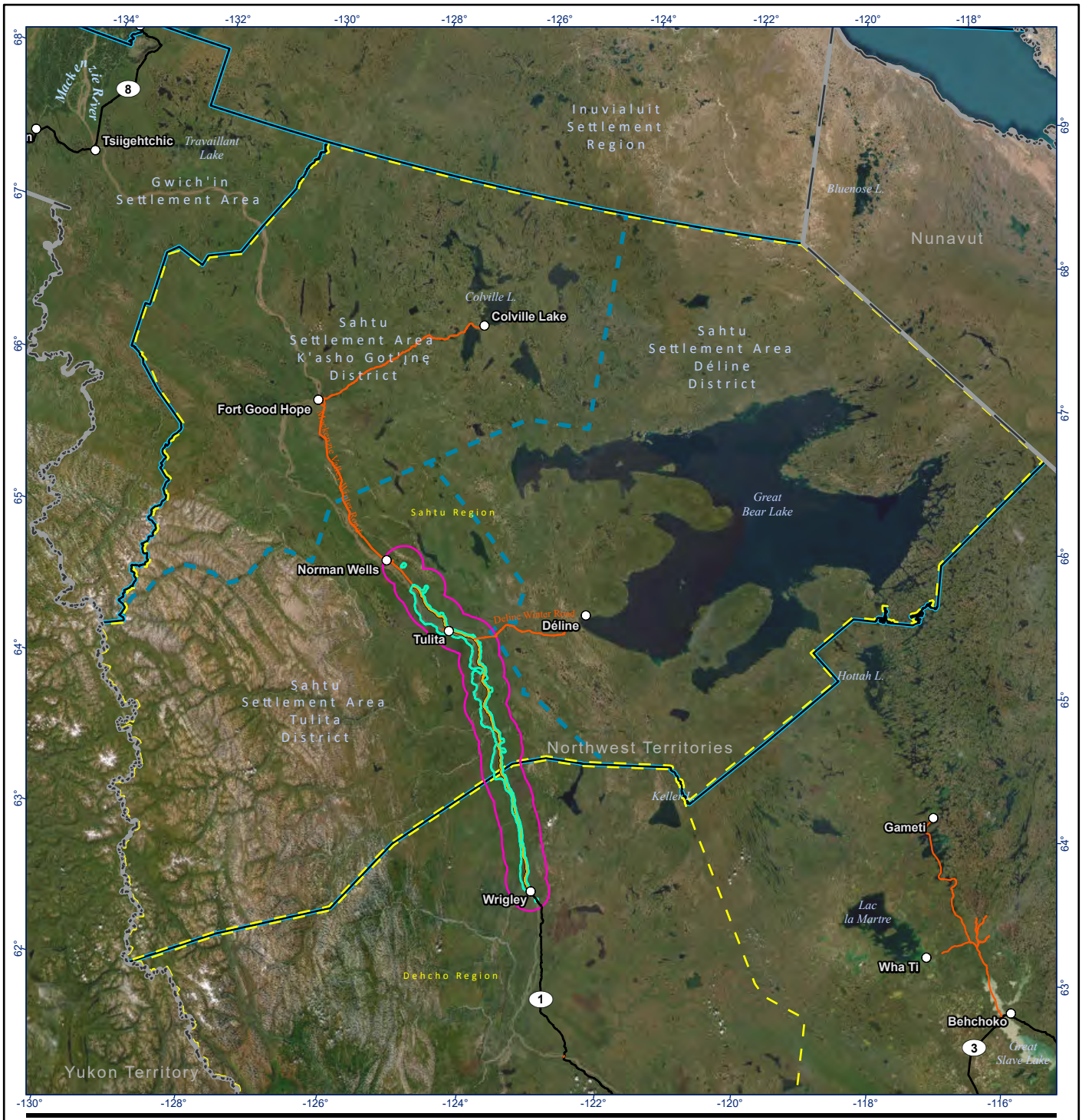
Table 1.1 Fish and Fish Habitat Topics in Terms of Reference and Corresponding Sections in this Technical Data Report

Terms of Reference[a]	Sections in This TDR
Description of fish habitat present at each of the planned water crossings including references	Section 3.2.2 Appendix A Appendix B
Fish species including forage fish (non-harvested) and any other aquatic resources of value present	Table 4.1
Seasonal and life cycle movements and sensitive periods	Section 4.2.1
Habitat requirements for each life stage	Section 4.2.1
Local and regional abundance, distribution and use of habitat types, including aquatic and riparian vegetation	Section 4.2.1
Known sensitive or important areas in terms of habitat type (e.g., spawning, overwintering, refugia, feeding), species and timing of use	Section 4.1
For species at risk or of concern, also describe specific location, population status, limits and size, sensitivity and limiting factors	Section 4.2.1.5 Section 4.2.1.6
Baseline contaminant concentrations in harvested species, that may change as a result of the highway and as available	Section 4.2
Any known issues with respect to health of harvested species (e.g., parasites, disease, condition)	Section 4.2
Species of particular importance to subsistence harvesters	Section 4.1

Terms of Reference[a]	Sections in This TDR
Species subject to exclusive or preferential rights granted by land claims	Section 4.1
species of particular importance to the guiding or outfitting industries	Section 4.1 Section 4.2.1
areas subject to exclusive harvesting rights granted to land claim beneficiaries	Section 4.1
harvest pressures (subsistence, sport fishing, and commercial harvesting) by species, season and geographic area	Section 4.1 Section 4.2.1
Listing of existing non-native species	Section 4.2

Note:

[a] Section 5.1.4 of MVEIRB, 2015 Terms of Reference was referred to in order to develop this TDR



- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Territorial Boundary

0 40 80 Kilometres

(At original document size of 8.5x11)
1:4,500,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0066 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
1.1

Title
Dehcho Region and Sahtu Region - Proposed Mackenzie Valley Highway Alignment – Issued for EA 2022

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

2 Study Areas

The Project is in the Mackenzie Valley region of the NT between Hodgson Creek (located approximately 1 km north of Wrigley) and Prohibition Creek (located approximately 28 km southeast of Norman Wells). The project highway alignment parallels the Mackenzie River to the east.

The Project is located within the Taiga Plains Low Subarctic, Taiga Cordillera Low Subarctic and Boreal Cordillera Level III ecoregions. Each of these ecoregions is distinguished by different climatic factors.

2.1 Local Study Area

The Local Study Area (LSA) for fish and fish habitat is defined as the collective area 300 metres (m) downstream and 100 m upstream of each watercourse crossing structure proposed to be constructed as part of the Project. The centreline reference point is defined as the mid-point where the highway preliminary routing corridor developed to support the DAR crosses a watercourse. This area provides local context for determining significance of Project specific and potential effects to be assessed in the DAR and to inform engineering design.

2.2 Regional Study Area

The Regional Study Area (RSA) is defined by a 15 km buffer on either side of the Project. The RSA includes the Mackenzie River and associated tributaries and drainages. A 15 km buffer provides regional context for determining significance of Project specific effects and potential cumulative effects to be assessed in the DAR.

3 Methods

3.1 Traditional Knowledge and Traditional Land and Resource Use

Traditional knowledge (TK) and traditional land and resource use (TLRU) were obtained through a review of existing published literature from past TK studies. For example, the Tulita Renewable Resources Council (TRRC) completed a TLRU study for the Tulita District relating to the Project (TRRC, 2022). In addition, the following published literature was reviewed:

- Auld and Kershaw (ed.), 2005
- Desseau, 2012
- Golder, 2015
- IMG-Golder Corporation, 2006
- TRRC, 2019

3.2 Fish and Fish Habitat Assessments

3.2.1 Desktop Assessment

Potential watercourses crossed by the project highway alignment were determined based on information included in the Project Description Report (PDR) for Construction of the Mackenzie Valley Highway Tulita District, Sahtu Settlement Area (5658 NWT Ltd. and GNWT, 2011), the PDR for the Mackenzie Valley Highway Extension Pehdzeh Ki Ndeh – Dehcho Region (Dessau, 2012), and the fish and fish habitat baseline report from the Mackenzie Gas Project (MGP) (Imperial Oil Resources Ventures Limited [IORVL], 2004), which follows a similar route to that of the Project. In 2011, fish habitat assessments were completed from a helicopter to identify potential watercourse crossings along the project highway alignment (5658 NWT Ltd. and GNWT, 2011; Dessau, 2012). Watercourse crossings were identified as either watercourses or drainages. Watercourses were identified as active channels with defined bed and banks, while drainages were vegetated and/or had no defined bed and banks (IORVL, 2004; 5658 NWT Ltd. and GNWT, 2011; Dessau, 2012).

During aerial surveys, (5658 NWT Ltd. and GNWT, 2011; Dessau, 2012) identified fish habitat potential based on the type of watercourse to be crossed and did not qualify the quality of habitat available. (5658 NWT and GNWT, 2011; Dessau, 2012) identified fish habitat potential as follows:

- non-fish bearing; features are not used by fish during any life stage.
- migratory channels; ephemeral features used by fish for migration only or contribute to downstream habitat quality.
- spawning, rearing, and feeding habitats; watercourses and drainages that are used by fish for at least one life stage as well as migration.

Reconnaissance and detailed and seasonal surveys at each crossing along the MGP route completed by IORVL (IORVL, 2004). Fish inventories were completed to determine species and life stages in the watercourses crossed by the MGP route, but the report does not provide a comprehensive inventory of fish species in each watercourse. Habitat suitability was evaluated for the potential of large-bodied species harvested for commercial, recreation, or subsistence purposes (e.g., northern pike, Arctic grayling, or groups of fish such as whitefish species) and assumed that all channels provided suitable habitat for some species while vegetated channels did not (IORVL, 2004); it did not describe quality of habitat; instead, it evaluated habitat potential for large-bodied species at each crossing location for

- overwintering
- spawning and incubating
- rearing
- adult feeding and holding

In addition to reviewing existing reports, information on crossings was found using publicly available aerial imagery. Existing watercourses with existing crossing structures that have been established for the MVWR will be utilized by the Project and have been previously assessed.

Primary sources for information on fish species presence was gathered from existing literature and Fisheries and Oceans Canada's (DFO) aquatic species at risk map (DFO, 2022). The resulting historical fish capture data was reviewed for the presence of fish species at risk listed under Schedule 1 of the *Species at Risk Act* (SARA) and the Northwest Territories Conference of Management Authorities (NTCMA) Species at Risk List. Other species designations and status reports were also considered: the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (GOC, 2022b) and the General Status of Ranks of Wild Species in the Northwest Territories (GNWT, 2016).

Life history strategies of the fish species with historical presence within the RSA were summarized based on published literature. Life history strategies were provided for species that are expected to be of value for subsistence or recreational fishing and are predominantly sport fish (e.g., Arctic grayling, northern pike, lake whitefish). Forage fish (e.g., cyprinids) and coarse fish (e.g., suckers) are expected to occur within the RSA; however, life history strategies were not provided because they are less valued for subsistence or recreational fishing although they are ecologically important to the aquatic system. Watercourse crossings identifiers were cross-referenced between the MGP (IORVL, 2004) and PDR (5658 NWT Ltd. and GNWT, 2011) reports and summarized based on both data sources.

3.2.2 Field Assessment

Field assessments were conducted in the Dehcho Region portion of the Project between September 16 and 24, 2020. Field assessments in the Sahtu Region were conducted between September 30 and October 11, 2021. Field assessments in the Sahtu settlement Area were conducted later than originally proposed due to delays in obtaining community and research study approvals due to COVID-19. This delay resulted in some watercourses not being assessed in the field or fish capture not being conducted at all watercourses due to freezing conditions, which could result in injury to fish. For potential stream crossings where field assessments were not conducted, information relies on the desktop assessment.

Field assessments were not conducted at watercourse crossings where there are existing watercourse crossing structures. The Great Bear River is also not included in this report because a proposed bridge over the river at Tulita is undergoing a separate regulatory process.

Features crossed by the Project were grouped into the following categories:

- drainage; ephemeral feature that does not have a defined bed and banks.
- watercourse; has defined bed and banks with flowing surface water that may be active year-round or seasonally.
- wetland; a waterbody with defined bed and banks but does not have flowing water. A wetland may have an inlet and/or an outlet, which connects it to another watercourse or waterbody.

The fish habitat assessment used procedures based on standard protocols outlined in Alberta Transportation's (AT) Fish Habitat Manual (AT, 2009) and R.L. & L. Environmental Services Ltd. (1992). Alberta protocols are used as there are no fish habitat assessment protocols established for the NT and are the Alberta protocols are accepted by regulators in the NT. At each crossing location, six transects were established to document channel characteristics along a 400 m reach. Transects were established at 100 m and 50 m upstream of the centreline and 100 m, 200 m, and 300 m downstream of the centreline. Where possible, the following information and observations were recorded at each transect:

- date and time
- photographs
- habitat-type (e.g., pool riffle, run) and area
- channel characteristics (e.g., channel and wetted widths, depths, gradient)
- bed material (substrate size distribution)
- obstructions to fish passage
- vegetation (instream and riparian)
- flood signs
- stage of stream

Bank materials, bank stability, bank slopes, cover, vegetation, and fish habitat were estimated visually. Channel width, wetted width, water depth, and bank heights were measured quantitively. Instream substrate composition was estimated visually at each transect.

Habitat characteristics were incorporated into a physical habitat classification system, which rated the quality of each macro-habitat type, based on physical characteristics (e.g., depth, cover, substrate) and life history requirements (e.g., rearing, spawning, migration, overwintering) of different fish species known or likely to occur in the vicinity of the Project. Fish habitat suitability for migration, spawning, rearing, and overwintering for waterbodies adjacent to the project highway alignment was rated (i.e., good, moderate, poor, or none) according to its suitability to support migration, spawning, rearing, and overwintering by fish species known or likely to be present within the waterbody.

Generally, sport fish spawning habitat was rated of higher quality (i.e., good) where there was abundant large gravel (suitable for redd construction) and coarse substrate, such as cobble (suitable for broadcast spawning). Proximity to cover was considered because it is important for some species, such as bull trout. For northern pike, flooded riparian vegetation is required for spawning. Consistent flow and suitable depth for the various species were considered in determination of quality. For coarse fish, similar attributes to sport fish were considered because the substrate utilized is similar overall. Forage fish exhibit a variety of spawning behaviours, and good spawning habitat typically includes instream woody debris, instream vegetation, or flooded riparian vegetation as well as the variety of substrates. In addition, forage fish are typically tolerant of lower flows and shallower depths. Ratings of moderate and poor were based on lower amounts of preferred spawning habitat at an area.

Rearing habitat was rated as good quality where flows were suitable for larval and juvenile fish and where there was abundant overhead and/or instream cover. Rearing habitat was rated as better quality where substrate was coarser and complex because it is more likely to support colonization of benthic invertebrate communities as a food source for fish. Ratings of moderate and poor were based on lower amounts of potential rearing habitat at an area.

Overwintering habitat was rated as good for sport and coarse fish where the watercourse does not freeze to bottom and consistent flows were maintained. Deep, high-quality pools were also considered as good overwintering habitat. These areas are likely to maintain sufficient dissolved oxygen concentrations for fish during the winter. Forage fish are generally small bodied, and many are more resilient to lower dissolved oxygen concentrations (e.g., brook stickleback, fathead minnow). These fish are able to successfully overwinter in wetlands (depth greater than 1.5 m), watercourses that do not freeze to the bottom, or that freeze near to bottom. Ratings of moderate and poor were based on lower amounts of potential overwintering habitat at an area.

Migration was rated as good where no barriers to migration were observed. Barriers such as cascades or rapids may not be passed by small-bodied forage fish but could be successfully jumped by an adult salmonid. Other barriers, such as beaver dams, may serve as partial barriers to larger-bodied fish, such as sport and coarse fish, while forage fish are able to migrate past them. Ratings of moderate and poor were based on increasing potential for blockages to fish passage due to flow levels or other natural potential barriers at an area.

4 Results

4.1 Traditional Knowledge and Traditional Land and Resource Use

4.1.1 Sahtu Region

Fishing is an important cultural and social activity in the Sahtu Region (Auld and Kershaw, 2005). The Mackenzie River is an important area for fish harvesting but lakes are also fished (Sahtu Heritage Places and Sites Working Group, 2000). When wildlife were not available at different times of year, some fish species were always available (Auld and Kershaw, 2005). Streams in the Sahtu area are all fish bearing though fish may be only found at certain times of year (Golder, 2015).

Important fish species harvested include Lake whitefish (humpbacks), Lake trout, Northern pike (jackfish), Arctic grayling and Inconnu (coney) (Auld and Kershaw, 2005; Golder, 2015). Arctic grayling are commonly present in the Great Bear River (5658 NWT Ltd. and GNWT, 2011). Broad whitefish are also harvested (Tallman and Reist, 1997). There are no exclusive harvesting rights for fish; however, individuals wishing to fish in Sahtu or Métis private lands or special harvesting areas should contact the local Renewable Resource Council for permission to access the area.

4.1.2 Dehcho Region

Fish, especially whitefish (Dessau, 2012), are an important food source and of cultural significance for people in the Dehcho Region, although other fish species are also harvested. The Mackenzie River is an important fishing area (Dehcho Land Use Planning Committee, 2006). Subsistence fishing is a commonly practiced activity, with the Mackenzie River, Wrigley River, Willowlake River, the River Between Two Mountains, Blackwater Lake, Greasy Lake and Highland Lake being important waterbodies for subsistence harvesting. The primary species caught are lake whitefish, lake trout, inconnu and northern pike (IMG-Golder, 2006). Fish spawning sites are located near the mouths of the Ochre River and Blackwater River (Dessau, 2012). as well as other watercourses crossed by the project highway alignment. Fishing is in important in Trout Lake for TLRU (TRRC, 2022). There are lakes within the RSA which are important spawning areas and fish harvesting within the RSA is reported to occur in the summer and wintertime (TRRC, 2022). There are no exclusive harvesting rights for fish and permission to access lands is not required.

4.2 Fish Species

Previously, 28 fish species were documented within the RSA, based on existing data from 5658 NWT and GNWT (2011) and IORVL (2004). Field assessments in the Dehcho Region by K'alo-Stantec in 2020 included capture of an additional two species: brook stickleback (*Cluea inconstans*) and fathead minnow (*Pimephales promelas*). The 2021 field assessments in the Sahtu Region identified three additional species: finescale dace (*Chrosomus neogaeus*), pearl dace (*Margariscus margarita*) and northern redbelly dace (*Chrosomus eos*). These additional five species raise the total number of fish species documented in the RSA to 33. The capture of pearl dace and northern redbelly dace indicates northern range extensions for both these species in the NT. Table 4.1 provides the status for each species identified in the desktop assessment and field assessments.

Previous studies (IORVL, 2004) conducted in the LSA captured lake chub (*Couesius plumbeus),* slimy sculpin (*Cottus cognatus*), northern pike (*Esox lucius*), longnose sucker (*Catostomus catostomus)* and Arctic grayling (*Thymallus arcticus)*

There are no resident non-native fish within the LSA. Three Pacific salmon species (sockeye [*Oncorhyncus nerka*], chinook [*O. tshawytscha*], and coho [*O. kisutch*]) have been captured and are non-native and occasionally occur in the Mackenzie River system but are considered vagrant in the RSA. Chum salmon [*O. keta*] also occurs within the RSA; however, this species is unlikely to migrate up watercourses into the LSA due to the lack of adequate spawning habitat for this species. Only one spawning population of chum salmon has been reported in the Mackenzie River system, in the Liard River (R.L. & L. Environmental Services Ltd., 1980) a tributary to the Mackenzie River.

The western Arctic population of bull trout (*Salvelinus confluentus*) and Dolly Varden (*Salvelinus malma*) are considered populations of Special Concern under SARA (GOC, 2022a) and COSEWIC (GOC, 2022b). Both species are listed as "sensitive" in the NT by the Species at Risk Committee (GNWT, 2020). Inconnu (*Stenodus leucichthys*) and Arctic cisco (*Coregonus autumnalis*) are also listed as "sensitive" (GNWT, 2016). Species listed as "special concern" or "sensitive" have no additional regulatory requirements associated with them.

There are no fish consumption advisories for watercourses crossed by the project highway alignment identified by the GNWT Department of Health and Social Services (GNWT, 2021) and no baseline contaminant studies have been conducted for those watercourses. No concerns over parasites in fish have been reported.

Table 4.1 Potential Fish Species Within the RSA

Species Information			Legislated Protection	Scientific Review or Recommendation	
Family	**Common Name**	**Scientific Name**	***SARA*[a] (Federal)**	**COSEWIC[a] (Federal)**	**General Status[b] (Northwest Territories)**
Catostomidae	longnose sucker	*Catostomus*	No status	Not assessed	Secure
	white sucker	*Catostomus commersonii*	No status	Not assessed	Secure
Cottidae	slimy sculpin	*Cottus cognatus*	No status	Not assessed	Secure
	spoonhead sculpin	*Cottus ricei*	No status	Not at risk	Secure
Cyprinidae	emerald shiner	*Notropis atherinoides*	No status	Not assessed	Secure
	fathead minnow	*Pimephales promelas*	No status	Not assessed	Undetermined
	finescale dace	*Chrosomus neogaeus*	No status	Not assessed	Secure
	flathead chub	*Platygobio gracilis*	No status	Not assessed	Secure
	lake chub	*Couesius plumbeus*	No status	Not assessed	Secure
	longnose dace	*Rhinichthys cataractae*	No status	Not assessed	Secure
	northern redbelly dace	*Chrosomus eos*	No status	Not assessed	Secure
	pearl dace	*Semotilus margarita*	No status	Not assessed	Secure
	spottail shiner	*Notropis hudsonius*	No status	Not assessed	Secure
Esocidae	northern pike	*Esox lucius*	No status	Not assessed	Secure
Gadidae	burbot	*Lota lota*	No status	Not assessed	Secure
Gasterosteidae	brook stickleback	*Cluea inconstans*	No status	Not assessed	Secure
	ninespine stickleback	*Pungitius pungitius*	No status	Not assessed	Secure
Hiodontidae	goldeye	*Hiodon alosoides*	No status	Not assessed	Secure
Percidae	walleye	*Sander vitreus*	No status	Not assessed	Secure
Percopsidae	trout-perch	*Percopsis omiscomaycus*	No status	Not assessed	Secure
Peteromyzontidae	Arctic lamprey	*Lampetra arcticus*	No status	Not assessed	Undetermined

Species Information			Legislated Protection	Scientific Review or Recommendation	
Family	**Common Name**	**Scientific Name**	***SARA*[a] (Federal)**	**COSEWIC[a] (Federal)**	**General Status[b] (Northwest Territories)**
Salmonidae	Arctic cisco	*Coregonus autumnalis*	No status	Not assessed	Sensitive
	Arctic grayling	*Thymallus arcticus*	No status	Not assessed	Secure
	broad whitefish	*Coregonus nasus*	No status	Not assessed	Secure
	bull trout	*Salvelinus confluentus*	Special Concern	Special Concern	Sensitive
Salmonidae (cont'd)	Dolly Varden	*Salvelinus malma*	Special Concern	Special Concern	Sensitive
	Inconnu	*Stenodus leucichthys*	No status	Not assessed	Sensitive
	lake trout	*Salvelinus namaycush*	No status	Not assessed	Secure
	lake whitefish	*Coregonus clupeaformis*	No status	Not assessed	Secure
	least cisco	*Coregonus sardinella*	No status	Not assessed	Secure
	mountain whitefish	*Prosopium williamsoni*	No status	Not assessed	Secure
	round whitefish	*Prosopium cylindraceum*	No status	Not assessed	Secure
	Chum salmon	*Oncorhynchus keta*	No status	Not assessed	Undetermined

Notes:

[a] *Species at Risk Act* and COSEWIC (GOC, 2022b)

[b] General Status Ranks of Wild Species in the Northwest Territories (GNWT, 2016)

4.2.1 Life History Strategies

4.2.1.1 Lake Whitefish

Lake whitefish or humpback is a common species harvested by communities throughout the Mackenzie River system, including in the RSA. Spawning occurs in the fall in lakes and larger rivers (Scott and Crossman, 1998). There are no records of lake whitefish spawning in smaller streams, but they may utilize these streams to move between lakes and larger river systems for rearing. Lake whitefish are known to spawn in the Mackenzie River (Jessop and Lilly, 1975) and in larger tributaries of the Mackenzie River.

Spawning typically occurs between late September and early October (Reist and Bond, 1988) and eggs hatch in spring. Lake whitefish do not make redds but instead broadcast their eggs over cobble and gravel substrate (Scott and Crossman, 1998). In rivers, larval lake whitefish are swept downstream and move into backwaters of rivers as nursery areas (Sawatzky et al., 2007) and then move into lakes until they reach maturity (Evans et al., 2001). It is unknown if there are lake whitefish that reside in major rivers for their entire life history (Evans et al., 2001).

Adult lake whitefish diet consists mainly of aquatic insect larvae (e.g., chironomids), snails, clams, amphipods, and other bottom organisms (Scott and Crossman, 1998). Lake whitefish have also been known to feed on small fish and fish eggs (Scott and Crossman, 1998).

Lake whitefish would not be expected to occur in watercourses assessed in the LSA due to the lack of suitable habitat.

4.2.1.2 Least Cisco

The majority of information known about least cisco, a member of the whitefish family, in the Western Arctic is from the lower Mackenzie River and delta. Although they are known to occur throughout most of the Mackenzie River, least cisco is not known to occur in Great Slave Lake (Stewart and Low, 2000). Least cisco can be found in both lakes and rivers with some populations being only lake dwelling (Scott and Crossman, 1998).

Spawning occurs in late September to early October with eggs broadcast over sand or gravel. Hatching typically occurs in May (Sawatzky et al., 2007). Least cisco feed on aquatic and terrestrial insects (Scott and Crossman, 1998).

Least cisco would not be expected to occur in the streams assessed during this study due to the lack of suitable habitat.

4.2.1.3 Inconnu

Inconnu or coney is the only truly piscivorous (fish eating) whitefish and the largest member of the whitefish family. They may undertake long migrations; two tagged inconnu migrated almost 1,800 km from the Liard River to the Mackenzie River delta and Tuktoyaktuk (Stephenson et al., 2005). Inconnu have been grouped into three migratory types: fully anadromous, partially anadromous, and freshwater (Howland et al., 2001). All three migratory types may be found in the RSA.

Inconnu spawning occurs in October over coarse cobble substrate and some sand (Alt, 1969) in the Mackenzie River and larger tributary rivers (e.g., Peel River). After spawning, they migrate downstream to overwintering areas. Spawning of mature inconnu is believed to occur only every two to four years (Scott and Crossman, 1998). Inconnu are not known to migrate up streams into the LSA although may be found at the mouths of streams that enter the Mackenzie River.

4.2.1.4 Lake Trout

Lake trout are mainly found in deep, cold-water lakes but may also be found in some shallower lakes and larger rivers in the NT (Scott and Crossman, 1998). They spawn in the fall over cobble substrate along exposed shorelines and shoals of lakes (Callaghan et al., 2015). Lake trout spawning is not expected in the watercourses within the LSA due to the lack of spawning habitat potential in these systems.

Lake trout feed on zooplankton, other fish, and occasionally small mammals (Scott and Crossman, 1998). The presence of lake trout within the LSA is expected to be restricted to larger watercourses and used mainly for movement between lakes.

4.2.1.5 Bull Trout

Two types of bull trout have been identified in the Mackenzie Valley: migratory and non-migratory (Mochnacz et al., 2013). Bull trout have been reported in the Great Bear River (Mochnacz et al., 2013; IORVL, 2004; Reist et al., 2002). However, they are not thought to spawn in the Great Bear River system because they usually spawn in smaller, steeper gradient streams (Mochnacz et al., 2013; IORVL, 2004). It has been suggested bull trout in the eastern tributaries of the Mackenzie River, such as those within the RSA are individuals from tributaries on the west side of the Mackenzie River in search of feeding or overwintering areas (Mochnacz et al., 2013).

Bull trout are fall spawners, making redds in gravel substrate (COSEWIC, 2012). In the NT, bull trout spawn in alternate years (Mochnacz et al., 2013). Incubation can range from 35 days to four months, depending on water temperatures (COSEWIC, 2012). As bull trout age, their diet transitions from aquatic and terrestrial invertebrates to fish (Stewart et al., 2007).

The Western Arctic population of bull trout is considered “of special concern” under SARA (GOC, 2022a) and COSEWIC (GOC, 2022b) and is considered “sensitive” under the General Status Ranks of Wild Species in the NT (GNWT, 2016). The population is widely distributed throughout the Western Arctic drainage; however, populations are not abundant (COSEWIC, 2012). There are no population estimates for the NT, but there is evidence of decline within the Western Arctic Population in some locations

(COSEWIC, 2012). This species is particularly vulnerable to habitat degradation and fragmentation as a result of industrial development (e.g., oil, gas, and mining development, commercial forestry, road and urban development, , displacement and hybridization with introduced species (i.e., brook trout [*Salvelinus fontinalis*]), and overexploitation, which is exacerbated with misidentification (COSEWIC, 2012).

Bull trout are not expected to occur in the watercourses assessed during this study due to the lack of suitable habitat.

4.2.1.6 Dolly Varden

Dolly Varden are unlikely to occur within tributaries of the Mackenzie River in the RSA. This is because the southern range of the northern population of Dolly Varden is the Gayna River, which is downstream of Norman Wells and outside the RSA. Dolly Varden have been reported in previous studies conducted within the RSA; however, these fish were likely misidentified bull trout (Reist et al., 2002).

There are two forms of Dolly Varden: a riverine form and an anadromous form, which migrates to the Beaufort Sea to feed during the open water season (Stewart at al., 2010). Both forms construct redds in clear, groundwater-fed streams that do not freeze to the bottom in winter (Stewart et al., 2010). The age before migrations to the Beaufort Sea can vary depending on the population but typically occurs between two to four years (Stewart et al., 2010).

The Western Arctic population of Dolly Varden is considered “of special concern” under SARA (GOC, 2022a) and COSEWIC (GOC, 2022b) and is considered “sensitive” under the General Status Ranks of Wild Species in the Northwest Territories (GNWT, 2016). The population within the NT is not well understood, and the extent of its decline is not known but serious declines have been observed in some populations (COSEWIC, 2010). The known threats to the species include climate change, habitat loss through freshwater river desiccation, overharvesting, and changes to groundwater recharging at overwintering sites (COSEWIC, 2010). Additional potential threats include offshore infrastructure (which can disrupt anadromous forms), resource extraction that may alter habitat and increasing fishing pressure driven by development of transportation corridors (COSEWIC, 2010).

Dolly Varden are not expected to occur in the watercourses assessed in the LSA due to the lack of suitable habitat.

4.2.1.7 Arctic Grayling

Arctic grayling is found in clear, cold streams, rivers, and lakes (Scott and Crossman, 1998; Ford et al., 1995) and are present in numerous streams along the project highway corridor. Male Arctic grayling reach maturity at three to four years of age; females mature later at four to five years (Low and Read, 1987).

Arctic grayling spawn in the spring as ice-cover begins to break-up over gravel or cobble bottoms (Scott and Crossman, 1998). No redd is built; instead, eggs are broadcast over the substrates. Young-of-the-year remain in their natal streams for up to 15 months (Ford et al., 1995). Adults may move into larger

systems to overwinter (Scott and Crossman, 1998). Juveniles feed mainly on zooplankton and gradually shift to larger aquatic and terrestrial invertebrates as they mature (Scott and Crossman, 1998).

Arctic grayling have the potential to occur in the larger watercourses assessed in the LSA.

4.2.1.8 Northern Pike

Northern pike occur in rivers, streams, and lakes throughout the Mackenzie River Valley (Scott and Crossman, 1998). Spawning occurs just after ice-out in weedy areas on flooded terrestrial vegetation with eggs hatching 12 to 14 days later (Scott and Crossman, 1998). Spawning adults may remain in the stream or lake where they spawned or move downstream to associated systems (Evans et al., 2002). Pike fry move into slower waters in tributaries or into the mainstem Mackenzie River in late July (Jessop and Lilly, 1975).

Adult northern pike prefer shallow portions of rivers, with no velocity or slow water and areas with aquatic vegetation (Casselman and Lewis, 1996; Ford et al., 1995; Jessop and Lilly, 1975). In mid-August and September, pike will move from shallower areas to deeper overwintering areas before freeze-up (Jessop and Lilly, 1975).

Northern pike have the potential to occur in most watercourses along the project highway alignment.

4.2.1.9 Burbot

Burbot or loche is a freshwater cod and is the only freshwater fish that spawns in the winter in the Northwest Territories. Burbot spawn in lakes over sand, gravel, or cobble substrate. In rivers and streams, burbot typically spawn in low-velocity areas within main channels or in side-channels behind depositional bars over fine gravel, sand, or fine silt substrate (McPhail and Paragamian, 2000). It is expected that suitable spawning habitat for burbot does not exist in most watercourses in the LSA highway corridor due to their shallow water depth and high likelihood of being frozen to or near the bottom.

Juvenile burbot may use smaller streams during the open water season. Young burbot feed on mainly aquatic invertebrates moving to a diet of fish as they become adults (McPhail and Paragamian, 2000; Scott and Crossman, 1998).

Burbot have the potential to occur in larger watercourses in the LSA along the project highway alignment.

4.2.1.10 Forage Fish

A variety of forage fish are found in watercourses in the LSA with Slimy sculpin, ninespine stickleback and brook stickleback being three of the more common and abundant forage species captured during fisheries surveys conducted for the Mackenzie Gas Project (IORVL, 2004). Forage fish species found in watercourses in the LSA are identified in Table 4.2 and Table 4.3, spawn in late spring or summer in flowing or stagnant water over a wide range of substrate types depending on species preferences.

4.3 Watercourse Crossing Assessments

A summary of watercourse crossings in the Sahtu Region are provided in Table 4.2 and Figure A.1 to Figure A.4 in Appendix A. Based on the desktop assessment and literature review (i.e., IORVL, 2004; 5658 NWT Ltd. and GNWT, 2011), 27 watercourses are crossed by the Project. In addition, four drainages are crossed by the project highway corridor. Table 4.2 indicates where the MGP route and the project highway alignment cross the same watercourses and drainages.

A summary of watercourse crossings in the Dehcho Region are provided in Table 4.3 and Figure A.4 to Figure A.6 in Appendix A. Table 4.3 indicates where the MGP route crosses the same watercourses and drainages as the project highway alignment. K'alo-Stantec's field assessment data is included in Table 4.3. The determination of the type of water feature crossed by the project highway corridor (i.e., watercourse, drainage, wetland) shown in Table 4.3 is based on K'alo-Stantec's field assessments because they were completed most recently compared to 5658 NWT Ltd. and GNWT (2011) and IORVL (2004). K'alo-Stantec was not able to assess all the crossings due to weather and access conditions at the time of the survey.

Existing data is summarized for each crossing in the Sahtu Region and Dehcho Region in Sections 4..1 and 4.3.2, respectively. Station summary data sheets from the field assessments in the Dehcho Region are located provided in Appendix C.

Restricted Activity Timing Windows have been developed by DFO for periods when instream works are to be avoided in order to protect sensitive life stages of fish species. Because species presence is not known at all crossing locations, the restricted activity timing windows for Zone 2 recommended by DFO (2013) within the LSA permit instream work between July 15 and August 15. This was not refined further as comprehensive fish inventories were not completed at each watercourse in the LSA and so a conservative approach was adopted. Works in or near water which cannot avoid the Restricted Activity Timing Windows require a Request for Review to be submitted to DFO for those works.

Table 4.2 Watercourses Crossed by the Mackenzie Valley Highway Project Corridor and the MGP Route—in the Sahtu Region

Watercourses	Mackenzie Valley Highway Project Corridor				MGP Route				Known and Potential Fish Presence[a]
	KM Reference	Centreline UTM			MGP Crossing ID	UTM			
		Zone (W)	Easting	Northing		Zone (W)	Easting	Northing	
Unnamed watercourse	797.9	10	437740	7101829	RPR-375	10	437768	7101905	Brook stickleback, Finescale dace, Pearl dace, unidentified cyprinid[b]
Unnamed watercourse	805.5	10	435589	7108255	RPR-374	10	435644	7108244	Brook stickleback. Pearl dace[b]
Unnamed watercourse	812.7	10	434329	7115337	RPR-372	10	434385	7115279	Potential
Unnamed watercourse	815	10	432721	7117031	-	-	-	-	Unlikely
Unnamed watercourse	820.7	10	433131	7121799	RPR-370	10	433494	7121478	Potential
Unnamed watercourse	821.9	10	432580	7123103	-	-	-	-	Potential
Unnamed watercourse	823	10	431979	7123968	-	-	-	-	Potential
Unnamed watercourse	824.5	10	431072	7126467	-	-	-	-	Potential
Unnamed watercourse	826	10	431007	7126834	-	-	-	-	Potential
Unnamed watercourse	826.3	10	430947	7126834	-	-	-	-	Potential
Unnamed watercourse	828.6	10	429991	7129070	-	-	-	-	Potential
Unnamed watercourse	834.1	10	425724	7132189	-	-	-	-	Potential
Unnamed watercourse	835	10	425405	7132988	-	-	-	-	Potential
Unnamed watercourse	837.1	10	424624	7135022	RPR-355	10	424006	7133065	Potential
Unnamed watercourse	843.3	10	422310	7140408	-	-	-	-	Unlikely
Unnamed watercourse	846.4	10	419947	7142715	-	-	-	-	Potential
Unnamed watercourse	857.4	10	415860	7151196	RPR-350	10	415585	7151326	Potential
Unnamed watercourse	872.9	10	412679	7164554	-	-	-	-	Unlikely
Drainage	874	10	410998	7166150	-	-	-	-	Potential

Watercourses	Mackenzie Valley Highway Project Corridor				MGP Route				Known and Potential Fish Presence[a]
	KM Reference	Centreline UTM			MGP Crossing ID	UTM			
		Zone (W)	Easting	Northing		Zone (W)	Easting	Northing	
Drainage	875.5	10	410938	7167644	RPR-347	10	413223	7168155	Potential
Unnamed watercourse	876.6	10	410947	7168766	-	-	-	-	Potential
Unnamed watercourse	877.8	10	411245	7169818	-	-	-	-	Potential
Unnamed watercourse	879.1	10	411064	7169505	-	-	-	-	Potential
Unnamed watercourse	878.8	10	411627	7170638					Potential
Unnamed watercourse	879.4	10	411209	7168580	-	-	-	-	Potential
Unnamed watercourse	880.2	10	411595	7170626	RPR-346	10	412160	7171394	Potential
Unnamed watercourse	880.6	10	411800	7171054	-	-	-	-	Brook stickleback, Finescale dace, Pearl dace[b]
Unnamed watercourse	881	10	411798	7171042	RPR-346	10	412160	7171394	Potential
Unnamed watercourse	883.6	10	411615	7173282	-	-	-	-	Unlikely
Unnamed watercourse	884.3	10	411435	7174830					Potential
Unnamed watercourse	884.8	10	411300	7174635	RPR-344	10	411510	7174746	Potential
Unnamed watercourse	889	10	408491	7178378					Potential
Unnamed watercourse	891.4	10	406839	7178354	-	-	-	-	Potential
Unnamed watercourse	891.7	10	406854	7178332	-	-	-	-	Potential
Unnamed watercourse	892	10	407102	7180445	-	-	-	-	Potential
Unnamed watercourse	915.6	10	397368	7198303	-	-	-	-	Potential
Unnamed watercourse	918	10	394969	7198798					Potential
Unnamed watercourse	919.9	10	394956	7198775	RPR-333	10	394959	7198712	Potential
Twelve Mile Creek	922	10	392020	7198797	RPR-332	10	393165	7200177	Arctic grayling, burbot, northern pike, emerald shiner, spottail shiner, lake chub[c]

Watercourses	Mackenzie Valley Highway Project Corridor				MGP Route				Known and Potential Fish Presence[a]
	KM Reference	Centreline UTM			MGP Crossing ID	UTM			
		Zone (W)	Easting	Northing		Zone (W)	Easting	Northing	
Four Mile Creek	931	10	382776	7200651	-	-	-	-	Arctic grayling, burbot, northern pike, emerald shiner, lake chub[d]
Unnamed watercourse	940.1	10	375325	7203625	-	-	-	-	Potential
Unnamed watercourse	980.3	9	629551	7227955	RPR-314	9	627399	7227382	Potential
Unnamed watercourse	981.2	10	629352	7227768	-	-	-	-	Potential
Prohibition Creek	983	9	626464	7228215	RPR-313	9	626292	7227921	Arctic grayling, broad whitefish, cisco, longnose sucker, mountain whitefish, northern pike, round whitefish, trout-perch, lake chub, emerald shiner, spottail shiner, spoonhead sculpin, slimy sculpin[c]
Unnamed watercourse	987.2	9	623577	7230276	RPR-312	9	623642	7230364	Potential

Notes:

- Watercourse/waterbody was not crossed or assessed by IORVL (2004)

[a] Where fish presence was recorded, the species are listed. Description of fish habitat potential are provided in Section 3.2.2. No recorded fish presence does not necessarily indicate the absence of fish or that the area does not afford fish habitat. Unlikely is related to lack of connectivity or no defined channel.

[b] This report

[c] IORVL, 2004

[d] 5658 NWT Ltd. and GNWT, 2011

KM = kilometre marker

Table 4.3 Waterbodies Crossed by the Mackenzie Valley Highway Project Corridor and the MGP Route—in the Dehcho Region

Watercourses	Mackenzie Valley Highway Project Corridor				MGP Route				Known and Potential Fish Presence[a]
	KM Reference	Centerline UTM			MGP Crossing ID	UTM			
		Zone (W)	Easting	Northing		Zone (W)	Easting	Northing	
Unnamed Watercourse	696.8	10	473317	7015384	-	-	-	-	Unknown
Drainage	699.1	10	473070	7015812	-	-	-	-	Unlikely
Wetland Area	699.3	10	472880	7015938	-	-	-	-	Unlikely
Wetland Area	700.3	10	472322	7016741	-	-	-	-	Potential
Wetland Area	701.7	10	471421	7017918	-	-	-	-	Potential
Wetland Area	702.2	10	471183	7018318	-	-	-	-	Potential
Wetland Area	702.9	10	470932	7019008	-	-	-	-	Potential
Wetland Area	704.7	10	470653	7020732	-	-	-	-	Potential
Unnamed Watercourse	705.4	10	470824	7023125	-	-	-	-	Unknown
Wetland Area	710.4	10	471528	7027742	-	-	-	-	Unlikely
Wetland Area	715.6	10	469827	7031105	-	-	-	-	Unlikely
Drainage	718.8	10	467959	7035544	-	-	-	-	Unlikely
Wetland Area	719.9	10	468244	7035072	-	-	-	-	Potential
Unnamed watercourse	721.6	10	465977	7037399	-	-	-	-	Potential
Unnamed Watercourse	724.5	10	465535	7039921	-	-	-	-	Unknown
Unnamed Watercourse	727.4	10	465248	7042571	-	-	-	-	Potential
Unnamed Watercourse	732.7	10	463008	7047414	-	-	-	-	Potential
Bonnie Creek	733.7	10	462586	7048307	-	-	-	-	Potential
Unnamed Watercourse	736.5	10	462082	7050913	-	-	-	-	Potential
Unnamed Watercourse	738.7	10	462013	7051561	-	-	-	-	Potential
Unnamed Watercourse	737.4	10	461944	7051827	-	-	-	-	Unknown
Unnamed Watercourse	739.6	10	461404	7053882	-	-	-	-	Potential

Watercourses	Mackenzie Valley Highway Project Corridor				MGP Route				Known and Potential Fish Presence[a]
	KM Reference	Centerline UTM			MGP Crossing ID	UTM			
		Zone (W)	Easting	Northing		Zone (W)	Easting	Northing	
Unnamed Watercourse	740.8	10	461135	7055011	-	-	-	-	Potential
Unnamed Watercourse	741.7	10	460915	7055927	-	-	-	-	Potential
Unnamed Watercourse	742.7	10	460641	7057047	-	-	-	-	Potential
Strawberry Creek	745.7	10	459359	7059422	RPR-385	10	465200	7060223	Potential
Unnamed Watercourse	747.6	10	458952	7061042	-	-	-	-	Potential
Unnamed Watercourse	748.0	10	458839	7061453	-	-	-	-	Potential
Bobs Canyon Creek	752.6	10	456554	7065466	-	-	-	-	Potential
Drainage	752.8	10	456629	7065715	-	-	-	-	Unlikely
Unnamed Watercourse	765.5	10	451513	7076541	-	-	-	-	Potential
Unnamed Watercourse	767.2	10	451279	7078183	-	-	-	-	Unknown
Unnamed Watercourse	767.8	10	451423	7076769	-	-	-	-	Potential
Wetland Area	768.2	10	451373	7077141	-	-	-	-	Potential
Drainage	768.9	10	451297	7077881	-	-	-	-	Unlikely
Drainage	769.7	10	450566	7080565	-	-	-	-	Unlikely
Wetland Area	769.7	10	451333	7078638	-	-	-	-	Unlikely
Wetland Area	770.0	10	451254	7079001	-	-	-	-	Unlikely
Wetland Area	770.6	10	451104	7079480	-	-	-	-	Potential
Drainage	772.8	10	449199	7083419	RPR-380	10	450932	7083773	Unlikely
Unnamed Watercourse	774.1	10	448523	7084338	RPR-379	10	448927	7086017	Arctic grayling, longnose sucker[c]
Drainage	780.9	10	444236	7089533	REV3-AK	10	444426	7089450	Unlikely
Drainage	785.3	10	-	-	-	-	-	-	Unlikely
Drainage	787.3	10	-	-	-	-	-	-	Unlikely

Watercourses	Mackenzie Valley Highway Project Corridor				MGP Route				Known and Potential Fish Presence[a]
	KM Reference	Centerline UTM			MGP Crossing ID	UTM			
		Zone (W)	Easting	Northing		Zone (W)	Easting	Northing	
Wetland Area	789.0	10	441775	7094706	-	-	-	-	Unlikely
Wetland Area	789.4	10	441568	7095152	-	-	-	-	Unlikely
Wetland Area	791.2	10	440409	7096395	-	-	-	-	Unlikely
Wetland Area	791.8	10	439719	7096318	-	-	-	-	Unlikely
Wetland Area	793.1	10	438820	7097394	RPR-376	10	440272	7097726	Brook stickleback, fathead minnow[b]

Notes:

- Watercourse/waterbody was not crossed or assessed by the MGP project

[a] Where fish presence was recorded, the species are listed. Description of fish habitat potential are provided in Section 3.2.2. No recorded fish presence does not necessarily indicate the absence of fish or that the area does not afford fish habitat. Unlikely is related to lack of connectivity or no defined channel.

[b] This report

[c] IORVL 200

4.3.1 Sahtu Settlement Area

Station location maps and summary sheets for the 2021 field assessment are provided in Appendix B.

4.3.1.1 Crossing KM 797.9 – Unnamed Watercourse

Changes to the project highway alignment in 2021 moved the kilometre posting from kilometre marker (KM) 796.4 to KM 797.9 for this watercourse. At KM 796.4 site, which was assessed from the air (5658 NWT Ltd. and GNWT, 2011), the channel was approximately 15 m wide at high flow conditions. Habitat was run and pool habitat and a deep pool was observed near the existing winter road crossing. Substrate was comprised entirely of sand. There was small woody debris observed (15% cover) and beaver activity was noted in the upstream reaches of the watercourse. Riparian vegetation was deciduous trees (45%), coniferous trees (40%), grasses (10%) and forbs (5%). Live trees were observed growing within the active channel (5658 NWT Ltd. and GNWT, 2011).

The watercourse is crossed by the MGP route (RPR-375 [IORVL, 2004]). A previous assessment (5658 NWT Ltd. and GNWT, 2011) reported that it may provide rearing and migration habitat for forage fish as well as potential migration habitat for sportfish.

At the centreline of the KM 797.9 crossing site, the channel width and depth were 4.3 m and 0.9 m, respectively, and the banks stable . In the assessed area, the maximum channel width was 16.8 m with a maximum water depth of 1.2 m. Substrate was a mixture of organics and fines. Grasses were observed in the stream bed, and logjams were present upstream and downstream of the proposed crossing site. An old beaver dam was present 300 m downstream of the proposed crossing site before a downstream wetland area. Overhead cover was estimated at 10% consisting mostly of grasses. Instream cover was mostly comprised of woody debris and afforded 30% coverage within the area.

Fishing was conducted using minnow traps. Four species were captured: brook stickleback, finescale dace, pearl dace and one unidentified Cyprinid (minnow). Spawning is rated as moderate for forage fish, and none to poor for coarse and sportfish. Overwintering is rated as poor to moderate for all three fish categories. Rearing is rated as good for forage and coarse fish species and moderate for sportfish. Fish passage is rated as good to moderate for all three categories of fish.

4.3.1.2 Crossing KM 805.5 – Unnamed Watercourse

Changes to the project highway alignment in 2021 moved the kilometre posting from KM 803.4 to KM 805.5 for this watercourse. The proposed crossing location at KM 805.5 was assessed in the field in 2021. The location was a wetland with no defined channel with the exception of the centreline. The channel width at the centreline at KM 805.5 is 0.3 m. Average depth at the centreline was 0.45 m (0.36 m to 0.62 m) at the time of the assessment. Substrate composition was estimated at 20% organics and 80% fines. Dominant riparian vegetation is grasses and shrubs. The watercourse is connected to a lake upstream (5658 NWT Ltd. and GNWT, 2011).

Fishing was conducted using minnow traps. Two fish species were captured: brook stickleback and pearl dace. Spawning habitat is rated as good for forage fish and none for coarse and sport fish. Overwintering potential is rated as poor to moderate for forage fish and poor for coarse and sportfish. Rearing habitat is rated as good for forage fish and poor to moderate for coarse and sportfish. Fish passage is rated as moderate for forage fish and poor to moderate for coarse and sportfish.

4.3.1.3 Crossing KM 812.7 – Unnamed Watercourse

Changes to the project highway alignment in 2021 moved the kilometre posting from KM 811 to KM 812.7 for this watercourse. At the former KM 811 site, the channel was between 8 m and 15 m wide. Habitat was runs and pools. Substrate was entirely of sand. Some small woody debris and a beaver dam were observed on the west side of the winter road crossing. This debris was disrupting flow at the time of assessment, resulting in pooling. Log jams and sediment wedges were also observed. Riparian vegetation was primarily grass (40%) with shrubs (25%), deciduous trees (25%), and coniferous trees (10%) (5658 NWT Ltd. and GNWT, 2011). The watercourse has potential rearing habitat for forage fish and migration potential for all three categories of fish (5658 NWT Ltd. and GNWT, 2011).

At the proposed KM 812.7 crossing site, the channel width at the centreline was 1.37 m with an average depth of 0.14 m during the time of assessment. The maximum channel width in the assessed area was 1.8 m and a maximum depth was 0.57 m. There was woody debris throughout the assessed area and some minor logjams, which may result in partial barriers to fish passage. Centreline substrate composition was estimated to be 50% organics and 50% fines. Downstream substrate composition was more diverse with fines, small gravel, larger gravel, and cobble. There was some minor undercutting of the banks upstream of the centreline, with the channel becoming poorly defined and with low-water depths. The banks were stable at the centreline. Three beaver dams were present in the area: one at the downstream side of the centerline, one at a tributary to the watercourse 50 m upstream and one abandoned farther up the tributary where the channel is dry. The tributary flows parallel to the winter road and goes subsurface near the abandoned beaver dam.

Fishing was conducted using a backpack electrofisher but no fish were captured. Spawning habitat was rated as good for forage fish but poor for coarse and sportfish. Overwintering was rated as none to poor for all three categories of fish. Rearing was rated as good for forage and coarse fish and moderate for sport fish. Fish passage was rated as moderate to good for forage fish and moderate for coarse and sportfish.

4.3.1.4 Crossing KM 815 – Unnamed Watercourse

At the time of the assessment in 2021, the channel width at the centreline was 1.9 m with a water depth of 0.1 m at the time of the assessment. The maximum channel width was 2.5 m and maximum depth was 0.1 m in the assessed area. The watercourse drains into a wetland. Logjams were present upstream. At the centreline, the substrate was mainly fines (60%) with small gravel (20%) cobble (10%) and organic matter (10%). Overhead cover was 80%, mostly from deciduous trees. Instream cover was 30% consisting of woody debris. Banks were moderately stable consisting of organic material at the centreline.

Due to the shallow water depths, no fishing was conducted. Overall fish habitat is rated as poor.

4.3.1.5 Crossing KM 820.7 – Unnamed Watercourse

Changes to the project highway alignment moved the kilometre posting from KM 819.2 to KM 820.7 for this watercourse. At the former KM 819.2 crossing site, the channel was approximately 100 m wide. At the time of the assessment, the crossing was flooded. Substrate was entirely sand. Riparian vegetation was dominated by coniferous trees (90%) with grass (10%) and shrubs (10%). There appeared to be flooded riparian vegetation within the channel comprised of grass (5658 NWT Ltd. and GNWT, 2011). The watercourse is crossed by the MGP route (RPR-370 [IORVL, 2004]) approximately 600 m upstream of the alignment crossing. A previous assessment (5658 NWT Ltd. and GNWT, 2011) reported that the watercourse may provide seasonal rearing habitat for forage fish. No barriers to fish migration were observed (5658 NWT Ltd. and GNWT, 2011).

At KM 820.7, the channel was poorly defined within a floodplain. At the centreline, the channel width was 15.5 m and the water depth was 0.2 m. The maximum channel width was 95 m within a flooded area 100 m upstream from the centreline. The maximum depth in the assessed area was 0.5 m during the time of the assessment. The substrate at the centreline was 100% organics. The banks were moderately stable on the left bank and stable on the right bank. Overhead cover was 5% with instream cover estimated at 10%, which was contributed from grasses growing in the streambed. A beaver dam was present 300 m downstream of the centreline. An exposed culvert was present that had been installed at the winter road crossing.

Fishing was conducted using minnow traps and no fish were captured. Spawning is rated as poor to moderate for forage fish and none for coarse and sportfish. Overwintering potential is rated as poor for forage and coarse fish and none to poor for sportfish. Rearing is rated as moderate for forage fish, poor for coarse fish and none to poor for sport fish. Fish passage is rated as moderate for forage fish and poor to moderate for coarse and sportfish.

4.3.1.6 Crossing KM 821.9 – Unnamed Watercourse

The proposed crossing location was assessed from the air in 2010 (5658 NWT Ltd. and GNWT, 2011). It was observed that the channel was confined with cobble substrate and shallow flow. Fish habitat was run with some step pool. The channel width was approximately 2 m (5658 NWT Ltd. and GNWT, 2011). Riparian habitat consisted mostly of conifers with some deciduous trees, shrubs, and grasses. The watercourse is crossed by the MGP route (RPR-370 [IORVL, 2004]), approximately 1.2 km upstream of the project highway alignment crossing.

The proposed crossing location was assessed in the field in 2021. The channel width at the centreline was 1.3 m and the water depth at the time of assessment was 0.4 m. The maximum channel width in the assessed area was 2.4 m and maximum water depth at the time of assessment was 0.4 m. The channel was frozen to the stream bed between 100 m and 200 m downstream. At the centreline, the substrate was 50% fines, 30% small gravel and 20% large gravel. At the time of the assessment, the substrate was covered in leaves and woody debris. Both banks at the centreline were moderately stable.

Overhead cover was estimated at 30% consisting mainly of deciduous trees with conifers farther back. Instream cover consisted mainly of woody debris.

No fishing was conducted due to freezing conditions. Potential spawning habitat was rated as moderate and overwintering potential as poor for all three fish categories. Rearing habitat was rated as good for forage and coarse fish and moderate for sportfish. Fish passage was rated as moderate to good for all three fish categories.

4.3.1.7 Crossing KM 823 – Unnamed Watercourse

At the time of the assessment in October 2021, the watercourse was mostly frozen. Channel width at the centreline was 0.2 m with an average depth of approximately 0.2 m. Maximum channel width was 1.9 m, which was 100 m upstream of the centreline. Maximum water depth at the time of the assessment was 3.0 m. The substrate at the centreline and through most of the assessed portion of the watercourse was a mixture of large gravel, cobble and boulders. Overhead cover was estimated at 60%, consisting mainly of shrubs and deciduous trees. Instream cover was estimated at 40%, which consisted of woody debris and boulders. Woody debris and logjams were observed throughout the assessed reach. The banks at the centreline were moderately stable.

No fishing was conducted because the watercourse was mostly frozen. Fish habitat for rearing is rated at moderate to good for forage fish, moderate for coarse fish, and poor for sport fish. Overwintering potential is rated as none to poor for all three categories of fish. Rearing habitat is rated as good for forage and coarse fish species and rated moderate for sportfish. Fish passage is rated as moderate to good for all three categories of fish.

4.3.1.8 Crossing KM 824.5 – Unnamed Watercourse

At the proposed crossing location, the channel was approximately 10 m wide and the water depth was 0.1 m at the time of assessment. The watercourse is an outflow from a small lake with water flowing through a wetland area. There was no flow at the time of assessment and water appeared to be an impounded area (5658 NWT Ltd. and GNWT, 2011). A beaver lodge was noted on the lake upstream of the crossing location. The substrate was entirely sand. Riparian vegetation was shrubs (40%), grass (40%), deciduous trees (15%), and coniferous trees (5%). Grasses and flooded trees were observed within the partially confined channel (5658 NWT Ltd. and GNWT, 2011).

Habitat conditions suggests there is rearing potential for forage fish and spawning potential for northern pike (5658 NWT Ltd. and GNWT, 2011). Barriers to migration were not observed; however, migration is likely limited to small-bodied forage fish (5658 NWT Ltd. and GNWT, 2011).

A field assessment was not conducted at this crossing site in 2021.

4.3.1.9 Crossing KM 826 – Unnamed Watercourse

The channel was irregular with poor connectivity upstream of the centreline. Channel width at the centreline was1.8 m and the water depth was approximately 0.3 m at the time of the assessment. The maximum channel width was 3.0 m at 100 m upstream of the centreline. The maximum water depth was 0.3 m. Substrate at the centreline was estimated at 60% organics and 40% fines. Upstream of the centreline, the substrate was 100% fines, and downstream of the centreline, the substrate was 100%

organics. Overhead cover was estimated at 80%, consisting mainly of trees and shrubs. Instream cover was estimated at 80%, consisting mainly of woody debris. The banks at the centreline were moderately stable; however, 100 m downstream, the banks become unstable with signs of erosion. Evidence of a previous fire was observed in the assessed area.

Fishing was conducted using minnow traps, but no fish were captured. Spawning habitat is rated as moderate to good for forage fish and none for coarse and sportfish. Overwintering potential is rated as moderate to good for forage fish, moderate for coarse fish, and poor to moderate for sportfish. A ponded area upstream of the centreline may provide overwintering habitat. Rearing habitat is rated as moderate to good for all three categories of fish. Fish passage is rated as moderate for all three categories of fish.

4.3.1.10 Crossing KM 826.3 – Unnamed Watercourse

The watercourse was braided with debris jams and shrub islands. Channel width at the centreline was 1.1 m with an average depth of 0.1 m. The maximum channel width was 4.0 m upstream of the centreline. The maximum water depth was 0.3 m at the time of the assessment. The substrate consisted of 100% organics throughout the assessed reach. Overhead cover was estimated at 50% from shrubs and trees. Instream cover was estimated to be 40% provided by woody debris in the watercourse. The banks at the centreline were unstable. There was evidence of bank erosion on the left bank, 100 m downstream of the centreline. Signs of a previous fire in the upland area was observed.

Fishing was conducted using a backpack electrofisher but no fish were captured. Potential spawning habitat is rated as poor to moderate for forage fish and none for coarse or sportfish. Overwintering potential is rated as poor for forage fish and none for coarse and sportfish. Rearing habitat is rated as moderate for forage and coarse fish and poor to moderate for sportfish. Fish passage is rated as moderate for forage fish and poor for coarse and sportfish.

4.3.1.11 Crossing KM 828.6 – Unnamed Watercourse

The channel width at the centreline was 0.8 m and the water depth averaged 0.4 m at the time of the assessment. The maximum channel width in the assessed area was 1.9 m, with a maximum depth of 0.5 m at the time of the assessment. The substrate at the centreline was 60% fines, 30% small gravel and 10% large gravel. Fines and small gavel were the dominant substrate types in the assessed area. Overhead cover was estimated at 70%, dominated by overhanging trees. Instream cover was estimated at 40%, mainly contributed by woody debris. The banks were stable at the centreline. New plant growth resulting from a previous fire was observed in the upland area of the LSA.

No fishing was conducted due to freezing conditions. Spawning habitat is rated as moderate for forage fish and poor for coarse and sportfish. Overwintering potential is rated as poor for forage fish and none for coarse and sportfish. Rearing habitat is rated as poor to moderate for all three categories of fish. Fish passage is rated as moderate for forage fish and poor to moderate for coarse and sportfish.

4.3.1.12 Crossing KM 834.1 – Unnamed Watercourse

The channel width at the centreline was 1.1 m and the water depth was 0.1 m at the time of the assessment. The maximum channel width was 1.3 m and the maximum water depth was 0.6 m at the time of the assessment. Upstream of the centreline, there was low flow with some pooling. The substrate at the centreline was 100% fines. Downstream of the centreline, small and large gravel was present in addition to fines. Overhead cover was estimated at 70%, composed mainly of shrubs and deciduous trees. Instream cover was estimated at 40%, with undercut banks and woody debris. Logjams were present throughout the assessed reach. Unstable banks were present throughout the assessment area.

No fishing was conducted due to freezing conditions. Spawning habitat is rated as moderate for forage fish and poor for coarse and sportfish. Overwintering potential is rated as none to poor for all three categories of fish. Rearing habitat is rated as moderate for forage and coarse fish and poor to moderate for sportfish. Fish passage is rated as poor to moderate for all three categories of fish.

4.3.1.13 Crossing KM 835 – Unnamed Watercourse

At the time of the assessment, the area was covered in snow and the watercourse was mostly frozen over. Channel width at the centreline was 1.9 m and it was the maximum channel width of the assessed reach. The average water depth at the centreline was approximately 0.1 m. The maximum water depth of the assessed reach at the time of the assessment was 0.8 m. Substrate composition at the centreline and upstream was estimated to be 10% fines, 40% small gravel, 40% large gravel and 10 % cobble. Downstream, 200 m and 300 m from the centreline, the substrate was primarily organics. Overhead cover was estimated to be 70%, consisting of shrubs and deciduous trees. Instream cover was estimated to be 50%, consisting mainly of woody debris and undercut banks. At the centreline, the banks were unstable but most of the assessed reach had moderately stable banks.

No fishing was conducted due to freezing conditions. Spawning habitat is rated as moderate for forage fish and poor for coarse and sportfish. Overwintering potential is rated as none to poor for all three categories of fish. Rearing habitat is rated as moderate for forage fish and poor to moderate for coarse and sportfish. Fish passage is rated as poor to moderate for all three categories of fish.

4.3.1.14 Crossing KM 837.1 – Unnamed Watercourse

Changes to the project highway alignment moved the kilometre posting from KM 836.2 to KM 837.1. The watercourse was assessed from the air in 2010 and, at that time, the channel was dry. The channel width was estimated to be less than 2 m (5658 NWT Ltd. and GNWT, 2011). The watercourse is crossed by the MGP route (RPR-355 [IORVL, 2004]) downstream of the Project crossing. At the MGP route crossing location, instream habitat consisted of shallow run and riffle with coarse substrate (boulder, cobble and gravel) with few fines. Instream cover was provided by overhanging vegetation and woody debris. Riparian habitat was mainly shrubs, grasses, and forbes with some deciduous frees. There was evidence of a past fire (IORVL, 2004).

The new proposed crossing location was assessed in the field in 2021. The channel width at the centreline was 1.2 m and the average water depth was 0.1 m at the time of the assessment. The maximum channel width was 2.7 m and the maximum water depth in the assessed reach was 0.2 m at the time of the assessment. Step pools were created by downed woody debris in the upstream reach of the assessed area. Substrate composition at the centreline was a mixture of small gravel (20%), large gravel (35%), cobble (10%), and boulders (25%). The substrate composition was similar throughout the assessed reach. Overhead cover was estimated at 10%, dominated by shrubs. Instream cover was estimated at 30%, provided by cobble. The banks at the centreline were unstable but becoming moderately stable downstream of the centreline, although some undercutting of the banks was observed. Evidence of previous fire history was observed.

No fishing was conducted due to freezing conditions. Fishing conducted in 2002 for the MGP Project using a backpack electrofisher captured no fish (IORVL, 2004). Spawning habitat is rated as moderate to good for forage fish and moderate for coarse and sport fish. Overwintering potential is rated as none to poor for all three fish categories. Rearing habitat is rated as moderate for all three categories of fish. Fish passage is rated as moderate for forage fish and poor to moderate for coarse and sportfish.

4.3.1.15 Crossing KM 843.3 – Unnamed Watercourse

The site was snow covered at the time of the assessment in the fall of 2021. Most of the downstream assessed reach was a flooded area within the trees with no defined channel. Maximum depth was 0.39 m. Substrate was 30% fines, 30% small gravel, 30% large gravel and 10% cobble. Overhead cover was estimated at 60% created by deciduous trees. Instream cover was estimated at 80% provided by grasses and woody debris. The watercourse is not considered fish habitat and no fishing was conducted.

4.3.1.16 Crossing KM 846.4 – Unnamed Watercourse

The upstream section and centreline of the assessed reach was flooded with no defined channel, water was frozen and snow covered at the time of the assessment in the fall of 2021 and, therefore, no data could be collected for the centerline and upstream reach. From the centreline to 100 m downstream, the watercourse was also flooded with the channel banks becoming defined. Sinuous meanders develop downstream but could not be accessed for additional data collection because flooded portions upstream preventing downstream access to the downstream reach. At 100 m downstream, the channel width 1 was 2.5 m with an average depth of 0.7 m. The maximum water depth was 0.8 m at the time of the assessment. The substrate consisted of 40% organics and 60% fines. Overhead cover was estimated as 30%, consisting mostly of leaning branches from trees. Instream cover was estimated at 30%, provided by woody debris. Banks downstream were moderately stable.

No fishing was conducted due to freezing conditions. Spawning habitat for all three categories of fish is rated as poor as well as the potential for overwintering and fish passage. Rearing habitat is rated as moderate to good for forage fish, poor to moderate for coarse fish and poor for sportfish. The proposed crossing location is unlikely to allow fish passage.

4.3.1.17 Crossing KM 857.4 – Unnamed Watercourse

Changes to the project highway alignment in 2021 moved the kilometre posting from KM 855.9 to KM 857.4. The watercourse at KM 855.9 was assessed from the air in 2010. The area is an unconfined drainage/wetland approximately 100 m wide with no defined bed or banks. At the time of the assessment, water at the crossing location was impounded. The drainage is connected to a large lake to the northeast. Substrate was comprised of entirely of sand. Riparian vegetation was comprised of grass (50%), shrubs (30%), forbs (10%), and coniferous trees (10%). The drainage may provide spawning habitat for forage fish (5658 NWT Ltd. and GNWT, 2011). The watercourse is crossed by the MGP route (RPR-350 [IORVL, 2004]).

The upstream section of the assessed reach was flooded through low shrubs and grasses when assessed in October 2021. Flooding is likely related to beaver dams impounding water. Beaver dams were present upstream and downstream as well as one dam at the centreline. Approximately 130 m downstream, the channel converged with a larger channel. This second channel was flooded and meandered around debris dams. The channel width at the centreline was 2.3 m with an average depth of approximately 0.3 m. The maximum water depth was 0.6 m at the time of the assessment. Overhead cover was estimated at 10% with some small shrubs. Instream cover was estimated at 40% consisting mostly of woody debris and some grasses in the channel. The substrate at the centreline was approximately 60% organics and 40% fines. The substrate throughout the assessed reach was either organics or fines or a mixture of both.

No fishing was conducted due to freezing conditions. Spawning habitat is rated as moderate for forage fish and none for coarse and sportfish. Overwintering potential is rated as moderate for forage fish and poor for coarse and sportfish. Rearing habitat is rated as moderate to good for forage fish, poor to moderate for coarse fish, and poor for sportfish. Fish passage is rated poor for all three categories of fish. The downstream section of the assessed reach provides better fish habitat than at the centreline.

4.3.1.18 Crossing KM 872.9 – Unnamed Watercourse (Drainage)

Changes to the project highway alignment moved the kilometre posting from KM 871.6 to KM 872.9. The watercourse at KM 855.9 was assessed from the air in 2010. The drainage was approximately 12 m wide with a wetted area of approximately 2 m at the time of assessment. There were no defined bed or banks observed. Substrate was comprised entirely of sand. Small woody debris was abundant within the drainage. Riparian vegetation was grass (40%), shrubs (30%), and coniferous trees (30%). There is potential for rearing, spawning, and migration for forage provided by back-flooding from Big Smith Creek (5658 NWT Ltd. and GNWT, 2011).

At the time of the 2021 field assessment, the downstream was a flooded wetland area with submerged aquatic vegetation. The substrate was fines and organics throughout the assessed reach. Overhead cover was estimated at 10%; the area was mostly clear. Instream cover was estimated at 60%, dominated by aquatic vegetation. A rig mat was present over the crossing location. An exposed pipe from a pipeline was noted in the channel.

One minnow trap was set for one hour, but no fish were captured. It is unlikely the proposed crossing location provides fish habitat.

4.3.1.19 Crossing KM 874 – Drainage

At the proposed crossing location, the drainage was approximately 11 m wide with defined bed and banks. The crossing is at the downstream confluence of a series of lakes. Substrate is sand. There were trace small woody debris observed throughout the assessed area. Riparian vegetation was grass (40%), shrubs (30%), and coniferous trees (30%). Grass and dead trees were observed within the drainage (5658 NWT Ltd. and GNWT, 2011).

The upstream lakes likely provide habitat for northern pike and whitefish (5658 NWT Ltd. and GNWT, 2011). Based on observed conditions, the drainage has the potential to provide rearing habitat for forage fish and spawning habitat for sportfish (5658 NWT Ltd. and GNWT, 2011). There are no barriers to fish migration (5658 NWT Ltd. and GNWT, 2011).

The site was not assessed in the field in 2021.

4.3.1.20 Crossing KM 875.5 – Drainage

At the proposed crossing location, the drainage was approximately 50 m wide and there was an unconfined low area between two lakes. The substrate was entirely sand. Riparian vegetation was grass (40%), shrubs (30%), and coniferous trees (30%). Grasses and live coniferous trees were observed within the drainage area (5658 NWT Ltd. and GNWT, 2011).

The nearby lakes likely provide suitable habitat for northern pike and forage fish (5658 NWT Ltd. and GNWT, 2011). Based on observed conditions, the drainage may provide rearing and spawning habitat for forage fish and spawning habitat for northern pike (5658 NWT Ltd. and GNWT, 2011). No barriers to fish migration were observed. However, fish passage is likely limited to small-bodied forage fish at high flows (5658 NWT Ltd. and GNWT, 2011).

The site was not assessed in the field in 2021.

4.3.1.21 Crossing KM 876.6 – Unnamed Watercourse

At the proposed crossing location, the watercourse was approximately 11 m wide and the wetted width was 0.5 m at the winter road crossing and 1 m wide downstream of the winter road crossing. The substrate was entirely sand. Riparian vegetation was shrubs (40%), coniferous trees (40%), and grass (20%). Grasses and live coniferous trees were observed within the channel (5658 NWT Ltd. and GNWT, 2011).

Based on observed features, it is expected that this watercourse provides spawning and rearing habitat for forage fish and spawning habitat for sportfish (5658 NWT Ltd. and GNWT, 2011). No barriers to fish migration were observed but fish passage would be limited to high flows due to shallow water depths at other times of the year (5658 NWT Ltd. and GNWT, 2011).

The site was not assessed in the field in 2021.

4.3.1.22 Crossing KM 877.8 – Unnamed Watercourse

At the proposed crossing location, the channel was up to 20 m wide with a wetted width of 0.5 m (5658 NWT Ltd. and GNWT, 2011). The drainage was between a series of small lakes and was crossed by the existing winter road (5658 NWT Ltd. and GNWT, 2011). The substrate was entirely sand. Riparian vegetation was grass (40%), shrubs (30%), and coniferous trees (30%). Vegetation observed within the channel included shrubs and grass (5658 NWT Ltd. and GNWT, 2011).

Based on observed features, it is expected that this watercourse provides spawning and rearing habitat for forage fish (5658 NWT Ltd. and GNWT, 2011). No barriers to fish passage were observed but fish passage would be limited to periods of high flows due to shallow water depths at other times of the year (5658 NWT Ltd. and GNWT, 2011).

The site was not assessed in the field in 2021.

4.3.1.23 Crossing KM 878.8 – Unnamed Watercourse

At the proposed crossing location, the channel was approximately 2 m wide with a wetted width of 0.5 m (5658 NWT Ltd. and GNWT, 2011). The watercourse is a drainage from a series of small lakes. Habitat observed was predominately run. Substrate was cobble (50%) and boulder (50%). Riparian vegetation was coniferous trees (90%), shrubs (5%), and deciduous trees (5%) (5658 NWT Ltd. and GNWT, 2011).

Based on observed features, it is anticipated that this watercourse provides spawning habitat for forage fish (5658 NWT Ltd. and GNWT, 2011). No barriers to fish passage were observed but fish passage would be limited to periods of high flows due to shallow water depths at other times of the year (5658 NWT Ltd. and GNWT, 2011).

The site was not assessed in the field in 2021.

4.3.1.24 Crossing KM 879.1 – Unnamed Watercourse

The crossing location appears to be a wetland area and was frozen over at the time of the assessment in October 2021. The wetland is connected to the proposed crossing location at KM 879.4. Beaver activity was observed upstream of the centreline and there was a beaver lodge and impoundment downstream. Overhead cover was estimated at 30%, mainly provided by grasses. Instream cover could not be estimated because the watercourse was frozen. There are ponds located both upstream and downstream of the centreline.

No fishing was conducted due to frozen conditions. There is potential good habitat for forage fish during the open water season but likely poor for coarse and sportfish. Low oxygen levels (0.68 milligrams per litre [mg/L]) likely limits overwintering potential for fish.

4.3.1.25 Crossing KM 879.4 – Unnamed Watercourse

The watercourse was assessed in the fall of 2021. The channel width at the centreline was 5.2 m with an average water depth of approximately 0.4 m. The upstream portions of the assessment area were flooded. Maximum water depth in the assessed reach was 0.5 m at the time of the assessment. The substrate at the centreline was organics as well as upstream of the centreline; downstream was predominantly fines. Overhead cover was estimated at 60%, provided mainly by shrubs, while instream cover was estimated at 50%, mainly through woody debris in the water column. Grasses and aquatic vegetation were observed in the channel upstream of the centreline. The banks at the centreline were stable. Undercutting of the banks were observed 300 m downstream of the centreline. Aerial imagery of the area shows it is connected to the crossing at KM 879.1 on the upstream side and appears to have wetland characteristics upstream of T1 (100 m upstream), based on the aerial imagery, but it was snow covered at time of assessment.

No fishing was conducted due to unsafe conditions for electrofishing and freezing conditions. Spawning habitat is rated as poor to moderate for forage fish and none for coarse and sportfish. Overwintering potential is rated as poor to moderate for forage fish and poor for coarse and sportfish. Rearing habitat is rated as moderate for forage fish and poor to moderate for coarse and sport fish. Fish passage is rated as moderate to good for forage fish and moderate for coarse and sport fish.

4.3.1.26 Crossing KM 880.2 – Unnamed Watercourse

The channel width at the centreline was 2.7 m with an average water depth of 0.2 m at the time of the assessment. The maximum water depth in the assessed reach was 0.2 m at the time of the assessment. Upstream (at 100 m) of the centreline, the area was flooded with no defined channel. There is poor connectivity until 100 m downstream of the centreline where connectivity improves. The channel narrows 300 m downstream and has a steep grade with several logjams. Overhead cover was estimated at 30%, provided by shrubs and trees, while instream cover was estimated at 20%, mainly provided by woody debris. At the centreline, the left bank was stable while the right bank was moderately stable.

No fishing was conducted due to shallow water depths. The watercourse is unlikely to provide fish habitat.

4.3.1.27 Crossing KM 880.6 – Unnamed Watercourse

At the proposed crossing location, the watercourse was a large drainage channel from a lake. The watercourse is crossed by the MGP route (RPR-346 [IORVL, 2004]), approximately 830 m upstream of the project highway alignment crossing.

The channel width at the centreline was 1.8 m with an average water depth of 0.4 m at the time of the assessment in October 2021. Maximum water depth in the assessed reach was 0.6 m. A pipeline crossing exists 100 m downstream from the centreline. At this location there was some large boulders from rip-rap for a wooden banks support structure that was in place. Substrate at the centreline is 30% organics and 70% fines. Fines were the dominant substrate throughout the assessed reach. Overhead cover was estimated at 80%, provided mostly by shrubs. Instream cover was estimated at 40%, provided

mainly through woody debris. Banks at the centreline were stable; upstream and downstream of the centreline banks, were predominantly moderately stable.

Fishing was conducted using a backpack electrofisher. Three forage fish species were captured: brook stickleback, finescale dace, and pearl dace. Spawning habitat is rated as moderate for forage fish and none to poor for coarse and sport fish. Overwintering potential is rated as poor for all three categories of fish. Rearing habitat and fish passage is rated as good for all three categories of fish.

4.3.1.28 Crossing KM 883.6 – Unnamed Watercourse

The channel width at the centreline was 1.3 m with an average water depth of 0.3 m. The maximum water depth in the assessed reach was 0.3 m at the time of the assessment. The channel became undefined 50 m upstream from the centreline. Water was tinted an orange, copper colour. The substrate at the centreline was organics (100%). Organics was the dominant substrate type with some fines downstream. Overhead cover was estimated at 70%, provided mainly by shrubs. Instream cover was estimated at 10%, provided by woody debris. At the centreline and upstream, the banks were moderately stable transitioning to unstable 200 m downstream from the centreline.

No fishing was conducted due to freezing conditions. Fish habitat is rated as poor for all fish categories. The watercourse likely does not provide fish habitat.

4.3.1.29 Crossing KM 884.3 – Unnamed Watercourse

The proposed crossing location was assessed from the air in 2010 (5658 NWT Ltd. and GNWT, 2011). The watercourse is a drainage from a series of lakes. Channel width was estimated as 15 m, and it was ponded due to a beaver dam several metres downstream. Overhead cover was estimated at 1% to 25%, predominately consisting of a mix of conifer and deciduous trees. Substrate was sand (5658 NWT Ltd. and GNWT, 2011).

The site was not assessed in the field in 2021.

4.3.1.30 Crossing KM 889 – Unnamed Watercourse

The proposed crossing location was assessed from the air in 2010 (5658 NWT Ltd. and GNWT, 2011). The watercourse is connected to several lakes. The channel at the crossing was estimated to be approximately 15 m wide with a water depth of approximately 3 m. Overhead cover was estimated to be between 1% to 25%, consisting primarily of conifer trees with smaller amounts of deciduous trees and grasses. The substrate was sand. Water colour at the time of the survey was brown. The watercourse may provide habitat for forage and sport fish (5658 NWT and GNWT, 2011).

The site was not assessed in the field in 2021.

4.3.1.31 Crossing KM 884.8 – Unnamed Watercourse

The channel width at the centreline was 2.5 m with an average water depth of 0.3 m. The maximum water depth in the assessed reach was 0.6 m. Substrate at the centreline was 90% fines and 10% small gravel. Fines was the dominant substrate throughout the assessed reach. Overhead cover was estimated as 30%, provided mainly from shrubs. However, at the centreline, overhead cover was estimated as 60%. Instream cover was estimated at 60%, provided mainly through woody debris. Banks at the centreline and downstream were moderately stable; upstream they were unstable. According to a local wildlife monitor, a beaver dam 50 m upstream of the centreline collapsed the year before. This may have resulted in the unstable banks upstream.

Fishing was conducted using a backpack electrofisher. Two forage fish species were captured: brook stickleback and pearl dace. Spawning habitat is rated as moderate for forage fish and poor for coarse and sportfish. Overwintering potential is rated as poor for all three categories of fish. Rearing habitat is rated as moderate to good for forage fish, poor to moderate for coarse fish, and poor for sportfish. Fish passage was rated as moderate for forage fish and poor to moderate for coarse and sportfish.

4.3.1.32 Crossing KM 891.4 – Unnamed Watercourse

The channel width at the centreline was 12.5 m. A beaver dam at the centreline was impounding water upstream. Downstream from the centreline, channel width decreased to between 6.0 and 5.5 m. Water depth at the centreline could only be taken at one location due to safety concerns and was recorded as 1.3 m at the time of the assessment. The maximum water depth was estimated as greater than 1 m. Downstream of the centreline, water depths decreased to approximately 0.5 m. The substrate at the centreline was 100% fines. Downstream, the substrate was organics and fines. No substrate composition estimates were made for the upstream portion of the assessed reach. Overhead cover was estimated at 10%, provided mainly from conifer trees. Instream cover was estimated at 10%, largely provided by woody debris. Banks at the centreline were unstable, as well as downstream, but moderately stable upstream. Erosion of the banks were observed near the centreline and downstream.

No fishing was conducted due to freezing conditions and conditions were unsafe for electrofishing due to high flows and water depth. Spawning habitat is rated as moderate to good for forage fish and poor for coarse and sport fish. Overwintering potential is rated as moderate for all fish categories. Rearing habitat was rated as good and fish passage as moderate to good for all three fish categories.

4.3.1.33 Crossing KM 891.7 – Unnamed Watercourse

At the proposed crossing location, the channel was approximately 20 m wide and up to 2 m deep (5658 NWT Ltd. and GNWT, 2011). The watercourse drains a series of small upstream lakes. Substrate was entirely sand. There were trace amounts of large woody debris and a moderate amount of small woody debris observed throughout the assessed area. A beaver dam and small log jams were observed downstream from the proposed crossing location. Riparian vegetation was coniferous trees (85%), deciduous trees (5%), grass (5%), and shrubs (5%). Given the observed habitat conditions, the crossing likely provides rearing, spawning, and migration habitat for forage fish and sportfish (5658 NWT Ltd. and GNWT, 2011).

The site was not assessed in the field in 2021.

4.3.1.34 Crossing KM 915.6 – Unnamed Drainage

At the proposed crossing location, the drainage was between 3 m and 8 m wide and up to 0.2 m deep. The watercourse is a drainage from a series of upstream lakes. The substrate was entirely sand. Riparian vegetation was coniferous trees (75%), deciduous trees (15%), grass (5%), and shrubs (5%) and the drainage likely provides spawning and migration habitat for forage fish (5658 NWT Ltd. and GNWT, 2011).

The watercourse is crossed by the MGP route (RPR-333 [IORVL, 2004]) 87 m upstream of the proposed crossing location.

The site was not assessed in the field in 2021.

4.3.1.35 Crossing KM 918 – Unnamed Watercourse

The proposed crossing location was assessed from the air in 2010 (5658 NWT Ltd. and GNWT, 2011). The watercourse channel at the crossing site is approximately 8 m to 15 m wide with a water depth of approximately 0.2 m. The watercourse connects a series of lakes. Crown closure was estimated at 1% to 25% consisting of primarily conifer trees, with smaller amounts of deciduous trees, shrubs and grasses. Instream cover consisted of large woody debris. The substrate was sand. Water colour at the time of the assessment was brown. The watercourse may provide habitat for forage and sport fish (5658 NWT and GNWT, 2011).

The site was not assessed in the field in 2021.

4.3.1.36 Crossing KM 919.9 – Unnamed Watercourse

The channel width at the centreline was 37 m with a water depth of 0.2 m at the time of the assessment. The maximum water depth in the assessed reach was estimated to be greater than 2 m. Upstream, 100 m of the centreline, there was an entrance to a deep pool. Upstream 50 m, the area is flooded which extends downstream of the centreline. Downstream of the centreline, the channel becomes narrower and, by 300 m downstream, was only 1.3 m wide. Substrate at the centreline was estimated to be 30% organics, 60% fines, and 10% boulders. The boulders appear to be from rip-rap used for the winter road and not naturally occurring. Upstream, the substrate composition was 100% organics; downstream was a mixture of organics and fines. Overhead cover was estimated at 10% with overhanging grasses. Instream cover was also estimated at 10%, provided by vegetation. Banks at the centreline were stable.

Fishing was conducted using minnow traps but no fish were captured. Spawning habitat is rated as good for forage fish and none for coarse and sportfish. Overwintering potential is rated poor to moderate for forage fish and poor for coarse and sportfish. Rearing habitat is rated as good for forage fish, moderate for coarse fish, and poor to moderate for sportfish. Fish passage is rated as poor to moderate for all three categories of fish.

4.3.1.37 Crossing KM 922 – Twelve Mile Creek

At the proposed crossing location, the channel was approximately 1 m wide with a depth of 0.2 m at the time of assessment. The watercourse receives water from a series of small upstream lakes. Habitat was predominately run. Substrate was dominated by sand (90%) with limited gravel (10%). Small woody debris was observed throughout the watercourse, Riparian vegetation consisted of forbs (30%), grasses (20%), conifers (20%), deciduous trees (15%), and shrubs (15%) (5658 NWT Ltd. and GNWT, 2011).

Given the observed habitat conditions, Twelve Mile Creek likely provides spawning and rearing habitat for sportfish, forage fish, and coarse fish. There were no barriers to migration observed and no overwintering habitat present (5658 NWT Ltd. and GNWT, 2011). Arctic grayling, burbot, northern pike, emerald shiner, spottail shiner and lake chub were the most frequently captured species in Twelve Mile Creek (IORVL, 2004).

Twelve Mile Creek was assessed for the MGP route (crossing RPR-332 [IORVL, 2004]) approximately 1.7 km upstream of the project crossing.

The site was not assessed in the field in 2021.

4.3.1.38 Crossing KM 931 – Four Mile Creek

At the proposed crossing location, the channel was approximately 3 m wide and 0.5 m deep. Habitat was predominately run. A moderate amount of small woody debris was observed throughout the assessed area. The substrate was sand (90%) and gravel (10%). Riparian vegetation was forbs (30%), grass (20%), coniferous trees (20%), shrubs (15%), and deciduous trees (15%) (5658 NWT Ltd. and GNWT, 2011).

Juvenile Arctic grayling, burbot, northern pike, emerald shiner, spottail shiner, and lake chub have been captured at the confluence of Four Mile Creek and the Mackenzie River (5658 NWT Ltd. and GNWT, 2011). The upstream lakes provide suitable habitat for northern pike and whitefish (5658 NWT Ltd. and GNWT, 2011). Based on observed habitat conditions, Four Mile Creek provides suitable spawning, rearing, and migration habitat for species captured as well as bull trout and whitefish (5658 NWT Ltd. and GNWT, 2011).

The site was not assessed in the field in 2021.

4.3.1.39 Crossing KM 940.1 – Unnamed Watercourse

Channel width at the centreline was 1.5 m with an average water depth of 0.4 m at the time of the assessment. The maximum water depth in the assessed reach was 0.6 m. Substrate composition at the centreline was 60% organics and 40% fines. The substrate throughout the assessed reach was organics and fines. Overhead cover was 90%, provided by overhanging shrubs. Instream cover was 10%, provided by undercut banks. Banks at the centreline were moderately stable. A series of cascades with 0.25 m drops were present 200 to 300 m downstream from the centreline. These cascades may be barriers to fish passage.

No fishing was conducted due to snow and ice conditions. Spawning habitat is rated as moderate for forage fish and none for coarse and sportfish. Overwintering potential is rated as none to poor for all three categories of fish. Rearing habitat is rated as moderate to good for forage fish and poor to moderate for coarse and sportfish. Fish passage is rate as poor to moderate for all three categories of fish.

4.3.1.40 Crossing KM 980.3 – Unnamed Watercourse

At the proposed crossing location, the channel was approximately 1 m wide with a maximum depth of 0.2 m; it was dry in some locations. Habitat was predominately run. Substrate was predominantly boulders (70%) and cobble (30%). A moderate amount of small woody debris was observed throughout the assessed area. Riparian vegetation was coniferous trees (75%), shrubs (20%), and deciduous trees (5%). It is unknown whether this watercourse provides fish habitat.

The watercourse is crossed by the MGP route (RPR-314 [IORVL, 2004]) approximately 2.4 km downstream of the project crossing.

4.3.1.41 Crossing KM 981.2 – Unnamed Watercourse

The assessment was conducted in snow and 50% ice cover. The channel width at the centreline was 2.6 m with an average water depth of 0.1 m at the time of the assessment. The maximum water depth at the time of the assessment was 0.8 m. The substrate composition at the centreline was estimated to be 20% small gravel, 40% large gravel, 30% cobble and 10% boulders. The substrate upstream of the centreline was similar to the centreline. Downstream, 200 m and 300 m from the centreline, substrate composition changed to a mixture of fines and organics. Overhead cover was estimated at 40%, provided mainly by shrubs; instream cover was estimated at 25% cobble and boulders. Banks were moderately stable throughout the assessed reach except 300 m downstream of the centreline where the banks become unstable. Riffle and chutes occur throughout the assessed reach.

Fishing was conducted using a backpack electrofisher and no fish were captured. Spawning habitat is rated as moderate to good for all three categories of fish. Overwintering potential is ranked none to poor for all three categories of fish. Rearing habitat is rated as good for forage and coarse fish and moderate for sportfish. Fish passage is rated as moderate for all three categories of fish.

4.3.1.42 Crossing KM 983 – Prohibition Creek

At the proposed crossing location, Prohibition Creek was approximately 20 m wide with a depth of 0.2 m at the time of assessment. Habitat was predominately run (98%) with limited riffle habitat (2%). Substrate was cobble (60%), sand (20%), gravel (15%), and boulders (5%). Riparian vegetation was predominantly coniferous trees (70%) with some shrubs (20%) and grasses (10%) (5658 NWT Ltd. and GNWT, 2011).

Arctic grayling, broad whitefish, cisco, longnose sucker, mountain whitefish, northern pike, round whitefish, trout-perch, lake chub, emerald shiner, spottail shiner, spoonhead sculpin, and slimy sculpin have been previously captured in Prohibition Creek (IORVL, 2004). Given the observed habitat conditions, it is likely that spawning, rearing, and overwintering habitat for sportfish, forage fish, and

coarse fish exist in Prohibition Creek (IORVL, 2004; 5658 NWT Ltd. and GNWT, 2011). No barriers to migration were observed (5658 NWT Ltd. and GNWT, 2011).

Prohibition Creek is crossed by the MGP route (RPR-313 [IORVL, 2004]) approximately 470 m downstream from the proposed Project crossing.

The site was not assessed in the field in 2021.

4.3.1.43 Crossing KM 987.2 – Unnamed Watercourse

At the proposed crossing location, the channel was approximately 2.5 m wide and 0.1 m deep at the time of assessment. Habitat was predominately run habitat. Substrate was cobble (50%) and gravel (50%). Moderate small woody debris was observed at the crossing location. Riparian vegetation was predominately conifers (60%) with shrubs (25%), limited grass (10%), and deciduous trees (5%) (5658 NWT Ltd. and GNWT, 2011).

Fish sampling was conducted in 2002 and 2003 but no fish were captured (IORVL, 2004). Given the observed habitat conditions, it is anticipated that spawning and rearing habitat exists for sportfish, forage fish, and coarse fish in this unnamed watercourse (5658 NWT Ltd. and GNWT, 2011). At the MGP route crossing, it was reported that there was potential rearing habitat for Arctic grayling and juvenile suckers, but the lack of deep-water habitat could restrict adult feeding by large-bodied fish species (IORVL, 2004).

The unnamed watercourse is crossed by the MGP route (RPR-312 [IORVL, 2004]) approximately 100 m upstream of the project crossing.

The site was not assessed in the field in 2021.

4.3.2 Dehcho Region

Field Assessments were completed by K'alo-Stantec between September 16 and September 24, 2020. Station location maps for crossings assessed in the field and site summary sheets are provided in Appendix C.

4.3.2.1 Crossing KM 696.8 – Unnamed Watercourse

There is no existing data at the proposed crossing location The proposed crossing location was not assessed by K'alo-Stantec in 2020 due to difficulties accessing the site and time constraints related to weather.

4.3.2.2 Crossing KM 699.1 - Drainage

At the proposed crossing location, there is an ephemeral drainage which is oriented from east to west across the existing winter road. Ponded water was present on both sides of the winter road. However, there were no continuously defined channels on either side of the road and this drainage is unlikely to support fish. This drainage was not assessed by previous studies.

4.3.2.3 Crossing KM 699.3 - Wetland Area

A suspected wetland area with several small waterbodies is located adjacent to the project highway alignment at this crossing location. The inlet to the wetland area was accessed as an ephemeral drainage (WX-028). Neither the wetland nor inlet were not considered fish habitat due to the lack of connectivity to a fish-bearing waterbody and lack of overwintering potential. This wetland area was not assessed in previous studies.

4.3.2.4 Crossing KM 700.3 - Wetland Area

At the proposed crossing location, there is a wetland which has an outlet connecting it to the Mackenzie River. Substrate in the wetland was entirely organics. Wetland riparian vegetation was also observed. The maximum depth was approximately 3 m. An active beaver lodge was observed in the wetland.

Minnow trapping was conducted for approximately 45 hours; no fish were captured. However, this waterbody likely provides fish habitat because of its connectivity to the Mackenzie River as well as its depth. The outlet to the waterbody is on the downstream side of the project highway corridor. It does not appear that the wetland crosses the existing winter road. This crossing was not assessed in previous studies.

4.3.2.5 Crossing KM 701.7 - Wetland Area

At the proposed crossing location, there is a wetland with an outlet connecting it to the Mackenzie River. The substrate was entirely organics. Wetland riparian vegetation was observed. The maximum depth of the waterbody was 2 m.

Minnow trapping was completed for 46 hours; no fish were captured. However, it is expected to provide fish habitat due to its connectivity with the Mackenzie River. This crossing was not assessed in previous studies.

4.3.2.6 Crossing KM 702.2 - Wetland Area

A wetland area with numerous small ponds was located adjacent to the project highway alignment. Substrates in the ponds was entirely organic material. Wetland vegetation exists around each pond. The outlet of this wetland connects to the Mackenzie River across the alignment.

Minnow trapping was conducted for approximately 40 hours; no fish were captured. This wetland likely provides habitat for forage fish due to its connectivity with the Mackenzie River. This crossing was not assessed in previous studies.

4.3.2.7 Crossing KM 702.9 - Wetland Area

At the crossing location, there is a wetland with an ephemeral drainage connected to a larger waterbody to the west, located adjacent to the project highway alignment. Substrates were entirely organic matter. Wetland riparian vegetation surrounded the waterbody on all sides. The maximum measured depth was approximately 1 m.

Minnow trapping was conducted for approximately 45 hours; no fish were captured. However, the wetland may provide seasonal fish habitat for forage fish due to its connectivity with a larger waterbody. This wetland was not assessed in previous studies.

4.3.2.8 Crossing KM 704.7 – Wetland Area

At the proposed crossing location, there was a wetland area which was connected to a larger waterbody to the west. Substrate was organic material and wetland riparian vegetation was present. The maximum measured depth was approximately 1 m.

Minnow trapping was conducted for 46 hours; no fish were captured. This wetland likely provides seasonal fish habitat for forage fish because of its connectivity with a larger waterbody to the west. This wetland was not assessed in previous studies.

4.3.2.9 Crossing KM 705.4 – Unnamed Watercourse

There is no existing data for the watercourse at this proposed crossing location. The proposed crossing location was not assessed by K'alo-Stantec in 2020 due to difficulties accessing the site or time constraints related to weather.

4.3.2.10 Crossing KM 710.4 - Wetland Area

A wetland area was located adjacent to the project highway alignment. An outlet from the wetland was assessed as an ephemeral drainage (WX-006) and this outlet crosses the alignment. No inlet to the wetland was observed. The wetland and outlet are not considered to provide fish habitat because of lack of connectivity to larger waterbodies or watercourses. K'alo-Stantec only assessed the crossing 200 m to the southeast because of a nearby moose pasture and concerns of entering the pasture raised by the community of Wrigley. There is no previous data for the suspected wetland area.

4.3.2.11 Crossing KM 715.6 - Wetland Area

A small wetland with no inlets or outlets was located adjacent to the project highway alignment. This waterbody is not considered fish habitat due to its lack of connectivity with other waterbodies. This wetland was not assessed in previous studies.

4.3.2.12 Crossing KM 718.8 - Drainage

This is an ephemeral drainage, oriented east to west, at the proposed crossing location, which is at the existing winter road. This drainage did not have a defined channel bed or banks and there was no channelization for approximately 50 m upslope of the existing winter road; standing water was present only downslope of the proposed crossing. The drainage is unlikely to provide fish habitat because it does not have sufficient depth nor connectivity to fish-bearing waterbodies. The crossing was previously assessed (Dessau, 2012) approximately 36 m southeast of the proposed crossing location and no fish habitat potential was found.

4.3.2.13 Crossing KM 719.9 - Wetland Area

A wetland area with an outlet visible to the northwest was located adjacent to the project highway alignment. Substrate was organic material and the waterbody was surrounded by wetland riparian vegetation. The maximum depth was greater than 2 m.

Minnow trapping was conducted for 35 hours; no fish were captured. However, this wetland likely provides fish habitat for forage fish because of its suitable depth and an outlet with connectivity to other waterbodies in the area. This waterbody was not assessed in previous studies.

4.3.2.14 Crossing KM 721.6 – Unnamed Watercourse

At the proposed crossing location, the watercourse was approximately 1.9 m wide with a wetted width of 2.6 m. The wetted width was longer than the channel width due to undercut banks. The maximum depth was 0.6 m at the time of the assessment. Substrate was fines (50%), organics (25%), cobble (10%), boulder (10%), and large gravel (5%). Riparian vegetation was dominated by shrubs and grasses on both banks. Cover for fish was provided by trees and shrubs as well as boulders and woody debris instream. Riffles was the dominant habitat type observed and a small cascade was observed at the proposed crossing location. However, approximately 300 m downstream of the crossing location, shallow runs dominated.

Backpack electrofishing was completed for 450 seconds of effort; no fish were captured. Spawning habitat potential is rated as poor for all species due to unsuitable substrate and limited instream woody debris. Downstream of the proposed crossing location, there is more suitable habitat that includes riffles and flat habitat with abundant cover and woody debris that may afford spawning habitat for forage fish. Overwintering habitat potential is rated as poor to nil for all fish species because it is expected that the watercourse will freeze to the bottom in winter. Rearing habitat potential is rated as moderate for coarse and forage fish and poor-moderate for sportfish because it is likely limited by high water velocity in the riffle habitat. Fish passage potential for all fish species is rated as good with no obstructions observed.

The watercourse was not assessed in previous studies.

4.3.2.15 Crossing KM 724.5 – Unnamed Watercourse

There is no existing data at the proposed crossing location; it was not assessed by K'alo-Stantec in 2020 due to difficulties accessing the site or time constraints related to weather.

4.3.2.16 Crossing KM 727.4 – Unnamed Watercourse

At the proposed crossing location, the watercourse was 1.5 m wide with a wetted width of 1.1 m. The maximum dept was 0.5 m at the time of the assessment. The substrate was fines (50%), organics (30%), cobble (10%), large gravel (5%), and small gravel (5%). Riparian vegetation was shrubs. There was little instream or overhead cover within the assessed area. Cover for fish was provided by undercut banks, trees and shrubs, and woody debris.

Backpack electrofishing was completed for 432 seconds; no fish were captured. Spawning habitat potential is as rated poor for all fish species due to the lack of appropriate substrate, instream woody debris, and vegetation. Overwintering habitat is rated as poor to nil for all fish species as the watercourse is expected to freeze to bottom in winter. There is limited overhead cover, limited instream cover, and lack of substrate complexity for invertebrate populations. Therefore, habitat is rated as moderate for forage fish and coarse fish and poor to moderate for sportfish. Migration habitat for all fish species is rated as moderate because there were no obstructions observed. During periods of low flow, fish passage for large-bodied fish species may be restricted

The watercourse was not assessed in previous studies.

4.3.2.17 Crossing KM 732.7 – Unnamed Watercourse

At the proposed crossing location, the channel width was 0.66 m with a wetted width of 0.74 m (Dessau, 2012). The substrate was fines (80%), gravel (10%), and cobble (10%). Riparian vegetation was dominated by coniferous trees (Dessau, 2012). Overhead cover was estimated to be 90% for the entire site (Dessau, 2012).

This crossing was assessed by K'alo-Stantec in 2020. The channel was found to have a width of 0.9 m with a wetted width of 0.8 m at the time of the assessment. The maximum depth was 0.6 m. The substrate was fines (40%), boulder (35%), cobble (15%), and organics (10%). Riparian vegetation was predominantly shrubs and grasses. Overhead cover was provided by trees and shrubs and undercut banks. The dominant habitat type was riffle.

Spawning habitat was rated as poor for all fish species. Overwintering habitat was rated as poor because the watercourse is likely to freeze to the bottom in winter. Rearing habitat potential was rated as poor for all fish species because overhead cover is limited and instream cover was provided primarily by boulders. The amount of overhead cover may have changed since the previous assessment (Dessau, 2012) due to local changes in vegetation. Fish passage was rated as poor for forage fish because of high water velocity and steeper gradients at the confluence with the Mackenzie River (14% gradient) and downstream of the crossing location (16% gradient). Sport and coarse fish are more likely to migrate past the gradient barriers; however, water depth was shallow with abundant boulders and migration could be

limited by depth. Therefore, passage was rated as poor to moderate for sport and coarse fish. In a previous assessment fish habitat potential was rated as poor due to low flow and fine substrate In addition, to debris jams which likely impede fish migration (Dessau, 2012).

4.3.2.18 Crossing KM 733.7 - Bonnie Creek

At the proposed crossing location, the channel was 2.9 m wide with a wetted width of 2.4 m (Dessau, 2012). Substrate was boulder (60%), cobble (15%), fines (15%), and gravel (10%) with riparian vegetation comprised of deciduous trees (Dessau, 2012). Available instream cover to fish was estimated to be 65% (Dessau, 2012). Spawning fish habitat potential was rated as low, overwintering habitat potential was rated as low, and rearing habitat potential was rated as moderate (Dessau, 2012). It is suspected that Arctic grayling may be present within Bonnie Creek (Dessau, 2012).

Bonnie Creek was assessed by K'alo-Stantec in 2020. The confluence of Bonnie Creek with the Mackenzie River is located approximately 240 m downstream of the proposed crossing location. At the proposed crossing location, Bonnie Creek was 2.0 m wide with a wetted width of 2.2 m with a maximum depth of 0.5 m. Substrate was boulder (40%), cobble (20%), fines (20%), small gravel (15%), and organics (5%). Riparian vegetation was shrubs and grasses with some coniferous trees. The dominant habitat type was riffle with a shallow pool located approximately 100 m upstream and shallow run approximately 200 m downstream of the proposed crossing. No electrofishing was completed but the presence of Arctic grayling was suspected (Dessau, 2012).

Spawning habitat potential was rated as poor for all fish species due to the very coarse substrate with limited instream vegetation and woody debris. Overwintering habitat potential was rated as nil because the watercourse likely freezes to bottom in winter due to maximum water depth of 0.5 m. Rearing habitat was rated as moderate for forage fish and coarse fish and moderate for sport fish. The coarse substrate likely supports benthic invertebrate production and provides instream cover for fish, but otherwise there is limited overhead cover. Fish passage was rated as moderate for all fish species because no barriers were observed during the survey. However, fish passage during lower flows may be more difficult for fish due to the boulder substrate.

4.3.2.19 Crossing KM 736.5 – Unnamed Watercourse

At the proposed crossing location, the channel was 0.79 m wide with a wetted width of 0.77 m (Dessau, 2012). Substrate was entirely fines. Riparian vegetation was deciduous trees (Dessau, 2012). Instream cover for fish was estimated to be 80% (Dessau, 2012). Fish habitat potential was rated as low due to poor substrate and shallow depths (Dessau, 2012).

Crossing KM 736.48 was assessed by K'alo-Stantec in 2020. The watercourse was 0.9 m wide with a wetted width of 1.0 m at the proposed crossing location. The maximum depth was 0.7 m at the time of the assessment. Substrate was fines (30%), organics (20%), small gravel (20%), boulder (15%), cobble (10%), and large gravel (5%). Riparian vegetation was grass and shrubs with some deciduous trees. There was limited cover provided by woody debris and undercut banks. The dominant habitat type was riffles with some shallow runs approximately 100 m and 50 m upstream of the proposed crossing location.

No electrofishing was completed. Overall, fish habitat was rated as poor. Spawning habitat potential was rated as poor for all fish species because of the lack of coarse substrate and instream vegetation. Overwintering habitat potential was rated as poor because the watercourse is expected to freeze to the bottom in winter. Rearing habitat potential was rated as moderate for forage fish and coarse fish and poor to moderate for sportfish. There was some substrate complexity that may support benthic invertebrate production, and there was some cover for fish provided by woody debris and undercut banks. Migration was rated as moderate for all fish species due to instream large woody debris, which may affect passage. However, there were no barriers between the proposed crossing location and the Mackenzie River.

4.3.2.20 Crossing KM 738.7 – Unnamed Watercourse

At the proposed crossing location, the watercourse was 1.8 m wide with a wetted width of 1.1 m. Maximum measured depth was 0.7 m at the time of the assessment. The substrate was fines (40%), small gravel (20%), cobble (20%), organics (10%), large gravel (5%), and bedrock (5%). Riparian vegetation was grass and shrubs with some deciduous and coniferous trees. Limited cover was provided by undercut banks, woody debris, and boulders. The dominant habitat type at the crossing location was shallow run with riffles observed upstream and downstream.

Backpack electrofishing was completed for 573 seconds of effort; no fish were captured (K'alo-Stantec, 2021). Overall, fish habitat potential was rated as poor. Spawning habitat potential was rated as poor for all fish species. There are limited gravel substrates for species that construct redds and limited instream vegetation and woody debris for other fish species. Overwintering habitat potential was rated as poor for all fish species because the watercourse is likely to freeze to the bottom in winter. Rearing habitat was rated as moderate for forage fish and coarse fish and poor to moderate for sportfish. There is some substrate complexity to support benthic invertebrate production; however, fine substrates would likely limit this production to a smaller diversity of taxa. Migration potential was rated as good for all fish species because there were no known barriers between the crossing and the Mackenzie River. This crossing was not assessed by previous studies.

4.3.2.21 Crossing KM 737.4 – Unnamed Watercourse

There was no previous existing data at the proposed crossing location. The proposed crossing location was not assessed by K'alo-Stantec in 2020 due to difficulties accessing the site or time constraints related to weather.

4.3.2.22 Crossing KM 739.6 – Unnamed Watercourse

At the crossing location, this watercourse was 1.3 m wide with a wetted width of 1.3 m at the time of the assessment (Dessau, 2012). The substrate was gravel (50%), fines (45%), and cobble (5%). Riparian vegetation was dominated by alder trees (Dessau, 2012). Fish habitat potential was rated as moderate to low for rearing and spawning and low for overwintering (Dessau, 2012).

K'alo-Stantec assessed the proposed crossing location in 2020. At the proposed crossing location, the watercourse was 1.6 m wide with a wetted width of 1.18 m. The maximum measured depth was 0.5 m at the time of the assessment. The substrate was fines (40%), organics (20%), cobble (20%), small gravel (10%), and large gravel (10%). Riparian vegetation was shrubs and grass with some deciduous trees. There was limited overhead cover provided by undercut banks and limited instream cover provided by woody debris. The dominant habitat type was shallow run. Riffles were the dominant habitat type downstream of the proposed crossing location.

No electrofishing was completed; fish presence was assumed. Overall, fish habitat potential is poor. Spawning habitat potential for all fish species was rated as poor due to the limited depth, presence of predominantly fine substrates, and lack of instream vegetation and woody debris. Overwintering habitat potential for all fish species was rated as poor because the watercourse is likely to freeze to the bottom in winter. Rearing habitat potential was rated as good for all fish species because there was some substrate complexity to support benthic invertebrate production, and there was cover for juvenile fish from overhanging riparian vegetation and woody debris

Fish passage was rated as good for all fish species because no barriers were identified between the proposed crossing location downstream to the Mackenzie River. A logjam was observed approximately 50 m upstream of the proposed crossing that may partially impede fish passage upstream of the crossing, particularly for large bodied species.

4.3.2.23 Crossing KM 740.8 – Unnamed Watercourse

K'alo-Stantec assessed the proposed crossing location in 2020; there was no previous existing data at the proposed crossing location (Dessau, 2012). At the proposed crossing location, the channel was 1.3 m wide with a wetted width of 1.4 m. Wetted width was wider than the channel width due to the presence of undercut banks. The maximum depth was 0.4 m at the time of the assessment. The substrate was fines (70%), organics (20%), large gravel (5%), and cobble (5%). Riparian vegetation was grasses, shrubs, and coniferous trees. Cover was provided by woody debris and overhanging riparian vegetation. The dominant habitat type at the proposed and upstream of the crossing location consisted of shallow run habitat while riffles were present downstream of the proposed crossing location.

Backpack electrofishing was completed for 359 seconds of effort; no fish were captured. Overall, fish habitat was rated as poor. Spawning habitat potential was rated as poor for all fish species due to the fine substrate, limited instream vegetation and woody debris, and shallow depth. Overwintering habitat potential was rated as poor for all species because the watercourse is likely to freeze to the bottom in winter. Rearing habitat potential was rated as moderate to good for forage fish and coarse fish and moderate for sportfish. Fine substrate composition may limit benthic invertebrate production. However, there was overhead and instream cover and suitable flows for rearing fish. Passage potential was rated as moderate because there were no known barriers to migration downstream of the proposed crossing location to the Mackenzie River.

4.3.2.24 Crossing KM 741.7 - Unnamed Watercourse

There was no previous existing data at the proposed crossing location (Dessau, 2012). K'alo-Stantec assessed the proposed crossing location in 2020. At the proposed crossing location, the channel was 1.3 m wide with a wetted width of 1.0 m. Maximum depth was measured at 0.9 m depth at the time of the assessment. The substrate was entirely fines. Riparian vegetation was grasses and shrubs with deciduous and coniferous trees. Cover was provided by trees, shrubs, and woody debris. The dominant habitat type at the crossing location was shallow run with step pools upstream and riffles and shallow run habitat downstream of the proposed crossing location.

Backpack electrofishing was completed for 331 seconds; no fish were captured. Overall, fish habitat potential was rated as poor at the proposed crossing location. Spawning habitat potential was rated as nil for all fish species due to the fine substrates. Overwintering habitat was rated as poor for all fish species because the watercourse is likely to freeze to the bottom. Rearing habitat potential was rated as poor to moderate for forage fish and coarse fish and poor for sportfish because of the limited cover and lack of complex substrate to support benthic invertebrates and likely limited by depth. Passage was rated as moderate for all fish species as there are no barriers between the proposed crossing location.

4.3.2.25 Crossing KM 742.7 – Unnamed Watercourse

There was no previous existing data at the proposed crossing location (Dessau, 2012). K'alo-Stantec assessed the proposed crossing location in 2020. At the proposed crossing location, the channel was 1.0 m wide with a wetted width of 1.4 m. Wetted width was wider than channel width due to the presence of undercut banks. Maximum depth was 0.3 m at the time of the assessment. The substrate was fines (90%) with small gravel (10%). Riparian vegetation was shrubs with deciduous and coniferous trees. Overhead cover was limited and provided by trees and shrubs. The dominant habitat type was shallow run.

Backpack electrofishing was not completed due to safety concerns of walking over unstable banks. Overall, fish habitat potential was rated as poor. Spawning habitat potential was rated as poor for all fish species due to the fine substrates and shallow depths. Overwintering habitat potential was rated as poor for all fish species because the watercourse is likely to freeze to the bottom. Rearing habitat potential was rated as poor for all fish species due to the lack of substrate complexity for benthic invertebrates and limited cover. Passage was rated as poor for all fish species due to the shallow depth which likely limits fish passage to high flow periods.

4.3.2.26 Crossing KM 745.7 – Strawberry Creek

At the proposed crossing location, Strawberry Creek had a channel width of 8 m with a wetted width of 8 m (Dessau, 2012). Substrates were boulder (70%), fines (10%), gravel (10%), and cobble (10%) (Dessau, 2012). Riparian vegetation was willows and grasses (Dessau, 2012). Instream cover was provided in approximately 80% of the channel (Dessau, 2012). Fish habitat potential was rated as moderate for rearing and spawning with low overwintering habitat potential (Dessau, 2012).

Strawberry Creek is crossed by the MGP route (RPR-385 [IORVL, 2004]). The proposed crossing location was not assessed by K'alo-Stantec in 2020 due to access or time constraints related to weather.

4.3.2.27 Crossing KM 747.6 – Unnamed Watercourse

There is no previous existing data at the proposed crossing location (Dessau, 2012). K'alo-Stantec assessed the proposed crossing location in 2020. The confluence with the Mackenzie River is located approximately 110 m downstream from the proposed crossing location. The gradient between the proposed crossing and the river was approximately 30%. An existing culvert at the proposed crossing location was damaged at the outlet.

At the proposed crossing location, the channel was 1.3 m wide with a wetted width of 0.9 m. Maximum depth was measured at 0.1 m at the time of assessment. Substrate was boulder (30%), fines (25%), small gravel (20%), cobble (20%), and large gravel (5%). Riparian vegetation was grasses and shrubs with deciduous and coniferous trees. Cover was limited and provided by trees and shrubs and undercut banks. The dominant habitat type at the proposed crossing location was riffle with step pools upstream and downstream of the proposed crossing location.

Backpack electrofishing was completed for 213 seconds; no fish were captured. Overall, fish habitat was rated as poor. Spawning habitat potential was rated as poor for all fish species due to insufficient depth and unsuitable substrate. Overwintering habitat potential was rated as poor for all fish species as the watercourse likely freezes to bottom in winter. Rearing habitat potential was rated as poor for all fish species due lack of instream cover and insufficient depth. Passage was rated as poor for all species because the culvert had resulted in sloughing, which temporarily obstructed fish passage and because of the steep gradient (30%) upstream from the confluence with the Mackenzie River. In addition, there is a potential velocity barrier 100 m upstream from the proposed crossing location associated with the step pools.

4.3.2.28 Crossing KM 748.0 – Unnamed Watercourse

There is no previous existing data at the proposed crossing location (Dessau, 2012). K'alo-Stantec assessed the proposed crossing location in 2020. At the proposed crossing location, the channel was approximately 1.6 m wide with a wetted width of 1.0 m. Maximum depth was 0.6 m at the time of the assessment. The substrate was cobble (40%), fines (20%), boulder (15%), large gravel (15%), and small gravel (10%). Riparian vegetation was shrubs and grasses. Cover for fish was also provided by undercut banks, overhanging trees and shrubs, and boulders.

Backpack electrofishing was completed for 335 seconds of effort; no fish were captured. Overall, fish habitat potential was rated as poor. Spawning habitat was rated as poor for all species due to the coarse substrate and lack of instream vegetation. Overwintering habitat was rated as poor for all species because the watercourse is expected to freeze to the bottom in winter. Rearing habitat potential was rated as poor for all species due to limited cover. Passage was rated as poor for all species because of a gradient barrier (24% gradient over 20 m length) approximately 50 m upstream of the confluence of the Mackenzie River.

There is a culvert at this site associated with the winter road which is partially collapsed..

4.3.2.29 Crossing KM 752.6 – Bob's Canyon Creek

Bob's Canyon Creek is a tributary of the Mackenzie River. At the proposed crossing location, the channel width was 5.8 m and the wetted width was 4.8 m (Dessau, 2012). Substrate was boulder (40%), cobble (40%), and gravel (20%). Instream cover for fish was determined to be 70% (Dessau, 2012). Rearing habitat was rated as moderate, overwintering habitat was rated as low, and spawning habitat was rated as low (Dessau, 2012). The creek has been reported to freeze to the bottom (GNWT, 2010).

K'alo-Stantec assessed the proposed crossing location in 2020 approximately 50 m to the south from the location described in GNWT (2012). The proposed crossing is located approximately 200 m upstream from the confluence with the Mackenzie River. A large (7 m diameter) culvert is present at the existing winter road crossing location and was in good condition at the time of the assessment.

The channel at the road crossing location was 2.0 m wide with a wetted width of 1.8 m. Maximum depth was measured to be 0.48 m at the time of the assessment. The substrate was boulder (40%), fines (25%), small gravel (20%), and cobble (15%). Riparian vegetation was shrubs and grasses with deciduous trees. Cover was limited and provided by trees, shrubs, undercut banks, and instream woody debris.

Backpack electrofishing was not completed because it had been reported the creek was unlikely to provide fish habitat (GNWT, 2010). Overall, fish habitat potential was rated as poor due to the overall steep gradient (15% and 17% slopes near confluence with Mackenzie River). Spawning habitat was rated as poor for all fish species due to lack of suitable spawning substrate and surfaces (e.g., woody debris, instream vegetation). Overwintering habitat was rated a poor for all fish species because it is expected the watercourse freezes to the bottom in winter. Rearing habitat was rated as poor for forage fish and poor to moderate for coarse fish and sportfish. This was because, although there is cover for juvenile fish and substrates suitable for diverse benthic invertebrate production, the channel gradient is likely too steep for juvenile fish of most species. Passage was rated as poor for all fish species because of the two gradient impediments (15% and 17%) near the confluence with the Mackenzie River; also, there are some smaller cascades, which may be challenging for some smaller bodied fish to migrate past.

4.3.2.30 Crossing KM 752.8 – Drainage

This is an ephemeral drainage that does not provide fish habitat (Dessau, 2012). The drainage was a dry, vegetated gully during the assessment (Dessau, 2012). K'alo-Stantec did not assess the drainage in 2020 due to access or time constraints related to weather.

4.3.2.31 Crossing KM 765.5 – Unnamed Watercourse

There is no previous existing data at the proposed crossing location (Dessau, 2012). K'alo-Stantec assessed the proposed crossing location in 2020. At the proposed crossing location, the channel measured 1.5 m wide with a wetted width of 1.6 m. Wetted width was wider than channel width due to the presence of undercut banks. Maximum depth was 0.6 m at the time of the assessment. The substrate

was boulder (40%), cobble (20), fines (20%), organics (10%), and small gravel (10%). Riparian vegetation was grasses and shrubs with deciduous and coniferous trees. Cover was provided by overhanging trees, shrubs, woody debris, and instream boulders.

Backpack electrofishing was completed for 651 seconds; no fish were captured. Overall, fish habitat potential was rated as moderate. Spawning habitat was rated as poor to moderate for forage fish and coarse fish and poor for sportfish because of inappropriate substrate size (i.e., few gravels). Overwintering habitat was rated as poor for all fish species because the watercourse is likely to freeze to the bottom in winter. Rearing habitat was rated as good for all fish species due to the substrate complexity, which likely supports benthic invertebrate production, and cover is provided to juvenile fish from woody debris, undercut banks, instream boulders, and overhanging vegetation. Fish passage was rated as good for all fish species because there were no barriers to migration between the Mackenzie River and the proposed crossing location.

4.3.2.32 Crossing KM 767.2 – Unnamed Watercourse

There is no previous existing data at the proposed crossing location. The proposed crossing location was not assessed by K'alo-Stantec in 2020 due to difficulties accessing the site or time constraints related to weather.

4.3.2.33 Crossing KM 767.8 – Unnamed Watercourse

This watercourse, not previously reported, was identified during K'alo-Stantec's 2020 field program. The confluence of this unnamed tributary with the Mackenzie River is approximately 400 m downstream of the proposed crossing location. No formal fish and fish habitat assessment was completed because the crossing has similar morphology to the crossing at KM 765.51 (WX-045) and has connectivity with the Mackenzie River; the tributary was assumed to be fish-bearing.

4.3.2.34 Crossing KM 768.2 – Wetland Area

This wetland, not previously reported, was identified during K'alo-Stantec's 2020 field program. A beaver impoundment was observed, which extended onto the existing winter road. However, no inlet was observed. The beaver dam appears to be active. The substrate was organics. Riparian vegetation was wetland species. Maximum depth was greater than 2 m at the time of the assessment and, therefore, may not freeze to the bottom in winter. The wetland may afford fish habitat potential because it is close to the Mackenzie River and is unlikely to freeze to the bottom. Small-bodied fish may be able to migrate past the beaver dam to access the wetland.

4.3.2.35 Crossing KM 768.9 - Drainage

There is no previous existing data at the proposed crossing location (Dessau, 2012). At the proposed crossing location, an ephemeral drainage flows from west to east across the existing winter road. There were no defined banks approximately 25 m downslope of the existing winter road and water was flowing through grasses and sedges approximately 70 m downslope. There was intermittent channelization approximately 50 m upslope of the existing winter road crossing. This drainage is unlikely to support fish because it does not have connectivity to any other waterbodies that may be fish-bearing.

4.3.2.36 Crossing KM 769.7 - Drainage

There is no previous existing data at the proposed crossing location (Dessau, 2012). At the proposed crossing location is an ephemeral drainage oriented along the winter road. Standing water was present both upslope and downslope of the existing winter road. However, no defined channel or banks were observed. This drainage is unlikely to support fish due to its lack of connectivity with fish-bearing waterbodies.

4.3.2.37 Crossing KM 769.7 –Wetland Area

There is no previous existing data at the proposed crossing location (Dessau, 2012). A wetland area with a shallow pond was present adjacent to the project highway alignment. However, no outlet or inlet were observed. This wetland area is not considered fish habitat because of its lack of connectivity to any fish-bearing waterbodies.

4.3.2.38 Crossing KM 770.0 – Wetland Area

There is no previous existing data at the proposed crossing location (Dessau, 2012). A small pond and wetland area were present adjacent to the project highway alignment. However, no outlet or inlet were observed. The pond intrudes into the project highway corridor. The pond and wetland were not considered fish habitat because there was no observed connectivity with any fish-bearing waterbodies.

4.3.2.39 Crossing KM 770.6 – Wetland Area

This wetland, not previously reported, was identified during K'alo-Stantec's 2020 field program. The inlet to this wetland is an ephemeral drainage. The outlet drained the wetland to the west. The substrate in the wetland was organic material. Riparian vegetation was wetland species. Maximum depth was measured to be greater than 2 m. Minnow trapping was completed within the unclassified waterbody for 40 hours; no fish were captured. The wetland was assumed to provide fish habitat because it has an inlet and outlet and depth greater than 2 m, so is unlikely to freeze to the bottom in winter.

4.3.2.40 Crossing KM 772.8 - Drainage

At the proposed crossing location, an ephemeral drainage flows along and across the winter road Standing water was present on both sides of the road. However, there was no defined channel bed or stream banks on either side of the road. For this reason, this drainage is unlikely to support fish and was not considered fish habitat. The drainage is crossed by the MGP route (RPR-380 [IORVL, 2004]). Like the K'alo-Stantec assessment, no fish habitat was identified (IORVL, 2004).

4.3.2.41 Crossing KM 774.1 – Unnamed Watercourse

At the proposed crossing location, this unnamed tributary did not have a defined channel, and a beaver dam was present (Dessau, 2012). Overall fish habitat quality was determined to be low and unlikely to provide overwintering habitat due to shallow water depths (Dessau, 2012). Potential rearing and feeding habitat were observed approximately 50 m downstream of the proposed crossing location (Dessau, 2012).

The watercourse is crossed by the MGP route (RPR-379 [IORVL, 2004]). The report described the channel width as ranging between 1.2 m and 4.2 m with a wetted width of 3 m and a maximum depth of 0.4 m. However, most of the watercourse was less than 0.3 m deep (IORVL, 2004). Habitat was shallow runs with riffles and pools accounting for approximately 20% of the total available habitat. Substrate was coarse gravel and cobble but was moderately embedded with fine material. Cover was provided by woody debris, overhanging vegetation, and boulders in riffles. Riparian vegetation was grass, forbs, and shrubs within a deciduous forest. A fish inventory was completed in the spring and summer; one Arctic grayling was captured in the spring and one juvenile longnose sucker was captured in the summer (IORVL, 2004).

K'alo-Stantec assessed the proposed crossing location in 2020. At the proposed crossing location, the channel was 4.1 m wide with a wetted width of 4.3 m. Wetted width was wider than channel width due the presence of undercut banks. Maximum depth at the proposed crossing was 0.6 m at the time of the assessment. The substrate was boulder (40%), cobble (30%), fines (15%), organics (10%), and large gravel (5%). Riparian vegetation was shrubs and grass with deciduous and coniferous trees. Cover was limited and provided by woody debris and instream boulders. The dominant habitat throughout the assessed area was run habitat . No fish inventory was conducted because fish presence was known.

Overall, fish habitat was rated as moderate. Spawning habitat was rated as poor for all fish species due to a lack of suitable substrates and limited instream vegetation and woody debris. Overwintering habitat was rated as poor for all species. Although pools were observed throughout the assessed area, their depths were shallow and the watercourse likely freezes to or near the bottom. Rearing habitat was rated as moderate for all fish species because the substrate is suitable for benthic invertebrate production and there is instream and overhead cover for juvenile fish. Passage was rated as good for all fish species with no barriers to fish passage observed between the Mackenzie River and the proposed crossing location.

4.3.2.42 Crossing KM 780.9 – Drainage

At the proposed crossing location, there were no defined stream banks, and the crossing is located on an ephemeral drainage (Dessau, 2012; IORVL, 2004). Flow is expected to occur only during the spring run-off and be dry for the rest of the year (Dessau, 2012). There is no fish habitat potential at this location (Dessau, 2012; IORVL, 2004). K'alo-Stantec did not assess this crossing in 2020 due to access or time constraints related to weather.

4.3.2.43 Crossing KM 785.3 – Drainage

At the proposed crossing location, there was no defined channel and there were no channel substrates or surface flow (Dessau, 2012). A barrier to fish passage, a 2 m vertical drop near the crossing location, was observed (Dessau, 2012). The drainage does not provide fish habitat (Dessau, 2012). K'alo-Stantec did not assess this crossing in 2020 due to access or time constraints related to weather.

4.3.2.44 Crossing KM 787.3 – Drainage

There is no suitable fish habitat present at this site and the crossing is a dry, vegetated gully at the proposed crossing location (Dessau, 2012). K'alo-Stantec did not assess the crossing in 2020.

4.3.2.45 Crossing KM 789.0 (SWA-5) - Wetland Area

There is no previous existing data at the proposed crossing location (Dessau, 2012). A wetland area was present adjacent to the project highway alignment. No outlet or inlet were observed connecting the wetland to another waterbody. This wetland area is not considered fish habitat because it does not have connectivity to a fish-bearing waterbody.

4.3.2.46 Crossing KM 789.4 - Wetland Area

There is no previous existing data at the proposed crossing location (Dessau, 2012). A wetland area with a small waterbody was present adjacent to the project highway alignment. No outlet or inlet were observed connecting the wetland to another waterbody. This wetland is not considered fish habitat because there is no connectivity to a fish-bearing waterbody.

4.3.2.47 Crossing KM 791.2 - Wetland Area

There is no previous existing data at the proposed crossing location (Dessau, 2012). A wetland area with a small shallow waterbody is present adjacent to the project highway alignment. No outlet or inlet were observed connecting the wetland to another waterbody. This wetland is not considered fish habitat because there is no connectivity to a fish-bearing waterbody.

4.3.2.48 Crossing KM 791.8 - Wetland Area

There is no previous existing data at the proposed crossing location (Dessau, 2012). A wetland area with a small shallow waterbody and several smaller ponds were present adjacent to the project highway alignment. No outlet or inlet were observed. This wetland area is not considered fish habitat because there is no connectivity to a fish-bearing waterbody.

4.3.2.49 Crossing KM 793.1 - Wetland Area

There is no previous existing data at the proposed crossing location (Dessau, 2012). The area is crossed by the MGP route (RPR-376 [IORVL, 2004]). The crossing to be vegetated and did not provide fish habitat.

A wetland area was present adjacent to the project highway alignment in 2020. An outlet draining to the Mackenzie River was difficult to identify. Instead, large shallow ponded areas surrounded by wetland vegetation were visible. The Substrate was entirely organic material. A culvert (900 millimetres [mm] diameter) was placed across the existing winter road between two wetland areas. Some flow was observed in the culvert during the site visit. Minnow trapping (87 hours of effort) captured 120 brook stickleback and 60 fathead minnows. Therefore, this wetland area does provide fish habitat, at least for forage fish species.

5 Summary

All permanent watercourses that are proposed to be crossed by the Project drain into the Mackenzie River. There are 33 fish species within the RSA, which includes the Mackenzie River. However, not all species are expected to utilize every watercourse that would be crossed by the project highway alignment (e.g., chum salmon). Two species, Bull trout and Dolly Varden, are listed under Schedule 1 of the *Species at Risk Act* as a species of “special concern” and are also ranked as “sensitive” under the Northwest Territories Species Ranking. Inconnu and Arctic cisco are also considered “sensitive” under the NT Species Ranking; however, no additional regulatory restrictions apply to this species because of these listings.

Two species of fish, finescale dace and pearl dace captured in field assessments in the Sahtu Settlement Area represent northern range extensions for these two species.

Based on a desktop review of existing information and field assessments, 39 of the 43 potential watercourse and wetland crossings within the Sahtu Region were found to provide fish habitat or have the potential to provide fish habitat. It is unlikely four other unnamed watercourses to be crossed by the project highway alignment could provide fish habitat. Most of the watercourses that have the potential to provide fish habitat would likely only support forage fish species.

In the Dehcho Region, desktop assessments of 49 watercourses or wetlands were conducted and augmented by field assessments conducted in September 2020. Field assessments focused on locations where there was not an existing crossing structure. There were 25 watercourses assessed in the field. Of the 49 watercourses and wetlands 18 were unlikely to provide fish habitat and another 5 are unknown whether they provide fish habitat as there is no previous data on these watercourses and field assessments have not been conducted at this time. All other watercourses are known to provide fish habitat or have the potential to provide fish habitat. Most of the watercourses that have the potential to provide fish habitat would likely only support forage fish species.

6 Closure

This TDR was prepared for the sole benefit of GNWT to describe existing conditions related to fish and fish habitat within the Project LSA and RSA. If you have any questions, please do not hesitate to contact the undersigned.

Respectfully submitted,

K'alo-Stantec Limited

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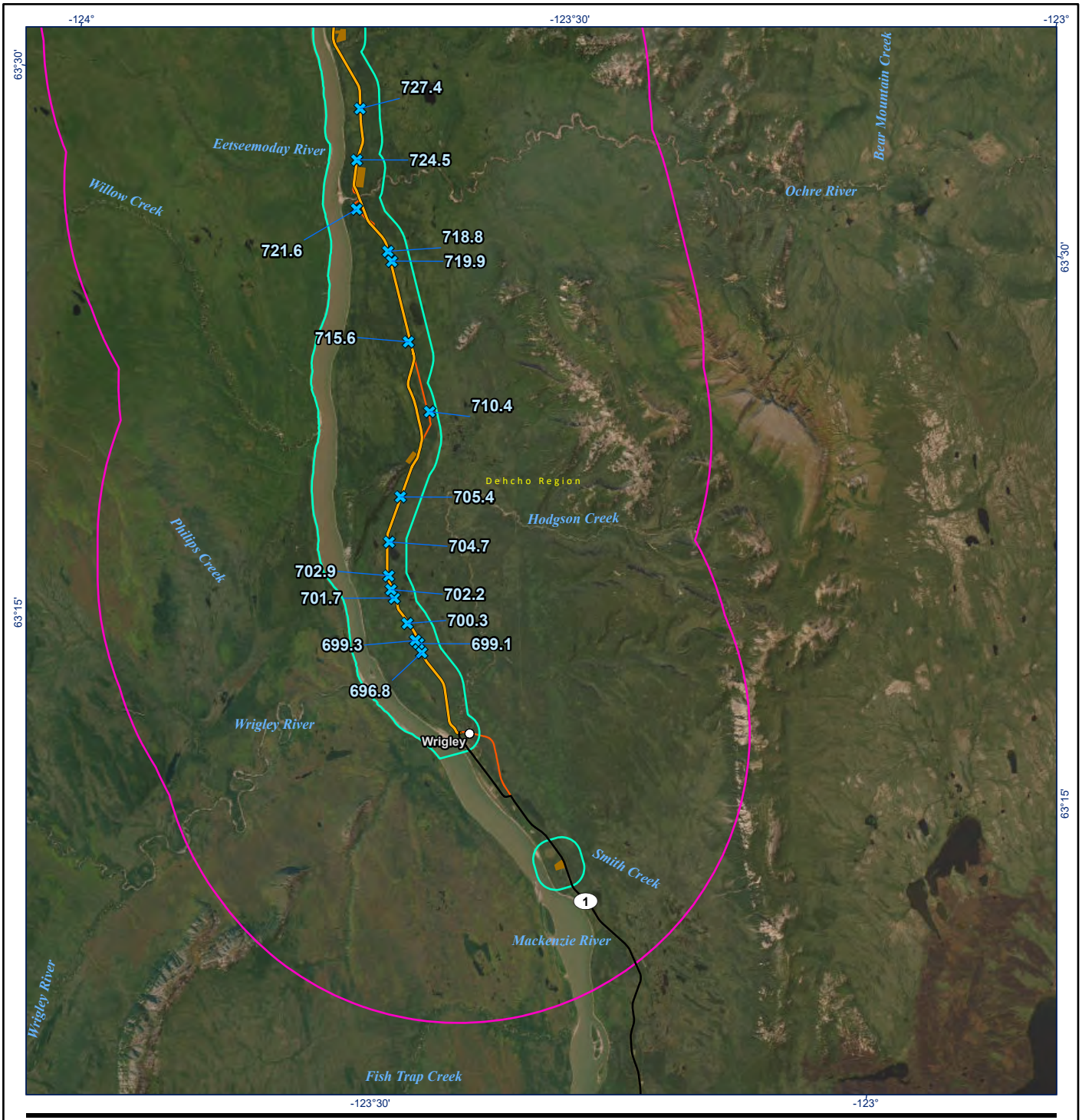
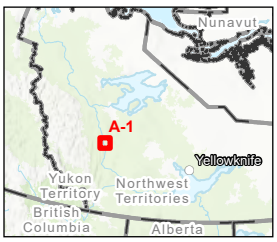
Appendix A Watercourse Crossing Locations





- Assessed Proposed Watercourse Crossing
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- Prohibition Creek Access Road
- Proposed Great Bear River Bridge Project
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 2.5 5 Kilometres

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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0067-REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.1

Title
Assessed Proposed Watercourse Crossings
Sites Km 727.4 to Km 699.1

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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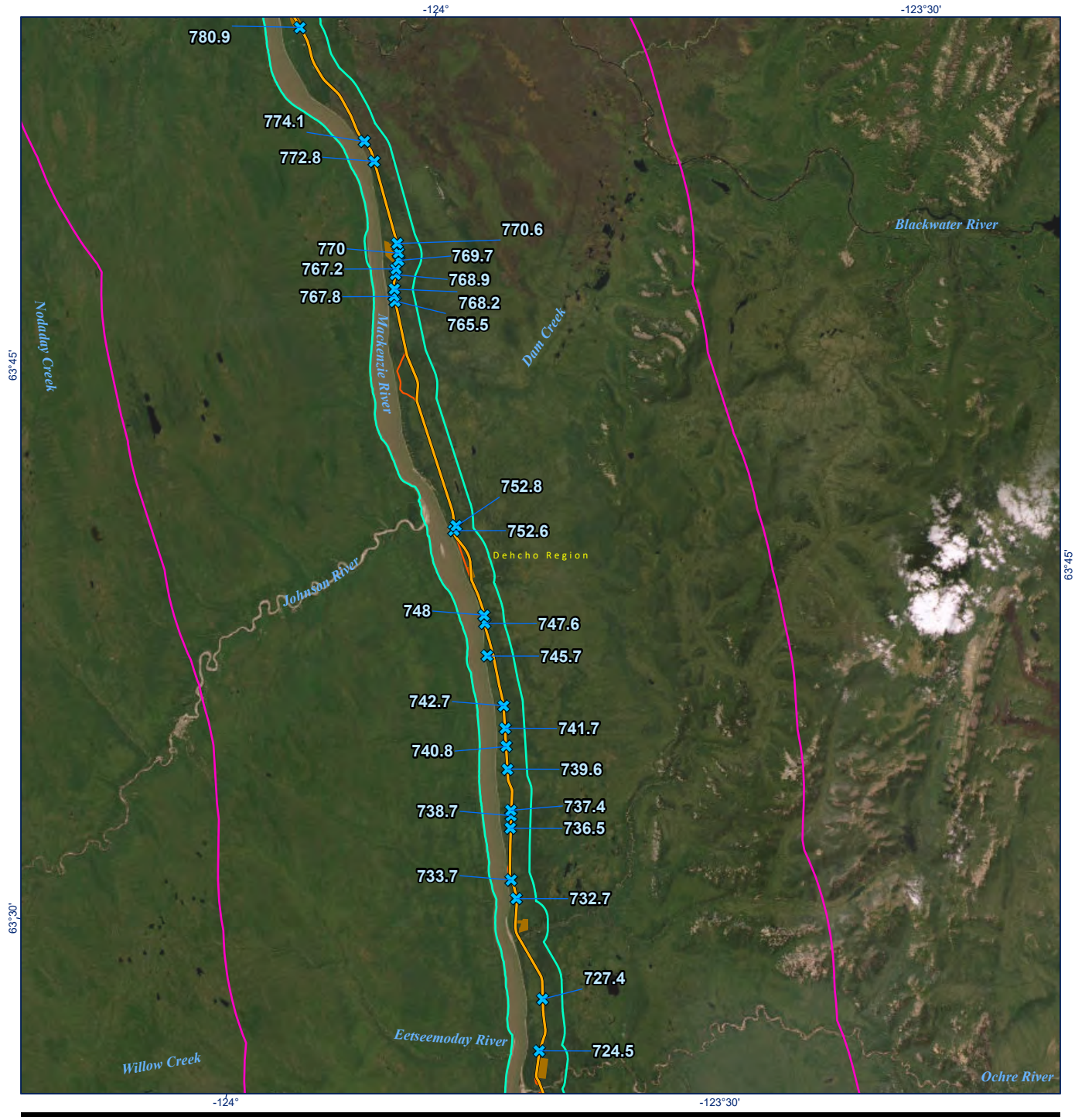

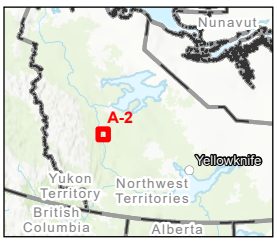

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Figure No.
A.2

Title
Assessed Proposed Watercourse Crossings
Sites Km 780.9 to Km 724.5

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
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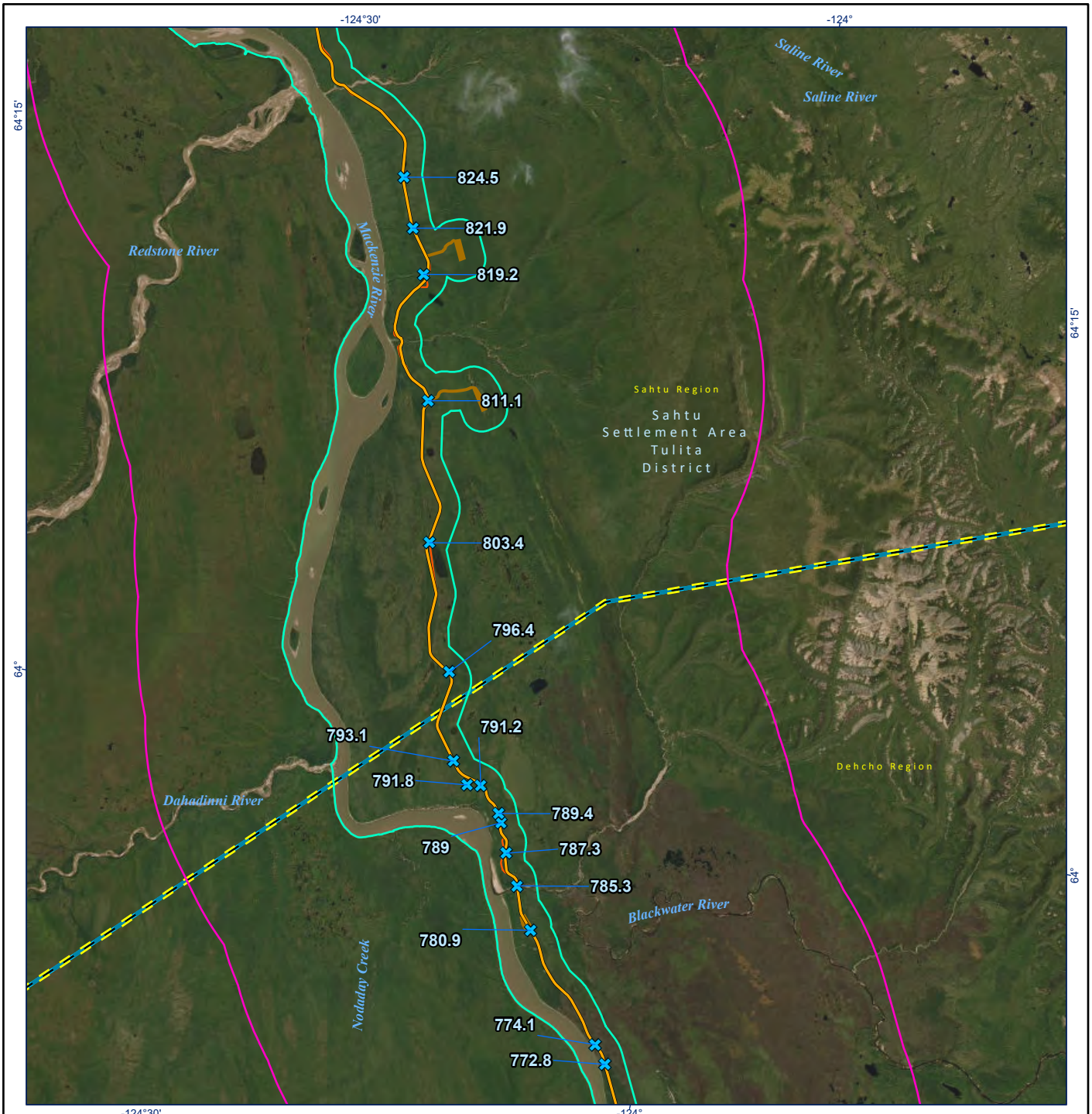

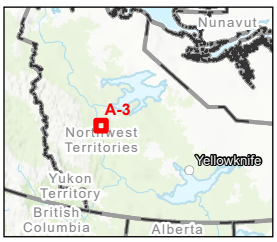

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Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.3

Title
Assessed Proposed Watercourse Crossings
Sites Km 824.5 to Km 774.1

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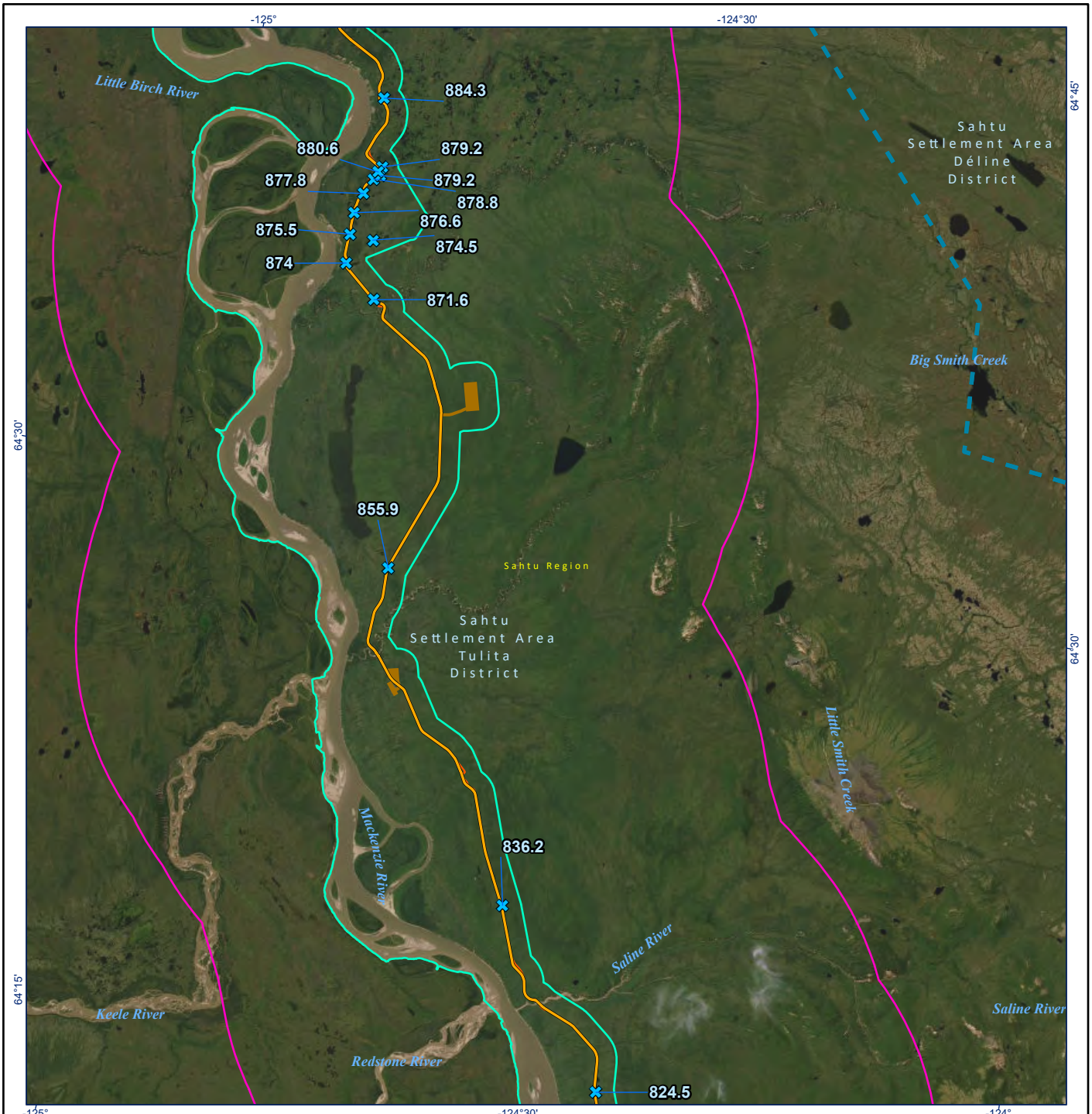

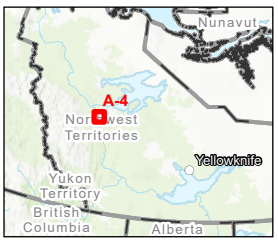

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Project Location
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Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0067-REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.4

Title
Assessed Proposed Watercourse Crossings
Sites Km 884.3 to Km 824.5

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
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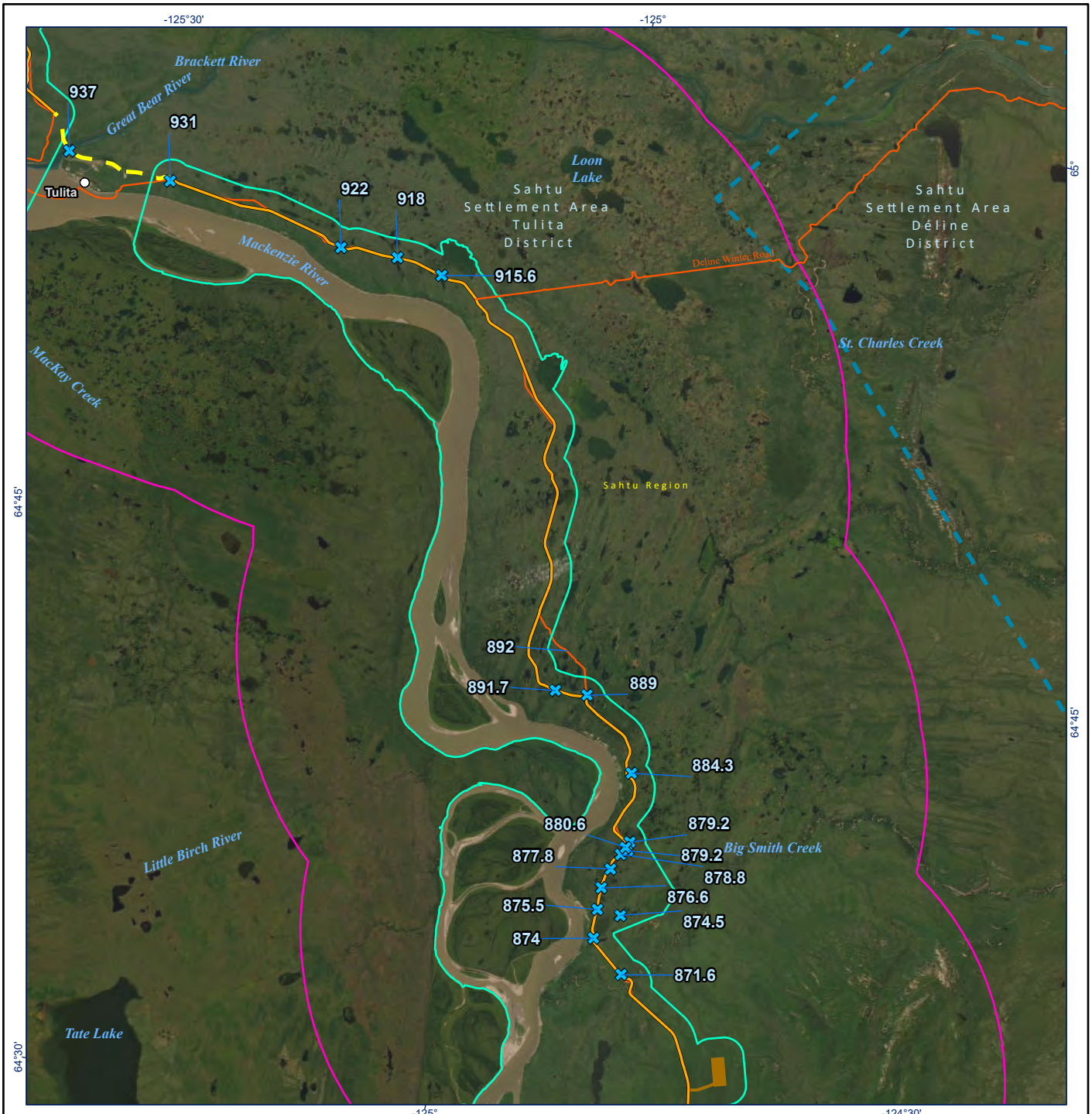
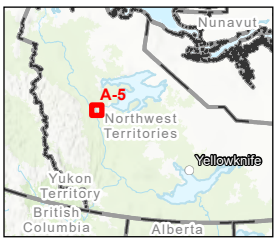




- Assessed Proposed Watercourse Crossing
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- Prohibition Creek Access Road
- Proposed Great Bear River Bridge Project
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 2.5 5 Kilometres

(At original document size of 8.5x11)
1:300,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0067-REVC

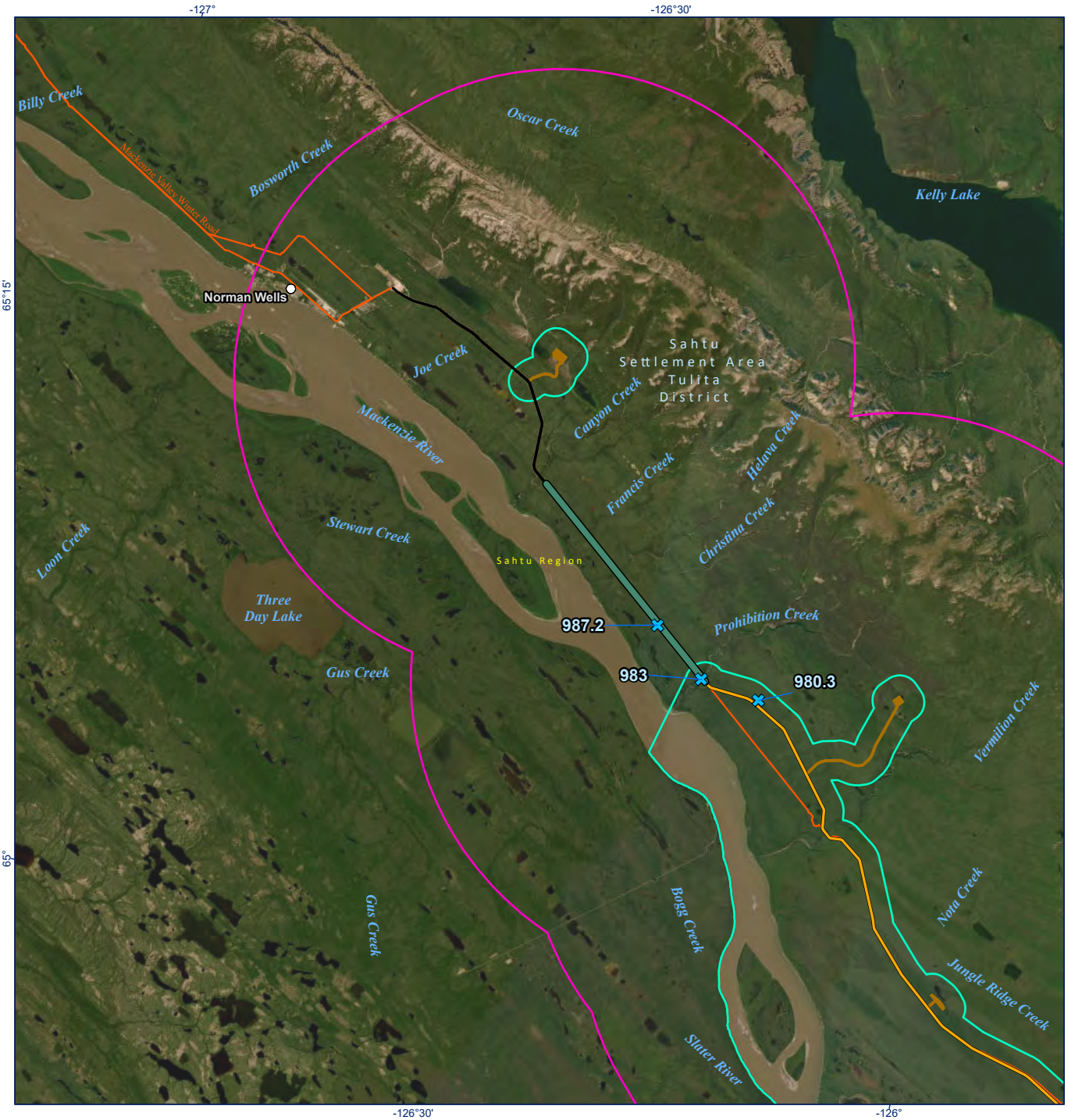
Government of Northwest Territories
Mackenzie Valley Highway Project

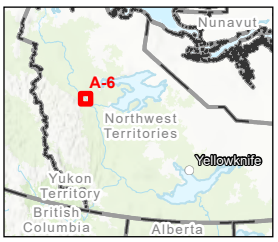
Figure No.
A.5

Title
Assessed Proposed Watercourse Crossings
Sites Km 937 to Km 871.6

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.





- Assessed Proposed Watercourse Crossing
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
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0 2.5 5 Kilometres

(At original document size of 8.5x11)
1:300,000

N

Kálo-Stantec

Notes

1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0067-REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.6

Title
Assessed Proposed Watercourse Crossings
Sites Km 987.2 to Km 980.3

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Appendix B Station Location Maps and Summary Sheets – Sahtu Settlement Area

Mackenzie Valley Highway

Site 797.9 Unnamed Watercourse

UTM Location: 10W 437740 7101829 **Survey Date:** 10/1/2021; 10:55

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)		2 (↑50)		3 (CL)		4 (↓100)		5 (↓200)		6 (↓300)	
Channel Width (m)	4.1		5.8		4.3		13.0		16.8		-	
Wetted Width (m)	2.7		3.7		3.7		7.1		5.6		-	
Depth at LDB + 25% (m)	0.4		0.3		0.9		0.9		0.2		-	
Depth at LDB + 50% (m)	0.3		0.6		0.9		1.2		0.4		-	
Depth at LDB + 75% (m)	0.3		0.6		0.5		0.8		0.4		-	
Max.BankfullDepth (m)	1.3		1.0		1.2		0.90		0.72		-	
Gradient (%)	1		1		1		1		1		-	
Dominant Habitat Unit	DD		FL		FL		FL		DD		WL	
Stream Bed												
Substrate (% of Transect Area) Organics	50		20		40		30		60		100	
Fines	50		80		60		70		30		0	
Small Gravel	0		0		0		0		0		0	
Large Gravel	0		0		0		0		0		0	
Cobble	0		0		0		0		0		0	
Boulder	0		0		0		0		0		0	
Bedrock	0		0		0		0		0		0	
Embeddedness	N		N		N		N		N		N	
Bank Measurements	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Bank Height (m)	0.9	1.0	1.0	0.6	0.2	0.2	0.3	0.3	0.4	0.3	-	-
Bank Slope (°)	90	60	50	50	90	60	30	30	80	50	-	-
Bank Stability	US	US	MS	MS	S	S	S	S	MS	MS	-	-
Dom. Bank Material	F	F	F	F	F	F	O	F	O	F	-	-
Subdom. Bank Material	O	O	O	O	O	O	F	O	F	BL	-	-
Dom. Riparian Veg.	G	G	G	G	G	G	G	G	C	M	G	G
Subdom. Riparian Veg.	S	S	G	D	G	G	M	C	G	G	G	G

Habitat Inventory / Reach Data

Instream Cover (%):	30	Overhead Cover (%):	10
Dom. Instream Cover:	WD	Dom. Overhead Cover:	C
Subdom. Instream Cover:	G	Subdom. Overhead Cover:	S
Maximum Depth (m)	1.2	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	10:55
Water Temperature (°C):	4.5
Dissolved Oxygen (mg/L):	10.49
Sp. Conductivity (µs/cm):	339
pH:	7.50
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	IR
Islands:	O
Bars:	N
Coupling:	PC
Confinement:	OC
Flow Stage:	Flood

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	None-Poor	None-Poor
Overwintering:	Poor-Moderate	Poor-Moderate	Poor-Moderate
Rearing:	Good	Good	Moderate
Passage:	Moderate-Good	Moderate-Good	Moderate-Good

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
Minnow Trap (MT)	72.0	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
BROOK STICKLEBACK	-	13	-	0.18	2.5%
PEARL DACE	-	20	-	0.28	3.9%
-	-	1	-	0.01	0.2%
FINESCALE DACE	-	477	-	6.63	93.3%

General Comments

Grasses in stream, slight undercutting and exposed roots on left bank 100 m upstream. Logjams upstream and downstream of crossing. Occasional vegetation bars. Crossing was cleared for winter road, abundant grasses instream. Old beaver dam 300m downstream prior to wetland area. Could not measure some aspects due to flooding. The one fish not identified in the table is tentatively as Northern redbelly dace.

Mackenzie Valley Highway

Site 812.7 Unnamed Watercourse

UTM Location: 10W 434329 7115337 **Survey Date:** 10/1/2021; 16:17

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	-	1.3	1.37	1.18	1.6	1.8
Wetted Width (m)	-	0.76	1.12	0.75	0.75	1
Depth at LDB + 25% (m)	-	0.13	0.18	0.38	0.13	0.09
Depth at LDB + 50% (m)	-	0.21	0.14	0.51	0.17	0.09
Depth at LDB + 75% (m)	-	0.25	0.11	0.57	0.19	0.09
Max.BankfullDepth (m)	-	0.55	0.7	0.95	0.75	0.56
Gradient (%)	1	1	1	1	2	3
Dominant Habitat Unit	R2	R3	FL	FL	R2	RF
Stream Bed						
Substrate (% of Transect Area) – Organics	100	30	50	0	0	0
Substrate (% of Transect Area) – Fines	0	20	50	30	10	20
Substrate (% of Transect Area) – Small Gravel	0	50	0	40	30	30
Substrate (% of Transect Area) – Large Gravel	0	0	0	0	10	40
Substrate (% of Transect Area) – Cobble	0	0	0	10	50	10
Substrate (% of Transect Area) – Boulder	0	0	0	0	0	0
Substrate (% of Transect Area) – Bedrock	0	0	0	20	0	0
Embeddedness	N	M	N	L	N	L

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	-	-	0.3	0.3	0.5	0.6	0.5	0.4	0.6	0.6	0.43	0.52
Bank Slope (°)	-	-	90	70	80	80	80	80	70	75	50	45
Bank Stability	-	-	S	S	S	S	MS	MS	MS	MS	S	S
Dom. Bank Material	O	O	SG	SG	O	O	F	F	SG	SG	F	F
Subdom. Bank Material	F	F	O	O	F	F	O	O	F	F	O	O
Dom. Riparian Veg.	D	D	D	D	S	S	D	D	D	D	D	D
Subdom. Riparian Veg.	S	S	S	S	D	D	S	S	S	S	S	S

Habitat Inventory / Reach Data

Instream Cover (%):	30	Overhead Cover (%):	70
Dom. Instream Cover:	Co	Dom. Overhead Cover:	M
Subdom. Instream Cover:	UCB	Subdom. Overhead Cover:	S
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	16:17
Water Temperature (°C):	0.1
Dissolved Oxygen (mg/L):	12.53
Sp. Conductivity (µs/cm):	435
pH:	7.74
Turbidity (NTU):	CLEAR

Channel Characteristics

Pattern:	IR
Islands:	N
Bars:	N
Coupling:	DC
Confinement:	FC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Good	Poor	Poor
Overwintering:	None-Poor	None-Poor	None-Poor
Rearing:	Good	Good	Moderate
Passage:	Moderate-Good	Moderate	Moderate

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB)	263	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
225	30	12	150

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED	-	-	-	-	-
	-	-	-	-	
	-	-	-	-	
	-	-	-	-	
	-	-	-	-	

General Comments

This channel had excellent spawning potential, and consisted of good fish habitat. There is a small change in grade near 300 m downstream but this would not affect fish passage. There is woody debris throughout and some minor logjam which may creat partial barriers to fish passage. There is trace undercut banks upstream, and channel becomes poorly defined with low water depths at 100 m upstream. There were several beaver dams at this site. One at the crossing on the downstream side of centerline, one at a tributary to the channel approximately 50 m upstream, and one further upstream the tributary watercourse (however, this channel was dry). The second channel goes runs parallel to the winter road and goes subsurface near an abandoned and dry beaver dam.

Mackenzie Valley Highway

Site 815 Unnamed Watercourse

UTM Location: 10W 432721E 7117031N **Survey Date:** 10/2/2021; 13:05

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.8	2.4	1.9	1.8	2.5	-
Wetted Width (m)	1.3	1.0	1.4	1.0	0.6	-
Depth at LDB + 25% (m)	0.1	0.1	0.1	0.0	0.0	-
Depth at LDB + 50% (m)	0.1	0.1	0.1	0.0	0.1	-
Depth at LDB + 75% (m)	0.1	0.0	0.1	0.0	0.0	-
Max.BankfullDepth (m)	0.5	0.6	0.4	0.4	0.1	-
Gradient (%)	-	-	-	-	-	-
Dominant Habitat Unit	R2	DD	R2	IP1	WL	-
Stream Bed						
Substrate (% of Transect Area) Organics	0	0	10	10	90	-
Fines	30	0	60	10	10	-
Small Gravel	30	20	20	40	0	-
Large Gravel	20	40	0	20	0	-
Cobble	20	40	10	20	0	-
Boulder	0	0	0	0	0	-
Bedrock	0	0	0	0	0	-
Embeddedness	L	N	L	M	H	-

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.3	-	-	-	-
Bank Slope (°)	70	60	30	80	50	30	90	90	-	-	-	-
Bank Stability	MS	MS	MS	MS	MS	MS	MS	MS	-	-	-	-
Dom. Bank Material	O	O	F	F	O	F	SG	F	SG	F	-	-
Subdom. Bank Material	F	F	O	O	SG	SG	O	O	O	O	-	-
Dom. Riparian Veg.	S	S	S	S	S	S	D	D	D	D	-	-
Subdom. Riparian Veg.	C	D	G	G	G	G	S	S	S	S	-	-

Habitat Inventory / Reach Data

Instream Cover (%):	30	Overhead Cover (%):	80
Dom. Instream Cover:	WD	Dom. Overhead Cover:	S
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	G
Maximum Depth (m)	-	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	13:05
Water Temperature (°C):	2.3
Dissolved Oxygen (mg/L):	12.13
Sp. Conductivity (µs/cm):	760
pH:	8.37
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	ME
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	FC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor-Moderate	Poor	None-Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Poor-Moderate	Poor-Moderate	None-Poor
Passage:	Poor-Moderate	Poor	Poor

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings			
Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

Fish habitat is poor, unlikely to hold fish due to lack of outlet downstream (converts to wetland) and logjams upstream. Crossing is eroded with two culverts that are not in line with watercourse. Not deep enough for minnow traps and too much woody debris/ too narrow for electrofishing. Not suitable for fish due to woody debris barriers throughout crossing section and poor connectivity. Minor undercutting of banks upstream.

TETRA TECH

Mackenzie Valley Highway

Site 820.7 Unnamed Watercourse

UTM Location: 10W 433131 7121700 **Survey Date:** 10/6/2021; 14:00

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)		2 (↑50)		3 (CL)		4 (↓100)		5 (↓200)		6 (↓300)	
Channel Width (m)	3.4		13.5		15.5		95.0		7.1		3.2	
Wetted Width (m)	3.4		4.9		11.6		25.0		4.9		1.2	
Depth at LDB + 25% (m)	0.1		0.1		0.2		0.2		0.4		0.1	
Depth at LDB + 50% (m)	0.2		0.1		0.2		0.2		0.5		0.1	
Depth at LDB + 75% (m)	0.1		0.1		0.3		0.3		0.4		0.1	
Max.BankfullDepth (m)	0.0		1.3		0.7		2.0		1.0		0.5	
Gradient (%)	2		2		1		1		1		2	
Dominant Habitat Unit	FL		FL		IP1		IP1		IP1		BD	
Stream Bed												
Substrate (% of Transect Area) Organics	100		30		100		60		100		0	
Fines	0		0		0		40		0		25	
Small Gravel	0		30		0		0		0		20	
Large Gravel	0		20		0		0		0		25	
Cobble	0		10		0		0		0		10	
Boulder	0		10		0		0		0		20	
Bedrock	0		0		0		0		0		0	
Embeddedness	N		H		N		N		N		H	
Bank Measurements	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Bank Height (m)	0.0	0.2	0.4	1.3	0.2	0.4	0.3	0.3	0.2	0.5	0.20	0.20
Bank Slope (°)	10	10	15	3	10	40	10	30	30	40	30	70
Bank Stability	US	US	MS	US	MS	S	MS	MS	MS	MS	US	US
Dom. Bank Material	O	O	O	O	O	O	O	O	F	F	F	SG
Subdom. Bank Material	F	F	F	F	F	F	F	F	O	O	O	LG
Dom. Riparian Veg.	S	S	G	G	G	G	G	G	G	G	G	G
Subdom. Riparian Veg.	G	G	S	S	S	C	M	M	D	G	G	G

Instream Cover (%):	10	Overhead Cover (%):	5
Dom. Instream Cover:	G	Dom. Overhead Cover:	C
Subdom. Instream Cover:	EV	Subdom. Overhead Cover:	-
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Quality Data		Channel Characteristics	
Time of Day (HH:MM):	14:01	Pattern:	ME
Water Temperature (°C):	2.3	Islands:	O
Dissolved Oxygen (mg/L):	10.47	Bars:	N
Sp. Conductivity (µs/cm):	731	Coupling:	DC
pH:	7.72	Confinement:	OC
Turbidity (NTU):	Clear	Flow Stage:	Pooled

Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor-Moderate	None	None
Overwintering:	Poor	Poor	None-Poor
Rearing:	Moderate	Poor	None-Poor
Passage:	Moderate	Poor-Moderate	Poor-Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
Minnow Trap (MT)	50.0	(hr)

Electrofisher Settings			
Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					

General Comments

Poorly defined channel within floodplain with pockets of grasses throughout. Upstream of 300 m downstream is a beaver dam. There was limited crown cover due to flooded region, which likely fills during freshet. Aquatic vegetation growing throughout. Exposed culvert along winter road.

Mackenzie Valley Highway

Site 821.9 Unnamed Watercourse

UTM Location: 10W 432580 7123103 **Survey Date:** 10/9/2021; 11:13

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.2	1.5	1.3	1.4	1.2	2.1
Wetted Width (m)	1.3	1.3	0.9	1.0	0.2	0.9
Depth at LDB + 25% (m)	0.1	0.2	0.4	0.0	0.0	0.1
Depth at LDB + 50% (m)	0.3	0.3	0.4	0.2	0.0	0.1
Depth at LDB + 75% (m)	0.3	0.2	0.4	0.1	0.0	0.1
Max.BankfullDepth (m)	0.57	0.49	0.71	0.70	0.23	0.68
Gradient (%)	2	2	1	2	2	1
Dominant Habitat Unit	P3	IP3	R2	R2	DR	FL
Stream Bed						
Substrate (% of Transect Area) Organics	20	40	0	0	40	30
Fines	30	0	50	0	30	40
Small Gravel	50	60	30	100	30	30
Large Gravel	0	0	20	0	0	0
Cobble	0	0	0	0	0	0
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	N	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.3	0.2	0.2	0.2	0.3	0.3	0.5	0.5	0.1	0.2	0.6	0.6
Bank Slope (°)	40	60	90	90	30	20	90	100	45	45	30	30
Bank Stability	US	US	US	US	MS	MS	US	US	MS	MS	MS	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	S	S	S	M	S	S	D	D	S	S	C	S
Subdom. Riparian Veg.	D	D	M	S	G	G	D	D	D	D	S	C

Habitat Inventory / Reach Data

Instream Cover (%):	-	Overhead Cover (%):	30
Dom. Instream Cover:	-	Dom. Overhead Cover:	WD
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	S
Maximum Depth (m)	0.4	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	11:13
Water Temperature (°C):	1.4
Dissolved Oxygen (mg/L):	7.52
Sp. Conductivity (µs/cm):	1,097
pH:	7.78
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	ST
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	OC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	Moderate	Moderate
Overwintering:	Poor	Poor	Poor
Rearing:	Good	Good	Moderate
Passage:	Moderate-Good	Moderate-Good	Moderate-Good

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Some sign of grasses under snow as well. Undercut on left bank occasionally in upstream reach. Abundant woody debris and leaves resting on top of sediment throughout, Dry channel between 100 m and 200 m downstream, frozen to bed and not enough flow. Debris buildup occasionally thoughout,the watercourse creating potential barriers to fish. Woody debris overhanging throughout. No fishing conducted due to freezing conditions..

TETRA TECH

Km 823

Mackenzie Valley Highway

Site 823 Unnamed Watercourse

UTM Location: 10W 431979 7123968 **Survey Date:** 10/6/2021; 16:00

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.9	1.3	0.2	0.2	0.1	0.0
Wetted Width (m)	2.5	1.0	0.1	0.0	0.1	0.0
Depth at LDB + 25% (m)	2.2	1.7	0.2	0.2	0.3	0.0
Depth at LDB + 50% (m)	3.0	1.0	0.1	0.2	0.1	0.0
Depth at LDB + 75% (m)	1.7	1.4	0.4	0.4	0.3	0.0
Max.BankfullDepth (m)	4.1	2.3	0.97	0.84	0.77	0.43
Gradient (%)	3	2	2	2	1	1
Dominant Habitat Unit	R1	RF	R1	R1	R1	R1
Stream Bed						
Substrate (% of Transect Area) — Organics	0	0	0	0	0	0
Substrate (% of Transect Area) — Fines	0	0	0	10	40	0
Substrate (% of Transect Area) — Small Gravel	0	0	0	30	20	10
Substrate (% of Transect Area) — Large Gravel	20	30	30	40	30	20
Substrate (% of Transect Area) — Cobble	30	30	30	20	0	60
Substrate (% of Transect Area) — Boulder	45	39	30	0	10	10
Substrate (% of Transect Area) — Bedrock	5	1	20	0	0	0
Embeddedness	L	L	N	L	L	L

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.8	1.1	0.6	0.4	0.6	0.4	0.4	0.4	0.5	0.4	0.4	0.4
Bank Slope (°)	90.0	80.0	65.0	40.0	80.0	80.0	30.0	60.0	80.0	60.0	30.0	70.0
Bank Stability	MS	MS	MS	MS	MS	MS	MS	MS	US	US	MS	MS
Dom. Bank Material	F	F	O	O	F	F	F	F	O	O	O	O
Subdom. Bank Material	O	O	F	F	O	O	O	O	F	F	F	F
Dom. Riparian Veg.	D	C	S	S	S	S	S	S	S	S	S	S
Subdom. Riparian Veg.	S	S	C	C	C	C	M	M	C	C	C	C

Habitat Inventory / Reach Data

Instream Cover (%):	40	Overhead Cover (%):	60
Dom. Instream Cover:	Co	Dom. Overhead Cover:	S
Subdom. Instream Cover:	UCB	Subdom. Overhead Cove	C
Maximum Depth (m)	3.0	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	16:00
Water Temperature (°C):	0.3
Dissolved Oxygen (mg/L):	11.60
Sp. Conductivity (µs/cm):	1,123
pH:	8.14
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	ST
Islands:	I
Bars:	N
Coupling:	CO
Confinement:	OC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate-Good	Poor-Moderate	Poor
Overwintering:	None-Poor	None-Poor	None-Poor
Rearing:	Good	Good	Moderate
Passage:	Moderate-Good	Moderate-Good	Moderate-Goo

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundanc (% of total)

General Comments

Low water levels at time of assessment and was mostly frozen. Abundant woody debris and logjams throughout reach, some bank erosion and some undercut banks. No fishing was conducted due to freezing and frozen conditions.

TETRA TECH

Mackenzie Valley Highway

Site 826 Unnamed Watercourse

UTM Location: 10W 431007 7126445 **Survey Date:** 10/8/2021; 13:37

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	3.0	0.8	1.8	1.3	1.0	1.0
Wetted Width (m)	2.1	0.6	1.1	0.6	0.8	0.6
Depth at LDB + 25% (m)	0.2	0.3	0.3	0.0	0.2	0.1
Depth at LDB + 50% (m)	0.2	0.3	0.3	0.1	0.2	0.1
Depth at LDB + 75% (m)	0.2	0.2	0.2	0.2	0.2	0.1
Max.BankfullDepth (m)	0.54	0.51	0.69	0.34	0.46	0.48
Gradient (%)	2	2	2	3	4	4
Dominant Habitat Unit	FL	R3	R3	DD	DD	DD
Stream Bed						
Substrate (% of Transect Area) — Organics	0	0	60	100	100	100
Fines	100	100	40	0	0	0
Small Gravel	0	0	0	0	0	0
Large Gravel	0	0	0	0	0	0
Cobble	0	0	0	0	0	0
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	N	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.3	0.4	0.2	0.2	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.4
Bank Slope (°)	45	60	45	45	80	90	10	10	80	50	50	50
Bank Stability	MS	US	MS	MS	MS	MS	US	US	US	US	US	US
Dom. Bank Material	O	O	O	O	F	F	O	O	O	O	F	O
Subdom. Bank Material	F	F	F	F	O	O	F	F	F	F	O	F
Dom. Riparian Veg.	G	G	G	G	G	G	S	S	S	S	S	S
Subdom. Riparian Veg.	S	S	S	S	S	S	G	G	G	G	G	G

Habitat Inventory / Reach Data

Instream Cover (%):	80	Overhead Cover (%):	80
Dom. Instream Cover:	WD	Dom. Overhead Cover:	WD
Subdom. Instream Cover:	DP	Subdom. Overhead Cove	-
Maximum Depth (m)	0.3	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	13:40
Water Temperature (°C):	2.0
Dissolved Oxygen (mg/L):	11.82
Sp. Conductivity (µs/cm):	439
pH:	7.82
Turbidity (NTU):	..ightly Turbi

Channel Characteristics

Pattern:	ME
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	OC
Flow Stage:	Pooled

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate-Good	None	None
Overwintering:	Moderate-Good	Moderate	Poor-Moderate
Rearing:	Moderate-Good	Moderate-Good	Moderate-Goo
Passage:	Moderate	Moderate	Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
Minnow Trap (MT)	44.7	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundanc (% of total)
NO FISH CAPTURED					

General Comments

Upstream has a ponded area that may provide good overwintering habitat. The channel is irregular with poor connectivity upstream of centerline with limited overhanging vegetation and subsurface flow around historic beaver dam.

Downstream has abundant woody debris over channel and good cover from shrubs. There is evidence that there was a fire previously here. Approximately 200 m downstream, banks are unstable with occasional erosion throughout stretch. Most of the overhanging vegetation is shrubs.

TETRA TECH

Mackenzie Valley Highway

Site 826.3 Unnamed Watercourse

UTM Location: 10W 430947 7126834 **Survey Date:** 10/8/2021; 15:17

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)		2 (↑50)		3 (CL)		4 (↓100)		5 (↓200)		6 (↓300)	
Channel Width (m)	4.0		2.7		1.1		1.6		2.9		1.1	
Wetted Width (m)	4.0		2.3		0.9		1.1		1.8		0.8	
Depth at LDB + 25% (m)	0.1		0.2		0.1		0.1		0.1		0.1	
Depth at LDB + 50% (m)	0.2		0.3		0.1		0.2		0.2		0.2	
Depth at LDB + 75% (m)	0.1		0.3		0.1		0.1		0.2		0.2	
Max.BankfullDepth (m)	1.6		0.52		0.34		0.41		0.70		0.40	
Gradient (%)	2		2		2		2		2		2	
Dominant Habitat Unit	DD		R3		R3		R3		R3		R3	
Stream Bed												
Substrate (% of Transect Area) Organics	100		90		100		100		70		100	
Fines	0		10		0		0		30		0	
Small Gravel	0		0		0		0		0		0	
Large Gravel	0		0		0		0		0		0	
Cobble	0		0		0		0		0		0	
Boulder	0		0		0		0		0		0	
Bedrock	0		0		0		0		0		0	
Embeddedness	N		N		N		N		N		N	
Bank Measurements	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Bank Height (m)	1.4	0.3	0.2	0.2	0.2	0.1	0.3	0.1	0.5	0.4	0.2	0.2
Bank Slope (°)	85.0	20.0	30.0	30.0	70.0	40.0	50.0	50.0	60.0	60.0	40.0	20.0
Bank Stability	US	MS	MS	MS	US	US	US	MS	US	US	MS	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	S	S	G	G	S	S	S	S	S	S	S	S
Subdom. Riparian Veg.	C	C	S	S	C	C	C	C	D	D	D	D

Habitat Inventory / Reach Data

Instream Cover (%):	40	Overhead Cover (%):	50
Dom. Instream Cover:	WD	Dom. Overhead Cover:	S
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	M
Maximum Depth (m)	0.3	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	15:17
Water Temperature (°C):	1.2
Dissolved Oxygen (mg/L):	10.08
Sp. Conductivity (µs/cm):	663
pH:	7.81
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	ME
Islands:	O
Bars:	BR
Coupling:	CO
Confinement:	FC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor-Moderate	None	None
Overwintering:	Poor	None	None
Rearing:	Moderate	Moderate	Poor-Moderate
Passage:	Moderate	Poor	Poor

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB)	164	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
225	30	12	280

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					-

General Comments

Braided with debris jams throughout. Inconsistent wetted width due to channel interrupted by shrub islands. Poor connectivity despite defined channels. Natural debris jam throughout. Signs of historic fire in upland area. Some erosion on left bank 100 m downtream that could couple the channel. The crossing has coupling potential as well. Upstream pond may provide limited overwintering potential for forage fish but shallow water depth and organic substrate would make it unlikely coarse or sportfish could overwinter..

TETRA TECH

Mackenzie Valley Highway

828.6 Unnamed Watercourse

UTM Location: 10W 429991 7129070 **Survey Date:** 10/9/2021; 13:30

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	0.9	0.6	0.8	1.8	1.9	1.6
Wetted Width (m)	0.3	0.6	0.7	0.8	1.3	0.6
Depth at LDB + 25% (m)	0.1	0.5	0.4	0.3	0.4	0.3
Depth at LDB + 50% (m)	0.2	0.5	0.4	0.4	0.5	0.3
Depth at LDB + 75% (m)	0.2	0.5	0.3	0.4	0.3	0.3
Max.BankfullDepth (m)	0.76	0.81	0.49	0.98	0.83	0.88
Gradient (%)	1	1	3	1	1	1
Dominant Habitat Unit	R2	R2	R2	R2	R2	R2
Stream Bed						
Substrate (% of Transect Area) – Organics	0	0	0	0	10	0
Substrate (% of Transect Area) – Fines	60	0	60	40	40	40
Substrate (% of Transect Area) – Small Gravel	40	30	30	40	40	60
Substrate (% of Transect Area) – Large Gravel	0	40	10	20	10	0
Substrate (% of Transect Area) – Cobble	0	30	0	0	0	0
Substrate (% of Transect Area) – Boulder	0	0	0	0	0	0
Substrate (% of Transect Area) – Bedrock	0	0	0	0	0	0
Embeddedness	L	L	L	L	M	L

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.6	0.3	0.3	0.3	0.1	0.1	0.47	0.54	0.4	0.3	0.6	0.5
Bank Slope (°)	80	20	45	45	20	10	65	65	30	70	50	80
Bank Stability	MS	MS	S	S	S	S	MS	MS	MS	MS	S	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	C	S	M	M	S	S	S	S	D	D	D	D
Subdom. Riparian Veg.	S	G	G	G	C	C	G	M	S	S	S	S

Habitat Inventory / Reach Data

Instream Cover (%):	40	Overhead Cover (%):	70
Dom. Instream Cover:	WD	Dom. Overhead Cover:	WD
Subdom. Instream Cover:	UCB	Subdom. Overhead Cover:	S
Maximum Depth (m)	0.5	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	13:37
Water Temperature (°C):	0.3
Dissolved Oxygen (mg/L):	11.31
Sp. Conductivity (µs/cm):	733
pH:	7.92
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	ST
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	FC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	Poor	Poor
Overwintering:	Poor	None	None
Rearing:	Poor-Moderate	Poor-Moderate	Poor-Moderate
Passage:	Moderate	Poor-Moderate	Poor-Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Some instream grasses in upstream reach. Woody debris overhanging throughout. Crossing is cleared, coupled area with grasses and same channel width. Downstream has moderate riffles over woody debris and trace undercut banks. New growth in upland due to historic fire. No fishing was conducted due to freezing conditions.

TETRA TECH

Mackenzie Valley Highway

Site 834.1 Unnamed Watercourse

UTM Location: 10W 425724 7132189 **Survey Date:** 10/10/2021; 13:51

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	0.9	1.1	1.1	1.3	0.9	0.9
Wetted Width (m)	0.9	0.9	0.6	0.7	0.7	0.9
Depth at LDB + 25% (m)	0.1	0.1	0.1	0.1	0.1	0.1
Depth at LDB + 50% (m)	0.1	0.1	0.1	0.1	0.1	0.1
Depth at LDB + 75% (m)	0.1	0.1	0.1	0.1	0.6	0.2
Max.BankfullDepth (m)	0.20	0.30	0.49	0.87	0.76	0.50
Gradient (%)	1	1	1	1	1	1
Dominant Habitat Unit	R1	R1	R2	R1	R1	R1
Stream Bed						
Substrate (% of Transect Area) Organics	20	20	0	0	0	0
Fines	80	80	100	20	60	10
Small Gravel	0	0	0	30	30	40
Large Gravel	0	0	0	10	10	30
Cobble	0	0	0	40	0	20
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	L	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.1	0.1	0.2	0.1	0.4	0.4	0.8	0.5	0.2	0.1	0.34	0.24
Bank Slope (°)	20	20	20	20	90	90	70	70	30	30	80	80
Bank Stability	US	US	US	US	US	US	US	US	MS	MS	US	US
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	G	G	S	S	D	D	S	S	S	S	S	S
Subdom. Riparian Veg.	S	S	D	D	G	G	D	D	D	D	D	D

Habitat Inventory / Reach Data

Instream Cover (%):	40	Overhead Cover (%):	70
Dom. Instream Cover:	UCB	Dom. Overhead Cover:	S
Subdom. Instream Cover:	C	Subdom. Overhead Cover:	M
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	13:50
Water Temperature (°C):	1.1
Dissolved Oxygen (mg/L):	9.42
Sp. Conductivity (µs/cm):	736
pH:	7.44
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	IR
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	OC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	Poor	Poor
Overwintering:	None-Poor	None-Poor	None
Rearing:	Moderate	Moderate	Poor-Moderate
Passage:	Poor-Moderate	Poor-Moderate	Poor-Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Upstream has low flow with some pooling. Thick deciduous forest throughout. Mostly overhanging vegetation and shrubs for cover. Minor undercutting downstream on both banks. Downed woody debris throughout, signs of bank erosion and logjams throughout. No fishing conducted due to freezing conditions.

TETRA TECH

Mackenzie Valley Highway

Site 835 Unnamed Watercourse

UTM Location: 10W 425405 7132988 **Survey Date:** 10/10/2021; 14:56

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.1	1.4	1.9	1.0	1.0	1.0
Wetted Width (m)	0.3	0.3	1.1	1.0	0.5	0.8
Depth at LDB + 25% (m)	0.1	0.1	0.1	0.2	0.1	0.1
Depth at LDB + 50% (m)	0.1	0.1	0.1	0.2	0.1	0.1
Depth at LDB + 75% (m)	0.1	0.1	0.2	0.1	0.1	0.1
Max.BankfullDepth (m)	0.39	0.48	0.58	0.58	0.37	0.42
Gradient (%)	3	2	1	1	2	1
Dominant Habitat Unit	R2	R2	R1	R1	DD	R2
Stream Bed						
Substrate (% of Transect Area) — Organics	0	0	0	0	100	80
Fines	10	10	10	40	0	20
Small Gravel	30	30	40	20	0	0
Large Gravel	40	40	40	10	0	0
Cobble	20	20	10	30	0	0
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	L	N	L	M	L	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.3	0.3	0.4	0.3	0.4	0.4	0.3	0.2	0.3	0.3	0.34	0.31
Bank Slope (°)	45	45	90	70	90	90	70	70	40	80	45	50
Bank Stability	MS	MS	MS	MS	US	US	MS	MS	US	US	MS	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	S	S	S	S	S	D	D	D	D	D	D	M
Subdom. Riparian Veg.	G	G	G	G	G	G	S	S	S	S	S	S

Habitat Inventory / Reach Data

Instream Cover (%):	50	Overhead Cover (%):	70
Dom. Instream Cover:	WD	Dom. Overhead Cover:	S
Subdom. Instream Cover:	UCB	Subdom. Overhead Cove	D
Maximum Depth (m)	0.8	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	15:00
Water Temperature (°C):	0.1
Dissolved Oxygen (mg/L):	11.78
Sp. Conductivity (µs/cm):	1,001
pH:	8.07
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	ST
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	CO
Flow Stage:	High

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	Poor	Poor
Overwintering:	None-Poor	None-Poor	None-Poor
Rearing:	Moderate	Poor-Moderate	Poor-moderate
Passage:	Poor-moderate	Poor-moderate	Poor-Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundanc (% of total)

General Comments

Fire evidence in upland. Abundant woody debris throughout. Shallow water with unstable banks at the centerline. Some undercut banks in downstream reach. Snow covering site at time of visit and mostly frozen over. No fishing conducted due to freezing conditions.

Mackenzie Valley Highway

Site 837.1 Unnamed Watercourse

UTM Location: 10W 424624 7135022 **Survey Date:** 10/11/2021; 12:34

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.5	1.7	1.2	2.7	2.1	1.9
Wetted Width (m)	1.3	1.3	0.9	1.3	1.0	1.4
Depth at LDB + 25% (m)	0.2	0.2	0.1	0.0	0.1	0.2
Depth at LDB + 50% (m)	0.2	0.2	0.2	0.1	0.1	0.2
Depth at LDB + 75% (m)	0.0	0.2	0.1	0.1	0.1	0.1
Max.BankfullDepth (m)	0.65	0.59	0.45	0.45	0.41	0.62
Gradient (%)	2	3	3	5	3	3
Dominant Habitat Unit	R2	R2	R2	RF	R2	R2
Stream Bed						
Substrate (% of Transect Area) — Organics	0	0	0	0	0	0
Substrate (% of Transect Area) — Fines	0	0	0	0	0	10
Substrate (% of Transect Area) — Small Gravel	10	25	20	10	20	30
Substrate (% of Transect Area) — Large Gravel	30	30	35	45	30	45
Substrate (% of Transect Area) — Cobble	30	30	10	30	40	5
Substrate (% of Transect Area) — Boulder	30	10	25	20	10	0
Substrate (% of Transect Area) — Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	N	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.4	0.4	0.2	0.4	0.2	0.3	0.4	0.3	0.2	0.3	0.4	0.3
Bank Slope (°)	90	90	70	70	70	70	10	10	30	20	60	55
Bank Stability	MS	US	US	US	US	US	MS	MS	MS	MS	MS	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	LG	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	SG	SG	F	F	F
Dom. Riparian Veg.	C	S	S	S	S	C	S	S	S	S	S	S
Subdom. Riparian Veg.	S	C	D	D	C	S	G	G	G	G	G	G

Habitat Inventory / Reach Data

Instream Cover (%):	30	Overhead Cover (%):	10
Dom. Instream Cover:	C	Dom. Overhead Cover:	S
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	-
Maximum Depth (m)	0.2	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	12:34
Water Temperature (°C):	1.1
Dissolved Oxygen (mg/L):	12.27
Sp. Conductivity (µs/cm):	482
pH:	8.20
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	ME
Islands:	N
Bars:	SD
Coupling:	DC
Confinement:	OC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate-Good	Moderate	Moderate
Overwintering:	None-Poor	None-Poor	None-Poor
Rearing:	Moderate	Moderate	Moderate
Passage:	Moderate	Poor-moderate	Poor-moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Step pools created naturally from downed woody debris in upstream reach. Downstream has emergent boulders and cobbles instream. Minor undercutting of bank in downstream. Fire history in upland. Gravel bar on left bank 200 m downstream. Limited overhanging vegetation in downstream reach. Downed trees created step pools. Challenging for forage fish but good habitat. No fishing conducted due to freezing conditions.

TETRA TECH

Mackenzie Valley Highway

Site 843.3 Unnamed Watercourse

UTM Location: 10W 422310 7140408 **Survey Date:** 10/11/2021; 14:20

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Water Quality Data

Time of Day (HH:MM):	14:20
Water Temperature (°C):	0.5
Dissolved Oxygen (mg/L):	11.83
Sp. Conductivity (µs/cm):	577
pH:	8.07
Turbidity (NTU):	Clear

Habitat Inventory / Reach Data

Instream Cover (%):	80	Overhead Cover (%):	60
Dom. Instream Cover:	G	Dom. Overhead Cover:	D
Subdom. Instream Cover:	WD	Subdom. Overhead Cover:	S
Maximum Depth (m)	-	Dom. Aquatic Veg. Type:	0

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Maximum depth was 0.39 m. Substrate was 30% fines, 30% small gravel, 30% large gravel and 10% cobble. Snow cover at the site at time of visit, most of the downstream reach was a flooded area within the trees and no defined channel. No suitable fish habitat for any fish.

TETRA TECH

Mackenzie Valley Highway

Site 846.4 Unnamed Watercourse

UTM Location: 10W 419947 7142715 **Survey Date:** 10/11/2021; 15:00

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	-	-	-	2.5	2.3	2.1
Wetted Width (m)	-	-	-	2.3	1.9	1.7
Depth at LDB + 25% (m)	-	-	-	0.5	0.2	0.1
Depth at LDB + 50% (m)	-	-	-	0.7	0.5	0.5
Depth at LDB + 75% (m)	-	-	-	0.8	0.2	0.4
Max.BankfullDepth (m)	-	-	-	1.5	0.84	0.63
Gradient (%)	-	-	-	1	1	1
Dominant Habitat Unit	P1	P1	P1	P1	R1	R1
Stream Bed						
Substrate (% of Transect Area) Organics	-	-	-	40	40	40
Fines	-	-	-	60	60	60
Small Gravel	-	-	-	0	0	0
Large Gravel	-	-	-	0	0	0
Cobble	-	-	-	0	0	0
Boulder	-	-	-	0	0	0
Bedrock	-	-	-	0	0	0
Embeddedness	-	-	-	0	0	0

Bank Measurements	1 (↑100) Left	1 (↑100) Right	2 (↑50) Left	2 (↑50) Right	3 (CL) Left	3 (CL) Right	4 (↓100) Left	4 (↓100) Right	5 (↓200) Left	5 (↓200) Right	6 (↓300) Left	6 (↓300) Right
Bank Height (m)	-	-	-	-	-	-	0.7	0.3	0.3	0.2	0.1	0.1
Bank Slope (°)	-	-	-	-	-	-	90	90	70	20	5	40
Bank Stability	-	-	-	-	-	-	MS	MS	MS	MS	MS	MS
Dom. Bank Material	-	-	-	-	-	-	O	O	O	O	O	O
Subdom. Bank Material	-	-	-	-	-	-	F	F	F	F	F	F
Dom. Riparian Veg.	-	-	-	-	-	-	S	S	S	S	S	S
Subdom. Riparian Veg.	-	-	-	-	-	-	G	G	D	D	D	D

Habitat Inventory / Reach Data

Instream Cover (%):	30	Overhead Cover (%):	30
Dom. Instream Cover:	WD	Dom. Overhead Cover:	-
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	-
Maximum Depth (m)	0.8	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	14:00
Water Temperature (°C):	0.1
Dissolved Oxygen (mg/L):	12.21
Sp. Conductivity (µs/cm):	264
pH:	7.97
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	SI
Islands:	S
Bars:	N
Coupling:	PC
Confinement:	OC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Moderate-Good	Poor-moderate	Poor
Passage:	Poor	Poor	Poor

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

The upstream area was flooded with no defined channel and frozen over with snow cover at time of assessment. Most of the downstream reach was flooded as well until approximately 100 m downstream, where the channel banks became more defined. The channel developed sinuous meanders downstream. Current crossing is not suitable for fish passage. No fishing conducted due to freezing conditions.

TETRA TECH

Mackenzie Valley Highway

Site 857.4 Unnamed Watercourse

UTM Location: 10W 415860 7151196 **Survey Date:** 10/11/2021; 16:28

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.5	10.0	2.3	0.6	2.3	-
Wetted Width (m)	1.4	10.0	1.4	0.5	2.0	-
Depth at LDB + 25% (m)	0.2	0.5	0.2	0.2	0.5	-
Depth at LDB + 50% (m)	0.2	-	0.4	0.3	0.6	-
Depth at LDB + 75% (m)	0.1	-	0.2	0.2	0.4	-
Max.BankfullDepth (m)	0.28	0.50	0.56	0.40	0.73	0.00
Gradient (%)	1	1	2	2	1	1
Dominant Habitat Unit	R1	IP1	BD	R3	DD	FL
Stream Bed						
Substrate (% of Transect Area) – Organics	80	0	60	80	60	0
Substrate (% of Transect Area) – Fines	20	100	40	20	40	100
Substrate (% of Transect Area) – Small Gravel	0	0	0	0	0	0
Substrate (% of Transect Area) – Large Gravel	0	0	0	0	0	0
Substrate (% of Transect Area) – Cobble	0	0	0	0	0	0
Substrate (% of Transect Area) – Boulder	0	0	0	0	0	0
Substrate (% of Transect Area) – Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	N	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.1	0.1	-	-	0.2	0.2	0.2	0.2	0.2	0.1	-	-
Bank Slope (°)	10	10	30	30	25	10	5	5	10	10	30	30
Bank Stability	MS	MS	US	US	MS	MS	US	MS	MS	MS	MS	MS
Dom. Bank Material	O	O	-	-	O	O	O	O	O	O	-	-
Subdom. Bank Material	F	F	-	-	F	F	F	F	F	F	-	-
Dom. Riparian Veg.	S	S	S	S	S	S	S	S	S	S	M	M
Subdom. Riparian Veg.	G	G	G	G	G	G	G	C	G	G	C	C

Habitat Inventory / Reach Data

Instream Cover (%):	40	Overhead Cover (%):	10
Dom. Instream Cover:	WD	Dom. Overhead Cover:	C
Subdom. Instream Cover:	G	Subdom. Overhead Cover:	S
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	16:28
Water Temperature (°C):	0.5
Dissolved Oxygen (mg/L):	9.45
Sp. Conductivity (µs/cm):	163
pH:	7.92
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	IR
Islands:	I
Bars:	N
Coupling:	PC
Confinement:	FC
Flow Stage:	Pooled

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	None	None
Overwintering:	Moderate	Poor	Poor
Rearing:	Moderate-Good	Poor-moderate	Poor
Passage:	Poor	Poor	Poor

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

The upstream reach was mostly low shrubs and grasses as it was likely flooded in past due to downstream beaver dam, poorly defined channel. Some grasses instream at the crossing. There were two beaver dams, just upstream of the centerline crossing over the winter road. There was a smaller beaver dam at the winter road. Watercourse converged with larger channel approximately 130 m downstream. There were multiple beaver dams downstream as well. Could not assess parts of T2 and T6 locations because the water was frozen over and was unsafe to assess. Channel width for T6 was measured from aerial imagery. At 200 m downstream, the second channel was flooded and meandered around debris dams (likely from previous backflooding from impoundment). The downstream area would be more suitable fish habitat than in the channel that crosses the proposed highway alignment. No fishing conducted due to freezing conditions.

TETRA TECH

Mackenzie Valley Highway

Site 872.9 Unnamed Watercourse

UTM Location: 10W 412679 7164554 **Survey Date:** 10/2/2021; 15:17

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Water Quality Data

Time of Day (HH:MM):	15:17
Water Temperature (°C):	0.1
Dissolved Oxygen (mg/L):	12.53
Sp. Conductivity (µs/cm):	435
pH:	7.74
Turbidity (NTU):	Clear

Habitat Inventory / Reach Data

Instream Cover (%):	60	Overhead Cover (%):	10
Dom. Instream Cover:	AQ	Dom. Overhead Cover:	-
Subdom. Instream Cover:	G	Subdom. Overhead Cover:	-
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
Minnow Trap (MT)	1.0	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					

General Comments

Wetland habitat, poor connectivity with rigmat over the crossing. Exposed pipe from a pipeline in the channel. One minnow trap was set but pulled after 1 hr when it was noted that there was no connectivity and no defined channel. The downstream area is flooded wetland with submerged aquatic vegetation. Substrate was all fines and organics. Not fish habitat.

TETRA TECH

Mackenzie Valley Highway

Site 879.1 Unnamed Watercourse

UTM Location: 10W 411064 7169505 **Survey Date:** 10/9/2021; 16:16

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Water Quality Data

Time of Day (HH:MM):	16:16
Water Temperature (°C):	0.6
Dissolved Oxygen (mg/L):	0.68
Sp. Conductivity (µs/cm):	151
pH:	6.44
Turbidity (NTU):	Lightly Turbid

Habitat Inventory / Reach Data

Instream Cover (%):	0	Overhead Cover (%):	30
Dom. Instream Cover:	-	Dom. Overhead Cover:	G
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	C
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
Minnow Trap (MT)	36.5	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					

General Comments

Very low dissolved oxygen - was measured multiple times in multiple locations and got same result. Frozen cover throughout, generally a marshy bog. This wetland was connected to the watercourse crossing at Site 879.4. Beaver activity in the upstream and a beaver lodge and impoundment downstream. Potential good habitat for forage fish but low DO levels may not make it suitable for larger bodied fish. No fishing conducted due to frozen conditions.

Mackenzie Valley Highway

Site 879.4 Unnamed Watercourse

UTM Location: 10W 411209 716858 **Survey Date:** 10/9/2021; 16:34

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.5	2.9	5.2	1.2	1.9	1.0
Wetted Width (m)	1.3	2.5	5.2	0.9	1.9	1.0
Depth at LDB + 25% (m)	0.3	0.5	0.2	0.2	0.1	0.0
Depth at LDB + 50% (m)	0.3	0.5	0.4	0.2	0.2	0.1
Depth at LDB + 75% (m)	0.3	0.4	0.5	0.2	0.1	0.2
Max.BankfullDepth (m)	0.31	0.54	0.46	0.39	0.56	0.59
Gradient (%)	1	1	2	3	1	1
Dominant Habitat Unit	IP1	IP1	IP1	R2	R1	R1
Stream Bed						
Substrate (% of Transect Area) Organics	100	100	100	0	0	0
Fines	0	0	0	90	100	100
Small Gravel	0	0	0	10	0	0
Large Gravel	0	0	0	0	0	0
Cobble	0	0	0	0	0	0
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	0	0	0	0	0	0

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.4	0.2	0.4	0.4
Bank Slope (°)	0	0	0	0	10	10	40	40	20	40	75	40
Bank Stability	S	S	S	S	S	S	US	US	MS	US	MS	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	G	G	G	G	G	G	S	S	S	S	S	M
Subdom. Riparian Veg.	S	S	S	S	S	S	M	M	C	C	M	S

Habitat Inventory / Reach Data

Instream Cover (%):	50	Overhead Cover (%):	60
Dom. Instream Cover:	WD	Dom. Overhead Cover:	S
Subdom. Instream Cover:	UC	Subdom. Overhead Cover:	M
Maximum Depth (m)	0.5	Dom. Aquatic Veg. Type:	G

Water Quality Data

Time of Day (HH:MM):	16:36
Water Temperature (°C):	0.6
Dissolved Oxygen (mg/L):	10.81
Sp. Conductivity (µs/cm):	193
pH:	7.37
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	ME
Islands:	N
Bars:	N
Coupling:	CO
Confinement:	FC
Flow Stage:	Flood

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor-Moderate	None	None
Overwintering:	Poor-moderate	Poor	Poor
Rearing:	Moderate	Poor-Moderate	Poor-Moderate
Passage:	Moderate-Good	Moderate	Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Some instream aquatic vegetation and grasses instream in upstream reach, within the flooded area. The upstream area is flooded throughout trees and downstream is confined to valley. Some undercut banks 300 m downstream. Aerial imagery of the area shows the watercourse is connected to Site 879.1 on the upstream side, and appears to have wetland characteristics upstream of T1 (100 m upstream) based on the aerial imagery. The area was snow covered at the time of the assessment. No fishing was conducted due to unsafe conditions for electrofishing and freezing conditions.

Mackenzie Valley Highway

Site 880.2 Unnamed Watercourse

UTM Location: 10W 411595 7170626 **Survey Date:** 10/1/2021; 16:23

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	-	1.2	2.7	2.6	3.2	0.9
Wetted Width (m)	-	0.8	0.7	1.0	0.7	0.5
Depth at LDB + 25% (m)	-	0.1	0.1	0.1	0.1	0.1
Depth at LDB + 50% (m)	-	0.2	0.2	0.1	0.1	0.1
Depth at LDB + 75% (m)	-	0.1	0.2	0.1	0.1	0.1
Max.BankfullDepth (m)	-	0.4	1.0	0.5	0.5	0.6
Gradient (%)	-	1.0	2.0	2.0	8.0	8.0
Dominant Habitat Unit	WL	R2	R2	R2	R2	R2
Stream Bed						
Substrate (% of Transect Area) — Organics	-	90	0	60	10	10
Substrate (% of Transect Area) — Fines	-	10	100	40	80	90
Substrate (% of Transect Area) — Small Gravel	-	0	0	0	10	0
Substrate (% of Transect Area) — Large Gravel	-	0	0	0	0	0
Substrate (% of Transect Area) — Cobble	-	0	0	0	0	0
Substrate (% of Transect Area) — Boulder	-	0	0	0	0	0
Substrate (% of Transect Area) — Bedrock	-	0	0	0	0	0
Embeddedness	-	N	N	N	L	N

Bank Measurements	1 (↑100) Left	1 (↑100) Right	2 (↑50) Left	2 (↑50) Right	3 (CL) Left	3 (CL) Right	4 (↓100) Left	4 (↓100) Right	5 (↓200) Left	5 (↓200) Right	6 (↓300) Left	6 (↓300) Right
Bank Height (m)	-	-	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Bank Slope (°)	-	-	20	20	45	80	45	50	10	80	45	45
Bank Stability	-	-	MS	MS	S	MS	US	MS	US	US	MS	MS
Dom. Bank Material	-	-	O	O	O	O	O	O	F	F	O	O
Subdom. Bank Material	-	-	F	F	F	F	F	F	O	O	F	F
Dom. Riparian Veg.	-	-	S	S	S	S	S	S	S	S	C	C
Subdom. Riparian Veg.	-	-	C	C	C	C	C	C	C	C	S	S

Habitat Inventory / Reach Data

Instream Cover (%):	20	Overhead Cover (%):	30
Dom. Instream Cover:	-	Dom. Overhead Cover:	-
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	-
Maximum Depth (m)	0.2	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	16:23
Water Temperature (°C):	2.5
Dissolved Oxygen (mg/L):	9.47
Sp. Conductivity (µs/cm):	195
pH:	7.87
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	IR
Islands:	N
Bars:	N
Coupling:	DC
Confinement:	OC
Flow Stage:	Low

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	None	None	None
Overwintering:	None	None	None
Rearing:	None	Poor	None
Passage:	None-Poor	None-Poor	None-Poor

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					

General Comments

100 m upstream is a flooded area and no defined channel. Poor connectivity all the way to 100 m downstream of crossing. Abundant grasses instream and woody debris blocking channel. 100 m downstream of proposed alignment is just upstream of existing winter road. There is a soft organic bottom with minor undercuts. Some underground flow where banks have coupled previously. 200 m downstream looks like it was flooded a few years ago but has since had new growth. 300 m downstream is a narrow channel with steep grade and several logjams. Woody debris throughout. No fishing conducted due to shallow water depths.

Mackenzie Valley Highway

Site 880.6 Unnamed Watercourse

UTM Location: 10W411800 7171054 | **Survey Date:** 10/5/2021; 16:30

Legal Location: - | **Zone:**

Crew Initials: TM & MAN | **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	2.5	2.2	1.8	2.8	2.7	1.9
Wetted Width (m)	2.3	1.6	1.5	1.9	2.0	1.1
Depth at LDB + 25% (m)	0.2	0.3	0.2	0.3	0.3	0.5
Depth at LDB + 50% (m)	0.3	0.3	0.4	0.4	0.5	0.5
Depth at LDB + 75% (m)	0.4	0.2	0.6	0.3	0.2	0.4
Max.BankfullDepth (m)	0.67	0.65	0.78	0.66	0.83	1.1
Gradient (%)	1	1	2	4	5	5
Dominant Habitat Unit	FL	FL	R1	CA	R1	R1
Stream Bed						
Substrate (% of Transect Area) – Organics	0	10	30	10	10	10
Substrate (% of Transect Area) – Fines	100	90	70	80	70	90
Substrate (% of Transect Area) – Small Gravel	0	0	0	0	20	0
Substrate (% of Transect Area) – Large Gravel	0	0	0	0	0	0
Substrate (% of Transect Area) – Cobble	0	0	0	0	0	0
Substrate (% of Transect Area) – Boulder	0	0	0	10	0	0
Substrate (% of Transect Area) – Bedrock	0	0	0	0	0	0
Embeddedness	0	0	0	0	0	0

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.3	0.2	0.3	0.2	0.2	0.2	0.3	0.2	0.4	0.2	0.3	0.5
Bank Slope (°)	25	70	10	20	30	10	10	25	60	10	60	80
Bank Stability	MS	US	MS	MS	S	S	MS	MS	MS	MS	S	MS
Dom. Bank Material	O	F	F	O	O	O	F	F	F	F	F	O
Subdom. Bank Material	F	O	O	F	F	F	O	O	SG	O	O	F
Dom. Riparian Veg.	S	S	S	S	S	S	S	S	S	S	S	S
Subdom. Riparian Veg.	C	C	G	G	D	G	S	S	M	M	D	C

Habitat Inventory / Reach Data

Instream Cover (%):	40	Overhead Cover (%):	80
Dom. Instream Cover:	WD	Dom. Overhead Cover:	S
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	C
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	16:30
Water Temperature (°C):	1.6
Dissolved Oxygen (mg/L):	13.61
Sp. Conductivity (µs/cm):	240
pH:	7.66
Turbidity (NTU):	Moderately Turbid

Channel Characteristics

Pattern:	ST
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	CO
Flow Stage:	High

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	None-poor	None-Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Good	Good	Good
Passage:	Good	Good	Good

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB)	246	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
200	30	12	200

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundanc (% of total)
BROOK STICKLEBACK	2	-	2.86	-	40.0%
FINESCALE DACE	1	-	1.43	-	20.0%
PEARL DACE	2	-	2.86	-	40.0%

General Comments

100 m downstream is located along pipeline, some large boulders in transect from riprap for wooden bank support that was in place. Some in stream grass throughout. Lots of woody debris in water. High flow rate wth occasional riffle sections. Occasional natural small debris dams.

TETRA TECH

Mackenzie Valley Highway

Site 883.6 Unnamed Watercourse

UTM Location: 10W 411615 7173282 **Survey Date:** 10/5/2021; 11:53

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	2.4	-	1.3	2.1	3.1	3.4
Wetted Width (m)	2.0	-	1.3	1.3	0.5	1.1
Depth at LDB + 25% (m)	0.0	-	0.3	0.2	0.1	0.1
Depth at LDB + 50% (m)	0.1	-	0.3	0.1	0.1	0.1
Depth at LDB + 75% (m)	0.2	-	0.2	0.1	0.1	0.0
Max.BankfullDepth (m)	0.46	-	0.41	0.44	1.1	2.0
Gradient (%)	1	-	2	2	6	8
Dominant Habitat Unit	WL	-	R1	R1	RF	RF
Stream Bed						
Substrate (% of Transect Area) — Organics	100	100	100	90	0	60
Fines	0	0	0	10	0	40
Small Gravel	0	0	0	0	0	0
Large Gravel	0	0	0	0	0	0
Cobble	0	0	0	0	0	0
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	N	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.2	0.3	-	-	0.1	0.1	0.3	0.2	0.9	1.1	0.7	1.9
Bank Slope (°)	5	45	-	-	5	5	20	25	60	70	80	90
Bank Stability	MS	MS	-	-	MS	MS	MS	MS	US	US	US	US
Dom. Bank Material	O	O	-	-	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	-	-	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	G	D	-	-	S	S	S	S	S	S	C	C
Subdom. Riparian Veg.	S	S	-	-	C	D	M	M	C	D	S	S

Instream Cover (%):	10	Overhead Cover (%):	70
Dom. Instream Cover:	WD	Dom. Overhead Cover:	S
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	M
Maximum Depth (m)	0.3	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	11:56
Water Temperature (°C):	2.8
Dissolved Oxygen (mg/L):	2.54
Sp. Conductivity (µs/cm):	355
pH:	7.16
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	IR
Islands:	O
Bars:	N
Coupling:	PC
Confinement:	OC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Poor	Poor	Poor
Passage:	Poor	Poor	Poor

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

50 m upstream was the winter road and no defined channel was present (depths recorded at deep pools). The water was snow covered and had low flow upstream. Some overhanging vegetation and abundant downed woody debris. Orange copper look to water, flow is low with occasional pool pockets to the side, dominated by organic debris (leaves and sticks).Slope increased at 300 m downstrea, with steep slopes, riffles with minor cascades and organic islands. Abundant moss throughout. Flowing water, 250 m downstream there was erosion on the left bank. No fishing conducted due to freezing conditions.

Mackenzie Valley Highway

Site 884.8 Unnamed Watercourse

UTM Location: 10W 411300 7174635 **Survey Date:** 09/30/2021; 14:24

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	10.5	8.4	2.5	2.3	3.1	2.0
Wetted Width (m)	3.0	2.2	1.0	0.8	1.3	1.3
Depth at LDB + 25% (m)	0.5	0.1	0.3	0.3	0.2	0.2
Depth at LDB + 50% (m)	0.6	0.1	0.4	0.2	0.2	0.3
Depth at LDB + 75% (m)	0.3	0.1	0.2	0.2	0.2	0.3
Max.BankfullDepth (m)	2.0	2.1	0.82	0.97	0.72	1.0
Gradient (%)	-	-	-	-	-	-
Dominant Habitat Unit	IP1	FL	R2	R2	R1	R1
Stream Bed						
Substrate (% of Transect Area) Organics	0	0	0	20	20	60
Fines	0	90	90	80	80	40
Small Gravel	0	10	10	0	0	0
Large Gravel	0	0	0	0	0	0
Cobble	0	0	0	0	0	0
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	VH	M	H	N	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.5	1.4	0.5	2.0	0.4	0.4	0.5	0.7	0.5	0.3	0.60	0.70
Bank Slope (°)	45	45	60	60	90	90	80	80	70	70	60	60
Bank Stability	US	US	US	US	MS	MS	MS	MS	MS	US	MS	MS
Dom. Bank Material	F	F	F	F	F	F	O	O	F	F	F	F
Subdom. Bank Material	O	O	O	O	O	O	F	F	O	O	O	O
Dom. Riparian Veg.	G	G	G	G	D	D	G	G	S	C	G	G
Subdom. Riparian Veg.	S	S	C	C	S	S	S	C	G	S	D	D

Habitat Inventory / Reach Data

Instream Cover (%):	60	Overhead Cover (%):	30
Dom. Instream Cover:	WD	Dom. Overhead Cover:	S
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	G
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	14:22
Water Temperature (°C):	3.2
Dissolved Oxygen (mg/L):	-
Sp. Conductivity (µs/cm):	338
pH:	7.70
Turbidity (NTU):	ightly Turbi

Channel Characteristics

Pattern:	IR
Islands:	O
Bars:	BR
Coupling:	CO
Confinement:	CO
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Moderate-Good	Poor-Moderate	Poor
Passage:	Moderate	Poor-Moderate	Poor-Moderate

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB)	471	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
190	30	12	300

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
BROOK STICKLEBACK	3	-	0.64	-	9.4%
PEARL DACE	29	-	6.16	-	90.6%

General Comments

No crown cover from crossing to 100 m upstream, and no overhanging vegetation. Significant erosion on banks. Partially coupled. The wildlife monitor mentioned that a beaver dam approximately 50 m upstream of centerline was blown out a year ago. A lot of bank instability at that location. Ice scarring is 2 m high at 50 m upstream and at the crossing. Crown cover is 60% at crossing. In downstream reach, there are woody debris throughout.

Mackenzie Valley Highway

Site 891.4 Unnamed Watercourse

UTM Location: 10W 406839 7178354 **Survey Date:** 10/11/2021; 11:00

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)		2 (↑50)		3 (CL)		4 (↓100)		5 (↓200)		6 (↓300)	
Channel Width (m)	17.0		15.0		12.5		5.5		5.8		6.0	
Wetted Width (m)	-		-		-		5.0		5.0		-	
Depth at LDB + 25% (m)	-		-		1.3		0.5		0.5		-	
Depth at LDB + 50% (m)	-		-		-		0.5		0.5		-	
Depth at LDB + 75% (m)	-		-		-		0.3		0.7		-	
Max.BankfullDepth (m)	-		-				0.52		0.65		-	
Gradient (%)	3		3		3		3		3		3	
Dominant Habitat Unit	R1		RF		BD		R1		R1		FL	
Stream Bed												
Substrate (% of Transect Area) Organics	-		-		0		30		30		-	
Fines	-		-		100		40		70		-	
Small Gravel	-		-		0		-		-		-	
Large Gravel	-		-		0		-		-		-	
Cobble	-		-		0		30		-		-	
Boulder	-		-		0		-		-		-	
Bedrock	-		-		0		-		-		-	
Embeddedness	-		-		N		M		M		-	
Bank Measurements	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Bank Height (m)	-	-	-	-	1.3	-	-	-	-	-	-	-
Bank Slope (°)	80	80	70	70	65	65	50	50	50	50	50	50
Bank Stability	MS	MS	MS	US	US	US	US	US	US	US	US	US
Dom. Bank Material	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	C	C	C	C	C	C	C	C	C	C	C	C
Subdom. Riparian Veg.	G	G	G	G	G	G	G	G	G	G	G	G

Habitat Inventory / Reach Data

Instream Cover (%):	10	Overhead Cover (%):	10
Dom. Instream Cover:	WD	Dom. Overhead Cover:	C
Subdom. Instream Cover:	C	Subdom. Overhead Cover:	S
Maximum Depth (m)	>1	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	11:00
Water Temperature (°C):	3.3
Dissolved Oxygen (mg/L):	10.25
Sp. Conductivity (µs/cm):	340
pH:	8.04
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	ST
Islands:	N
Bars:	N
Coupling:	CO
Confinement:	CO
Flow Stage:	High

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate-Good	Poor	Poor
Overwintering:	Moderate	Moderate	Moderate
Rearing:	Good	Good	Good
Passage:	Moderate-Good	Moderate-Good	Moderate-Good

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Upstream of the centerline was a slightly impounded area as a result of the beaver dam at the centerline. The channel was wide providing moderate to good fish habitat. Steep banks on either side made access not possible for assessment of 100 m and 50 m upstream as well as 300 m downstream, therefore aerial assessments were completed instead. No barriers were observed with the exception of the beaver dam. Erosion of bank was more significant near the centerline and downstream, with increasing bank stability upstream. No fishing conducted due to freezing conditions and unsafe conditions for electrofishing due to high flows and water depth

TETRA TECH

Mackenzie Valley Highway

Site 919.9 Unnamed Watercourse

UTM Location: 10W 394956 7198775 **Survey Date:** 9/30/2021; 10:27

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	43.0	44.0	37.0	18.0	3.1	1.3
Wetted Width (m)	27.0	44.0	37.0	18.0	1.8	0.6
Depth at LDB + 25% (m)	0.7	0.6	0.2	1.1	0.3	0.3
Depth at LDB + 50% (m)	1.1	1.4	0.2	1.2	0.3	0.4
Depth at LDB + 75% (m)	0.8	0.4	0.2	1.1	0.2	0.3
Max.BankfullDepth (m)	1.5	1.9	0.29	1.3	0.70	0.77
Gradient (%)	-	-	-	-	-	-
Dominant Habitat Unit	IP1	WL	WL	WL	WL	IP1
Stream Bed						
Substrate (% of Transect Area) Organics	100	100	30	30	60	60
Fines	0	0	60	70	40	40
Small Gravel	0	0	0	0	0	0
Large Gravel	0	0	0	0	0	0
Cobble	0	0	0	0	0	0
Boulder	0	0	10	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	VH	VH	L	H	H	H

Bank Measurements	1 (↑100) Left	1 (↑100) Right	2 (↑50) Left	2 (↑50) Right	3 (CL) Left	3 (CL) Right	4 (↓100) Left	4 (↓100) Right	5 (↓200) Left	5 (↓200) Right	6 (↓300) Left	6 (↓300) Right
Bank Height (m)	0.3	0.5	0.6	0.6	0.1	0.1	0.1	0.1	0.2	0.4	0.37	0.23
Bank Slope (°)	0	0	0	0	0	0	10	10	10	10	70	70
Bank Stability	S	S	S	S	S	S	S	S	MS	MS	MS	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	C	C	G	C	G	S	G	S	S	C	D	D
Subdom. Riparian Veg.	S	S	C	S	S	G	S	G	S	G	G	G

Habitat Inventory / Reach Data

Instream Cover (%):	10	Overhead Cover (%):	10
Dom. Instream Cover:	OHV	Dom. Overhead Cover:	G
Subdom. Instream Cover:	G	Subdom. Overhead Cover:	S
Maximum Depth (m)	>2	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	10:27
Water Temperature (°C):	2.9
Dissolved Oxygen (mg/L):	5.96
Sp. Conductivity (µs/cm):	182
pH:	6.50
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	ME
Islands:	O
Bars:	BR
Coupling:	DC
Confinement:	UN
Flow Stage:	Flood

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Good	None	None
Overwintering:	Poor-Moderate	Poor	Poor
Rearing:	Good	Moderate	Poor-Moderate
Passage:	Poor-Moderate	Poor-Moderate	Poor-Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
Minnow Trap (MT)	46.6	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					

General Comments

100 m upstream is the entrance of a deep pool flooded in floodplain. at 50 m upstream is a flooded area that crosses downstream of centerline. Downstream is braided with organic islands in the middle throughout to 100 m downstream, where beaver dam is present. An existing culvert is present at crossing with pooling on either side with vegetation islands. Entire reach had poorly defined channel that was largely flooded.Two minnow traps were set on either side of the crossing.

Mackenzie Valley Highway

Site 940.1 Unnamed Watercourse

UTM Location: 10W 375325 7203625 **Survey Date:** 10/8/2021; 18:00

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)		2 (↑50)		3 (CL)		4 (↓100)		5 (↓200)		6 (↓300)	
Channel Width (m)	1.9		2.2		1.5		1.4		1.0		1.3	
Wetted Width (m)	1.1		1.7		1.0		1.1		0.9		1.0	
Depth at LDB + 25% (m)	0.2		0.3		0.4		0.4		0.2		0.1	
Depth at LDB + 50% (m)	0.4		0.3		0.4		0.3		0.1		0.2	
Depth at LDB + 75% (m)	0.3		0.2		0.3		0.5		0.3		0.2	
Max.BankfullDepth (m)	0.51		0.47		0.93		0.68		0.40		0.32	
Gradient (%)	1		1		1		1		5		8	
Dominant Habitat Unit	R1		R1		R1		R1		P2		SP	
Stream Bed												
Substrate (% of Transect Area) Organics	40		40		60		100		30		60	
Fines	60		60		40		0		70		30	
Small Gravel	0		0		0		0				0	
Large Gravel	0		0		0		0		0		10	
Cobble	0		0		0		0		0		0	
Boulder	0		0		0		0		0		0	
Bedrock	0		0		0		0		0		0	
Embeddedness	N		N		N		N		N		N	
Bank Measurements	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Bank Height (m)	0.1	0.1	0.2	0.1	0.4	0.5	0.2	0.1	0.0	0.1	0.1	0.1
Bank Slope (°)	20	5	25	30	20	20	10	10	10	10	10	10
Bank Stability	MS	MS	MS	MS	MS	MS	US	MS	S	MS	MS	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	S	S	S	S	S	S	S	S	D	D	S	S
Subdom. Riparian Veg.	G	G	G	G	G	G	D	D	S	S	D	D

Habitat Inventory / Reach Data

Instream Cover (%):	10	Overhead Cover (%):	90
Dom. Instream Cover:	UC	Dom. Overhead Cover:	S
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	G
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	18:09
Water Temperature (°C):	0.2
Dissolved Oxygen (mg/L):	12.54
Sp. Conductivity (µs/cm):	597
pH:	8.29
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	ME
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	OC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	None	None
Overwintering:	None-Poor	None-Poor	None-Poor
Rearing:	Moderate-Good	Poor-Moderate	Poor-Moderate
Passage:	Poor-Moderate	Poor-Moderate	Poor-Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Snow and ice cover throughout at time of assessment. Overhanging shrubs cover 90-100% of stream throughout. Grasses compressed by snow. Uplands show signs of fire in past, with abundant woody debris throughout. No instream vegetation. 200 DS: Significant flow with several cascades. Upstream passage, along with the increased gradient, would be difficult for all fish species.Step pools are present downstream 300 m and cascade drops 0.25m with 0.36m pool depth (i.e. natural barriers). No fishing conducted due to snow and ice conditions.

TETRA TECH

Mackenzie Valley Highway

Site 981.2 Unnamed Watercourse

UTM Location: 10W 629352 7227768 **Survey Date:** 10/7/2021; 15:30

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.4	2.2	2.6	2.0	4.0	1.4
Wetted Width (m)	0.9	1.1	1.4	1.5	1.4	0.7
Depth at LDB + 25% (m)	0.1	0.1	0.0	0.2	0.5	0.2
Depth at LDB + 50% (m)	0.1	0.1	0.1	0.1	0.4	0.2
Depth at LDB + 75% (m)	0.1	0.1	0.2	0.1	0.4	0.2
Max.BankfullDepth (m)	0.45	0.71	1.0	0.52	0.86	0.57
Gradient (%)	4	4	4	2	2	2
Dominant Habitat Unit	RF	RF	RF	R1	R1	R2
Stream Bed						
Substrate (% of Transect Area) Organics	0	0	0	0	0	0
Fines	10	10	0	0	30	20
Small Gravel	40	10	20	40	70	80
Large Gravel	30	25	40	50	0	0
Cobble	20	50	30	10	0	0
Boulder	0	5	10	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	N	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.3	0.3	0.6	0.5	0.9	0.7	0.3	0.3	0.3	0.4	0.3	0.4
Bank Slope (°)	70	90	50	90	90	90	35	50	20	30	90	70
Bank Stability	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	US	US
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	S	S	S	S	S	S	S	S	S	S	S	S
Subdom. Riparian Veg.	G	G	S	C	G	G	C	C	G	G	C	C

Habitat Inventory / Reach Data

Instream Cover (%):	25	Overhead Cover (%):	40
Dom. Instream Cover:	Co	Dom. Overhead Cover:	S
Subdom. Instream Cover:	Bo	Subdom. Overhead Cover:	C
Maximum Depth (m)	0.8	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	15:30
Water Temperature (°C):	0.2
Dissolved Oxygen (mg/L):	12.77
Sp. Conductivity (µs/cm):	961
pH:	8.54
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	ME
Islands:	I
Bars:	N
Coupling:	CO
Confinement:	OC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate-Good	Moderate-Good	Moderate-Good
Overwintering:	None-Poor	None-Poor	None-Poor
Rearing:	Good	Good	Moderate
Passage:	Moderate	Moderate	Moderate

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB)	485	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
235	30	12	100

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					

General Comments

Assessment done in snow and 50% ice cover frozen. Upstream has some undercut banks and large cobbles present under banks. There are riffle sections throughout with chutes abundant. Some step pools upstream from woody debris. Some logjams downstream that may be fish passage barriers. Good flow 300 m downstream, some woody debris causing riffling with minor undercutting and exposed roots on bank. Grasses covered in snow on bank.

TETRA TECH

Mackenzie Valley Highway

Site 805.5 Unnamed Watercourse

UTM Location: 10W 435589 7108255 **Survey Date:** 10/1/2021; 13:13

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Water Quality Data

Time of Day (HH:MM):	13:13
Water Temperature (°C):	4.1
Dissolved Oxygen (mg/L):	9.10
Sp. Conductivity (µs/cm):	257
pH:	7.53
Turbidity (NTU):	Clear

Habitat Inventory / Reach Data

Instream Cover (%):		Overhead Cover (%):	30
Dom. Instream Cover:		Dom. Overhead Cover:	-
Subdom. Instream Cover:		Subdom. Overhead Cover:	-
Maximum Depth (m)		Dom. Aquatic Veg. Type:	-

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
Minnow Trap (MT)	44.4	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
BROOK STICKLEBACK	-	106	-	2.39	67.9%
PEARL DACE	-	50	-	1.13	32.1%

General Comments

The site was a flooded wetland and only had a defined channel at the crossing location. An assessment at the crossing identified the substrate to be 20% organics and 80% fines. Channel width as it crossed the winter road was 0.3 m but was undefined upstream and downstream of the crossing due to flooding. Wetted width at the crossing was 0.14m and the average depth was 0.45 m (0.36 m to 0.62m). Dominant riparian vegetation was grasses with shrubs.

Appendix C Station Location Maps and Summary Sheets – Dehcho Territory

Table B.1 Substrate Classifications for Stream Bed and Banks

Code	Substrate	Size Range
O	Organics	NA
F	Fines	<2mm
SG	Small gravel	2-16mm
LG	Large gravel	17-64mm
C	Cobble	65-256mm
BL	Boulder	>256mm
BD	Bedrock	NA

Table B.2 Embeddedness

Code	Class	Description
N	Non-embedded	All rock substrates (i.e., gravel, cobble, boulders)
L	Low embeddedness	<25% embedded
M	Medium embeddedness	25-50% embedded
H	High embeddedness	51-75% embedded
VH	Very high embeddedness	>75% embedded

Table B.3 Bank Stability

Code	Description
S	Stable
MS	Moderately stable
US	Unstable

Table B.4 Riparian Vegetation

Code	Description
N	None
G	Grass
S	Shrub
C	Coniferous
D	Deciduous forest
M	Mixed coniferous and deciduous forest
W	Wetland (e.g., muskeg, marsh, swamp, or bog)

Table B.5 Instream and Overhead Cover Types

Code	Description
AV	Aquatic vegetation
BL	Boulders
DC	Depth or clarity (turbid) of water
OV	Overhanging vegetation
TS	Trees and/or shrubs overhead
UC	Undercut bank
WD	Woody debris

Table B.6 Stream Channel Pattern

Code	Description
ST	Straight
SI	Sinuous
IR	Irregular, wandering
IM	Irregular, meandering
ME	Regular meanders
TM	Torturous meander

Table B.7 Channel Islands

Code	Type	Description
N	None	No islands in channel
O	Occasional	No overlapping islands, average spacing less than ten channel widths
I	Infrequent	Infrequent overlapping, average spacing less than ten channel widths
F	Frequent	Not overlapping, average spacing less than ten channel widths
S	Split	Islands overlap frequently or continuously, usually two or three flow branches
AN	Anatomizing	Continuously overlapped islands, with multiple flow branches

Table B.8 Sediment Bars

Code	Type	Description
N	None	No bars present
SD	Side bar/point bar	Sediment deposition intermittent along the sides of the stream
DG	Diagonal bar	Mid-stream sediment deposition diagonally aligned to stream axis
MD	Mid-channel bar	Mid-stream deposition aligned parallel to stream axis
SP	Span	Sediment deposition continuous along the sides of the stream
BR	Braided	Sediment deposition forms a number of small channels separated by bars

Table B.9 Coupling

Code	Type	Description
DC	Decoupled	Sediment mobilized on the hill slope by a land-slide normally would not enter the stream channel
PC	Partially coupled	A portion of the sediment mobilized on the hill slope by a landslide enters the stream channel
CO	Coupled	Sediment mobilized on the hillslope by landslide activity directly enters the stream channel

Table B.10 Confinement

Code	Type	Description
EN	Entrenched	Entrenched channels are confined by fluvial eroded gullies or valleys or bedrock walls
CO	Confined	Confined channels are prevented or restricted from lateral migration by the valley walls
FC	Frequently Confined	Frequently confined channels are restricted from lateral migration by the valley walls, but are able to store sediments on a valley flat (typically, < channel width)
OC	Occasionally Confined	Occasionally confined channels are able to store sediments on a valley flat (typically 1 to 10 channel widths)
UN	Unconfined	Unconfined channels are not restricted from lateral migration by the valley walls.
N/A	Not Applicable	Confinement is not always applicable to every stream reach, such as a channel flowing across a fan or cone onto a valley flat.

Table B.11 Channel and Flow Characterization

Code	Type	Description
NDC	No defined channel	Site lacks a defined bed and bank (i.e., no channel scour).
EPH	Ephemeral	Water only present during certain times of the year (e.g., spring freshet). Includes dry channels that exhibit a defined bed and bank (i.e., scour)
INT	Intermittent	Water is not continuous in space. Example: areas of sub-surface flow
PER	Permanent	Water is likely present at all times of the year

Table B.12 Flow Stage

Type	Description
Dry	Water not present
Pooled	Water only present as unconnected pools or standing in bottom depressions. No flow
Low	Water flowing as threads within the channel; most bed material is exposed and little of the lower banks are wet
Moderate	Water flowing throughout the normal bed and in contact with the lower portions of banks; some bars are exposed
High	Water fills most of the channel and is in contact with the middle and upper portions of banks
Flood	Water is bankfull or over banks and into the floodplain

Table B.13 Habitat Unit Classification for Small Streams

Habitat Unit	Class	Code	Description
Falls		FA	Highly turbulent whitewater caused by water free-falling over a vertical drop. Falls formed from a full spanning flow obstruction, often bedrock. Slope < 100%.
Cascade		CA	Series of small falls or steps and pools; stepped longitudinal profile. Substrate of bedrock or boulder accumulations. Highly turbulent, high velocity, > 7% slope, mainly whitewater.
Rapid		RA	Steps and pocket pools common, cobble/boulder substrate with some exposed boulders at lower flows. Considerable turbulence, some whitewater, fast velocity (> 0.5 m/s), 4-7% slope.
Chute		CH	Area of channel constriction, usually due to bedrock intrusions; associated with channel deepening and increased velocity.
Riffle		RF	Partially to totally submerged pebble to cobble substrate, causing moderate turbulence and ripples, little to no whitewater (some whitewater at points of constriction), moderate velocity (0.2 to 0.5 m/s), usually < 0.5 m depth, 1 - 4% slope.
Run			Runs are typically deep, slow to swift flowing sections (> 0.2 m/s), with gravel to boulder substrate. Defined thalweg, moderate slope and with no surface turbulence. Run units are differentiated into three classes, based on depth.
	1	R1	Deepest run (> 1 m), slow to fast water velocity, coarse substrate (cobble to boulder), high instream cover from substrate and depth.
	2	R2	Moderate depth (0.6 - 1.0 m), slow to fast water velocity, coarse substrate (cobble to boulder), moderate instream cover from substrate and depth.
	3	R3	Shallowest depth (0.3 - 0.6 m), slow to fast water velocity, coarse substrate (gravel to cobble), low instream cover.
Glide		GL	Glides are shallow (< 0.3 m deep), wide, slow flowing (< 0.2 m/s), non-turbulent and lack a defined thalweg. Substrate is usually silt/sand but may sometimes consist of gravel to small cobble. Featureless with low instream cover.
Flat		FL	Area characterized by low velocity and near-uniform flow; differentiated from pool habitat by high channel uniformity; more depositional than R3 habitat
Sheet		ST	Shallow water reach that flows uniformly over smooth bedrock. Non-turbulent.
Pool			Pools are deeper and wider than channel units immediately above or below it and are usually formed by the scouring or plunging action of water. Sub-surface velocities are slow (water surface may be fast and substrate usually composed of fines or small gravel.
	1	P1	High quality pool habitat based on depth and size. High instream cover from instream features (*i.e.*, logs/boulders) and depth (> 1.2 m deep), provides overwintering habitat.
	2	P2	Shallower than P1 (0.6 - 1.2 m deep), moderate to high instream cover, not suitable for overwintering but provides juvenile and adult fish rearing habitat during open water.
	3	P3	Shallow (< 0.6 m deep) and small, low instream cover. Not suitable for overwintering or adult holding habitat but may provide rearing habitat for juvenile fish during open water.
Step Pool		SP	Series of pools separated by short riffles or cascades. Generally found in high gradient, confined mountain streams dominated by boulder substrate. The length of the turbulent water cannot exceed the mean wetted width; otherwise, classify the pools and turbulent water separately.

Table B.14 Water Clarity/Turbidity Codes

Code	Definition
C	Turbid
L	Moderately turbid
M	Lightly turbid
T	Clear

Dehcho Territory Fish and Fish Habitat

030CF: Drainage

UTM Location: 10U 473070 7015812 **Survey Date:** September 16, 2020

km Marker: 699.1 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing south on existing winter road

Photo 2. Subsurface flows to east of existing winter road

Photo 3. Water with subsurface flow to west of existing winter road

Photo 4. Facing downslope at drainage crossing

General Comments

Chance find ephemeral drainage oriented from east to west across the existing winter road, does not have continuously defined bed or banks. Not fish habitat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

SWA: Wetland Area

UTM Location: 10U 472880 7015938 **Survey Date:** September 23, 2020

km Marker: 699.3 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing west from helicopter

Photo 2. Facing east toward existing winter road from helicopter

Photo 3. Facing south from helicopter

Photo 4. Aerial imagery of survey area

General Comments

Wetland area adjacent to proposed Project corridor. An inlet was observed and assessed (WX-028) as an ephemeral drainage. No outlet was observed. No fish habitat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

UWB: Wetland Area

UTM Location: 10U 472322 7016741 **Survey Date:** September 23, 2020

km Marker: 700.3 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing west toward beaver lodge

Photo 2. Riparian vegetation during minnow trapping

Photo 3. Aerial imagery showing survey area

Fish Sampling Data

Method	Effort		Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
Electrofishing	-	(s)	NO FISH CAPTURED	-	0	-	0.00	-
Minnow Trap	44.8	(hr)						

Water Quality Data

Time of Day (HH:MM):	17:36
Water temperature (°C):	6.34
Dissolved Oxygen (mg/L):	6.63
Sp. Conductivity (µS/cm):	-
pH:	6.62
Turbidity (NTU):	-

General Comments

Wetland area with an outlet connected to the Mackenzie River. Organic substrate and wetland vegetation. Maximum depth approximately 3 m. Active beaver lodge. Wetland affords potential fish habtiat.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

UWB-7: Wetland Area

UTM Location: 10U 471421 7017918 **Survey Date:** September 16, 2020

km Marker: 701.7 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing west from existing winter road

Photo 2. Facing north along edge of wetland area

Photo 3. Facing west from existing winter road

Photo 4. Outlet to west of wetland area

Fish Sampling Data

Method	Effort	
Electrofishing	-	(s)
Minnow Trap	46	(hr)

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED	-	0	-	0.00	-

Water Quality Data

Time of Day (HH:MM):	10:53
Water temperature (°C):	5.85
Dissolved Oxygen (mg/L):	17.1
Sp. Conductivity (µS/cm):	131
pH:	6.61
Turbidity (NTU):	-

General Comments

Outlet visible to Mackenzie River. Organic substrate with wetland vegetation. Maximum depth measured approximately 2 m. Active beaver impoundment observed. No fish captured in minnow traps. Fish habitat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

SWA-1: Wetland Area

UTM Location: 10U 471183 7018318 **Survey Date:** September 23, 2020

km Marker: 702.2 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing southeast showing outlet

Photo 2. Facing east, outlet in red circle

Photo 3. Facing west from existing winter road

Photo 4. Minnow trap location near existing winter road

Fish Sampling Data

Method	Effort		Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
Electrofishing	-	(s)	NO FISH CAPTURED	-	0	-	0.00	-
Minnow Trap	39.6	(hr)						

Water Quality Data

Time of Day (HH:MM):	16:55
Water temperature (°C):	8.04
Dissolved Oxygen (mg/L):	4.62
Sp. Conductivity (µS/cm):	102.00
pH:	5.02
Turbidity (NTU):	-

General Comments

Outlet visible to Mackenzie River. Organic substrate with riparian wetland vegetation. No fish captured during minnow trapping. Fish habitat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

UWB-1: Wetland Area

UTM Location: 10U 470932 7019008 **Survey Date:** September 16, 2020

km Marker: 702.9 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing wet towards larger body of water

Photo 2. Facing west showing inlet as ephemeral drainage

Photo 3. Aerial imagery showing survey area

Fish Sampling Data

Method	Effort		Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
Electrofishing	-	(s)	NO FISH CAPTURED	-	0	-	0.00	-
Minnow Trap	44.8	(hr)						

Water Quality Data

Time of Day (HH:MM):	14:22
Water temperature (°C):	7.86
Dissolved Oxygen (mg/L):	13.08
Sp. Conductivity (µS/cm):	109.00
pH:	6.77
Turbidity (NTU):	-

General Comments

Wetland area with an inlet assessed as an ephemeral drainage (WX-031). Inlet provides connectivity to a larger waterbody to the west. Organic substrate and wetland vegetation with a maximum depth of approximately 1 m. No fish captured in minnow traps. Larger waterbody to west may afford fish habitat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

UWB-2: Wetland Area

UTM Location: 10U 470653 7020732 **Survey Date:** September 23, 2020

km Marker: 704.7 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing north across wetland

Photo 2. Facing west showing connection to larger waterbody

Photo 3. Facing west showing larger waterbody

Photo 4. Facing south with UWB-2 and larger waterbody visible

Fish Sampling Data

Method	Effort		Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
Electrofishing	-	(s)	NO FISH CAPTURED	-	0	-	0.00	-
Minnow Trap	46	(hr)						

Water Quality Data

Time of Day (HH:MM):	12:27
Water temperature (°C):	7.98
Dissolved Oxygen (mg/L):	7.05
Sp. Conductivity (µS/cm):	65.00
pH:	7.82
Turbidity (NTU):	-

General Comments

Wetland is connected to a larger waterbody to the west. Wetland area has organic substrate and wetland vegetation. Maximum depth measured approximately 1 m. Larger waterbody likely has fish habtiat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

SWA-3: Wetland Area

UTM Location: 10U 471528 7027742 **Survey Date:** September 16, 2020

km Marker: 710.35 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Showing outlet, an ephemeral drainage

Photo 2. Facing south down existing winter road, no visible outlet

Photo 3. Water with subsurface flow to west of existing winter road

General Comments

Wetland area adjacent to proposed construction corridor. The outlet was assessed as an ephemeral drainage. There was no inlet visible on the ground. A full survey could not be completed due to nearby moose pasture. No fish habitat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

UWB-3: Wetland Area

UTM Location: 10U 469827 7031105 **Survey Date:** September 20, 2020

km Marker: 715.6 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing north from helicopter

Photo 2. Facing northeast from helicopter

Photo 3. Facing east towards existing winter road from helicopter

General Comments

Wetland area adjacent to proposed Project. No inlet or outlet were observed. No fish habitat potential.

Prepared by: LD Reviewed by: DC

Stantec Document Classification: Stantec Internal

Dehcho Territory Fish and Fish Habitat

WX-035: Drainage

UTM Location: 10U 467959 7035544 **Survey Date:** September 22, 2020

km Marker: 718.79 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing north across existing winter road

Photo 2. No channelization 40 m east of existing winter road

Photo 3. Standing water on west side of existing winter road

Photo 4. No channelization 50 m east of existing winter road

General Comments

Ephemeral drainage oriented east-west across the existing winter road. No defined bed or banks observed. Some standing, isolated water was observed and was discontinuous on the west side of the existing winter road. No connectivity to the Mackenzie River was observed. River is approximately 2 km to the west. No fish habitat potential.

Prepared by: LD Reviewed by: DC

Stantec Document Classification: Stantec Internal

Dehcho Territory Fish and Fish Habitat

UWB-4: Wetland Area

UTM Location: 10U 468244 7035072 **Survey Date:** September 22, 2020

km Marker: 719.9 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing south from helicopter

Photo 2. Facing north from helicopter showing outlet

Photo 3. Facing east showing minnow trap

Photo 4. Facing southeast along wetland edge

Fish Sampling Data

Method	Effort		Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
Electrofishing	-	(s)	NO FISH CAPTURED	-	0	-	0.00	-
Minnow Trap	35	(hr)						

Water Quality Data

Time of Day (HH:MM):	12:27
Water temperature (°C):	7.98
Dissolved Oxygen (mg/L):	7.05
Sp. Conductivity (µS/cm):	65.00
pH:	7.82
Turbidity (NTU):	-

General Comments

Wetland area. Outlet visible at northwest end of wetland. Organic substrate and wetland vegetation observed. Maximum depth is greater than 2 m. Wetland affords fish habtiat potential.

Prepared by: LD Reviewed by: DC

Stantec Document Classification: Stantec Internal

Dehcho Territory Fish and Fish Habitat

WX-036: Unnamed Watercourse

UTM Location: 10U 465977 7037399 **Survey Date:** Septemeber 22, 2020
km Maker: 721.61 **Zone:** 2
Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Physical Channel Transect Data

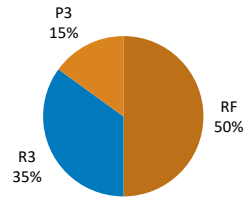
Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	2.7	2.2	1.8	1.9	1.6	1.2
Wetted Width (m)	1.9	2.1	1.7	2.6	1.4	1.7
Depth at LDB + 25% (m)	0.1	0.2	0.2	0.2	0.1	0.2
Depth at LDB + 50% (m)	0.2	0.1	0.2	0.2	0.3	0.2
Depth at LDB + 75% (m)	0.3	0.1	0.4	0.2	0.3	0.2
Max.Bankfull Depth (m)	0.6	0.5	0.7	0.6	0.9	0.5
Gradient (%)	2	5	6	5	4	3
Dominant Habitat Unit	RF	RF	RF	RF	RF	R3
Stream Bed						
Substrate (% of Transect Area) Organics	25	25	25	25	25	25
Fines	50	50	50	50	50	50
Small Gravel	0	0	0	0	0	0
Large Gravel	5	5	5	5	5	5
Cobble	10	10	10	10	10	10
Boulder	10	10	10	10	10	10
Bedrock	0	0	0	0	0	0
Embeddedness	H	H	H	H	H	H

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.3	0.3	0.2	0.3	0.4	0.3	0.3	0.4	0.6	0.6	0.3	0.3
Bank Slope (°)	40	30	150	150	120	120	130	160	110	70	130	150
Bank Stability	MS	MS	S	S	MS	MS	S	S	S	MS	S	S
Dom. Bank Material	F	F	F	F	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	O	O	O	F	LG	SG	C	F	F	F	F
Dom. Riparian Veg.	G	G	G	G	S	S	G	G	N	N	G	G
Subdom. Riparian Veg.	S	S	D	D	G	G	D	D	D	D	D	D

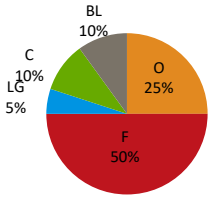
Habitat Inventory / Reach Data

Instream Cover (%):	11	Overhead Cover (%):	24
Dom. Instream Cover:	WD	Dom. Overhead Cover:	TS
Subdom. Instream Cover	DC	Subdom. Overhead Cove	UB
Maximum Depth (m)	0.4	Dom. Aquatic Veg. Type:	-

Habitat Distribution



Substrate Composition



Water Quality Data

Time of Day (HH:MM):	14:03
Water Temperature (°C):	2.9
Dissolved Oxygen (mg/L)	8.59
Sp. Conductivity (µs/cm)	81.0
pH:	6.27
Turbidity (NTU):	-

Channel Characteristics

Pattern:	SI
Islands:	N
Bars:	SD
Coupling:	CO
Confinement:	FC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Moderate	Moderate	Poor-Moderate
Passage:	Good	Good	Good

Photo 1: Facing upstream 200 m downstream of centerline.

Photo 2: Facing upstream at centerline.

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB)	450	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
400	30	12	346

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED	0	-	0.00	-	-

General Comments

No fish captured or observed during fish assessment. Rearing habitat may be limited by velocity in riffle habitat throughout assessed reach. No known barrier between crossing location and Mackenzie River.

Prepared by: LD Reviewed by: DC

Stantec Document Classification: Stantec Internal

Dehcho Territory Fish and Fish Habitat

WX-038: Unnamed Watercourse

UTM Location: 10U 465248 7042571 **Survey Date:** September 22, 2020
km Marker 727.36 **Zone:** 2
Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Physical Channel Transect Data

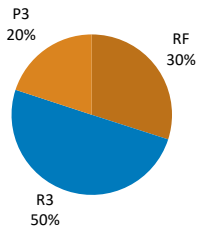
Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.6	1.1	1.5	1.4	2.3	0.9
Wetted Width (m)	1.1	1.0	1.1	1.2	1.8	0.8
Depth at LDB + 25% (m)	0.1	0.2	0.3	0.3	0.2	0.3
Depth at LDB + 50% (m)	0.1	0.2	0.3	0.3	0.2	0.4
Depth at LDB + 75% (m)	0.1	0.2	0.2	0.1	0.1	0.4
Max.Bankfull Depth (m)	0.5	0.6	0.5	0.5	0.6	0.7
Gradient (%)	1	4	4	3	1.5	1.5
Dominant Habitat Unit	RF	RF	R3	R3	R3	R3
Stream Bed						
Substrate (% of Transect Area) Organics	30	30	30	30	30	30
Fines	50	50	50	50	50	50
Small Gravel	5	5	5	5	5	5
Large Gravel	5	5	5	5	5	5
Cobble	10	10	10	10	10	10
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	H	H	H	H	H	H

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.3
Bank Slope (°)	80	60	100	90	45	50	80	30	50	40	90	90
Bank Stability	MS	MS	MS	MS	US	US	MS	MS	US	US	MS	MS
Dom. Bank Material	O	O	O	O	O	F	O	F	F	F	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	O	O	O	F	F
Dom. Riparian Veg.	G	G	G	G	N	N	G	G	N	N	G	G
Subdom. Riparian Veg.	S	S	S	S	S	S	S	S	S	S	S	S

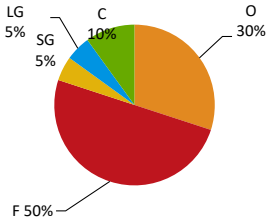
Habitat Inventory / Reach Data

Instream Cover (%):	9	Overhead Cover (%):	21
Dom. Instream Cover:	DC	Dom. Overhead Cover:	UB
Subdom. Instream Cover	-	Subdom. Overhead Cove	WD
Maximum Depth (m)	0.4	Dom. Aquatic Veg. Type:	-

Habitat Distribution



Substrate Composition



Water Quality Data

Time of Day (HH:MM):	17:26
Water Temperature (°C):	2.5
Dissolved Oxygen (mg/L)	9.26
Sp. Conductivity (µs/cm)	74.0
pH:	7.53
Turbidity (NTU):	-

Channel Characteristics

Pattern:	ME
Islands:	N
Bars:	DG
Coupling:	CO
Confinement:	FC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Moderate	Moderate	Poor-Moderate
Passage:	Moderate	Moderate	Moderate

Photo 1: Facing up at 50 m upstream from centerline

Photo 2: Facing upstream at centerline.

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB)	432	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
400	30	12	317

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED	0	-	0.00	-	-

General Comments

High approach banks, fish habitat mostly limited by overall depth. No known barriers from Mackenzie River may provide seasonal fish habitat. No fish captured or observed during fish assessments.

Prepared by: LD Reviewed by: DC

Stantec Document Classification: Stantec Internal

Dehcho Territory Fish and Fish Habitat

Drainage 1: Unnamed Watercourse

UTM Location: 10U 463008 7047414 **Survey Date:** September 24, 2020
km Marker: 732.74 **Zone:** 2
Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Physical Channel Transect Data

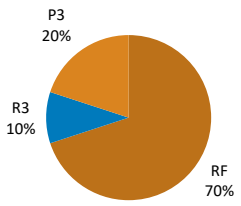
Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6
Channel Width (m)	0.9	0.9	0.9	1.7	1.1	1.6
Wetted Width (m)	0.8	0.9	0.8	1.7	0.9	1.2
Depth at LDB + 25% (m)	0.2	0.2	0.2	0.3	0.0	0.1
Depth at LDB + 50% (m)	0.2	0.2	0.2	0.0	0.1	0.0
Depth at LDB + 75% (m)	0.1	0.1	0.3	0.1	0.1	0.2
Max.Bankfull Depth (m)	0.6	0.7	0.6	0.4	0.4	0.5
Gradient (%)	4	5	5	14	6	9
Dominant Habitat Unit	RF	RF	RF	RF	RF	RF
Stream Bed						
Substrate (% of Transect Area) – Organics	10	10	10	10	10	10
Fines	40	40	40	40	40	40
Small Gravel	0	0	0	0	0	0
Large Gravel	0	0	0	0	0	0
Cobble	15	15	15	15	15	15
Boulder	35	35	35	35	35	35
Bedrock	0	0	0	0	0	0
Embeddedness	M	M	M	M	M	M

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.4	0.4	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.2
Bank Slope (°)	90	90	100	80	90	90	90	90	100	90	50	90
Bank Stability	S	MS	MS	MS	S	S	S	S	S	S	MS	S
Dom. Bank Material	O	F	F	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	O	O	O	F	F	F	F	O	O	F	O
Dom. Riparian Veg.	G	G	G	S	S	S	G	G	G	G	S	S
Subdom. Riparian Veg.	S	S	S	G	S	G	G	C	C	C	S	S

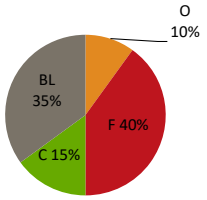
Habitat Inventory / Reach Data

Instream Cover (%):	5	Overhead Cover (%):	22
Dom. Instream Cover:	DC	Dom. Overhead Cover:	TS
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	UB
Maximum Depth (m)	0.3	Dom. Aquatic Veg. Type:	-

Habitat Distribution



Substrate Composition



Water Quality Data

Time of Day (HH:MM):	13:52
Water Temperature (°C):	3.3
Dissolved Oxygen (mg/L):	8.55
Sp. Conductivity (µs/cm):	88.0
pH:	6.47
Turbidity (NTU):	-

Channel Characteristics

Pattern:	ST
Islands:	N
Bars:	SD
Coupling:	CO
Confinement:	EN
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Poor	Poor	Poor
Passage:	Poor	Poor-Moderate	Poor-Moderate

Photo 1: Facing upstream 50 m downstream from centerline.

Photo 2: Facing downstream 100 m downtream of centerline.

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					-

General Comments

Velocity and gradient barriers for fish at confluence with Mackenzie River and downstream of centerline (14% and 16% slope, respectively). Fish assessment not completed as fish presence was known.

Prepared by: LD Reviewed by: DC

Stantec Document Classification: Stantec Internal

Dehcho Territory Fish and Fish Habitat

Bonnie Creek

UTM Location: 10U 462586 7048307 **Survey Date:** September 23, 2020
km Marker: 733.71 **Zone:** 2
Crew Initials: LD MAN **Restricted Activity Timing Window** August 15 to July 15

Physical Channel Transect Data

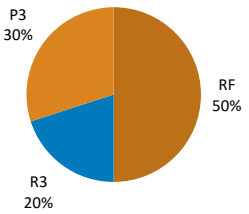
Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	3.4	3.1	2.0	3.0	3.1	-
Wetted Width (m)	3.0	3.2	2.2	3.1	2.3	-
Depth at LDB + 25% (m)	0.1	0.2	0.2	0.2	0.3	-
Depth at LDB + 50% (m)	0.1	0.2	0.2	0.1	0.4	-
Depth at LDB + 75% (m)	0.1	0.3	0.2	0.2	0.3	-
Max.Bankfull Depth (m)	0.4	0.5	0.7	0.5	0.7	-
Gradient (%)	4	4	9	5	2	-
Dominant Habitat Unit	P3	RF	RF	RF	R3	-
Stream Bed						
Substrate (% of Transect Area) Organics	5	5	5	5	5	-
Fines	20	20	20	20	20	-
Small Gravel	15	15	15	15	15	-
Large Gravel	0	0	0	0	0	-
Cobble	20	20	20	20	20	-
Boulder	40	40	40	40	40	-
Bedrock	0	0	0	0	0	-
Embeddedness	M	M	M	M	M	-

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.2	0.2	0.2	0.2	0.5	0.6	0.3	0.3	0.2	0.3	-	-
Bank Slope (°)	90	90	110	90	90	100	120	110	90	40	-	-
Bank Stability	S	MS	MS	MS	S	S	S	S	MS	MS	-	-
Dom. Bank Material	O	O	O	O	O	O	O	O	O	F	-	-
Subdom. Bank Material	F	F	F	F	F	F	SG	SG	F	O	-	-
Dom. Riparian Veg.	G	S	S	S	S	S	G	G	G	G	-	-
Subdom. Riparian Veg.	C	G	G	G	C	G	S	S	S	S	-	-

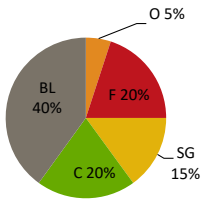
Habitat Inventory / Reach Data

Instream Cover (%):	15	Overhead Cover (%):	25
Dom. Instream Cover:	BL	Dom. Overhead Cover:	TS
Subdom. Instream Cover:	WD	Subdom. Overhead Cove	UB
Maximum Depth (m)	0.4	Dom. Aquatic Veg. Type:	-

Habitat Distribution



Substrate Composition



Water Quality Data

Time of Day (HH:MM):	10:47
Water Temperature (°C):	0.8
Dissolved Oxygen (mg/L):	12.03
Sp. Conductivity (µs/cm):	80.0
pH:	6.61
Turbidity (NTU):	-

Channel Characteristics

Pattern:	SI
Islands:	N
Bars:	DG
Coupling:	CO
Confinement:	EN
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	None	None	None
Rearing:	Moderate	Moderate	Moderate-Good
Passage:	Moderate	Moderate	Moderate

Photo 1: Facing upstream from 100 meters up for centerline

Photo 2: Facing upstream 100 meters down from Centerline.

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					-

General Comments

Confluence with Mackenzie River approximately 240 meters downstream from centerline, no fish barriers observed. Fish assessment not completed as fish presence was known.

Prepared by: LD Reviewed by: DC

Stantec Document Classification: Stantec Internal

Dehcho Territory Fish and Fish Habitat

Drainage 2 Unnamed Watercourse

UTM Location: 10U 462082 7050913 **Survey Date:** September 23, 2020

km Marker: 736.48 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

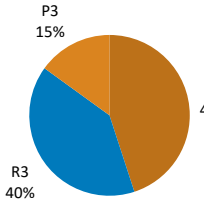
Physical Channel Transect Data

Transect # (Location)	1 (↑100)		2 (↑50)		3 (CL)		4 (↓100)		5 (↓200)		6 (↓300)	
Channel Width (m)	0.8		1.1		0.9		1.2		1.3		1.2	
Wetted Width (m)	0.9		1.0		1.0		1.0		0.9		1.7	
Depth at LDB + 25% (	0.2		0.1		0.3		0.1		0.3		0.1	
Depth at LDB + 50% (	0.2		0.1		0.3		0.2		0.3		0.1	
Depth at LDB + 75% (	0.2		0.1		0.3		0.3		0.1		0.1	
Max.Bankfull Depth (	0.6		0.4		0.7		0.5		0.4		0.2	
Gradient (%)	6		4		4		10		7		6	
Dominant Habitat Un	R3		R3		RF		R3		RF		RF	
Stream Bed												
Substrate (% of Transect Area) Organics	20		20		20		20		20		20	
Fines	30		30		30		30		30		30	
Small Gravel	20		20		20		20		20		20	
Large Gravel	5		5		5		5		5		5	
Cobble	10		10		10		10		10		10	
Boulder	15		15		15		15		15		15	
Bedrock	0		0		0		0		0		0	
Embeddedness	M		M		M		M		M		M	
Bank Measurements	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Bank Height (m)	0.3	0.3	0.3	0.3	0.3	0.4	0.2	0.2	0.2	0.3	0.2	0.3
Bank Slope (°)	110	130	70	50	120	160	80	70	110	80	130	160
Bank Stability	S	S	MS	US	S	S	MS	MS	S	S	S	S
Dom. Bank Material	O	O	F	F	O	O	F	F	O	O	O	O
Subdom. Bank Mater	F	F	O	O	F	F	O	O	F	F	F	F
Dom. Riparian Veg.	N	N	G	G	G	G	G	G	G	G	G	G
Subdom. Riparian Ve	S	S	S	S	S	S	S	S	S	S	S	S

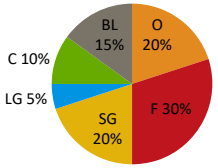
Habitat Inventory / Reach Data

Instream Cover (%):	7	Overhead Cover (%):	16
Dom. Instream Cover:	WD	Dom. Overhead Cover:	UB
Subdom. Instream Cover	DC	Subdom. Overhead Cove	TS
Maximum Depth (m)	0.3	Dom. Aquatic Veg. Type:	-

Habitat Distribution



Substrate Composition



Water Quality Data

Time of Day (HH:MM):	10:27
Water Temperature (°C):	0.7
Dissolved Oxygen (mg/L)	8.88
Sp. Conductivity (µs/cm)	78.0
pH:	6.52
Turbidity (NTU):	-

Channel Characteristics

Pattern:	SI
Islands:	N
Bars:	N
Coupling:	CO
Confinement:	CO
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Moderate	Moderate	Poor-Moderate
Passage:	Moderate	Moderate	Moderate

Photo 1: Facing downstream 200 m downstream of centerline.

Photo 2: Facing upstream 100 m upstream of centerline.

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts Freq. (Hz) Duty Cycle (%) Dist. (m)

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					-

General Comments

No known barriers between Mackenzie River and proposed crossing location or within assessed reach. Fish assessment not completed as fish presence was known. Fish habitat was limited by depth at the time of assessment.

Prepared by: LD Reviewed by: DC

Stantec Document Classification: Stantec Internal

Dehcho Territory Fish and Fish Habitat

WX-039: Unnamed Watercourse

UTM Location: 10U 462013 7051561 **Survey Date:** Septemeber 23, 2020
km Marker: 738.7 **Zone:** 2
Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Physical Channel Transect Data

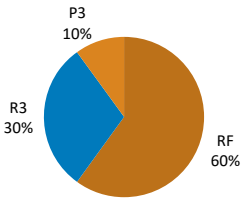
Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.4	0.9	1.8	1.1	1.4	1.5
Wetted Width (m)	1.2	1.0	1.1	1.0	1.0	1.1
Depth at LDB + 25% (m)	0.2	0.1	0.2	0.3	0.2	0.1
Depth at LDB + 50% (m)	0.2	0.2	0.2	0.3	0.2	0.0
Depth at LDB + 75% (m)	0.2	0.2	0.1	0.2	0.1	0.1
Max.Bankfull Depth (m)	0.6	0.6	0.7	0.7	0.6	0.5
Gradient (%)	3	4	2	1	3	3
Dominant Habitat Unit	RF	RF	R3	R3	RF	RF
Stream Bed						
Substrate (% of Transect Area) Organics	10	10	10	10	10	10
Fines	40	40	40	40	40	40
Small Gravel	20	20	20	20	20	20
Large Gravel	5	5	5	5	5	5
Cobble	20	20	20	20	20	20
Boulder	0	0	0	0	0	0
Bedrock	5	5	5	5	5	5
Embeddedness	M	M	M	M	M	M

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.3	0.3	0.3	0.3	0.4	0.5	0.3	0.4	0.2	0.3	0.3	0.2
Bank Slope (°)	95	110	120	110	90	50	90	90	80	40	100	90
Bank Stability	MS	MS	MS	MS	MS	US	MS	MS	MS	US	US	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	F
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	O
Dom. Riparian Veg.	G	G	G	G	G	G	G	G	G	G	G	G
Subdom. Riparian Veg.	C	C	S	S	S	S	C	S	S	S	S	S

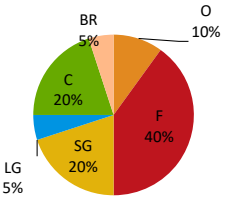
Habitat Inventory / Reach Data

Instream Cover (%):	9	Overhead Cover (%):	15
Dom. Instream Cover:	DC	Dom. Overhead Cover:	TS
Subdom. Instream Cover:	BL	Subdom. Overhead Co'	UB
Maximum Depth (m)	0.3	Dom. Aquatic Veg. Typ	-

Habitat Distribution



Substrate Composition



Water Quality Data

Time of Day (HH:MM):	13:27
Water Temperature (°C):	0.4
Dissolved Oxygen (mg/L):	9.08
Sp. Conductivity (µs/cm):	67.0
pH:	6.99
Turbidity (NTU):	-

Channel Characteristics

Pattern:	IR
Islands:	N
Bars:	SD
Coupling:	CO
Confinement	FC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Moderate	Moderate	Poor-Moderate
Passage:	Good	Good	Good

Photo 1: Facing down fom 50 m upstream from centerline.

Photo 2: Facing upstream at centerline.

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB)	573	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
350	30	12	378

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED	0	-	0.00	-	-

General Comments

No fish captured or observed during fish assessment. No known barrier from Mackenzie River. Watercourse may provide seasonal fish habitat. Predominantly fines and organic substrate combined with low depth and cover limit fish habitat ratings.

Prepared by: LD Reviewed by: DC

Stantec Document Classification: Stantec Internal

Dehcho Territory Fish and Fish Habitat

Drainage 3 Unnamed Watercourse

UTM Location: 10U 461404 7053822 **Survey Date:** September 21, 2020

km Marker: 739.55 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Physical Channel Transect Data

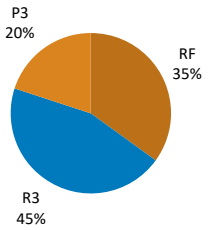
Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	2.4	2.2	1.6	1.7	2.4	1.7
Wetted Width (m)	1.9	1.1	1.2	1.4	2.2	1.4
Depth at LDB + 25% (m)	0.1	0.2	0.2	0.2	0.1	0.1
Depth at LDB + 50% (m)	0.1	0.2	0.2	0.2	0.1	0.2
Depth at LDB + 75% (m)	0.2	0.2	0.2	0.1	0.1	0.3
Max.Bankfull Depth (m)	0.5	0.6	0.5	0.7	0.3	0.6
Gradient (%)	2	4	3	3	2	4
Dominant Habitat Unit	R3	R3	R3	RF	RF	R3
Stream Bed						
Substrate (% of Transect Area) Organics	20	20	20	20	20	20
Fines	40	40	40	40	40	40
Small Gravel	10	10	10	10	10	10
Large Gravel	10	10	10	10	10	10
Cobble	20	20	20	20	20	20
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	H	H	H	H	H	H

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.2	0.4	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.2	0.3	0.2
Bank Slope (°)	80	90	30	70	40	80	50	80	90	100	30	150
Bank Stability	S	S	MS	MS	MS	MS	MS	MS	MS	S	US	S
Dom. Bank Material	O	O	F	F	F	F	O	O	O	O	F	O
Subdom. Bank Material	F	F	O	O	O	O	F	F	F	F	O	F
Dom. Riparian Veg.	S	S	C	S	S	S	S	S	C	S	S	S
Subdom. Riparian Veg.	G	G	S	G	G	G	G	G	G	G	G	G

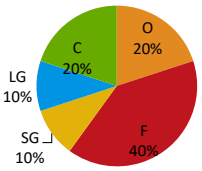
Habitat Inventory / Reach Data

Instream Cover (%):	13	Overhead Cover (%)	11
Dom. Instream Cover:	WD	Dom. Overhead Cov	TS
Subdom. Instream Cover:	DC	Subdom. Overhead	UB
Maximum Depth (m)	0.3	Dom. Aquatic Veg. T	-

Habitat Distribution



Substrate Composition



Water Quality Data

Time of Day (HH:MM):	17:23
Water Temperature (°C):	2.2
Dissolved Oxygen (mg/L):	9.29
Sp. Conductivity (µs/cm):	103
pH:	7.55
Turbidity (NTU):	-

Channel Characteristics

Pattern:	ME
Islands:	N
Bars:	DG
Coupling:	CO
Confinement	FC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Good	Good	Good
Passage:	Good	Good	Good

Photo 1: Facing upstrea 200 m downstream from centerline.

Photo 2: Facing downstream 50 m upstream of centerline.

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts | Freq. (Hz) | Duty Cycle (%) | Dist. (m)

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					-

General Comments

Potential for erosion concerns upstream of centerline, stream does a sharp "S" bend and parallels existing winter road for approximately 20 m. No know barriers between crossing and Mackenzie River. Fish assessment not completed as fish presence was known.

Prepared by: LD Reviewed by: DC

Stantec Document Classification: Stantec Internal

Dehcho Territory Fish and Fish Habitat

WX-040: Unnamed Watercourse

UTM Location: 10U 461135 7055011 | **Survey Date:** Septemeber 21, 2020
km Marker: 740.75 | **Zone:** 2
Crew Initials: LD MAN | **Restricted Activity Timing Window** August 15 to July 15

Physical Channel Transect Data

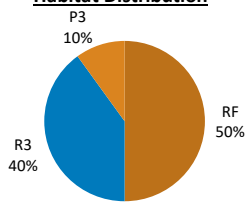
Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.5	1.9	1.3	1.2	1.4	1.1
Wetted Width (m)	1.1	1.6	1.4	1.0	1.3	1.1
Depth at LDB + 25% (	0.3	0.1	0.3	0.3	0.2	0.3
Depth at LDB + 50% (	0.3	0.1	0.2	0.3	0.2	0.4
Depth at LDB + 75% (	0.1	0.1	0.1	0.2	0.3	0.3
Max.Bankfull Depth (	0.6	0.4	0.4	0.4	0.5	0.6
Gradient (%)	4	2	4	-	4	3
Dominant Habitat Un	RF	R3	R3	RF	RF	RF
Stream Bed						
Substrate (% of Transect Area) Organics	20	20	20	20	20	20
Fines	70	70	70	70	70	70
Small Gravel	0	0	0	0	0	0
Large Gravel	5	5	5	5	5	5
Cobble	5	5	5	5	5	5
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	M	M	M	M	M	M

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.2	0.3	0.2	0.2	0.2	0.1	0.2	0.2	0.3	0.2	0.1	0.2
Bank Slope (°)	80	20	40	70	100	100	70	45	90	110	100	90
Bank Stability	MS	US	US	US	S	S	MS	MS	MS	MS	S	S
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Mater	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	G	G	G	G	G	G	G	G	G	G	S	S
Subdom. Riparian Ve	S	S	S	S	C	S	S	S	S	S	G	G

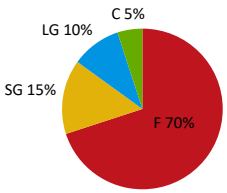
Habitat Inventory / Reach Data

Instream Cover (%):	8	Overhead Cover (%):	17
Dom. Instream Cover:	DC	Dom. Overhead Cover:	TS
Subdom. Instream Cover:	WD	Subdom. Overhead Cover:	WD
Maximum Depth (m)	0.4	Dom. Aquatic Veg. Type:	-

Habitat Distribution



Substrate Composition



Water Quality Data

Time of Day (HH:MM):	16:25
Water Temperature (°C):	2.5
Dissolved Oxygen (mg/L):	17.83
Sp. Conductivity (µs/cm):	83.0
pH:	7.99
Turbidity (NTU):	-

Channel Characteristics

Pattern:	IR
Islands:	N
Bars:	DG
Coupling:	CO
Confinement:	CO
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Moderate-Good	Moderate-Good	Moderate
Passage:	Moderate	Moderate	Moderate

Photo 1: Facing downstream at centerline

Photo 2: Facing downstream 100 m upstream of centerline.

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB	359	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
300	30	12	367

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED	0	-	0.00	-	-

General Comments

No fish captured or observed during fish assessment. No known barrier from Mackenzie River, likely provides seasonal fish habitat. Low depth and cover limit fish habitat, with potential for rearing in run habitat.

Prepared by: LD Reviewed by: DC

Stantec Document Classification: Stantec Internal

Dehcho Territory Fish and Fish Habitat

WX-041: Unnamed Watercourse

UTM Location: 10U 460915 7055927 **Survey Date:** Septemeber 20, 2020
km Marker: 741.74 **Zone:** 2
Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Physical Channel Transect Data

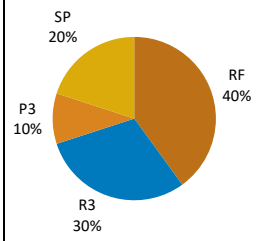
Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	0.9	1.3	1.2	1.3	1.7	0.8
Wetted Width (m)	0.6	0.7	1.0	1.0	1.1	0.9
Depth at LDB + 25% (m)	0.3	0.1	0.5	0.1	0.1	0.2
Depth at LDB + 50% (m)	0.2	0.0	0.6	0.2	0.1	0.2
Depth at LDB + 75% (m)	0.2	0.2	0.5	0.3	0.2	0.3
Max.Bankfull Depth (m)	0.7	0.7	0.9	0.6	0.5	0.6
Gradient (%)	7	6	4	-	4	6
Dominant Habitat Unit	SP	SP	R3	RF	R3	RF
Stream Bed						
Substrate (% of Transect Area) Organics	0	0	0	0	0	0
Fines	100	100	100	100	100	100
Small Gravel	0	0	0	0	0	0
Large Gravel	0	0	0	0	0	0
Cobble	0	0	0	0	0	0
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	VH	VH	VH	VH	VH	VH

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.3	0.3	0.3	0.4	0.3	0.4	0.2	0.3	0.4	0.3	0.3	0.3
Bank Slope (°)	80	80	90	50	45	70	80	90	80	80	100	120
Bank Stability	MS	MS	MS	US	MS	MS	MS	S	US	US	S	S
Dom. Bank Material	F	F	F	F	F	F	O	O	F	F	F	F
Subdom. Bank Material	O	O	O	O	O	O	F	F	O	O	O	O
Dom. Riparian Veg.	G	G	N	G	G	G	G	G	G	G	G	G
Subdom. Riparian Veg.	S	D	S	S	S	S	S	S	S	S	S	S

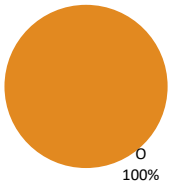
Habitat Inventory / Reach Data

Instream Cover (%):	2	Overhead Cover (%):	15
Dom. Instream Cover:	DC	Dom. Overhead Cover:	TS
Subdom. Instream Cover	-	Subdom. Overhead Cove	WD
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Habitat Distribution



Substrate Composition



Water Quality Data

Time of Day (HH:MM):	18:07
Water Temperature (°C):	4.0
Dissolved Oxygen (mg/L)	8.94
Sp. Conductivity (µs/cm):	62.0
pH:	7.24
Turbidity (NTU):	-

Channel Characteristics

Pattern:	IR
Islands:	N
Bars:	MD
Coupling:	CO
Confinement:	FC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	None	None	None
Overwintering:	Poor	Poor	Poor
Rearing:	Poor-Moderate	Poor-Moderate	Poor
Passage:	Moderate	Moderate	Moderate

Photo 1: Facing down at 200 m downstream from centerline

Photo 2: Facing up at 100 m downstream of centerline.

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB)	331	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
300	30	12	321

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED	0	-	0.00	-	-

General Comments

No suitable substrate for spawning. No known barriers between proposed crossing location and the Mackenzie River. Some rearing habitat present in runs throughout assessed reach but limited by depth and instream cover. No fish captured during fish assessments.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

WX-042: Unnamed Watercourse

UTM Location: 10U 460641 7057047 **Survey Date:** Septemeber 20, 2020
km Marker: 742.74 **Zone:** 2
Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

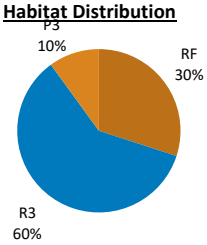
Physical Channel Transect Data

Transect # (Location)	1 (↑100)		2 (↑50)		3 (CL)		4 (↓100)		5 (↓200)		6 (↓300)	
Channel Width (m)	0.6		0.6		1.0		1.6		1.4		0.8	
Wetted Width (m)	1.1		1.2		1.4		2.0		1.8		1.1	
Depth at LDB + 25% (m)	0.1		0.1		0.1		0.1		0.1		0.1	
Depth at LDB + 50% (m)	0.1		0.2		0.1		0.1		0.1		0.1	
Depth at LDB + 75% (m)	0.1		0.1		0.0		0.0		0.2		0.1	
Max.Bankfull Depth (m)	0.6		0.7		0.3		0.4		0.9		0.4	
Gradient (%)	3		1		-		4		-		-	
Dominant Habitat Unit	R3		R3		R3		RF		R3		R3	
Stream Bed												
Substrate (% of Transect Area) Organics	0		0		0		0		0		0	
Fines	90		90		90		90		90		90	
Small Gravel	10		10		10		10		10		10	
Large Gravel	0		0		0		0		0		0	
Cobble	0		0		0		0		0		0	
Boulder	0		0		0		0		0		0	
Bedrock	0		0		0		0		0		0	
Embeddedness	VH		VH		VH		VH		VH		VH	
Bank Measurements	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Bank Height (m)	0.3	0.4	0.3	0.3	0.1	0.1	-	0.4	0.3	0.4	0.2	0.3
Bank Slope (°)	70	70	60	60	20	20	-	50	-	-	110	70
Bank Stability	US	US	US	US	US	US	US	US	US	US	US	US
Dom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Subdom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Dom. Riparian Veg.	N	N	S	S	N	N	S	S	S	S	S	S
Subdom. Riparian Veg.	G	G	G	G	S	S	N	N	N	N	N	N

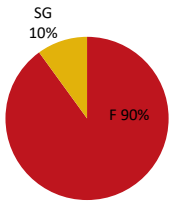
Habitat Inventory / Reach Data

Instream Cover (%):	0	Overhead Cover (%):	19
Dom. Instream Cover:	-	Dom. Overhead Cover:	TS
Subdom. Instream Cover	-	Subdom. Overhead Cove	OV
Maximum Depth (m)	0.2	Dom. Aquatic Veg. Type:	-

Habitat Distribution



Substrate Composition



Water Quality Data

Time of Day (HH:MM):	14:15
Water Temperature (°C):	2.9
Dissolved Oxygen (mg/L)	10.00
Sp. Conductivity (µs/cm)	96.0
pH:	7.32
Turbidity (NTU):	-

Channel Characteristics

Pattern:	IR
Islands:	F
Bars:	BR
Coupling:	CO
Confinement:	FC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Poor	Poor	Poor
Passage:	Poor	Poor	Poor

Photo 1: Facing up 200 m downstream from centerline

Photo 2: Facing up 100 m downstream from centerline.

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts Freq. (Hz) Duty Cycle (%) Dist. (m)

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED	-	-	-	-	-

General Comments

Fish assessment not completed due to safety concerns from unstable banks. Fish habitat rated as poor due to low depth, predominantly fine and organic substrate and lack of instream cover.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

WX-043: Unnamed Watercourse

UTM Location: 10U 458952 7061042 **Survey Date:** September 20, 2020
km Marker: 747.56 **Zone:** 2
Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

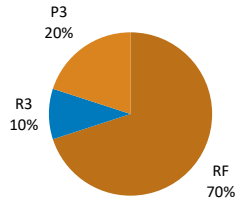
Physical Channel Transect Data

Transect # (Location)	1 (↑100)		2 (↑50)		3 (CL)		4 (↓100)		5 (↓200)		6 (↓300)	
Channel Width (m)	0.9		-		1.3		1.3		-		-	
Wetted Width (m)	2.1		-		0.9		0.9		-		-	
Depth at LDB + 25% (	0.8		-		0.1		0.1		-		-	
Depth at LDB + 50% (	0.1		-		0.0		0.1		-		-	
Depth at LDB + 75% (	0.2		-		0.0		0.1		-		-	
Max.Bankfull Depth (	0.1		-		0.1		0.4		-		-	
Gradient (%)	16		-		2		14		-		-	
Dominant Habitat Un	SP		-		RF		SP		-		-	
Stream Bed												
Substrate (% of Transect Area) Organics	0		-		0		0		-		-	
Fines	25		-		25		25		-		-	
Small Gravel	20		-		20		20		-		-	
Large Gravel	5		-		5		5		-		-	
Cobble	20		-		20		20		-		-	
Boulder	30		-		30		30		-		-	
Bedrock	0		-		0		0		-		-	
Embeddedness	L		L		L		L		-		-	
Bank Measurements	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Bank Height (m)	-	-	-	-	0.2	0.1	0.2	0.2	-	-	-	-
Bank Slope (°)	-	-	-	-	70	60	90	60	-	-	-	-
Bank Stability	S	S	-	-	US	US	MS	MS	-	-	-	-
Dom. Bank Material	O	O	-	-	F	F	O	C	-	-	-	-
Subdom. Bank Mater	LG	SG	-	-	F	O	C	O	-	-	-	-
Dom. Riparian Veg.	G	G	-	-	G	G	G	G	-	-	-	-
Subdom. Riparian Ve	G	G	-	-	G	S	S	S	-	-	-	-

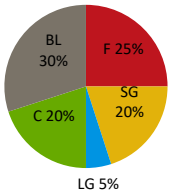
Habitat Inventory / Reach Data

Instream Cover (%):	6	Overhead Cover (%):	10
Dom. Instream Cover:	BL	Dom. Overhead Cover:	TS
Subdom. Instream Cover	DC	Subdom. Overhead Cove	UB
Maximum Depth (m)	0.8	Dom. Aquatic Veg. Type:	-

Habitat Distribution



Substrate Composition



Water Quality Data

Time of Day (HH:MM):	10:45
Water Temperature (°C):	2.6
Dissolved Oxygen (mg/L)	113.20
Sp. Conductivity (µs/cm):	90.0
pH:	-
Turbidity (NTU):	-

Channel Characteristics

Pattern:	IR
Islands:	N
Bars:	N
Coupling:	CO
Confinement:	CO
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Poor	Poor	Poor
Passage:	Poor	Poor	Poor

Photo 1: Facing upstream 100 m upstream of centerline.

Photo 2: Facing downstream 50 m downstream of centerline.

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB	213	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
355	30	12	131

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED	0	-	0.00	-	-

General Comments

Existing culvert at this site is broken on the inlet and bank is sloughing on the outlet causing a temporary barrier to fish (see crossing WX-043 Culvert). Confluence with Mackenzie River located approximately 110 m downstream. Potential gradient barrier (30% slope) with step pools 30 m upstream of confluence. Potential velocity barrier at step pools 100 m upstream from centerline. No transect completed at 50 m upstream as stream became inaccessible in root bridge complexes for approximately 50 m. No fish were captured or observed during the fish assessment.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

WX-043: Culvert

UTM Location:	10U 458952 7061042	**Survey Date:**	September 16, 2020
km Marker:	-	**Zone:**	2
Crew Initials:	LD MAN	**Restricted Activity Timing Window:**	August 15 to July 15

Site Photographs

Photo 1. Facing right downstream bank towards inlet

Photo 2. Facing left downstream bank towards inlet

Photo 3. Facing upstream showing damaged culvert

Photo 4. Culvert outlet

General Comments

Culvert associated with watercourse crossed at WX-043. 1,500 mm diameter culvert. Culvert appears to be collapsed and broken, especially at inlet. Evidence of ice jams against existing winter road.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

WX-044 Unnamed Watercourse

UTM Location: 10U 458839 7061453 **Survey Date:** September 20, 2020
km Marker: 748.02 **Zone:** 2
Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

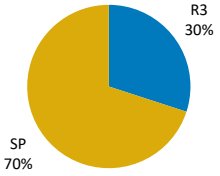
Physical Channel Transect Data

Transect # (Location)	1 (↑100)		2 (↑50)		3 (CL)		4 (↓100)		5 (↓200)		6 (↓300)	
Channel Width (m)	1.2		1.6		1.6		0.8		1.7		-	
Wetted Width (m)	1.0		0.5		1.0		0.9		1.4		-	
Depth at LDB + 25% (m)	0.1		0.2		0.1		0.1		0.1		-	
Depth at LDB + 50% (m)	0.1		0.3		0.1		0.1		0.1		-	
Depth at LDB + 75% (m)	0.1		0.3		0.2		0.1		0.1		-	
Max.Bankfull Depth (m)	0.7		0.5		0.6		0.4		0.4		-	
Gradient (%)	15		16		-		2		11		-	
Dominant Habitat Unit	SP		SP		SP		R3		SP		-	
Stream Bed												
Substrate (% of Transect Area) Organics	0		0		0		0		0		-	
Fines	20		20		20		20		20		-	
Small Gravel	10		10		10		10		10		-	
Large Gravel	15		15		15		15		15		-	
Cobble	40		40		40		40		40		-	
Boulder	15		15		15		15		15		-	
Bedrock	0		0		0		0		0		-	
Embeddedness	L		L		L		L		L		-	
Bank Measurements	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Bank Height (m)	0.4	0.5	0.1	0.2	0.4	0.4	0.1	0.2	0.3	0.3	-	-
Bank Slope (°)	100	110	30	110	30	70	90	110	100	130	-	-
Bank Stability	S	S	MS	S	US	MS	S	S	S	S	-	-
Dom. Bank Material	O	O	F	F	F	F	O	O	O	O	-	-
Subdom. Bank Material	SG	C	O	O	O	O	F	F	LG	F	-	-
Dom. Riparian Veg.	G	G	G	G	S	S	S	S	S	S	-	-
Subdom. Riparian Veg.	S	S	S	S	G	G	G	G	G	G	-	-

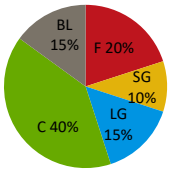
Habitat Inventory / Reach Data

Instream Cover (%):	8	Overhead Cover (%):	18
Dom. Instream Cover:	DC	Dom. Overhead Cover:	UB
Subdom. Instream Cover	BL	Subdom. Overhead Cove	TS
Maximum Depth (m)	0.3	Dom. Aquatic Veg. Type:	-

Habitat Distribution



Substrate Composition



Water Quality Data

Time of Day (HH:MM):	12:13
Water Temperature (°C):	3.8
Dissolved Oxygen (mg/L)	12.09
Sp. Conductivity (µs/cm):	74.0
pH:	6.59
Turbidity (NTU):	-

Channel Characteristics

Pattern:	IR
Islands:	N
Bars:	N
Coupling:	CO
Confinement:	CO
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Poor	Poor	Poor
Passage:	Poor	Poor	Poor

Photo 1: Facing upstream 100 m downstream from centerline.

Photo 2: Facing upstream 50 m upstream of centerline.

Fish Sampling Data

Method	Effort	
No Electrofishing	335	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
375	30	12	251

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED	0	-	0.00	-	-

General Comments

No fish captured or observed during fish assessment. Gradient barrier identified 50 m upstream from confluence with Mackenzie River, 24 % gradient over 20 m of stream length. Culvert collapsed under existing road, see WX-044 Culvert summary data sheet.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

WX-044: Culvert

UTM Location:	10U 458839 7061453	**Survey Date:**	September 16, 2020
km Marker:	-	**Zone:**	2
Crew Initials:	LD MAN	**Restricted Activity Timing Window:**	August 15 to July 15

Site Photographs

Photo 1.Facing outlet, culvert collapsed in centre

Photo 2. Facing outlet of culvert

Photo 3. Facing downstream towards culvert inlet

Photo 4. Facing downstream towards culvert inlet

General Comments

Culvert associated with watercourse crossed at WX-044. 1,500 mm diameter culvert. Culvert appears to be collapsed and sediment hase accumulated within the culvert near the outlet.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

Bob's Canyon Creek

UTM Location: 10U 456554 7065466 **Survey Date:** Septmeber 19, 2020

km Marker: 752.61 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Physical Channel Transect Data

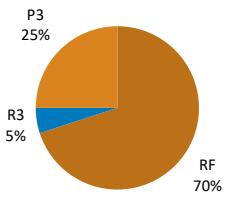
Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓150)	6 (↓300)
Channel Width (m)	1.7	3.4	2.0	2.5	1.9	-
Wetted Width (m)	1.5	2.5	1.8	2.75	1.65	-
Depth at LDB + 25% (m)	0.2	0.2	0.2	0.1	0.3	-
Depth at LDB + 50% (m)	0.2	0.3	0.2	0.1	0.2	-
Depth at LDB + 75% (m)	0.2	0.1	0.4	0.1	0.1	-
Max.Bankfull Depth (m)	0.4	0.4	0.48	0.35	0.5	-
Gradient (%)	5	7	4	5	6	-
Dominant Habitat Unit	RF	RF	RF	RF	RF	-
Stream Bed						
Substrate (% of Transect Area) Organics	0	0	0	0	0	-
Fines	25	25	25	25	25	-
Small Gravel	20	20	20	20	20	-
Large Gravel	0	0	0	0	0	-
Cobble	15	15	15	15	15	-
Boulder	40	40	40	40	40	-
Bedrock	0	0	0	0	0	-
Embeddedness	L	L	L	L	L	

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.2	0.2	0.1	0.2	0.1	0.2	0.3	0.2	0.2	0.2	-	-
Bank Slope (°)	110	90	70	45	90	80	90	140	100	90	-	-
Bank Stability	MS	MS	US	US	MS	MS	MS	MS	S	S	-	-
Dom. Bank Material	O	O	F	F	O	O	F	F	O	O	-	-
Subdom. Bank Material	F	F	O	O	F	F	O	O	SG	F	-	-
Dom. Riparian Veg.	S	S	S	S	S	S	G	S	G	G	-	-
Subdom. Riparian Veg.	G	G	N	G	G	G	S	G	S	S	-	-

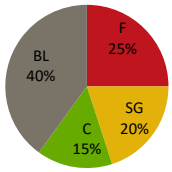
Habitat Inventory / Reach Data

Instream Cover (%):	4	Overhead Cover (%):	24
Dom. Instream Cover:	DC	Dom. Overhead Cover:	TS
Subdom. Instream Cover	-	Subdom. Overhead Cove	UB
Maximum Depth (m)	0.4	Dom. Aquatic Veg. Type:	-

Habitat Distribution



Substrate Composition



Water Quality Data

Time of Day (HH:MM):	21:47
Water Temperature (°C):	5.1
Dissolved Oxygen (mg/L)	88.10
Sp. Conductivity (µs/cm):	52.0
pH:	8.01
Turbidity (NTU):	-

Channel Characteristics

Pattern:	IR
Islands:	N
Bars:	DG
Coupling:	CO
Confinement:	OC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Poor	Poor-Moderate	Poor-Moderate
Passage:	Poor	Poor	Poor

Photo 1: Facing upstream at 50 m upstream from centerline.

Photo 2: Facing downstream at 150 m downstream from centerline.

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts Freq. (Hz) Duty Cycle (%) Dist. (m)

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					-

General Comments

Overall poor fish habitat due to steep gradient. Two potential gradient barriers (15% and 17% slope) near confluence with Mackenzie River, approximately 200 m downstream from centerline. Large (7,000 mm diameter) culvert on Bob's Canyon Creek at existing winter road appears in good condition. Fish assessment not completed as fish presence was known.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

WX-045: Unnamed Watercourse

UTM Location: 10U 451513 7076541 **Survey Date:** September 18, 2020
km Marker: 765.51 **Zone:** 2
Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

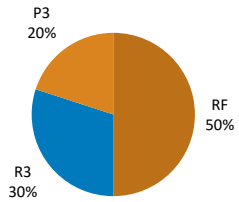
Physical Channel Transect Data

Transect # (Location)	1 (↑100)		2 (↑50)		3 (CL)		4 (↓100)		5 (↓200)		6 (↓300)	
Channel Width (m)	2.1		3.0		1.5		2.7		2.7		3.2	
Wetted Width (m)	1.9		2.2		1.6		2.7		2.5		2.7	
Depth at LDB + 25% (	0.2		0.1		0.2		0.3		0.3		0.2	
Depth at LDB + 50% (	0.2		0.2		0.2		0.3		0.4		0.1	
Depth at LDB + 75% (	0.3		0.2		0.3		0.2		0.4		0.1	
Max.Bankfull Depth (	0.5		0.7		0.6		0.5		0.9		0.4	
Gradient (%)	3		3		4		2		5		11	
Dominant Habitat Un	RF		RF		R3		RF		RF		RF	
Stream Bed												
Substrate (% of Transect Area) Organics	10		10		10		10		10		10	
Fines	20		20		20		20		20		20	
Small Gravel	10		10		10		10		10		10	
Large Gravel	0		0		0		0		0		0	
Cobble	20		20		20		20		20		20	
Boulder	40		40		40		40		40		40	
Bedrock	0		0		0		0		0		0	
Embeddedness	M		M		H		M		M		M	
Bank Measurements	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Bank Height (m)	0.2	0.2	0.3	0.3	0.4	0.3	0.2	0.2	0.3	0.4	0.2	0.2
Bank Slope (°)	100	90	100	90	90	90	110	90	110	90	150	90
Bank Stability	S	S	S	S	MS	MS	S	S	S	S	S	S
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	F	O
Subdom. Bank Mater	F	F	F	F	F	F	F	BL	F	SG	O	C
Dom. Riparian Veg.	S	S	S	S	G	G	G	G	S	S	G	G
Subdom. Riparian Ve	G	G	G	G	G	S	S	S	G	G	S	S

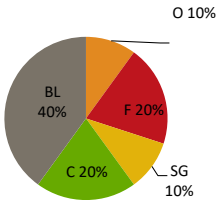
Habitat Inventory / Reach Data

Instream Cover (%):	10	Overhead Cover (%):	22
Dom. Instream Cover:	BL	Dom. Overhead Cover:	TS
Subdom. Instream Cover	DC	Subdom. Overhead Cove	WD
Maximum Depth (m)	0.4	Dom. Aquatic Veg. Type:	-

Habitat Distribution



Substrate Composition



Water Quality Data

Time of Day (HH:MM):	17:04
Water Temperature (°C):	4.6
Dissolved Oxygen (mg/L)	19.25
Sp. Conductivity (µs/cm):	81.0
pH:	7.31
Turbidity (NTU):	-

Channel Characteristics

Pattern:	ST
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	OC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor-Moderate	Poor-Moderate	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Good	Good	Good
Passage:	Good	Good	Good

Photo 1: Facing upstream 100 m downstream of centerline.

Photo 2: Facing upstream at centerline.

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB	651	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
405	30	12	377

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED	0	-	0.00	-	-

General Comments

No fish captured or observed during fish assessment. No known barriers between proposed crossing location and the Mackenzie River. Run habitat with cover could provide rearing habitat for sport, forage, and coarse fish.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

New 1: Unnamed Watercourse

UTM Location: 10U 451423 7076769 **Survey Date:** September 16, 2020

km Marker: 767.8 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing downstream at centreline

Photo 2. Facing upstream at centreline

Photo 3. Facing downstream at centreline

General Comments

Previously unreported watercourse. Fish and fish habtiat assessment not completed. Crossing location appears similar to WX-045 and therefore it is assumed it affords fish habitat potential. The confluence with the Mackenzie River is located approximately 400 m downstream from the proposed crossing location.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

New-3: Wetland Area

UTM Location: 10U 451373 7077141 **Survey Date:** September 16, 2020

km Marker: 770.6 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing east along impoundment

Photo 2. Facing southeast along impoundment

Photo 3. Facing northeast along impoundment

Photo 4. Aerial imagery showing wetland area

General Comments

Previously unreported wetland. Beaver impoundment observed within wetland. No inlet was visible from the aerial survey but the outlet appears to drain across the existing winter road. Substrate was organic and wetland vegetation observed. Maximum depth was greater than 2 m. A fish habtiat assessment was not completed. Fish habitat potential is assumed.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

WX-046: Drainage

UTM Location: 10U 451297 7077881 **Survey Date:** September 16, 2020

km Marker: 768.9 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Flow through grasses and sedges 70 m west of winter road

Photo 2. No defined bed or banks 35 m west of winter raod

Photo 3. Section of intermittent channelization, 50 m east of winter road

Photo 4. Facing west at existing winter road

General Comments

Ephemeral drainage oriented east to west across the existing winter road. Drainage does not have continuously defined bed or banks. No known connectivity with the Mackenzie River located approximately 1 km to the west. No fish habitat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

WX-047: Drainage

UTM Location: 10U 450566 7080565 **Survey Date:** September 18, 2020

km Marker: 769.66 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing north, water along existing winter road

Photo 2. Facing downslope 50 m below existing winter road

Photo 3. Facing downslope 25 m down from existing winter road

Photo 4. Facing downslope 50 m down ffrom existing winter road

General Comments

Ephemeral drainage oriented east to west. Drainage runs along existing winter road for approximately 100 m. Discontinous to the west of existing winter road. No known connectivity with the Mackenzie River. No defined bed or banks. No fish habitat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

SWA-4: Wetland Area

UTM Location: 10U 451333 7078639 **Survey Date:** September 23, 2020

km Marker: 769.7 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 2. Facing northwest towards existing winter road from helicopter

Photo 3. Aerial imagery of Wetland area

General Comments

Wetland area adjacent to proposed construction corridor. No visible inlet or outlet. No fish habitat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

UWB-5: Wetland Area

UTM Location: 10U 451254 7079001 **Survey Date:** September 18, 2020

km Marker: 770 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing north from helicopter

Photo 2. Aerial imagery showing wetland location

General Comments

Wetland area adjacent to proposed construction corridor. No inlet or outlet visible. No fish habitat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

New-2: Wetland Area

UTM Location: 10U 451104 7079480 **Survey Date:** September 18, 2020

km Marker: 770.6 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing downslope showing inlet 50 m east of impoundment

Photo 2. Facing south along impoundment

Photo 3. Facing north along impoundment

Photo 4. Facing west along impoundment

Fish Sampling Data

Method	Effort		Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
Electrofishing	-	(s)	NO FISH CAPTURED	-	0	-	0.00	-
Minnow Trap	40	(hr)						

Water Quality Data

Time of Day (HH:MM):	11:04
Water temperature (°C):	7.4
Dissolved Oxygen (mg/L):	8.33
Sp. Conductivity (µS/cm):	169.00
pH:	7.53
Turbidity (NTU):	-

General Comments

Previously unreported site. Impoundment as result of active beaver dam. Inlet is an ephemeral drainage and an outlet is visible to the west. Organic substrate and wetland vegetation in riparian area. Maximum measured depth greater than 2 m. No fish captured in minnow traps. Fish habitat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

WX-048: Drainage

UTM Location: 10U 449199 7083419 **Survey Date:** September 16, 2020

km Marker: 772.83 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing upslope 60 m upslope from winter road

Photo 2. Water visible on existing winter road

Photo 3. Facing upslope 25 m upslope of winter road

Photo 4. Now channelization visible

General Comments

Ephemeral drainage, oriented northeast to southwest across the existing winter road. No defined bed or banks. Does not afford fish habitat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

Drainage 4 Unnamed Watercourse

UTM Location: 10U 448523 7084338 **Survey Date:** September 18, 2020

km Marker: 774.04 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

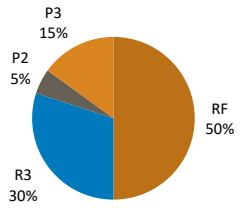
Physical Channel Transect Data

Transect # (Location)	1 (↑100)		2 (↑50)		3 (CL)		4 (↓100)		5 (↓200)		6 (↓300)	
Channel Width (m)	4.2		5.1		4.1		4.1		6.0		6.5	
Wetted Width (m)	3.6		4.8		4.3		3.5		5.1		4.9	
Depth at LDB + 25% (	0.3		0.3		0.5		0.4		0.5		0.3	
Depth at LDB + 50% (	0.3		0.4		0.5		0.4		0.5		0.3	
Depth at LDB + 75% (	0.6		0.4		0.4		0.4		0.4		0.3	
Max.Bankfull Depth (	0.8		0.7		0.6		0.9		0.9		0.7	
Gradient (%)	1		-		-		5		5		4	
Dominant Habitat Un	R2		RF		R2		RF		RF		RF	
Stream Bed												
Substrate (% of Transect Area) Organics	10		10		10		10		10		10	
Fines	15		15		15		15		15		15	
Small Gravel	0		0		0		0		0		0	
Large Gravel	5		5		5		5		5		5	
Cobble	30		30		30		30		30		30	
Boulder	40		40		40		40		40		40	
Bedrock	0		0		0		0		0		0	
Embeddedness	H		H		H		H		H		H	
Bank Measurements	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Bank Height (m)	0.4	0.3	0.3	0.2	0.2	0.1	0.3	0.2	0.2	0.5	0.4	0.3
Bank Slope (°)	40	70	120	110	90	130	70	30	20	40	20	90
Bank Stability	MS	MS	S	S	MS	S	S	S	S	MS	S	S
Dom. Bank Material	F	O	O	O	O	F	O	O	O	O	O	O
Subdom. Bank Mater	O	F	F	F	O	O	F	F	F	F	F	F
Dom. Riparian Veg.	G	S	S	S	S	S	S	S	S	G	S	S
Subdom. Riparian Ve	S	G	C	G	G	G	G	G	G	S	S	S

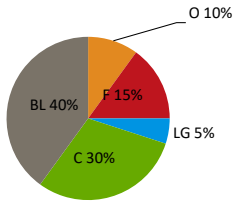
Habitat Inventory / Reach Data

Instream Cover (%):	18	Overhead Cover (%):	9
Dom. Instream Cover:	BL	Dom. Overhead Cover:	WD
Subdom. Instream Cover	DC	Subdom. Overhead Cover:	GF
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Habitat Distribution



Substrate Composition



Water Quality Data

Time of Day (HH:MM):	09:04
Water Temperature (°C):	4.8
Dissolved Oxygen (mg/L)	11.29
Sp. Conductivity (µs/cm):	121
pH:	7.39
Turbidity (NTU):	-

Channel Characteristics

Pattern:	TM
Islands:	F
Bars:	BR
Coupling:	CO
Confinement:	FC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Moderate	Moderate	Moderate
Rearing:	Moderate	Moderate	Moderate
Passage:	Good	Good	Good

Photo 1: Facing downstream 100 m upstream from centerline.

Photo 2: Facing upstream 100 m downstream of centerline.

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts Freq. (Hz) Duty Cycle (%) Dist. (m)

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					-

General Comments

No barrier observed at confluence with Mackenzie River. No spawning habitat present, overwintering potential in pools and cover sufficient for rearing habitat. Fish assessment not completed as fish presence was known.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

SWA-5: Wetland Area

UTM Location: 10U 441775 7094706 **Survey Date:** September 23, 2020

km Marker: 774.04 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing south over winter road from helicopter

Photo 2. Aerial imagery showing survey area

General Comments

Wetland adjacent to proposed Project corridor. No inlet or outlet were observed from aerial survey. No fish habitat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

SWA-6: Wetland Area

UTM Location: 10U 441568 7095152 **Survey Date:** September 18, 2020

km Marker: 789.4 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing north from helicopter

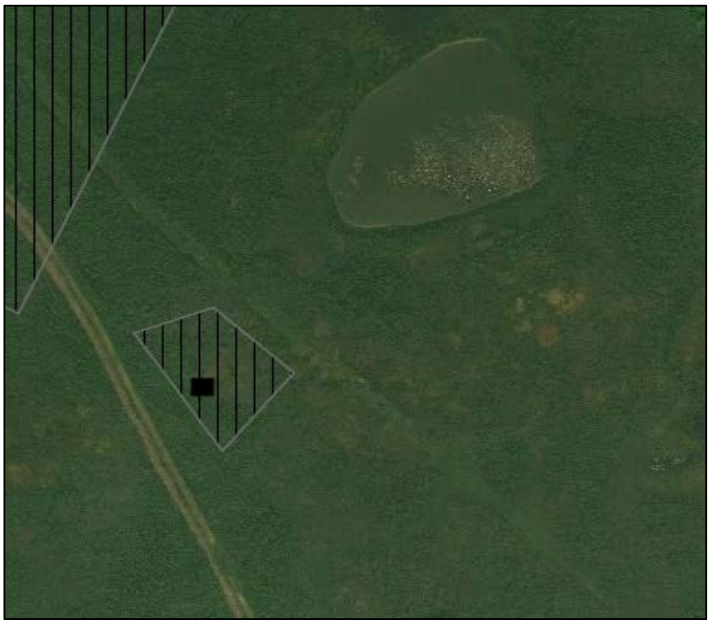


Photo 2. Aerial imagery showing survey area

General Comments

Wetland area adjacent to proposed construction corridor. No inlet our outlet visible from aerial survey. Does not afford fish habtiat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

SWA-8: Wetland Area

UTM Location: 10U 440409 7096395 **Survey Date:** September 21, 2020

km Marker: 791.2 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing east towards existing winter road from helicopter

Photo 2. Facing north from helicopter

General Comments

Wetland area adjacent to proposed Project. No inlet or outlet visible from aerial survey. No fish habtiat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

SWA-9: Wetland Area

UTM Location: 10U 439719 7096318 **Survey Date:** September 21, 2020

km Marker: 791.8 **Zone:** 2

Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

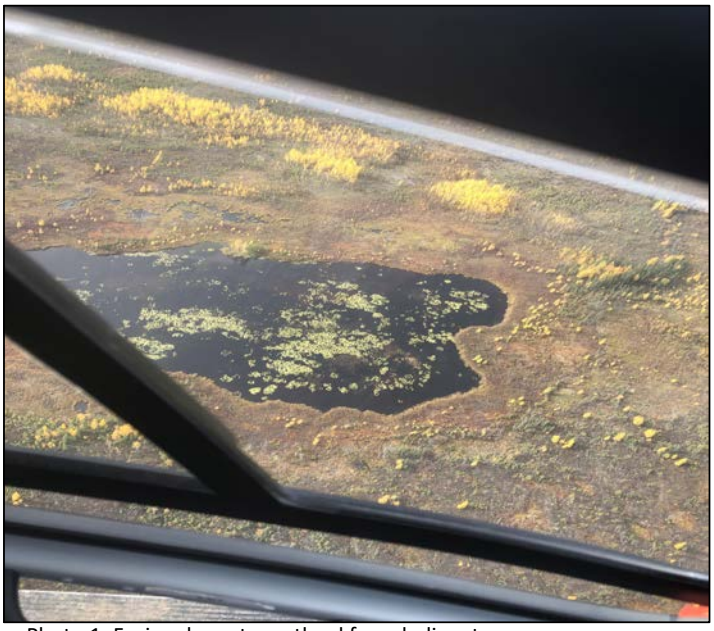


Photo 1. Facing down to wetland from helicopter

Photo 2. Aerial imagery showing survey location

General Comments

Wetland area adjacent to proposed Project. No inlet or outlet visible from aerial survey. No fish habtiat potential.

Prepared by: LD Reviewed by: DC

Dehcho Territory Fish and Fish Habitat

SWA-10: Wetland Area

UTM Location: 10U 438820 7097394 **Survey Date:** September 18, 2020
km Marker: 793.1 **Zone:** 2
Crew Initials: LD MAN **Restricted Activity Timing Window:** August 15 to July 15

Site Photographs

Photo 1. Facing northwest from helicopter

Photo 2. Facing south along existing winter road

Photo 3. Facing northwest from middle of beaver dam complex

Photo 4. Minnow trap location in wetland near existing winter road

Fish Sampling Data

Method	Effort		Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
Electrofishing	-	(s)	Brook stickleback	-	120	-	14.93	66.7
Minnow Trap	87	(hr)	Fathead minnow	-	60	-	7.46	33.3

Water Quality Data

Time of Day (HH:MM):	16:55
Water temperature (°C):	8.04
Dissolved Oxygen (mg/L):	4.62
Sp. Conductivity (µS/cm):	102.00
pH:	6.21
Turbidity (NTU):	-

General Comments

Outlet with connection to Mackenzie River. Old beaver dam complex observed but does not appear to be active. A 900 mm diameter culvert is across the existing winter road between two wetland areas. Brook stickleback and fathead minnow captured so wetlands afford fish habitat.

Prepared by: LD Reviewed by: DC

APPENDIX 18A

Vegetation and Wetlands Technical Data Report

Mackenzie Valley Highway Project
Technical Data Report—Vegetation and Wetlands

Prepared for:

Government of the Northwest Territories

Prepared by:

K'alo-Stantec Limited

December 2022

Project No.: 144903025

K'alo-Stantec

Limitations and Sign-off

This document entitled Mackenzie Valley Highway Project Technical Data Report—Vegetation and Wetlands was prepared by K'alo-Stantec Limited ("K'alo-Stantec") for the account of Government of Northwest the Territories (the "Client") to support the regulatory review process for its Developers Assessment Report (DAR) (the "Application") for the Mackenzie Valley Highway Project (the "Project"). In connection therewith, this document may be reviewed and used by the Department of Infrastructure (INF) for the Government of the Northwest Territories participating in the review process in the normal course of its duties. Except as set forth in the previous sentence, any reliance on this document by any other party or use of it for any other purpose is strictly prohibited. The material in it reflects K'alo-Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between K'alo-Stantec and the Client. The information and conclusions in the document are based on the conditions existing at the time the document was published and does not take into account any subsequent changes. In preparing the document, K'alo-Stantec did not verify information supplied to it by the Client or others, unless expressly stated otherwise in the document. Any use which another party makes of this document is the responsibility and risk of such party. Such party agrees that K'alo-Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other party as a result of decisions made or actions taken based on this document.

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K'alo-Stantec

Executive Summary

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells to replace the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT).

This technical data report (TDR) presents data and analysis of landcover/plant assemblages, forest characteristics (e.g., tree heights and timber volume), fire, plant species of conservation concern (SOCC), and weeds for the Dehcho and Sahtu regions intersected by the project highway alignment.

Coniferous forest is the most abundant landcover type/plant assemblage in upland areas within the Local Study Area (LSA) (44.8%) and the Regional Study Area (RSA) (32.5%) in the Dehcho Region. Wetlands occupy 19.6% of the LSA and 29.0% of the RSA in the Dehcho Region.

Large portions of the LSA and RSA have burned in the past; however, fires in the LSA are not common: a maximum of two fires have occurred per decade recorded (1990-1999).

No plant SOCC occurrences have been documented within the Dehcho Region of the LSA or RSA; however, several species reported by Dessau (2012) were previously considered plant SOCC but are no longer listed due to changes in territorial rankings. Nine alien and three invasive alien plant species have been documented in the RSA in the Dehcho Region. Appendix B provides a list of additional alien and invasive alien plant species in the RSA that have been documented, although specific distributions of these species are not known.

Upland areas in the Sahtu Region are similarly dominated by coniferous forest in both the LSA (28.3%) and RSA (31.3%). Wetlands occupy 25.5% of the LSA and 25.3% of the RSA.

Fires in the LSA and RSA have occurred in multiple areas with portions within the Sahtu Region burning at least once per decade. Less than 1% to 61.1% of the LSA burned each decade between 1960 and 2019.

In the RSA, seven vascular plant SOCC have been documented, six of which are considered *sensitive* and one considered *may be at risk*, territorially. Ten alien and three invasive alien plant species have been documented in the RSA in the Sahtu Region. Appendix B provides a list of additional alien and invasive alien plant species in the RSA that have been documented, although specific distributions of these species are not known.

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APPENDIX B ALIEN AND INVASIVE ALIEN PLANT DETAILS

Abbreviations

%	percent
AKEPIC	Alaska Exotic Plants Information Clearinghouse
cm	centimetre
CNFDB	Canadian National Fire Database
COSEWIC	Committee on The Status of Endangered Wildlife in Canada
DAR	Developer's Assessment Report
EOSD	Earth Observation of Sustainable Development of Forests
GNWT	Government of the Northwest Territories
ha	hectare
INF	Department of Infrastructure
km	kilometre
LSA	Local Study Area
m	metre
m^3	cubic metre
m^3/ha	cubic metres per hectare
MVWR	Mackenzie Valley Winter Road
NT/NWT	Northwest Territories
PDA	Project Development Area
PDR	Project Description Report
ROW	right-of-way
RSA	Regional Study Area
SARA	*Species At Risk Act*
SD	standard deviation
SOCC	species of conservation concern
TDR	technical data report
the Project	Mackenzie Valley Highway Project
TK	traditional knowledge
TLRU	traditional land and resource use
ToR	Terms of Reference

Glossary

Alien plant species	Plants introduced to the Northwest Territories from Eurasia or other parts of North America as a result of human activities (Oldham and Delisle-Oldham, 2016).
Invasive alien plant species	Plants introduced to the Northwest Territories from Eurasia or other parts of North America as a result of human activities and with potential to cause significant ecological harm to native ecosystems, economy, or society (Carriere, 2008 and GNWT, 2015). Invasive alien plant species have the potential to be invasive due to high rates of dispersal and establishment (Snyder and Anions, 2008).
May be at Risk	Species that may be at risk of extinction or extirpation. NatureServe S-rank equaling S1 to S2 (Working Group on General Status of NWT Species, 2016).
Sensitive	Species that are not at high risk of extinction or extirpation but may require some special attention or protection to prevent them from becoming at risk. NatureServe S-rank equaling S3. May include species assessed as special concern by Committee on The Status of Endangered Wildlife in Canada (COSEWIC) or SARA (Working Group on General Status of NWT Species, 2016).
the Project	Mackenzie Valley Highway Project

1 Introduction

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells to replace the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT; Figure 1.1).

The Project is subject to an environmental assessment and the requirements of Part 5 of the *Mackenzie Valley Resource Management Act*. This technical data report (TDR) presents the existing baseline conditions for vegetation to support the Developer's Assessment Report (DAR), as required by the Terms of Reference (ToR; MVEIRB, 2015).

With respect to vegetation and wetlands, this TDR provides a description of existing conditions within the study areas based on available desktop information, including:

- vegetation and vegetation assemblages
- identification of species or assemblages that are considered species of conservation concern (SOCC), valued, protected or designated (e.g., vulnerable, threatened, endangered); for any species at risk or of concern, as well as location, population status, limits and size, sensitivity and limiting factors
- historic and current human use of vegetation, including subsistence and commercial harvesting, (e.g., berry picking, forestry)
- baseline contaminant concentrations in harvested species or vegetation (e.g., berries) that may change as a result of the highway and as available
- locations and quantities of merchantable timber (based on desktop timber volumes)
- listing and locations of existing non-native plant species
- frequency of forest fires; and, post-fire vegetation succession, if applicable

Vegetation and wetland baseline data has important influence on wildlife habitat, including old growth forest, as discussed in Caribou and Moose TDR (EDI, 2022), Wildlife and Wildlife Habitat TDR (K'alo-Stantec, 2022a) and Birds and Bird Habitat TDR (K'alo-Stantec, 2022b). The influence of vegetation on thermal exchange between air and ground, therefore influencing overall ice-rich soils and permafrost distribution is discussed in the Soils, Terrain and Permafrost TDR (K'alo-Stantec, 2022c). Due to low resolution of available permafrost information, permafrost extent could not be quantified or correlated with vegetation assemblages (i.e., land cover) in this TDR.

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Territorial Boundary

0 40 80 Kilometres

(At original document size of 8.5x11)
1:4,500,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2022-06-03
TR by AJ on 2022-06-03

Client/Project
Government of Northwest Territories
Mackenzie Valley Highway Project

144903025-0048 REVB

Figure No.
1.1

Title
Project Overview

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Imagery: Earthstar Geographics World Topographic Map: Esri, FAO, NOAA, NRCan World Hillshade: Esri, USGS

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

2 Study Areas

The Project is located in the Mackenzie Valley region of the NT between Hodgson Creek (located approximately 1 km north of Wrigley) and Prohibition Creek (located approximately 28 km southeast of Norman Wells) (Figure 1.1). The Project parallels the Mackenzie River, located to the west, and generally follows the MVWR. The Project is located within three ecoregions, each distinguished by different degrees of climatic factors (Figure 2.1).

Two study areas, the Local Study Area (LSA) and the Regional Study Area (RSA), are used to evaluate potential project-related effects and potential cumulative effects. The LSA and RSA are relatively anthropogenically undisturbed except for communities, the existing MVWR, and the Norman Wells Pipeline. Oil and gas exploration and production infrastructure in the RSA occurs on the west side of and in the Mackenzie River near Norman Wells (Auld and Kershaw, 2005). Other existing disturbances include quarries and borrow sources, a fibre optic line, and bridges associated with the MVWR.

2.1 Project Development Area

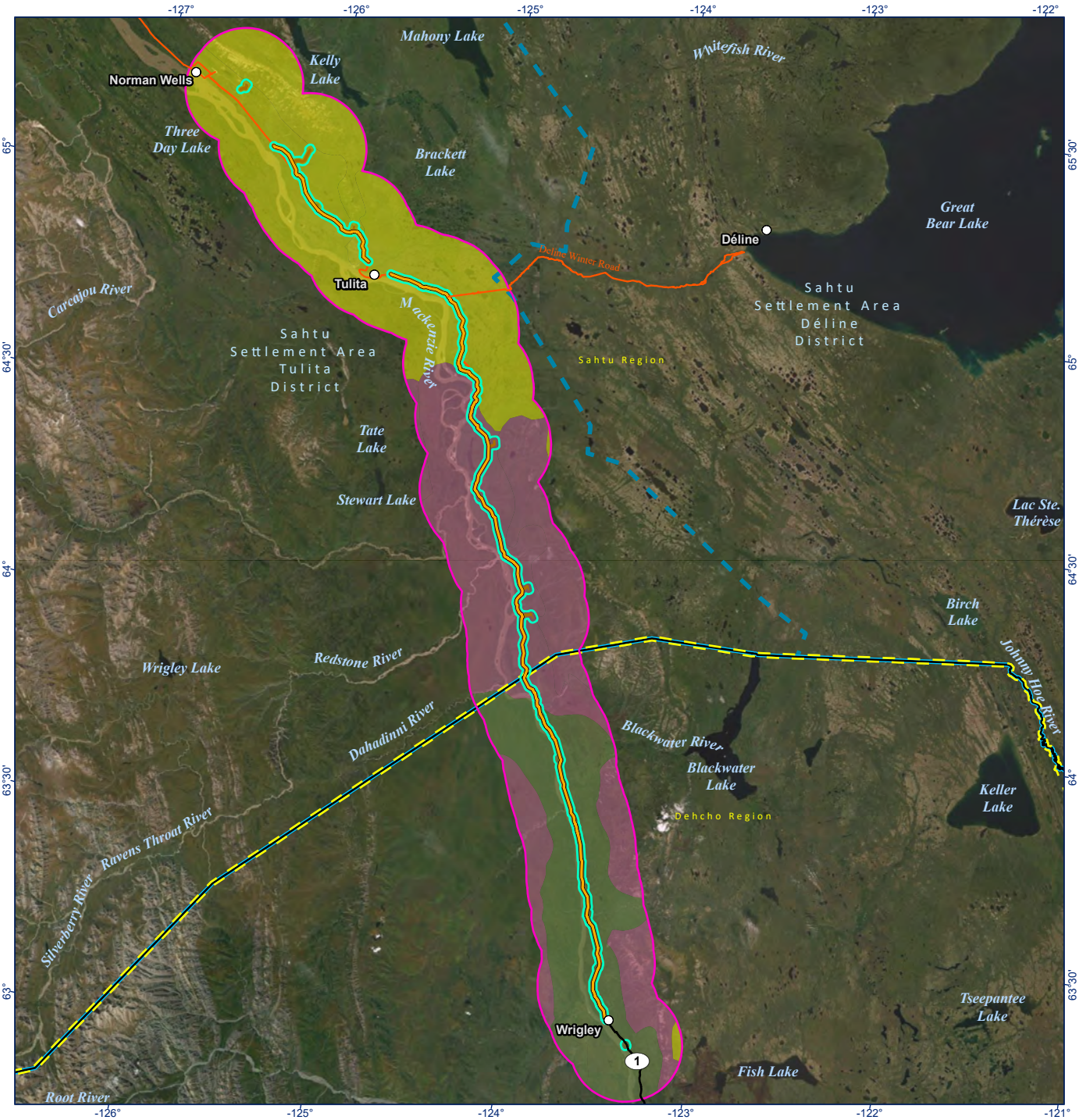
This is the area of direct Project disturbance within which works and activities will occur (footprint), and includes a new two-lane gravel highway, 60 metres (m) wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps and quarry/borrow sites with access roads on a 30 m ROW.

2.2 Local Study Area

The Local Study Area (LSA) for vegetation and wetlands is consistent with that for wildlife and wildlife habitat and is a 1 km buffer around the project highway alignment centreline and proposed borrow/quarry access roads and quarry sites (Figure 2.1). The size of the LSA is based on measurable extent of Project-related effects (direct or indirect) on vegetation and wetlands, while also considering recommended setback distances for wildlife and wildlife habitat features consistent with guidance provided by Environment and Climate Change Canada (Dufour, 2020, pers. comm.). Results of this TDR are presented for the LSA by region; Dehcho Region and Sahtu Region.

2.3 Regional Study Area

The Regional Study Area (RSA) for vegetation and wetlands is consistent with that for wildlife and wildlife habitat and is a 15 km buffer around the Project's proposed road alignment centreline (Figure 2.1), which provides context for determining significance of Project-specific effects and potential cumulative effects; the RSA is consistent with other highway projects in the NT (e.g., Inuvik to Tuktoyaktuk Highway [Kiggiak - EBA Consulting Ltd., 2011]) and follows recommendations from Environment and Climate Change Canada (Dufour, 2020, pers. comm.). Results of this TDR are presented for the RSA by region; Dehcho Region and Sahtu Region.



- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary

Ecoregion

- Boreal Cordillera High Boreal
- Taiga Cordillera Low Subarctic
- Taiga Plains,Low Subarctic
- Settlement Area Boundary

0 10 20 Kilometres
(At original document size of 8.5x11)
1:600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2022-05-20
TR by AJ on 2022-05-20

Client/Project
144903025-0058 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
2.1

Title
Vegetation and Wetlands Study Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Imagery: Earthstar Geographics
World Topographic Map: Esri, FAO, NOAA, NRCan
World Hillshade: Esri, USGS

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

2.4 Intersected Ecoregions

2.4.1 Taiga Plains Low Subarctic

The Taiga Plains Low Subarctic is a Level III ecoregion in the central third of the Taiga Plains (Level II) (Ecosystem Classification Group, 2007). The Taiga Plains Low Subarctic ecoregion extends north to the Taiga Plains High Subarctic ecoregion (Level III) and extends 650 km south to the Taiga Plains High Boreal ecoregion (Level III) and includes outlying Cameron Plateau along the NT-AB border (Ecosystem Classification Group, 2007). To the west, the Taiga Plains Low Subarctic ecoregion is bordered by the Taiga Cordillera ecoregion (Level II); to the east, by the Taiga Shield ecoregion (level II); and to the northeast, by Great Bear Lake (Ecosystem Classification Group, 2007). The ecoregion is characterized by undulating plains, upland communities of white and black spruce, and permafrost-influenced wetlands (Ecosystem Classification Group, 2007). Human activity within the Taiga Plains Low Subarctic ecoregion includes industrial activities such as mining, petroleum extraction, and forestry (Wiken, 1986).

The northern section of the Project is located within the North Mackenzie Plain Low Subarctic ecoregion, a Level IV classification within the Taiga Plains Low Subarctic ecoregion. The North Mackenzie Plain Low Subarctic ecoregion parallels the Mackenzie River and consists of level to undulating terrain. The North Mackenzie Plains ecoregion has been subject to recent burns, which have influenced vegetation community and structure, resulting in a patchwork of low-canopy black spruce and successional shrublands and regenerating forests communities (Ecosystem Classification Group, 2007). Vegetation consists of white and black spruce (*Picea mariana*), Alaska paper birch#(*Betula neoalaskana)*, and dwarf birch *(Betula nana)* communities. Occurrences of trembling aspen and jack pine occur on well-drained sites south of Tulita. Bogs and fens occupy approximately 15% of the ecoregion (Ecosystem Classification Group, 2007).

A small section of the project highway alignment north of Tulita intersects the Norman Range Low Subarctic ecoregion, a Level IV classification within the Taiga Plains Low Subarctic ecoregion. The Norman Range Low Subarctic ecoregion is located northeast of the North Mackenzie Plain ecoregion and is more rugged terrain. Southwest portions of this ecoregion are composed of mixedwood deciduous and coniferous forest. Upland deciduous areas typically contain trembling aspen and Alaska paper birch; and coniferous forests typically contain white and black spruce. Bogs and fens cover approximately 4% of the ecoregion (Ecosystem Classification Group, 2007). The Sahtu Land Use plan states that plants are harvested in Norman Range Low Subarctic ecoregion by Sahtu and Pehdzeh Ki/Dehcho First Nations; this harvesting is discussed in the Cultural and Traditional Land Use TDR (K'alo-Stantec, 2022d).

2.4.2 Taiga Cordillera Low Subarctic

The Taiga Cordillera Low Subarctic ecoregion (Level III) consists of mountain ranges, foothills, tundra and spruce woodlands located in the central third of the Taiga Cordillera (Level II). In comparison to the Taiga Plains, the Taiga Cordillera Low Subarctic ecoregion has very few waterbodies and peatland establishment (Ecosystem Classification Group, 2010). Human activity within the Taiga Cordillera Low Subarctic ecoregion includes hunting, fishing, trapping, and tourism (Wiken, 1986).

Central sections of the project highway alignment intersect the Central Mackenzie Plain ecoregion, a Level IV classification within the Taiga Cordillera Low Subarctic ecoregion. The Central Mackenzie Plain is located between the Dahadinni and Blackwater Rivers to the south and the boundary of the Taiga Plains ecoregion to the north. Topography includes level to gently sloping terrain, which supports a diverse array of forest types. Almost half the ecoregion has been exposed to fires, leading to widespread shrubby and deciduous community development. Black spruce – shrub – moss woodlands are common and similar in structure to the North Mackenzie Plain ecoregion. Jack pine *(Pinus banksiana)* and trembling aspen *(Populus tremuloides)* occur but are limited to southern sections. Wetlands occupy approximately 10% to 20% of the ecoregion and consist of mainly peatlands (Ecosystem Classification Group, 2010). The Sahtu Land Use plan states that plants are harvested in Norman Range Low Subarctic ecoregion by Sahtu and Pehdzeh Ki/Dehcho First Nations and is discussed in the Cultural and Traditional Land Use TDR (K'alo-Stantec, 2022d).

2.4.3 Boreal Cordillera High Boreal

The Boreal Cordillera High Boreal ecoregion (Level III) is in the southeast portion of the Boreal Cordillera (Level II), south of the Taiga Cordillera Low Subarctic ecoregion. In comparison to the Taiga Cordillera Low Subarctic, the Boreal Cordillera High Boreal has a milder climate, greater precipitation and taller, more dense stands of spruce woodlands. Mixedwood forest of trembling aspen, white spruce, paper birch, and balsam poplar are common (Ecosystem Classification Group, 2010). Human activity includes mining, forestry, and tourism (Wiken, 1986).

Southern portions of the project highway alignment intersect the Central Mackenzie Valley ecoregion, a Level IV classification within the Taiga Cordillera High Boreal ecoregion. The Central Mackenzie Valley ecoregion is bordered by the Dahadinni and Blackwater Rivers to the north and by higher elevation slopes to the south, east, and west. Topography is undulating terrain, rolling slopes, and level plains. Northern sections consist of closed black spruce woodlands and peat plateaus. Southern sections near Wrigley are composed of productive mixedwood stands of trembling aspen and white spruce *(Picea glauca).* Wetlands occupy less than 10% of the entire ecoregion and consist mainly of peat plateaus, sedge fens, northern ribbed fens, and horizontal fens (Ecosystem Classification Group, 2010). The Sahtu Land Use plan states that plants are harvested within the Dehcho Region along portions of the Mackenzie River by Sahtu Dene and Métis and is discussed in K'alo-Stantec (2022d).

3 Review of Existing Data

3.1 Traditional Knowledge and Traditional Land and Resource Use

This section presents a review of relevant traditional knowledge (TK) and traditional land and resource (TLRU) use information summarized from publicly available sources for consideration for baseline reporting that provides information on existing conditions and potential Project effects, as identified by Indigenous groups.

3.1.1 Methods

TK and TLRU plant information for the Dehcho and Sahtu regions was determined using publicly available reports:

Dehcho Region

- IMG-Golder Corporation (2006) – Renewable Resource Assessment of the Pehdzeh Ki Ndeh Area of Interest. Prepared for the Canadian Parks and Wilderness Society, Northwest Territories Chapter. Yellowknife.
- Dehcho Land Use Planning Committee (2006) – Respect for the Land: The Dehcho Land Use Plan – Final Draft
- Dehcho First Nations. 2011. Traditional Knowledge Assessment of Boreal Caribou (Mbedzih) in the Dehcho Region. Prepared by Dehcho First Nations for the Canadian Wildlife Service. Published by the Dehcho First Nations Fort Simpson, Northwest Territories.
- Dessau. 2012. Mackenzie Valley Highway Extension Pehdzeh Ki Ndeh – Dehcho Region. Project Description Report. Prepared for Government of the Northwest Territories, Department of Transport.
- NWT Bureau of Statistics. 2018. NWT Community Survey. NWT Bureau of Statistics.

Sahtu Region

- EBA Engineering Consultants (2006) – Traditional Knowledge Study Report Tulita, NT, Great Bear River Bridge.
- The Sahtu Heritage Places and Sites Joint Working Group (2000) – Rakekée Gok'é Godi: Places We Take Care Of.
- McDonald, R. 2010. Boreal Caribou Traditional Knowledge Collection Study: The Sahtu Settlement Area. Edited by Andrea Hrynkiw and Glen Guthrie and McDonald. For the Canadian Wildlife Service, Environment Canada.
- 5658 NWT Ltd. and the Government of Northwest Territories (2011) – Project Description Report for Construction of the Mackenzie Valley Highway Tulita District, Sahtu Settlement Area.

- Sahtu Land Use Planning Board (2013) – Sahtu Land Use Plan. Government of Northwest Territories. Good Hope.
- Golder. 2015. Central Mackenzie Surface Water and Groundwater Baseline Assessment. Report 1: Technical State of Knowledge. Report Number: 1401835 Final Report 1. May 21, 2015.
- Tulita Renewable Resource Council (2019) – Traditional Knowledge Study for the Great Bear River Bridge Project. Prepared by Tulita Renewable Resource Council.

Information was also obtained from the Tulita Renewable Resources Council's Project-specific TLRU study (Tulita Renewable Resource Council, 2022).

3.1.2 Results

3.1.2.1 Dehcho Region

A review of the available information indicates 140 plants or groups of plants are used for traditional purposes in the Dehcho Region (Table 3.1 and Table 3.2), with 122 expected in the ecoregions intersected by the LSA and RSA. Most of the expected plants, 101, are ranked *secure* in the NT, three are ranked *sensitive* and seven are ranked *may be at risk* (GNWT, 2016a). Many plant species serve different purposes, such as for medicine, food, craft, ritual ceremonies, spiritual endeavours, and home fuel. For example, birch bark (*Betula papyrifera, Betula neoalaskana*) is used for baskets, berries are collected for food and for dyeing materials (e.g., blueberries [*Vaccinium* spp.]), and pasture sage (*Artemisia frigida*) is used for spiritual, ritual or medicinal purposes (IMG-Golder Corporation, 2006).

Both wood and wood pellets are an important fuel for heating homes in the Dehcho Region. Within the Dehcho Region, wood is used for house heating in 388 (36%) households with 265 (24%) homes reporting wood as their main heat source (NWT Bureau of Statistics, 2018). Wood pellets are used for house heating in 65 (6%) households with 30 (3%) homes reporting wood pellets as their main heat source (NWT Bureau of Statistics, 2018).

The most common berry picking location in the Dehcho Region is adjacent to the Mackenzie Highway towards Fort Simpson and along existing trails through Pehdzeh Ki Ndeh. People also pick berries along an existing pipeline corridor near Wrigley (IMG-Golder Corporation, 2006). Within the Dehcho Region, 38% of the general population reported gathering berries (NWT Bureau of Statistics, 2020), with 50% of indigenous population of Wrigley reporting engaging in berry gathering (NWT Bureau of Statistics, 2019a).

Recent changes in climate are include warmer temperatures, increased rain in November, milder winters and increasing summer storms. Boreal woodland caribou food sources are affected by precipitation. During colder times, food becomes less accessible because it is covered by more snow, making it harder for caribou to access. Climate change does not yet appear to be affecting ground or hanging lichens, although some monitoring of future changes to lichen due to climate change should be undertaken (Dehcho First Nations, 2011).

Contaminants may be a concern for certain traditional foods, including berries and medicinal teas, in some areas (GNWT, 2017). The GNWT publishes contaminant fact sheets on many traditional meats, but no fact sheets are published for plant species (GNWT, 2016b). The Northern Contaminants Program focuses on heavy metals and on persistent organic pollutants that can bioaccumulate in wildlife and human populations (Government of Canada, 2021). There are some studies that link increased industrial activity and dust generation to increases in concentrations of some heavy metals in berries (Shotyk, 2020). Heavy metals linked to dust by Shotyk (2020) include aluminum, chromium, iron, lead, scandium, thorium, vanadium, yttrium, and lanthanides. No specific data on contaminants in berries and plants has been found for the Dehcho Region.

Table 3.1 Traditional Plant Species – Dehcho Region

Form	Scientific Name [1]	Common Name(s)	Rank[2]
Tree	*Abies lasiocarpa**	alpine fir	-
Tree	*Betula papyrifera*	white birch, paper birch	Secure
Tree	*Larix laricina*	tamarack	Secure
Tree	*Picea glauca*	white spruce	Secure
Tree	*Picea mariana*	black spruce	Secure
Tree	*Pinus banksiana*	jack pine	Secure
Tree	*Pinus contorta*	lodgepole pine	Secure
Tree	*Populus balsamifera*	balsam poplar	Secure
Tree	*Populus tremuloides*	trembling aspen	Secure
Shrub	*Alnus rugosa**	mountain alder	-
Shrub	*Alnus tenufolia** (*Alnus tenuifolia*)	speckled alder, river alder	-
Shrub	*Amelanchier alnifolia*	Saskatoon	Secure
Shrub	*Andromeda polifolia*	dwarf bog rosemary	Secure
Shrub	*Arctostaphylos uva-ursi*	common bearberry, Kinnikinnick,	Secure
Shrub	*Arctostaphylos alpina* (Arctous alpina)*	alpine bearberry, torpedoberry	Secure
Shrub	*Arctostaphylos rubra* (Arctous rubra)*	red bearberry	Secure
Shrub	*Betula glandulosa*	bog birch	Secure
Shrub	*Betula occidentalis*	water birch	Secure
Shrub	*Betula pumila* var. *glandulifera*	dwarf birch	Secure
Shrub	*Chamaedaphne calyculata*	leatherleaf	Secure
Shrub	*Cornus sericea*	red osier dogwood	Secure
Shrub	*Potentilla fruticosa* (Dasiphora fruticosa)*	shrubby cinquefoil	Secure
Shrub	*Elaegnus commutata* (*Elaeagnus commutata*)	silverberry	Secure
Shrub	*Empetrum nigrum*	crowberry, black berry	Secure
Shrub	*Gaultheria hispidula**	creeping wintergreen, teaberry	-

Form	Scientific Name [1]	Common Name(s)	Rank[2]
Shrub	*Hudsonia tomentosa*	sand heather	Sensitive
Shrub	*Juniperus communis*	common juniper	Secure
Shrub	*Juniperus horizontalis*	creeping juniper	Secure
Shrub	*Kalmia polifolia*	northern bog laurel, pale bog laurel	Secure
Shrub	*Ledum groenlandicum*	common Labrador tea	Secure
Shrub	*Lonicera dioica*	twinning/ red honeysuckle	Secure
Shrub	*Lonicera involucrata**	bracted honeysuckle, black twin berry	-
Shrub	*Myrica gale*	sweet gale	Secure
Shrub	*Prunus pensylvanica*	pin cherry	Secure
Shrub	*Prunus virginiana*	choke cherry	Sensitive
Shrub	*Ribes americanum**	wild black currant	-
Shrub	*Ribes glandulosum*	skunk currant, wild red currant	Secure
Shrub	*Ribes hudsonianum*	northern black currant	Secure
Shrub	*Ribes lacustre*	bristly black currant	Secure
Shrub	*Ribes oxyacanthoides*	northern gooseberry, Canada gooseberry	Secure
Shrub	*Ribes triste*	wild red currant	Secure
Shrub	*Rosa acicularis*	prickly rose, rose hips	Secure
Shrub	*Rubus idaeus*	wild red raspberry red raspberry	Secure
Shrub	*Salix* spp.	multiple willow species, including diamond willow and red willow	N/A multiple species
Shrub	*Sorbus scopulina*	western mountain ash	Secure
Shrub	*Shepherdia canadensis*	buffaloberry, soopolallie, soapberry,	Secure
Shrub	*Symphoricarpos albus*	common snowberry	Undetermined
Shrub	*Symphoricarpos occidentalis*	western snowberry	Secure
Shrub	*Vaccinium myrtilloides*	common blueberry, velvet leaf blueberry	Sensitive[+]
Shrub	*Vaccinium caespitosum*	dwarf blueberry	Undetermined
Shrub	*Vaccinium oxycoccus* (*Vaccinium oxycoccos*)	small bog cranberry	Secure
Shrub	*Vaccinium vitis-idaea*	lingonberry, bog cranberry, cowberry, mountain cranberry	Secure
Shrub	*Viburnum edule*	low bush cranberry, mooseberry	Secure
Shrub	*Viburnum opulus**	high bush cranberry	-
Graminoid	*Acorus americanus (Acorus calamus)*	sweetflag, calamus	May Be At Risk[+]
Graminoid	*Calamagrostis canadensis*	blue-jointed reed grass, marsh reedgrass	Secure
Graminoid	*Carex aquatilis*	water sedge	Secure
Graminoid	*Phragmites australis** *(Phragmites communis)*	common reed	Undetermined

Form	Scientific Name [1]	Common Name(s)	Rank[2]
Graminoid	*Hierochloe odorata*	sweet-grass	Secure
Graminoid	*Hordeum jubatum*	fox-tail barley	Secure
Graminoid	*Schoenoplectus acutus*	bulrush	Secure
Graminoid	*Typha latifolia*	broad-leaf cattail	Secure
Graminoid	*Triglochin maritima*	seaside arrow-grass	Secure
Forb	*Achillea millefolium*	yarrow	Secure
Forb	*Actaea rubra*	red baneberry	Secure
Forb	*Agastache foeniculum*	giant hyssop	May Be At Risk+
Forb	*Allium textile**	wild onion and chives	-
Forb	*Androsace septentrionalis*	pygmyflower, fairy candelabra	Secure
Forb	*Angelica lucida (Coelopleurum gmelinii)*	seaside angelica	May Be At Risk
Forb	*Apocynum androsaemifolium*	spreading dogbane	Secure
Forb	*Artemisia campestris*	field sagewort	Secure
Forb	*Artemisia frigida*	pasture sage	Secure
Forb	*Aralia nudicalis* (*Aralia nudicaulis*)	wild sarsaparilla	Secure
Forb	*Aster ciliolatus** (*Symphyotrichum ciliolatum)*	Lindley's aster, fringed aster	Secure
Forb	*Aster laevis** (*Symphyotrichum laeve)*	smooth aster	Presence Expected
Forb	*Aster puniceus** (*Symphyotrichum puniceum)*	purple-stemmed aster	Undetermined
Forb	*Aster umbellatus**	flat-topped white aster	-
Forb	*Astragalus americanus*	American milk-vetch	Secure
Forb	*Boschniakia rossica*	northern ground-cone	Secure
Forb	*Calla palustris*	water calla	Secure
Forb	*Campanula rotundifolia**	bluebell	-
Forb	*Chenopodium album*	lamb's quarters	Alien
Forb	*Chenopodium capitatum*	strawberry blite	Secure
Forb	*Cicuta maculata*	water hemlock, spotted water-hemlock	Secure
Forb	*Claytonia tuberosa*	tuberous spring beauty	Secure
Forb	*Chimaphila umbellata*	pipsissewa	May Be At Risk+
Forb	*Cornus canadensis*	bunchberry	Secure
Forb	*Dryopteris carthusiana (Dryopteris spinulosa)*	spiney wood fern	May Be At Risk
Forb	*Epilobium angustifolium*	fireweed	Secure
Forb	*Equisetum arvense*	horsetail	Secure
Forb	*Fragaria vesca*	woodland strawberry, wild strawberry	Secure
Forb	*Fragaria virginiana*	wild strawberry,	Secure

Form	Scientific Name [1]	Common Name(s)	Rank[2]
Forb	*Galeopsis tetrahit*	hemp nettle	Alien
Forb	*Galium boreale*	northern bedstraw	Secure
Forb	*Geocaulon lividum*	northern comandra	Secure
Forb	*Geum aleppicum*	yellow avens	Secure
Forb	*Geum rivale**	purple avens	-
Forb	*Grindelia squarrosa**	gumweed	-
Forb	*Hedysarum alpinum*	American alpine sweet-vetch, sweetbroom	Secure
Forb	*Hellenium atumnale** *(Helenium autumnale)*	sneezeweed	Secure
Forb	*Heracleum lanatrum** *(Heracleum maximum, Heracleum lanatum)*	cow parsnip	Secure
Forb	*Heuchera richardsonii*	alum root	May Be At Risk[+]
Forb	*Leucanthemum vulgare*	ox-eye daisy	Invasive Alien
Forb	*Lycopodium annotinum*	clubmoss	Secure
Forb	*Maianthemum canadense*	wild lily-of-the-valley	Secure
Forb	*Matteauccia struthiopteris** *(Matteuccia struthiopteris)*	ostrich fern	Sensitive
Forb	*Mentha arvensis*	wild mint	Secure
Forb	*Mertensia paniculata*	lungwort, tall bluebells	Secure
Forb	*Mitella nuda*	mitrewort	Secure
Forb	*Oxyria digyna*	mountain sorrel	Secure
Forb	*Pedicularis langsdorffii*	lousewort	Secure
Forb	*Petasites sagittatus*	arrow-leaved coltsfoot	Not Assessed
Forb	*Plantago major*	broad-leaved plantain	Alien
Forb	*Polygonum amphibium*	water smartweed	Secure
Forb	*Polygonum viviparum* (*Bistorta vivipara*)	bistort, serpent grass	Secure
Forb	*Polypodium vulgare*	rock polypody fern	Secure
Forb	*Potentilla gracilis**	cinquefoil	-
Forb	*Pyrola asarifolia*	pink wintergreen	Secure
Forb	*Rubus arcticus*	dewberry, dwarf raspberry	Secure
Forb	*Rubus chamaemorus*	cloudberry, baked apple berry, yellowberry	Secure
Forb	*Rumex aquaticus*	western dock	Secure
Forb	*Sagittaria cuneata*	arrowhead	Secure
Forb	*Sarracenia purpurea*	pitcher plant	Secure
Forb	*Scutellaria galericulata*	marsh skullcap	Secure
Forb	*Sium suave*	water parsnip	Secure

Form	Scientific Name [1]	Common Name(s)	Rank[2]
Forb	*Solidago canadensis*	Canadian goldenrod	Secure
Forb	*Taraxacum officinale*	dandelion	Alien
Forb	*Urtica dioica*	stinging nettle	Secure
Forb	*Utricularia macrorhiza*	bladderwort	Secure
Forb	*Veratrum viride*	false hellebore	Secure
Forb	*Zigadenus elegans*	mountain death camus	Secure

Notes:

[1] Scientific name as reported by Dehcho Land Use Planning Committee (2006). Associated accepted synonym is provided in brackets where available.

[2] General NWT Rank as per NWT Species list (GNWT, 2016a) unless invasive. Alien plant rankings as described in Carriere (2008) and in Oldham and Delisle-Oldham (2016).

* Plant names that do not appear on the NWT Species list (GNWT, 2016a).

[+] Sensitive and At Risk Species not expected to occur in the Dehcho RSA.

Source: Adapted from Dehcho Land Use Planning Committee (2006) and IMG-Golder Corporation (2006).

Table 3.2 Additional Potential Traditional Plant Species – Dehcho Region

Form	Scientific Name [1]	Common Name(s)	Rank[2]
Tree	*Abies bifolia*	rocky mountain subalpine fir	Secure
Tree	*Betula neoalaskana*	Alaska paper birch	Secure
Shrub	*Alnus alnobetula (Alnus viridis)*	green alder	Secure
Shrub	*Alnus incana (Alnus incana* ssp. *tenuifolia)*	speckled alder (mountain alder, gray alder, hoary alder)	Secure
Forb	*Allium schoenoprasum*	wild chives	Secure
Forb	*Campanula alaskana*	bluebell, Alaska bellflower	Undetermined
Forb	*Campanula gieseckeana*	bluebell, Giesecke bellflower	Undetermined
Forb	*Nuphar polysepala (Nuphar lutea* ssp *polysepala)*	rocky mountain pond lily	May Be At Risk
Forb	*Nuphar variegata (Nuphar variegatum, Nuphar lutea)*	variegated pond lily	Secure[+]

Notes:

[1] Scientific name as per NWT Species list (GNWT, 2016a).

[2] Ranks as per GNWT 2016a.

[+] Species not expected to occur in the Dehcho RSA.

Source: NWT Plant list (GNWT, 2016a) of similar plants to those identified by Dehcho Land Use Planning Committee (2006) and IMG-Golder Corporation (2006) that reportedly do not occur in the NT.

3.1.2.2 Sahtu Region

A review of the available information indicates 24 plants or groups of plants are used for traditional purposes in the Sahtu Region and all 24 are expected to occur in the ecoregions intersected by the LSA and RSA (Table 3.3). Most of the plants, or plant groups, are ranked *secure* in the NT, with none of the of the identified traditional use species considered *sensitive* or *may be at risk* (GNWT, 2016a).

Table 3.3 Traditional Plant Species – Sahtu Region

Form	Scientific Name[1]	Common Name(s)	Rank[2]
Tree	*Betula neoalaskana*	resin birch, Alaska paper birch	Secure
Tree	*Betula papyrifera*	white birch, paper birch	Secure
Tree	*Picea glauca*	white spruce	Secure
Tree	*Picea mariana*	black spruce	Secure
Shrub	*Arctostaphylos uva-ursi*	common bearberry, Kinnikinnik,	Secure
Shrub	*Arctous alpina*	alpine bearberry, torpedoberry	Secure
Shrub	*Arctous rubra*	red bearberry	Secure
Shrub	*Betula glandulosa*	bog birch	Secure
Shrub	*Betula occidentalis*	water birch	Secure
Shrub	*Betula pumila var. glandulifera*	dwarf birch	Secure
Shrub	*Empetrum nigrum*	crowberry, black berry	Secure
Shrub	*Rosa acicularis*	prickly rose, rose hips	Secure
Shrub	*Ribes glandulosum*	skunk currant, wild red currant	Secure
Shrub	*Ribes hudsonianum*	northern black currant	Secure
Shrub	*Ribes lacustre*	bristly black currant	Secure
Shrub	*Ribes triste*	wild red currant	Secure
Shrub	*Rubus idaeus*	wild red raspberry red raspberry	Secure
Shrub	*Salix* spp.	multiple willow species, including diamond willow and red willow	N/A multiple species
Shrub	*Vaccinium caespitosum*	dwarf blueberry	Undetermined
Shrub	*Vaccinium oxycoccus*	small bog cranberry	Secure
Shrub	*Vaccinium vitis-idaea*	lingonberry, bog cranberry, cowberry, mountain cranberry	Secure
Shrub	*Viburnum edule*	low bush cranberry, mooseberry	Secure
Forb	*Rubus arcticus*	dewberry, dwarf raspberry	Secure
Forb	*Rubus chamaemorus*	cloudberry, baked apple berry, yellowberry	Secure

Notes:
1 Scientific name as per NWT Species list (GNWT, 2016a).
2 Ranks as per GNWT, 2016a.
Sources: EBA, 2006; 5658 NWT Ltd. and GNWT, 2011; Tulita Renewable Resource Council, 2019.

Wood for fuel and tools, and berries were identified as important for traditional use (EBA, 2006; 5658 NWT Ltd. and GNWT, 2011). Both wood and wood pellets are an important fuel for heating homes in the Sahtu Region. Within the Sahtu Region, wood is used for house heating in 274 (34%) households with 109 (13%) homes reporting wood as their main heat source (NWT Bureau of Statistics, 2018). Wood pellets are used for house heating in 18 (2%) households with 14 (2%) homes reporting wood pellets as their main heat source (NWT Bureau of Statistics, 2018).

Within the Sahtu Region, 34% of the general population reported gathering berries (NWT Bureau of Statistics, 2020), with 28% of the Indigenous population of Tulita and 32% of the Indigenous population of Norman Wells reporting they were engaged in berry gathering (NWT Bureau of Statistics, 2019b, 2019c).

Contaminants may be a concern for certain traditional foods, including berries and medicinal teas, in some areas (GNWT, 2017). The GNWT publishes contaminant fact sheets on many traditional meats, but no fact sheets are published for plant species (GNWT, 2016b). The Northern Contaminants Program focuses on heavy metals, and persistent organic pollutants, which can bioaccumulate in wildlife and human populations (Government of Canada, 2021). There are some studies that link increased industrial activity and dust generation to increases in concentrations of some heavy metals in berries (Shotyk, 2020). Heavy metals linked to dust (Shotyk, 2020) include aluminum, chromium, iron, lead, scandium, thorium, vanadium, yttrium, and lanthanides. No specific data on contaminants in berries and plants has been found for the Sahtu Region.

The Tulita Renewable Resources Council TLRU study developed for the Project (Tulita Renewable Resource Council, 2022) reports that:

- Country food is an important part of community residents' diet, and is shared among the community, family members, and friends in all seasons (particularly during spring and winter); and the community relies on and is in constant need of wildlife/country food for sustenance.
- Changes in the LSA such as increase of fires and disappearing plants have affected the ability to conduct TLRU.
- Harvesting plants and berries within the LSA, and along the MVWR in the summertime.
- Healing wood is harvested in the LSA.
- Firewood is harvested along the MVRW during the wintertime.
- More invasive species and vegetation in the LSA that have affected ability to conduct TLRU and recommend further studies to assess change / impact.
- Birch barks, willows and spruce branches are collected in the LSA and are used for medicinal purposes in the LSA.
- Plants and wildlife are still needed to conduct TLRU, food and hides (personal use).
- A berry harvesting area on the west side of Bear River, and near Plane Lake.
- Willows, birch bark and spruce boughs are harvested within the LSA.
- Blueberries are harvested within the LSA.

3.2 Literature Review

3.2.1 Methods

Available vegetation and wetland information was compiled to identify conditions in the study areas. The following data sources were reviewed:

- Earth Observation of Sustainable Development (EOSD) of Forests Northwest Territories geospatial database raster data – (Natural Resources Canada and GNWT, 2017)
- Canadian Wildland Fire Information System Datamart – Canadian National Fire Database fire polygon data (Canadian Forest Service, 2020)
- Species at Risk Act (SARA) Public Registry threatened and endangered species occurrences and ranking data – (Government of Canada, 2019)
- NWT species 2016-2020 – general status ranks of wild species in the Northwest Territories – (Working Group on General Status of NWT Species, 2016)
- Northwest Territories species monitoring Infobase – (GNWT, 2016a)
- Alien and invasive alien plant species occurrence data – (AKEPIC, 2020)
- Project Description Report (PDR) for Construction of the Mackenzie Valley Highway Tulita District, Sahtu Settlement Area – (5658 NWT Ltd. and GNWT, 2011)
- Project Description Report for Mackenzie Valley Highway Extension Pehdzeh Kı Ndeh – Dehcho Region – (Dessau, 2012)

3.2.1.1 Landcover/Plant Assemblages and Timber

Landcover/plant assemblages and timber within the LSA and RSA were quantified using EOSD NWT data (Natural Resources Canada and GNWT, 2017). This dataset is part of the Multisource Inventory Project (Natural Resources Canada, 2020) and uses an unsupervised classification and cluster analysis to classify landcover/plant assemblages.

The EOSD NWT dataset includes modelled cover type and density classes, as well as forest structure height and volume information based on Landsat TM imagery collected from 2007 to 2013. Mapping was done at a scale of 1:250,000 and refined through field evaluation by the GNWT (Natural Resources Canada and GNWT, 2017).

Crown Closure Class uses three categories with a range of percentage to quantify canopy closure coverage: sparse (6-25%), open (26-55%), and dense (56-100%).

Merchantable timber is defined by timber supply plans and, if timber supply plans are not available, by the Commercial Timber Harvest Planning and Operations Standard Operating Procedures Manual (GNWT Environment and Natural Resources, 2005). Generally, this includes soft-wood species with a diameter-at-breast-height of 18 centimetres (cm) and larger. Available timber data from EOSD does not include species-specific data; therefore, estimates of merchantable timber volumes were not completed. Included in this TDR are estimates of coniferous and mixedwood volumes in the LSA and RSA, which can be used

to inform future field data collection for determination of merchantable timber locations and volumes. Future merchantable timber estimates should address the amount of merchantable timber removed during ROW clearing and the potential for facilitating use of waste timber by communities.

No vegetation assemblages are considered rare in the Boreal Cordillera ecoregion or the Taiga Cordillera ecoregion (Working Group on General Status of NWT Species, 2016).

3.2.1.2 Fire History

Forest fire polygon data from the Canadian National Fire Database (CNFDB) (Canadian Forest Service, 2020) was examined for the frequency and extent of fire in the LSA and RSA and differences with landcover types/plant assemblages. CNFDB fire polygon data is compiled by Canadian fire agencies (provincial, territories and Parks Canada) and can be used for spatial and temporal analysis of fire effects at a landscape scale. CNFDB fire polygon data for NT is current as of 2019 (Canadian Forest Service, 2020). Frequency of burns, area burned (hectares [ha]), and proportion of area burned were determined by decade (1960 to 2019) for the LSA and RSA.

3.2.1.3 Plant SOCC

The Northwest Territories Species Monitoring Infobase was searched to identify known vascular and non-vascular plant SOCC that could potentially occur in the LSA and RSA (GNWT, 2016a).

Plant SOCC observations from the Mackenzie Gas Project (Mackenzie Project Environment Group, 2004) detailed in the Mackenzie Valley Highway Tulita District PDR (5658 NWT Ltd. and GNWT, 2011) and the PDR for Mackenzie Valley Highway Extension Pehdzeh Ki Ndeh – Dehcho Region (Dessau, 2012) were also reviewed for documented plant SOCC in the RSA.

3.2.1.4 Alien and Invasive Alien Plant Species

Alien plant species are defined as plants introduced to the NT from Eurasia or other parts of North America as a result of human activities (Oldham and Delisle-Oldham, 2016). Invasive alien plant species are those with potential to cause significant ecological harm to native environments through high rates of dispersal and establishment (Snyder and Anions, 2008). Some human developments and activities can promote the establishment and spread of alien and invasive alien plant species through introduction of propagules and increasing habitat invasiveness. Changes in disturbance frequency and intensity of natural habitats can alter species composition, including invasion by alien and invasive alien plant species. Invasive alien plant species are plants listed in Carriere (2008). Additional invasive alien plant species are plants which are described as ‘priority invasive plant species’ in Oldham and Delisle-Oldham (2016). Alien plant species are plants which appear in Oldham and Delisle-Oldham (2016) and GNWT (2015), but the latter does not specifically identify plant species as “Invasive Alien”; however, the report does list species that are invasive by nature. Additionally, alien species are identified in Working Group on General Status of NWT Species (2016). That report also does not specifically identify plant species as invasive alien.

Alien and alien invasive plant species potentially occurring in the RSA were identified using Oldham and Delisle-Oldham (2016), for which a field survey was conducted to identify occurrences of alien and invasive alien plant species along the Mackenzie Highway from the northern Alberta border to Wrigley, NT, and conducting a search of the Northwest Territories Species Monitoring Infobase (GNWT, 2016a) to identify potential alien and invasive alien plant species occurring within Level II ecoregions (Taiga Plains, Taiga Cordillera and Boreal Cordillera) intersected by the RSA. Occurrences identified in this TDR do not directly overlap the Project Development Area (PDA); however, they are within the RSA and indicate plants that may occur in the vegetation LSA or project PDA. Known occurrences of alien and invasive alien plant species in the RSA were determined using the Alaska Exotic Plants Information Clearinghouse (AKEPIC), a geospatial mapping tool which tracks occurrences of alien species (AKEPIC, 2020).

3.2.2 Results

3.2.2.1 Dehcho Region

Landcover/Plant Assemblages

Coniferous forest is the most abundant landcover type/plant assemblage in the Dehcho Region of the LSA, occupying 44.8% (9,512.2 ha), with similar proportions of sparse, open and dense stands present (Table 3.4). Broadleaf and mixedwood forests are also present, but are less common, with broadleaf forest occupying 3.5% (733.2 ha) and mixedwood forest occupying 4.4% (932.8 ha). Most coniferous forest cover types are located east of the Mackenzie River, whereas most broadleaf and mixedwood forest cover types are located west of the Mackenzie River, which has historically been burned (Figure 3.1). Figure 3.2 shows areas of sparse and open forest cover in the Dehcho Region portion of the LSA.

Remaining upland areas in the Dehcho Region of the LSA are largely composed of exposed land, 5.9% of the LSA (1,255.3 ha), low shrub, 1.6% of the LSA (347.4 ha), and tall shrub, 1.4% of the LSA (307.4 ha) (Table 3.4). Exposed land includes areas that naturally have less than 5% vegetative cover, such as shorelines of rivers and lakes, exposed rock, recently burned areas, and moraines; the areas also include cleared areas such as roads and areas of infrastructure development, including the two existing cleared ROW for the Norman Wells Pipeline and MVWR. Exposed land occurs predominantly along the east side of the Mackenzie River in the LSA in the Dehcho Region (Figure 3.1). Tall and low shrub are distributed predominately west of the Mackenzie River and, typically, associated with broadleaf stands and lower areas with open water.

Wetlands occupy 19.6% of the LSA in the Dehcho Region (4,152.9 ha). Treed and shrub wetlands are the most common wetland types, occupying 8.3% (1,768.5 ha) and 7.9% (1,667.2 ha), respectively. Wetlands are located throughout the LSA in the Dehcho Region, with the highest concentrations of wetlands occurring along watercourses adjacent to Mackenzie River (Figure 3.1).

Table 3.4 Landcover/Plant Assemblage Types in the LSA and RSA – Dehcho Region

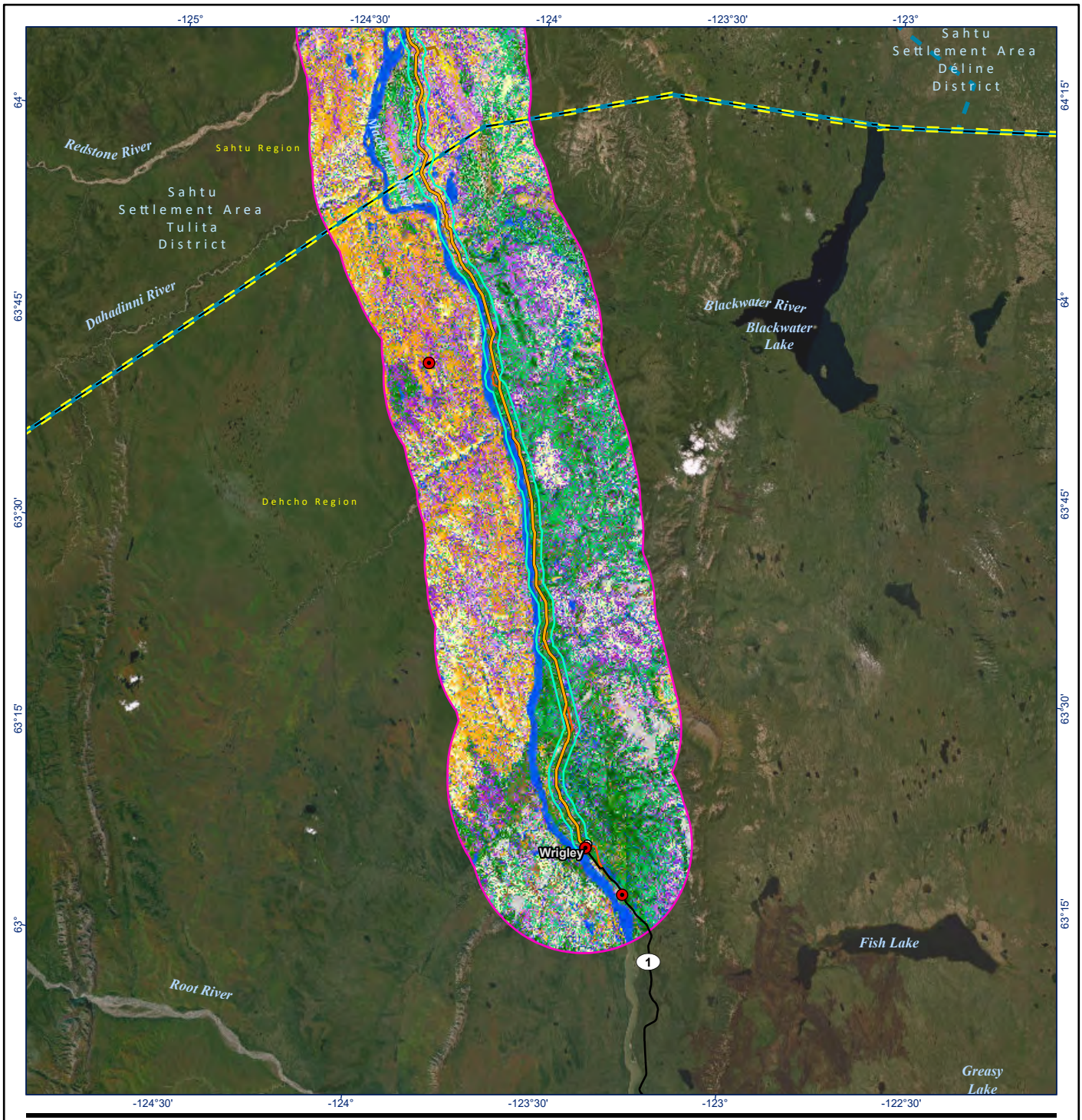
Landcover/Plant Assemblage Type	Cover Type Class	LSA		RSA	
		ha	%	ha	%
Broadleaf Forest	Broadleaf – Dense	665.0	3.1	43,789.4	12.2
	Broadleaf – Open	68.3	0.3	4,129.7	1.2
	Broadleaf Subtotal	**733.2**	**3.5**	**47,919.1**	**13.4**
Coniferous Forest	Coniferous – Dense	2,724.7	12.8	25,081.4	7.0
	Coniferous – Open	3,694.9	17.4	40,004.2	11.2
	Coniferous – Sparse	3,092.7	14.6	51,385.1	14.3
	Coniferous Subtotal	**9,512.2**	**44.8**	**116,470.7**	**32.5**
Mixedwood Forest	Mixedwood – Dense	825.5	3.9	6,772.1	1.9
	Mixedwood – Open	107.3	0.5	2,727.8	0.8
	Mixedwood Subtotal	**932.8**	**4.4**	**9,499.9**	**2.6**
Shrubland	Shrub – Tall	307.4	1.4	1,642.0	0.5
	Shrub – Low	347.4	1.6	38,961.7	10.9
	Shrubland Subtotal	**654.8**	**3.1**	**40,603.7**	**11.3**
Herbaceous and Un-vegetated	Herb	42.7	0.2	1,248.9	0.3
	Bryoids	7.0	<0.1	20.3	<0.1
	Rock/Rubble	44.1	0.2	4,877.5	1.4
	Exposed Land[1]	1,255.3	5.9	4,844.1	1.4
	Herbaceous and Un-vegetated Subtotal	**1,349.1**	**6.4**	**10,990.8**	**3.1**
	Upland Subtotal[2]	**13,182.0**	**62.1**	**225,484.3**	**62.9**
Wetland	Wetland – Treed	1,768.5	8.3	46,837.6	13.1
	Wetland – Shrub	1,667.2	7.9	44,668.8	12.5
	Wetland – Herb	717.3	3.4	12,623.9	3.5
	Wetland Subtotal[2]	**4,152.9**	**19.6**	**104,130.4**	**29.0**
Open Water		3,894.1	18.3	28,828.2	8.0
No data		0.0	0.0	95.5	0.0
Total[2]		**21,229.0**	**100.0**	**358,538.4**	**100.0**

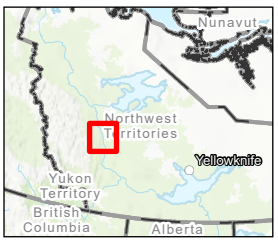
Notes:

[1] Exposed land includes areas which naturally have less than 5% vegetative cover such as shorelines of rivers and lakes, exposed rock, recently burned areas, and moraines, and includes cleared areas such as roads and areas of infrastructure development.

[2] Sub-totals and totals may not equal sums of individual values due to rounding.

Source: Natural Resources Canada and GNWT (2017).





Alien and Alien Invasive (weed) Occurrence*

Landcover Type

- Water
- Rock/Rubble
- Exposed Land
- Bryoids
- Shrub - Tall
- Shrub - Low
- Wetland - Treed
- Wetland - Shrub
- Wetland - Herb
- Herb
- Coniferous - Dense
- Coniferous - Open
- Coniferous - Sparse
- Broadleaf - Dense
- Broadleaf - Open
- Mixedwood - Dense
- Mixedwood - Open
- Mixedwood - Sparse

* More than one alien or alien invasive plant may occur at each mapped location

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 7.5 15 Kilometres

(At original document size of 8.5x11)
1:40,000,000

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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

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Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.1

Title
Landcover/Plant Assemblage Types within the Mackenzie Valley Highway Project LSA and RSA – Dehcho Region

Notes

1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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Figure 3.2 Upland Landcover/Plant Assemblage – Dehcho Region

Areas of open water (i.e., lakes, rivers and streams) are also common in the Dehcho Region of the LSA, occupying 18.3% of the LSA (3,894.1 ha), which occur primarily at Mackenzie River and associated watercourses (Figure 3.1). Herb, and rock/rubble areas are also present, both occupying 0.2% of the LSA at 42.7 ha and 44.1 ha, respectively. Bryoid dominated areas are uncommon, occupying less than 0.1% of the Dehcho Region of the LSA (7.0 ha).

Like the LSA, the RSA in the Dehcho Region is dominated by coniferous forest 32.5% (116,470.7 ha); however, cover decreases with stand density (Table 3.4). Broadleaf forests in the RSA occupy a greater proportion of landcover 13.4% (47,919.1 ha) than in the LSA. Compared to the LSA, relative abundance of mixedwood forest within the RSA is lower, representing just 2.6% (9,499.9 ha). Broadleaf and mixedwood forests are dominated by dense stands with 56% to 100% tree closure.

The remaining upland composition in the RSA in the Dehcho Region is mostly low shrub 10.9% (39,961.7 ha), followed by rock/rubble 1.4% (4,877.5 ha), exposed land 1.4% (4,844.1 ha), and tall shrub 0.5% (1,642.0 ha). Herb dominated areas are also present in the RSA, occupying 0.3% (1,248.9 ha). Small amounts of bryoid landcover/plant assemblage is also present in the RSA, but they are found at less than 0.1% (Table 3.4).

Wetlands cover 29.0% (104,130.4ha) of the RSA in the Dehcho Region, with similar proportions of treed wetlands and shrub wetlands, occupying 13.1% (46,837.6 ha) and 12.5% (44,668.8 ha), respectively. Herb wetlands are also present at 3.5% (12,623 ha). Wetlands are predominately located in areas associated with open water and broadleaf stands, occurring primarily adjacent to watercourses throughout the Dehcho Region.

A lower percentage of open water areas are observed in the RSA in the Dehcho Region 8.0% (28,828.2 ha), compared to the LSA (Table 3.4). This difference is due to the presence of the Mackenzie River in the LSA (Figure 3.1). Smaller areas of open water also occur and are surrounded by various wetland classes (Figure 3.3).

Coniferous forest has an average stand volume density of 40.2 cubic metres per hectare (m^3/ha; Standard Deviation [SD] = 17.7) (Table 3.5). Tree height in conifer stands in the LSA range from 5 m to 19 m with an average height of 9.1 m (SD = 2.2). Mixedwood forest has a greater average stand volume density (42.2 m^3/ha, SD = 13.6) than coniferous (40.2 m^3/ha, SD = 17.7), and deciduous forests (34.6 m^3/ha, SD = 17.9). Deciduous forest has slightly shorter minimum tree height (5 m) than mixedwood forest (6 m), but both have similar maximum tree heights of 17 m. Average tree height for deciduous forest is 8.5 m (SD = 2.2), whereas average tree height for mixedwood forest is 9.5 m (SD = 1.6) (Table 3.5). More detailed species information from ground data is needed to provide detailed merchantable timber volume estimates, but from volume metrics, merchantable timber is expected in the Dehcho Region of the LSA.

Figure 3.3 Open Water and Wetland Landcover/Plant Assemblage – Dehcho Region

Table 3.5 Tree Height, Stand Volume Density and Total Volume by Forest Type in the LSA – Dehcho Region

Landcover/Plant Assemblage Type	Tree Height (m)				Stand Volume Density (m^3/ha)				Total Volume[2] (m^3)
	Minimum	Maximum	Average	SD[1]	Minimum	Maximum	Average	SD[1]	
Coniferous	5	19	9.1	2.2	13	148	40.2	17.7	448,465
Deciduous	5	17	8.5	2.2	13	125	34.9	17.9	15,209
Mixedwood	6	17	9.5	1.6	17	125	42.2	13.6	26,803

Notes:
[1] Standard Deviation.
[2] Total volume determined by multiplying average stand volume by land cover area (ha) in the LSA.
Source: Natural Resources Canada and GNWT (2017).

Average stand volume density of coniferous forest in the RSA is lower than that of the LSA at 31.0 m^3/ha (SD = 21.7) (Table 3.6). Average tree height in coniferous forest is also shorter in the RSA than the LSA, equaling 7.7 m (SD = 2.5), with heights ranging from 4 m to 22 m (Table 3.6). Deciduous forest in the Dehcho Region of the RSA shares the same range of stand heights as coniferous forest; however, average height is 6.7 m and tree height is less variable (SD = 1.9). Mixedwood forest has an average stand volume density of 38.7 m^3/ha (SD = 19). Mixedwood forest ranges from 5 m to 21 m in height with an average tree height of 8.9 m (SD = 2.1). Average stand volume density of deciduous and mixedwood stands in the RSA is lower than the LSA. Average tree heights of deciduous and mixedwood stands in the LSA are taller than the RSA.

Table 3.6 Tree Height, Stand Volume Density and Total Volume by Forest Type in the RSA – Dehcho Region

Landcover/Plant Assemblage Type	Tree Height (m)				Stand Volume Density (m^3/ha)				Total Volume[2] (m^3)
	Minimum	Maximum	Average	SD[1]	Minimum	Maximum	Average	SD[1]	
Coniferous	4	22	7.7	2.5	10	180	31.0	21.7	3,927,036
Deciduous	4	22	6.7	1.9	10	182	23.2	14.9	1,190,127
Mixedwood	5	21	8.9	2.1	13	174	38.7	18.8	276,288

Notes:
[1] Standard Deviation
[2] Total volume determined by multiplying average stand volume by land cover area (ha) in the RSA.
Source: Natural Resources Canada and GNWT (2017).

Fire History

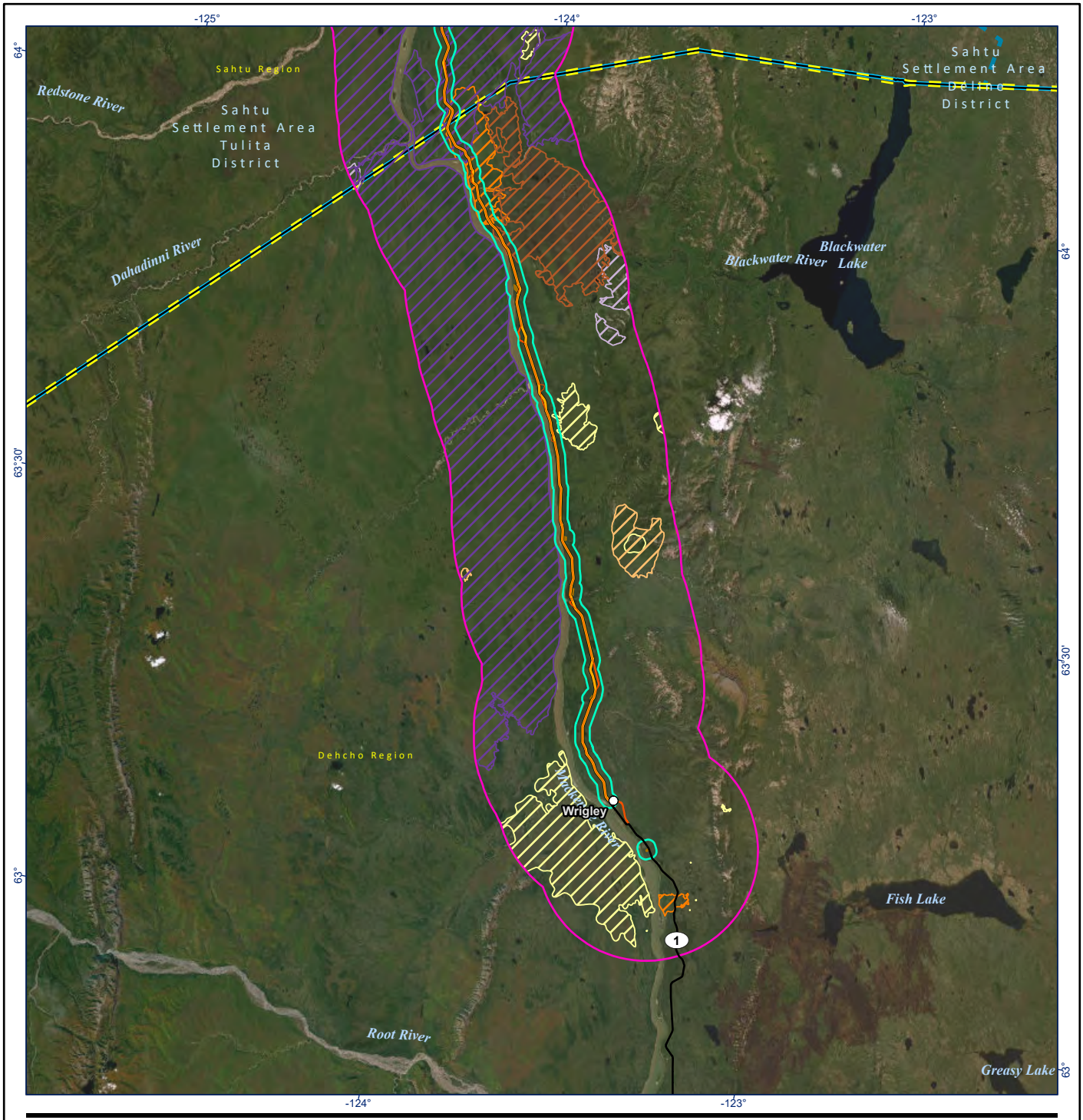
Between 1960 and 2019, five fires occurred within some portion of the LSA in the Dehcho Region, burning a total area of 4,830.3 ha (22.8% of the LSA) (Table 3.7). Total area burned within the Dehcho Region of the LSA ranged from 0 to 2,713.0 ha, with zero to two fires occurring per decade. Some areas burned more than once during this time, with certain areas experiencing burns in more than one decade. Most of the recorded fires have occurred west and northeast of the Mackenzie River. During the period of 1990-2009, the majority of the LSA west of the Mackenzie River had been affected by fire (Figure 3.4).

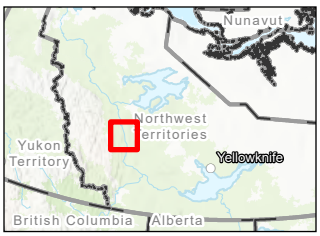
There were 24 fires within the RSA in the Dehcho Region between 1960 and 2019, burning a total of 182,269.2 ha (50.8% of the RSA) (Table 3.7). Fire sizes within the RSA ranged from 3,390.3 ha to 115,739.5 ha. In comparison to the LSA, the RSA burned more frequently, and had a greater proportion burned. This is likely an artifact of the size of the LSA and is not suspected to reflect a greater resistance to burning.

Table 3.7 Forest Fire Occurrence within the LSA and RSA from 1960 to 2019 – Dehcho Region

Time Period	Number of Fires		Total Area Burnt (ha)		Percent Area Burnt (%)	
	LSA	RSA	LSA	RSA	LSA	RSA
1960-1969	0	2	0.0	4,864.3	0.0	1.4
1970-1979	1	2	2,713.0	7,523.0	12.8	2.1
1980-1989	0	3	0.0	3,390.3	0.0	0.9
1990-1999	2	4	1,466.5	115,739.5	6.9	32.3
2000-2009	1	9	36.1	26,066.8	0.2	7.3
2010-2019	1	4	614.7	24,685.3	2.9	6.9
TOTAL	5	24	4,830.3	182,269.2	22.8	50.8

Source: Canadian Forest Service (2020).





National Fire Database
- 1960-1969
- 1970-1979
- 1980-1989
- 1990-1999
- 2000-2009
- 2010-2019
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- Region Boundary
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0 7.5 15 Kilometres

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Project Location
Wrigley to Norman Wells, NWT

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Mackenzie Valley Highway Project

Figure No.
3.4

Title
Area Burnt per Decade within the Mackenzie Valley Highway LSA and RSA between 1960 and 2019 - Dehcho Region

Notes
1. Coordinate System: NAD 1983 Northwest Territorries Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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Fires within the LSA of the Dehcho Region affected 2,819.8 ha of upland areas and 1,757.1 ha of wetland areas (Table 3.8). Fires within the RSA of the Dehcho Region affected 114,208.9 ha of upland areas and 59,383.3 ha of wetland areas (Table 3.8). All upland and wetland types were burned at least once in the LSA and RSA between 1960 and 2019. Areas burned of rock/rubble, exposed land and open water reflect the coarse scale of available data in fact, these areas likely did not actually burn.

Figure 3.5 is a box plot, which shows the median area burned per landcover/plant assemblage type in the LSA and RSA in the Dehcho Region between 1960 and 2019. The heavy horizontal bar in each box indicates median value, with inter-quartile range represented as upper and lower boundaries on opposite areas in the box. Standard deviation is represented as bars and outliers as points. This figure shows that fire size in the LSA and RSA of the Dehcho Region is highly variable.

Data on changes in plant composition with varying time since burned (i.e., succession) were not found for the LSA or RSA. Available studies indicate burned areas are dominated by plants capable of vegetative reproduction following fire, with a later increase in abundance of plants reproducing by seed and slower growing plants capable of vegetative reproduction. Plants with light abundant seeds and species also colonize burned areas rapidly and abundance decreases after a few years due to short life spans of the plants (Johnson, 1981). Trees required 5 to 6 years, on average, to reach a height of 0.3 m following high severity fires in High Boreal, Low Subarctic, and High Subarctic ecoregions of the Taiga Shield (Lewis et al., 2018). Following low to mixed-severity fires, trees took 10.7 years, on average, in the High Boreal ecoregion and 15.5 years in the Low Subarctic. Tree regeneration times may differ for the ecoregions intersected by the RSA.

Figure 3.5 Area Burned by Landcover/Plant Assemblage Type from 1960 to 2019 in the LSA and RSA – Dehcho Region

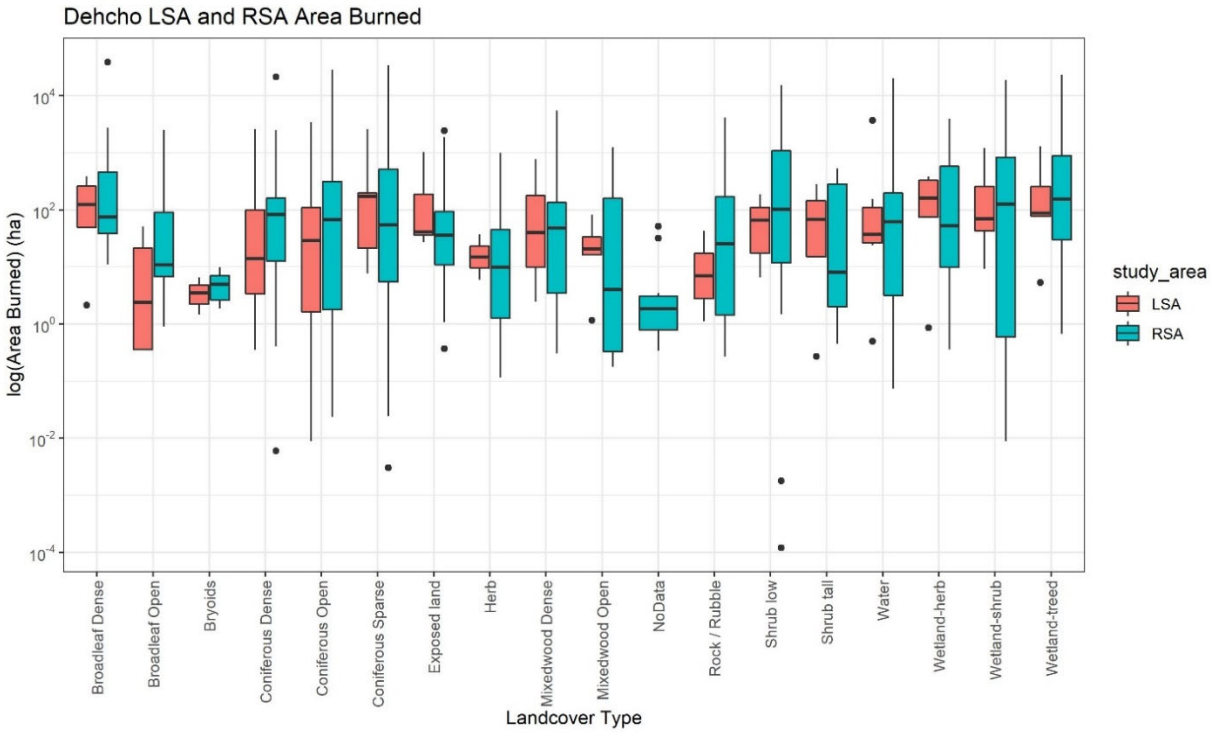


Table 3.8 Number of Fires per Landcover/Plant Assemblage Type and Total Area Burned from 1960 to 2019 – Dehcho Region

Landcover/Plant Assemblage Type [1]	Cover Type Class	Total number of Fires [2]		Total area burned (ha)	
		LSA	RSA	LSA	RSA
Broadleaf Forest	Broadleaf – Dense	10	47	565.3	41,556.8
	Broadleaf – Open	4	29	16.7	3,196.0
	Broadleaf Subtotal	**-**	**-**	**582.0**	**44,752.8**
Coniferous Forest	Coniferous – Dense	6	34	117.1	3,847.3
	Coniferous – Open	8	45	225.5	11,819.8
	Coniferous – Sparse	11	50	568.6	17,743.1
	Coniferous Subtotal	**-**	**-**	**911.2**	**33,110.2**
Mixedwood Forest	Mixedwood – Dense	2	24	42.7	1,322.8
	Mixedwood – Open	10	33	133.5	1,583.7
	Mixedwood Subtotal	**-**	**-**	**176.2**	**2,906.5**
Shrubland	Shrub – Low	11	54	341.3	27,963.2
	Shrub – Tall	10	36	498.8	1,578.6
	Shrubland Subtotal	**-**	**-**	**840.1**	**29,541.8**
Herbaceous and Un-vegetated	Herb	1	20	6.0	268.3
	Bryoids	9	14	11.6	23.8
	Rock/Rubble	1	10	1.1	827.9
	Exposed Land [3]	13	38	291.6	2,477.6
	Herbaceous and Un-vegetated Subtotal	**-**	**-**	**310.3**	**3,597.6**
	Upland Subtotal	**-**	**-**	**2,819.8**	**114,208.9**
Wetland	Wetland – Herb	10	47	564.4	9,136.9
	Wetland – Shrub	11	52	577.6	26,273.5
	Wetland – Treed	11	49	615.1	23,972.9
	Wetland Subtotal	**-**	**-**	**1,757.1**	**59,383.3**
Open Water		11	49	253.5	8,630.6
No Data		-	16	-	46.3
Total		**-**	**-**	**4,830.3**	**182,269.2**

Notes:

[1] Landcover/plant assemblage type in 2020. Landcover/plant assemblage may have been different prior to fire events.

[2] Many fires affected more than one vegetation type; therefore, the total number of fires are given for each vegetation type but cannot be summed among vegetation types.

[3] Exposed land includes areas which naturally have less than 5% vegetative cover such as shorelines of rivers and lakes, exposed rock, recently burned areas, and moraines, and includes cleared areas such as roads and areas of infrastructure development.

Source: Canadian Forest Service (2020)

Plant SOCC

A search of the Northwest Territories Species Monitoring Infobase (Working Group on General Status of NWT Species, 2016)—queried to the ecoregions (Boreal Cordillera and Taiga Cordillera) that are intersected by the RSA of the Dehcho Region—identified 107 vascular plant, bryophytes and lichen SOCC with potential to occur within the RSA, including 77 vascular plants, six mosses, and 24 lichens (Appendix A.1). Of the 77 vascular plants identified, 33 are listed territorially as *may be at risk* and 44 are listed as *sensitive* under the NWT General Species Rankings. Of the six moss species identified, four are listed territorially as *may be at risk* and two are listed as *sensitive* under the NWT General Species Rankings. Two lichen species are listed as *may be at risk* and 22 as *sensitive* (GNWT, 2016a). No plant or lichen SOCC occurring in the Boreal Cordillera ecoregion or the Taiga Cordillera ecoregion are listed under SARA or Committee on The Status of Endangered Wildlife in Canada (COSEWIC), and no vegetation assemblages are considered *rare*.

No plant SOCC occurrences have been documented within the Dehcho Region of the LSA or RSA (Dessau, 2012). Several species reported by Dessau (2012) were previously considered SOCC but have since been downgraded. Pre-construction field surveys should be conducted to evaluate plant SOCC occurrences of higher potential areas potentially impacted by the Project (e.g., riparian areas, uncommon plant assemblages).

Alien and Invasive Alien Plant Species

A search of the AKEPIC Data Portal (AKEPIC, 2020) found 14 locations of 12 alien and invasive alien plant species within the RSA in the Dehcho Region (Table 3.9). Nine of the species are classified as alien plant species and three as invasive alien species. Oldham and Delisle-Oldham (2016) identified 34 alien and invasive alien plant species, of which 22 species were classified as alien and 12 as invasive alien in the RSA in the Dehcho Region (Appendix B). Specific locations of these occurrences are not available; however, locations were sampled in ditches along human infrastructure.

Table 3.9 Alien and Invasive Alien Plant Species Recorded within the RSA – Dehcho Region

Listing	Scientific Name	Common Name	Number of Occurrences	Closest Occurrence to the PDA (km)
Alien	*Taraxacum officinale*	common dandelion	1	0.56
Alien	*Erucastrum gallicum*	common dog mustard	1	0.56
Alien	*Lappula squarrosa*	European stickseed	1	0.56
Alien	*Brassica rapa*	field mustard	1	8.77
Alien	*Thlaspi arvense*	field pennycress	1	8.77
Alien	*Matricaria discoidea*	pineapple weed	1	0.56
Alien	*Taraxacum erythrospermum*	rock dandelion	1	0.56
Alien	*Phleum pratense*	timothy	1	0.56
Alien	*Lepidium virginicum*	wild peppergrass	1	8.78
Invasive Alien	*Crepis tectorum*	narrow-leaf hawksbeard	3	0.56
Invasive Alien	*Phalaris arundinacea*	reed canary grass	1	6.39
Invasive Alien	*Melilotus albus*	white sweet-clover	1	8.78

Source: AKEPIC (2020)

3.2.2.2 Sahtu Region

Landcover/Plant Assemblages

Coniferous forest dominates upland area within the LSA in the Sahtu Region, occupying 28.3% (11,798.9 ha), with open and sparse stands being most abundant (Table 3.10). Broadleaf and mixedwood forests are also present, but less common, with broadleaf forest occupying 6.9% (2,892.5 ha) and mixedwood forest occupying 5.6% (2,315.2 ha) of the LSA. Coniferous forests are primarily distributed west and northeast of the Mackenzie River, broadleaf forests occur in the southwest portion of the LSA, and mixedwood forests are distributed throughout (Figure 3.6). Remaining upland areas in the LSA in the Sahtu Region are largely composed of low shrub at 16.6% (6,935.0 ha), followed by exposed land 4.1% (1,688.2 ha), and tall shrub 4.1% (1,688.7 ha) (Table 3.10). Exposed land occurs predominately adjacent to the Mackenzie River (Figure 3.6). Tall and low shrub landcover/plant assemblage types are located predominately in the northwest portion of the LSA and typically adjacent to conifer stands and near wetlands (Figure 3.6).

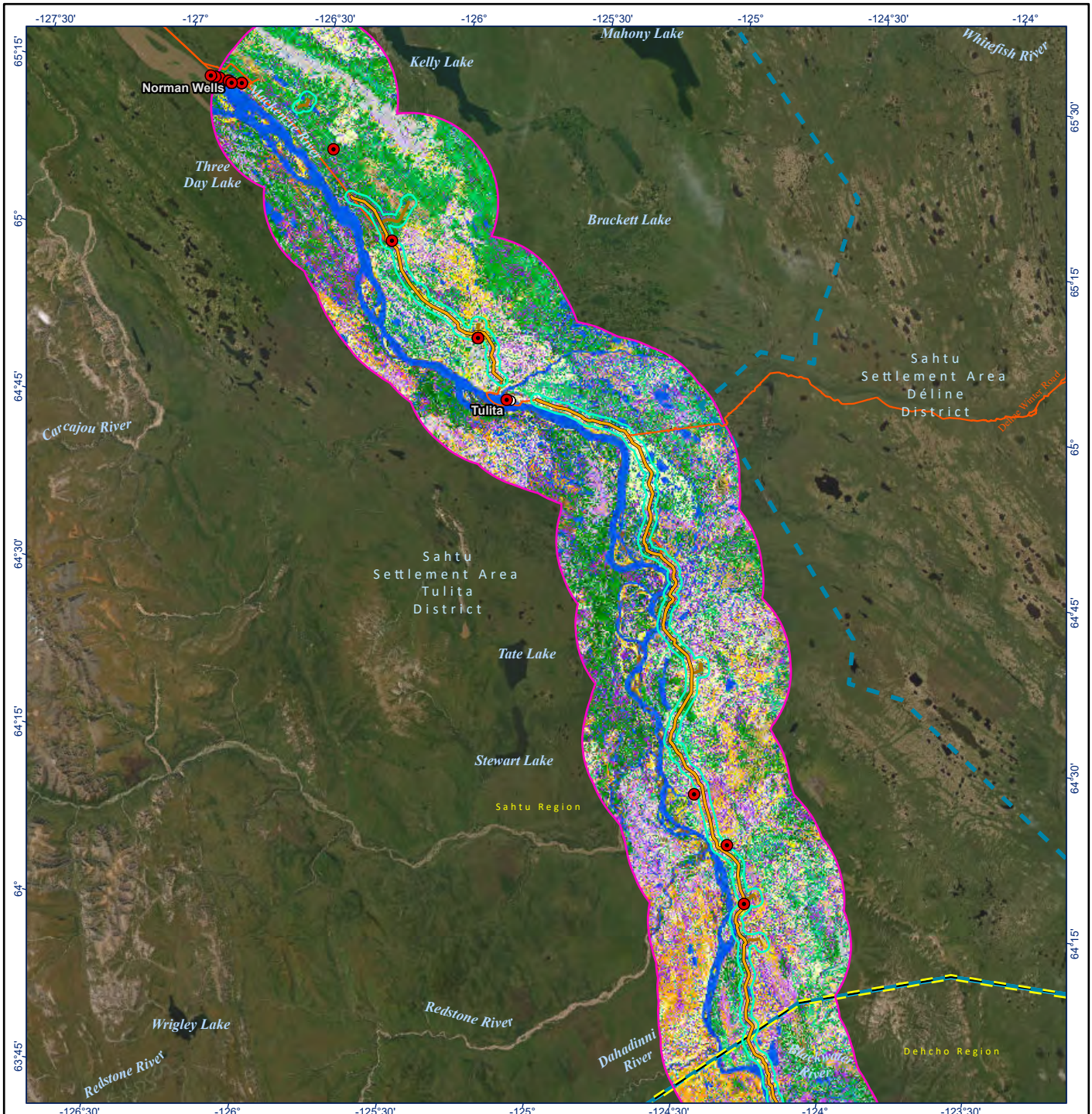
Table 3.10 Landcover/Plant Assemblage Types in the LSA and RSA – Sahtu Region

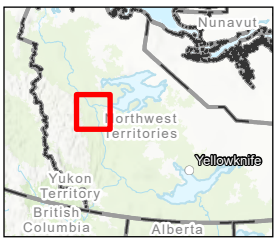
Landcover/Plant Assemblage Type	Cover Type Density	LSA		RSA	
		ha	%	ha	%
Broadleaf Forest	Broadleaf – Dense	2,004.4	4.8	34,264.7	5.3
	Broadleaf – Open	888.1	2.1	14,627.8	2.2
	Broadleaf Subtotal	**2,892.5**	**6.9**	**48,892.5**	**7.5**
Coniferous Forest	Coniferous – Dense	893.2	2.1	18,581.1	2.9
	Coniferous – Open	5,555.5	13.3	113,324.1	17.4
	Coniferous – Sparse	5,350.3	12.8	71,839.7	11.0
	Coniferous Subtotal	**11,798.9**	**28.3**	**203,744.8**	**31.3**
Mixedwood Forest	Mixedwood – Dense	318.9	0.8	7,492.9	1.1
	Mixedwood – Open	1,991.2	4.8	23,821.0	3.7
	Mixedwood – Sparse	5.1	<0.1	11.7	<0.1
	Mixedwood Subtotal	**2,315.2**	**5.6**	**31,325.7**	**4.8**
Shrubland	Shrub – Tall	1,688.7	4.1	16,523.1	2.5
	Shrub – Low	6,935.0	16.6	72,610.1	11.1
	Shrubland Subtotal	**8,623.7**	**20.7**	**89,133.2**	**13.7**
Herbaceous and Un-vegetated	Herb	191.0	0.5	4,093.5	0.6
	Bryoids	5.9	<0.1	137.1	0.0
	Rock/Rubble	62.2	0.1	10,281.4	1.6
	Exposed Land [1]	1,688.2	4.1	9,900.7	1.5
	Herbaceous and Un-vegetated Subtotal	**1,947.3**	**4.7**	**24,412.6**	**3.7**
	Upland Subtotal	**27,577.4**	**66.2**	**397,508.9**	**61.0**
Wetland	Wetland – Treed	4,121.8	9.9	64,770.4	9.9
	Wetland – Shrub	3,819.0	9.2	55,334.7	8.5
	Wetland – Herb	2,666.8	6.4	44,856.6	6.9
	Wetland Subtotal	**10,607.6**	**25.5**	**164,961.7**	**25.3**
Open Water		3,489.1	8.4	89,310.5	13.7
No Landcover Data		0.0	0.0	164.4	0.0
Total		**41,674.1**	**100.0**	**651,945.4**	**100.0**

Note:

[1] Exposed land includes areas which naturally have less than 5% vegetative cover, such as on the shorelines of rivers and lakes, exposed rock, recently burned areas, and moraines; it includes cleared areas, such as roads and areas of infrastructure development.

Source: Natural Resources Canada and GNWT (2017).





Alien and Alien Invasive (weed) Occurrence*

Landcover Type

- Water
- Rock/Rubble
- Exposed Land
- Bryoids
- Shrub - Tall
- Shrub - Low
- Wetland - Treed
- Wetland - Shrub
- Wetland - Herb
- Herb
- Coniferous - Dense
- Coniferous - Open
- Coniferous - Sparse
- Broadleaf - Dense
- Broadleaf - Open
- Mixedwood - Dense
- Mixedwood - Open
- Mixedwood - Sparse
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- Settlement Area Boundary
- Region Boundary
- District Boundary

* More than one alien or alien invasive plant may occur at each mapped location

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,000,000

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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project 144903025-0010-REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.6

Title
Landcover/Plant Assemblage Types within the Mackenzie Valley Highway Project LSA and RSA – Sahtu Region

Notes

1. Coordinate System: NAD 1983 Northwest Territorries Lambert
2. Data Sources: Government of Canada
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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Wetlands occupy 25.5% of the LSA in the Sahtu Region (10,607.6 ha). Treed and shrub wetlands are the most common wetland types in the LSA, occupying 9.9% (4,121.8 ha) and 9.2% (3,819.0 ha) of the LSA in the Sahtu Region, respectively. Wetlands are located throughout the LSA in the Sahtu Region with the highest concentrations occurring near areas of open water (Figure 3.6). Areas of open water (i.e., lakes, rivers, and streams) are also common in the LSA in the Sahtu Region, occupying 8.4% (3,489.1 ha) and primarily associated with the Mackenzie River and Three Day Lake in the northwest portion of the LSA (Figure 3.6). Herb, bryoid dominated areas and rock/rubble areas are uncommon, occupying less than 0.1% or less within the LSA in the Sahtu Region.

Like the LSA, the RSA in the Sahtu Region is dominated by coniferous forest, 31.3% (203,744.8 ha), with abundance decreasing with increased stand density (Table 3.10). In comparison to the LSA, proportions of broadleaf forest within the RSA were greater, 7.5% (48,892.5 ha), while proportions of mixedwood forest were lower, at 4.8% (31,325.7 ha). Remaining upland areas in the RSA in the Sahtu Region are largely composed of low shrub 11.1% (72,610.1 ha), followed by tall shrub 2.5% (16,523.1 ha), with similar proportions of rock/rubble 1.6% (10,281.4 ha) and exposed land 1.5% (9,900.7 ha) (Table 3.10). Areas of rock/rubble are located on steeper slopes (Figure 3.7) and other scattered areas in the LSA and RSA.

Figure 3.7 Unvegetated Rock/Rubble (foreground) in the LSA – Sahtu Region

Wetlands cover 25.3% (164,961.7 ha) of the RSA in the Sahtu Region, predominantly as treed wetlands 9.9% (64,770.4 ha). Shrub wetlands and herb wetlands are also present in the RSA in the Sahtu Region, occupying 8.5% (55,334 ha) and 6.9% (44,856.6 ha), respectively. Wetlands are located throughout the RSA in the Sahtu Region and are often located adjacent to areas of open water (Figure 3.8) and watercourses east of the Mackenzie River (Figure 3.6). Areas of open water are also present in the RSA, occupying 13.7% (89,310.5 ha) of the RSA.

Figure 3.8 Open Water Surrounded by Herb and Shrub Wetland in the LSA – Sahtu Region

Coniferous forest of the LSA in the Sahtu Region has an average stand volume density of 23.7 m^3/ha (SD = 12.4) (Table 3.11). Conifer forest tree heights range from 5 m to 17 m with an average height of 6.9 m (SD = 1.7). Mixedwood forest has a greater average stand volume density (32.2 m^3/ha, SD = 14.5) than deciduous forest (23.0 m^3/ha, SD = 10.6). Although deciduous cover types have a greater maximum height (18 m) than mixedwood cover types (15 m), the average tree height in mixedwood stands is greater than in deciduous stands, at 8.2 m (SD = 1.9) and 6.8 m (SD = 1.5), respectively (Table 3.11). More detailed species information from ground data is needed to provide detailed merchantable timber volume estimates, but from volume metrics, merchantable timber is expected in the Sahtu Region LSA.

Table 3.11 Cover Type and Stand Volume Density per Landcover/Plant Assemblage Type in the LSA – Sahtu Region

Landcover/Plant Assemblage Type	Tree Height (m)				Stand Volume Density (m^3/ha)				Total Volume[2] (m^3)
	Minimum	Maximum	Average	SD[1]	Minimum	Maximum	Average	SD[1]	
Coniferous	5	17	6.9	1.7	10	116	23.7	12.4	288,702
Deciduous	5	18	6.8	1.5	11	126	23.0	10.6	55,036
Mixedwood	5	15	8.2	1.9	14	88	32.2	14.5	47,027

Notes:
1 Standard deviation.
2 Total volume determined by multiplying average stand volume by land cover area (ha) in LSA.
Source: Canadian Forest Service (2020)

Coniferous forest in the RSA in the Sahtu Region has an average stand volume density of 25.7 m^3/ha (SD = 15.3) (Table 3.12). Average tree height in coniferous forest is 7.2 m (SD = 2.0), with heights ranging from 4 m to 21 m. Deciduous forest in the Sahtu Region has a similar range of stand height and similar average height as coniferous forest. The average stand volume density in mixedwood forest is 30.2 m^3/ha, (SD = 16.5). Mixedwood stands range from 5 m to 22 m with an average tree height of 7.8 m (SD = 2.0) (Table 3.12).

Table 3.12 Tree Height, Stand Volume Density and Total Volume per Forest Type in the RSA – Sahtu Region

Cover Type	Tree Height (m)				Stand Volume Density (m^3/ha)				Total Volume[2] (m^3)
	Minimum	Maximum	Average	SD[1]	Minimum	Maximum	Average	SD[1]	
Coniferous	4	21	7.2	2.0	9	166	25.7	15.3	5,590,767
Deciduous	4	19	7.0	2.0	10	149	24.8	15.1	1,040,433
Mixedwood	5	22	7.8	2.0	11	177	30.2	16.5	665,412

Notes:
1 Standard deviation.
2 Total volume is determined by multiplying average stand volume by land cover area (ha) in LSA.
Source: Canadian Forest Service (2020)

Fire History

From 1960 to 2019, 17 fires within the LSA in the Sahtu Region burned 33,041.3 ha (79.3% of the LSA) (Table 3.13). Fires were generally common in the LSA with every decade since 1960 experiencing at least one burn. The number of fires ranged from one (1960-1969, 2010-2019) to a maximum of five (1990-1999). The area burned, by decade, within the LSA in the Sahtu Region ranged from 156.8 ha (0.4% of the LSA) to 25,453.9 ha (61.1% of the LSA). Fires from 1960 to 1989 occurred primarily east of Tulita (Figure 3.9). From 1990 to 2019, fires occurred mostly in the southern and central parts of the LSA.

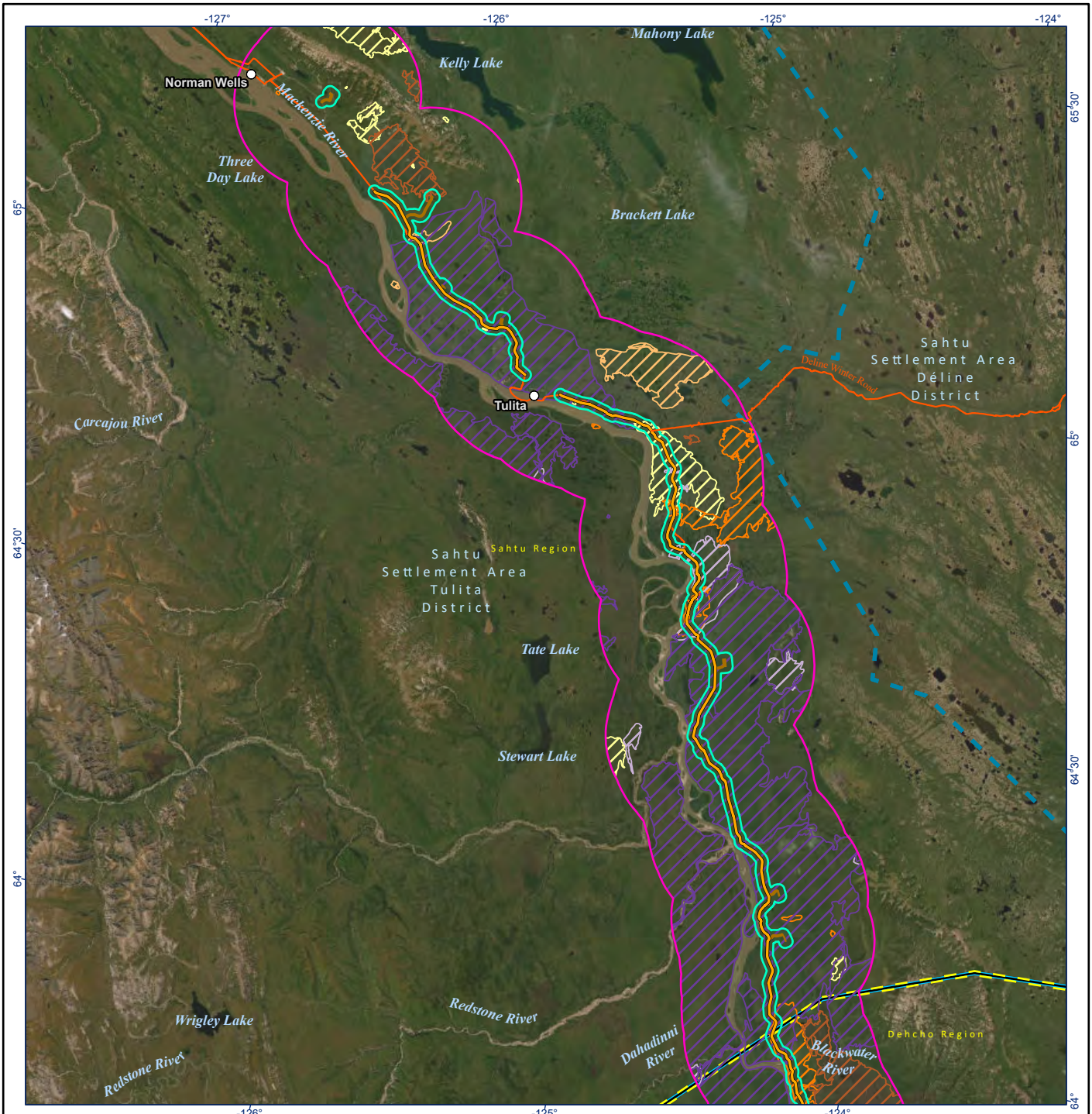
There were 47 fires in the RSA during the same time interval and covered a total of 325,204.0 ha (49.9% of the RSA) (Table 3.13). Like the LSA, the RSA had the highest frequency of burns and largest area burned from 1990 to 1999. During that period, 13 fires occurred in the RSA covering 253,799.8 ha (38.9% of the RSA). Fire size ranged from 8,965.7 ha to 253,799.8 ha.

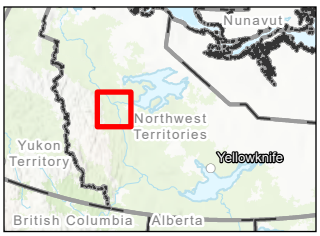
Fires within the LSA of the Sahtu Region affected 22,175.0 ha of upland areas and 8,799.6 ha of wetland areas (Table 3.14). Fires within the RSA of the Sahtu Region burned 203,518.8 ha of upland areas and 99,517.3 ha of wetlands. As with the Dehcho fire metrics, areas burned that were rock/rubble, exposed land and open water, reflecting the coarse scale of available data; in fact, these areas likely did not actually burn.

Table 3.13 Forest Fire Occurrence within the LSA and RSA from 1960 to 2019 – Sahtu Region

	Number of Fires		Total Area Burnt (ha)		Percent Area Burnt (%)	
Time Period	**LSA**	**RSA**	**LSA**	**RSA**	**LSA**	**RSA**
1960-1969	1	4	257.7	11,853.9	0.6	1.8
1970-1979	3	7	1,728.4	15,807.6	4.1	2.4
1980-1989	4	9	2,160.2	13,956.9	5.2	2.1
1990-1999	5	13	25,453.9	253,799.8	61.1	38.9
2000-2009	3	10	3,284.3	20,820.1	7.9	3.2
2010-2019	1	4	156.8	8,965.7	0.4	1.4
TOTAL	17	47	33,041.3	325,204.0	79.3	49.9

Source: Canadian Forest Service (2020)





National Fire Database
- 1960-1969
- 1970-1979
- 1980-1989
- 1990-1999
- 2000-2009
- 2010-2019

Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022

- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

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144903025-0009 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.9

Title
Area Burnt per Decade within the Mackenzie Valley Highway LSA and RSA between 1960 and 2019 - Sahtu Region

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Canadian Forest Service (2020), Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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Table 3.14 Number of Fires and Total Area Burned by Landcover/Assemblage Type from 1960 to 2019 – Sahtu Region

Landcover/ Assemblage Type [1]	Cover Type Class	Total Number of Fires in Each Cover Type [2]		Total Area Burned (ha)	
		LSA	RSA	LSA	RSA
Broadleaf Forest	Broadleaf – Dense	28	101	2,054.13	27,554.3
	Broadleaf – Open	14	89	837.3	8,929.6
Broadleaf Subtotal		**-**	**-**	**2,891.43**	**36,483.9**
Coniferous Forest	Coniferous – Dense	21	68	237.2	2,400.1
	Coniferous – Open	33	120	2,624.0	25,195.7
	Coniferous – Sparse	37	128	4,384.3	40,470.6
Coniferous Subtotal		**-**	**-**	**7,245.5**	**68,066.4**
Mixedwood Forest	Mixedwood – Dense	18	47	127.5	1,286.6
	Mixedwood – Open	31	89	1,518.6	11,078.2
	Mixedwood – Sparse	1	2	5.1	11.7
Mixedwood Subtotal		**-**	**-**	**1,651.2**	**12,376.5**
Shrubland	Shrub – Tall	35	97	1,703.7	12,137.1
	Shrub – Low	38	128	6,981.6	66,370.1
Shrubland Subtotal		**-**	**-**	**8,685.3**	**78,507.2**
Herbaceous and Un-vegetated	Exposed Land [3]	37	72	1,475.8	3,490.0
	Herb	10	44	166.3	3,056.5
	Bryoids	5	18	4.9	46.9
	Rock/Rubble	4	22	54.6	1,491.4
Herbaceous and Un-vegetated Subtotal		**-**	**-**	**1,701.6**	**8,084.8**
Upland Subtotal		**-**	**-**	**22,175.0**	**203,518.8**
Wetland	Wetland – Herb	35	126	1,905.6	20,343.5
	Wetland – Shrub	37	122	3,829.7	48,900.2
	Wetland – Treed	35	123	3,064.3	30,273.6
Wetland Subtotal		**-**	**-**	**8,799.6**	**99,517.3**
Open Water		35	120	2,066.6	22,113.4
No Data		-	32	-	54.7
Total		**-**	**-**	**33,041.3**	**325,204.0**

Notes:

[1] Landcover/assemblage type in 2020. Landcover/assemblage may have been different prior to fire events.

[2] Many fires affected more than one vegetation type; therefore, the total number of fires are given for each vegetation type but cannot be summed among vegetation types.

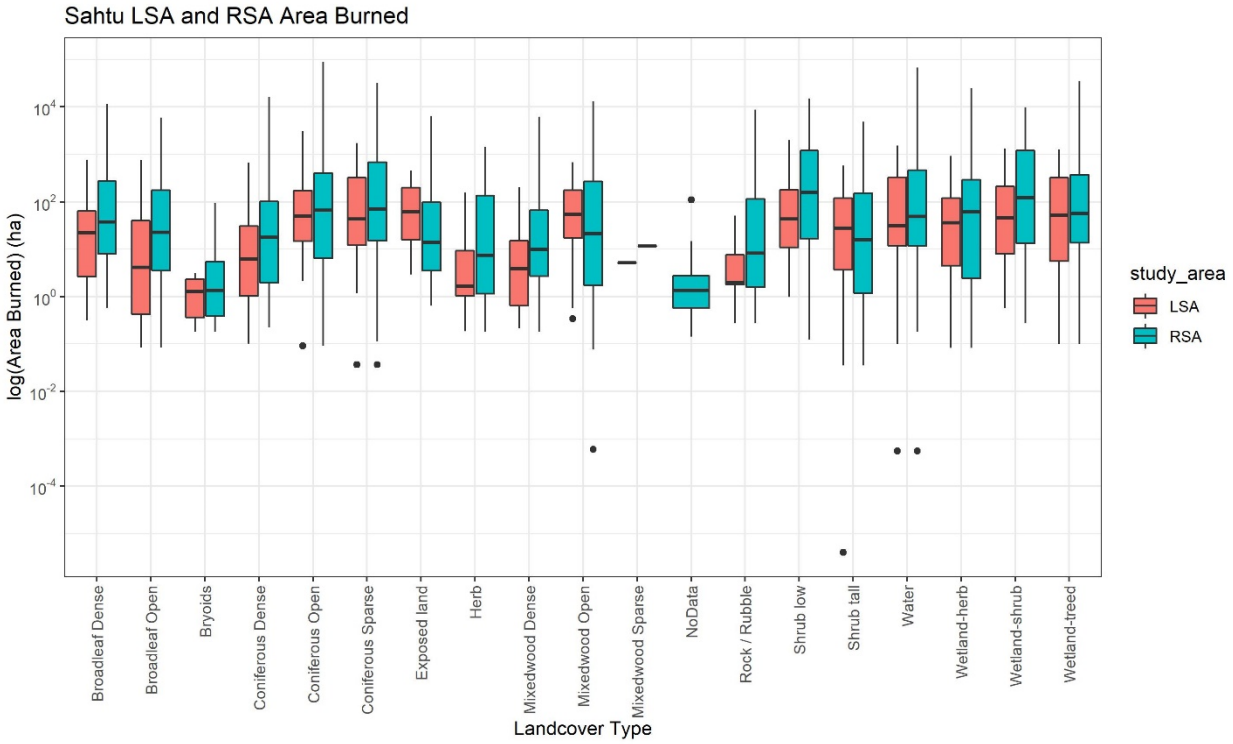
[3] Exposed land includes areas, which naturally have less than 5% vegetative cover, such as shorelines of rivers and lakes, exposed rock, recently burned areas, and moraines; the areas also include cleared areas such as roads and areas of infrastructure development.

Source: Canadian Forest Service (2020)

Figure 3.10 is a box plot showing the median area burned per landcover/assemblage type in the LSA and RSA in the Sahtu Region between 1960 and 2019. The heavy horizontal bar in each box indicates the median value, with inter-quartile ranges indicating upper and lower boundaries on opposite areas in the box. The standard deviation is represented by bars and by outliers as points. This figure shows fire size in the LSA and RSA of the Sahtu Region is highly variable.

Data on changes in plant composition with varying time since burned (i.e., succession) were not found for the LSA or RSA. Available studies indicated burned areas are dominated by plants capable of vegetative reproduction following fire, with a later increase in abundance of plants reproducing by seed and slower growing plants capable of vegetative reproduction. Plants with light abundant seeds and species also colonize burned areas rapidly; abundance decreases after a few years due to short life spans of the plants (Johnson, 1981). Trees required 5 to 6 years, on average, to reach a height of 0.3 m following high severity fires in High Boreal, Low Subarctic, and High Subarctic ecoregions of the Taiga Shield (Lewis et al., 2018). Following low to mixed-severity fires, trees took 10.7 years, on average, in the High Boreal ecoregion and 15.5 years in the Low Subarctic to reach a height of 0.3 m (Lewis et al., 2018). Tree regeneration times may differ for the ecoregions intersected by the RSA.

Figure 3.10 Area Burned by Landcover/Assemblage Type from 1960 to 2019 in the LSA and RSA – Sahtu Region



Plant SOCC

A search of the Northwest Territories Species Monitoring Infobase (Working Group on General Status of NWT Species, 2016)—queried to the Taiga Plains, Taiga Cordillera, and Boreal Cordillera ecoregions—identified 215 vascular, non-vascular plant and lichen SOCC with potential to occur within the Sahtu Region of the RSA (Appendix A.2). Of the 215 plants, 167 are vascular plants, 42 are lichens, and 6 are moss.

Of the 167 vascular plants identified, 85 are listed as *may be at risk* and 82 are listed as *sensitive* in the NT. Yukon aster (*Symphyotrichum yukonense*) and Tyrrell's willow (*Salix tyrrellii*) are on the SARA registry but were downgraded to *not at risk* in 1996 and 1999. Both species are still listed as *may be at risk* under NWT General Species Rankings (Working Group on General Status of NWT Species, 2016). Of the 42 lichen species identified, 6 are listed as *may be at risk* and 36 are listed as *sensitive*. No lichen species with potential to occur within the RSA are listed under COSEWIC. Of the eight moss species identified, four are listed as *may be at risk* and two are listed as *sensitive*, territorially. No moss species with potential to occur within the RSA are listed under COSEWIC (Working Group on General Status of NWT Species, 2016). No vegetation assemblages are considered SOCC.

5658 NWT Ltd. and GNWT (2011) identified seven plant SOCC documented during field surveys for the Mackenzie Gas Project in the Sahtu Region of the RSA. All seven plant SOCC occurrences were vascular plants, of which six were listed as *sensitive* and one as *may be at risk* in the NT (Table 3.15). None of these species are listed by SARA or COSEWIC (Government of Canada, 2019). The locations of these plants are within the Sahtu RSA, and, therefore, their potential presence in the Sahtu LSA is unknown. Pre-construction field surveys should be conducted to evaluate plant SOCC occurrences of higher potential areas potentially impacted by the Project (e.g., riparian areas, uncommon plant assemblages).

Table 3.15 Documented Plant SOCC Occurrences within the RSA – Sahtu Region

Scientific Name[1]	Common Name	NWT General Species Rank[1]	SARA Status[2]	COSEWIC Status[2]
Elymus canadensis	Canada nodding wild rye	Sensitive	-	-
Potamogeton natans	floating pondweed	Sensitive	-	-
Potamogeton foliosus	leafy pondweed	Sensitive	-	-
Juncus stygius	moor rush	Sensitive	-	-
Danthonia spicata	poverty wild oat grass	Sensitive	-	-
Najas flexilis	slender naiad	Sensitive	-	-
Rhynchospora alba	white beakrush	May Be At Risk	-	-

Notes:
1 Working Group on General Status of NWT Species (2016).
2 Government of Canada (2019)
Source: 5658 NWT Ltd. and the GNWT (2011)

Alien and Invasive Alien Plant Species

Forty-two locations of 13 alien and invasive alien plant species occurrences are documented within the RSA in the Sahtu Region (AKEPIC, 2020) (Table 3.16). Of these 13 species, 10 are classified as alien and 3 as invasive alien. In addition to documented occurrences, 36 alien and 7 invasive alien plant species have been identified in the RSA in the Sahtu Region without specific location attribution by Oldham and Delisle-Oldham (2016). These are presented in Appendix B.

Table 3.16 Alien and Invasive Alien Plant Species Recorded within the RSA – Sahtu Region

Listing	Scientific Name	Common Name	Number of Occurrences	Closest Occurrence to the PDA (km)
Alien	*Artemisia biennis*	biennial wormwood	4	0.92
Alien	*Capsella bursa-pastoris*	shepherd's purse	4	0.92
Alien	*Chenopodiastrum simplex (Chenopodium simplex; Chenopodium hybridum* var. *gigantospermum)*	maple-leaved goosefoot	1	0.92
Alien	*Chenopodium album*	lamb's quarters	4	0.92
Alien	*Descurainia sophia*	herb Sophia	6	0.15
Alien	*Lappula squarrosa*	European stickseed	1	14.55
Alien	*Matricaria discoidea*	pineapple weed	2	14.55
Alien	*Plantago major*	common plantain	6	0.15
Alien	*Polygonum aviculare*	prostrate knotweed	1	0.92
Alien	*Thlaspi arvense*	field pennycress	5	0.92
Invasive Alien	*Crepis tectorum*	narrow-leaf hawksbeard	2	0.92
Invasive Alien	*Melilotus albus*	white sweet-clover	3	14.55
Invasive Alien	*Trifolium hybridum*	alsike clover	3	14.55

Source: AKEPIC (2020)

4 Key Results and Findings

4.1 Dehcho Region

Coniferous forest is the most abundant landcover/assemblage type in upland areas within the LSA (44.8%) and the RSA (32.5%) in the Dehcho Region. Wetland cover types occupy 19.6% of the LSA and 29.0% of the RSA in the Dehcho Region. The most common wetland types in both LSA and RSA are treed and shrub wetlands. Large portions of the LSA and RSA have burned in the past; however, fires in the LSA are not common with a maximum of 2 fires per decade recorded (1990-1999). Percentage of the LSA burned ranged from 0% to 12.8% per decade from 1960 to 2019. Although coniferous forests had the greatest total volume in the LSA (448,465 m^3) and RSA (3,927,036 m^3), mixedwood forests had the highest stand volume density.

Except for the existing MVWR and the Enbridge Norman Wells Pipeline the LSA in the Dehcho Region is relatively anthropogenically undisturbed.

No plant SOCC have been documented in the RSA or LSA. Nine alien and three invasive alien plant species have been documented in the RSA in the Dehcho Region. Additional alien and invasive alien plant species documented in the RSA by Oldham and Delisle-Oldham (2016) can be found in Appendix B, although specific distributions of these species are not known.

4.2 Sahtu Region

Upland areas in the Sahtu Region are dominated by coniferous forest in both the LSA (28.3%) and RSA (31.3%). Wetlands occupy 25.5% of the LSA and 25.3% of the RSA. As with the Dehcho Region, large portions of the LSA and RSA in the Sahtu Region have burned in the past. Fires in the LSA and RSA are common, with portions within the Sahtu Region burning at least once per decade. Less than 1% to 61.1% of the LSA burned each decade between 1960 and 2019. Similar to the Dehcho Region, coniferous forests had the greatest total volume in the LSA (288,702 m^3) and RSA (5,590,767 m^3) and mixedwood forests had the highest stand volume density.

Except for the existing MVWR, the Enbridge Norman Wells Pipeline, and communities along these routes (e.g., Hamlet of Tulita), LSA in the Sahtu Region is relatively anthropogenically undisturbed but does contain some disturbance from oil and gas exploration and infrastructure west of Norman Wells (e.g., Auld and Kershaw, 2005).

In the RSA, seven vascular plant SOCC occurrences have been documented, six of which are considered “Sensitive” and one considered “May Be At Risk”. Ten alien and three invasive alien plant species have been documented in the RSA in the Sahtu Region. Additional alien and invasive alien plant species documented in the RSA by Oldham and Delisle-Oldham (2016) can be found in Appendix B, although specific distributions of these species are not known.

5 Closure

This TDR was prepared for the sole benefit of GNWT to describe existing conditions related to vegetation within the Project LSA and RSA. If you have any questions, please do not hesitate to contact the undersigned.

Respectfully submitted,

K'alo-Stantec Limited

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Appendix A Plant SOCC Details

A.1 Potential Plant SOCC Occurrences Within the RSA in the Dehcho Region

Group	Scientific Name[1]	Common Name	NWT General Species Rank [1]	NWT S Rank[1]	SARA Status[1]	COSEWIC Status[1]	Ecoregion[2]
Vascular Plant	*Agrostis exarata*	spike bentgrass	Sensitive	S3	-	-	Boreal Cordillera
Vascular Plant	*Angelica lucida*	seaside angelica	May Be At Risk	S2	-	-	Boreal Cordillera
Vascular Plant	*Arenaria longipedunculata*	long-stemmed sandwort	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Arnica latifolia*	mountain arnica	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Asplenium trichomanes-ramosum*	green spleenwort	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Athyrium filix-femina*	subarctic lady-fern	Sensitive	S2S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Blysmopsis rufa*	red clubrush	Sensitive	S3S4	-	-	Taiga Cordillera
Vascular Plant	*Botrychium minganense*	Mingan moonwort	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Botrychium spathulatum*	spatulate moonwort	May Be At Risk	S2	-	-	Boreal Cordillera
Vascular Plant	*Botrypus virginianus*	rattlesnake fern	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Cardamine pensylvanica*	Pennsylvania bittercress	Sensitive	S3S4	-	-	Taiga Cordillera
Vascular Plant	*Cardamine umbellata*	few-seeded bittercress	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Carex bebbii*	Bebb's sedge	Sensitive	S3	-	-	Boreal Cordillera
Vascular Plant	*Carex eleusinoides*	goosegrass sedge	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Carex filifolia*	thread-leaved sedge	Sensitive	S3	-	-	Boreal Cordillera
Vascular Plant	*Carex heleonastes*	Hudson Bay sedge	Sensitive	S3S4	-	-	Taiga Cordillera
Vascular Plant	*Carex hoodii*	Hood's sedge	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Carex loliacea*	rye-grass sedge	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Carex micropoda*	small-rooted sedge	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Carex peckii*	Peck's sedge	Sensitive	S3	-	-	Boreal Cordillera
Vascular Plant	*Carex retrorsa*	retrorse sedge	May Be At Risk	S2	-	-	Boreal Cordillera
Vascular Plant	*Cerastium maximum*	great chickweed	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Chrysosplenium wrightii*	Wright golden saxifrage	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Claytonia megarhiza*	alpine spring beauty	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Cryptogramma sitchensis*	Alaska parsley-fern	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Cryptogramma stelleri*	slender rock-brake	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Cystopteris montana*	mountain bladder-fern	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Danthonia spicata*	poverty wild oat grass	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Draba albertina*	slender whitlow-grass	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Draba incerta*	Yellowstone whitlow-grass	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Draba lonchocarpa*	lance-pod whitlow-grass	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Draba ogilviensis*	Ogilvie Range whitlow-grass	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Draba porsildii*	Porsild's whitlow-grass	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Drosera linearis*	slenderleaf sundew	Sensitive	S3	-	-	Taiga Cordillera

Group	Scientific Name[1]	Common Name	NWT General Species Rank [1]	NWT S Rank[1]	SARA Status[1]	COSEWIC Status[1]	Ecoregion[2]
Vascular Plant	*Dryopteris carthusiana*	spinulose wood-fern	May Be At Risk	S2	-	-	Boreal Cordillera
Vascular Plant	*Dryopteris expansa*	northern wood-fern	May Be At Risk	S2	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Eleocharis uniglumis*	one-glume spikerush	Sensitive	S3	-	-	Boreal Cordillera
Vascular Plant	*Elymus canadensis*	Canada nodding wild rye	Sensitive	S3	-	-	Boreal Cordillera
Vascular Plant	*Epilobium lactiflorum*	white-flower willowherb	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Erigeron denalii*	Denali fleabane (Mex's fleabane)	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Erythranthe guttata*	common large monkey flower	May Be At Risk	S2	-	-	Boreal Cordillera
Vascular Plant	*Festuca lenensis*	tundra fescue	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Gentiana prostrata*	pygmy gentian	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Geranium richardsonii*	Richardson geranium	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Geum glaciale*	glacier avens	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Hieracium albiflorum*	white-flowered hawkweed	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Koenigia islandica*	Iceland purslane	Sensitive	S3	-	-	Boreal Cordillera
Vascular Plant	*Liparis loeselii*	Loesel's twayblade	May Be At Risk	S2	-	-	Boreal Cordillera
Vascular Plant	*Listera cordata*	heart-leaved twayblade	Sensitive	S2S3	-	-	Boreal Cordillera
Vascular Plant	*Luetkea pectinata*	segmented luetkea	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Lysimachia europaea*	arctic starflower	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Matteuccia struthiopteris*	ostrich fern	Sensitive	S2S3	-	-	Boreal Cordillera
Vascular Plant	*Monarda fistulosa*	wild bergamot	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Nuphar polysepala*	rocky mountain pond lily	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Oxytropis scammaniana*	Scamman's locoweed	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Packera ogoturukensis*	Ogotoruk Creek groundsel	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Packera pauciflora*	alpine groundsel (few-flower ragwort)	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Penstemon gormanii*	Gorman's beardtongue	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Phegopteris connectilis*	northern beech fern	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Platanthera dilatata*	white bog orchid	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Potamogeton foliosus*	leafy pondweed	Sensitive	S3S4	-	-	Boreal Cordillera
Vascular Plant	*Potamogeton natans*	floating pondweed	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Potentilla villosula*	Beringian hairy potentilla	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Prunus virginiana*	choke cherry	Sensitive	S3	-	-	Boreal Cordillera
Vascular Plant	*Pseudocherleria macrocarpa*	long-pod stitchwort	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Ranunculus abortivus*	kidney-leaved buttercup	Sensitive	S3	-	-	Boreal Cordillera
Vascular Plant	*Ranunculus turneri*	Turner's buttercup	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Sagina saginoides*	alpine pearlwort	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Salix farriae*	Farr's willow	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Salix raupii*	Raup's willow	May Be At Risk	S2	-	-	Boreal Cordillera

Group	Scientific Name[1]	Common Name	NWT General Species Rank [1]	NWT S Rank[1]	SARA Status[1]	COSEWIC Status[1]	Ecoregion[2]
Vascular Plant	*Senecio sheldonensis*	Mount Sheldon ragwort	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Smelowskia media*	alpine smelowskia	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Streptopus amplexifolius*	clasping twisted stalk	Sensitive	S2S3	-	-	Taiga Cordillera
Vascular Plant	Symphyotrichum nahanniense	Nahanni aster	Sensitive	S3	Not Applicable	Special Concern	Taiga Cordillera
Vascular Plant	Tephroseris lindstroemii	twice-hairy groundsel	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Vaccinium membranaceum*	mountain huckleberry	May Be At Risk	S2	-	-	Boreal Cordillera
Vascular Plant	*Valeriana dioica*	wood valerian	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Veronica americana*	American speedwell	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Lichen	*Ahtiana sphaerosporella*	mountain candlewax lichen	Sensitive	S1S3	-	-	Taiga Cordillera
Lichen	*Arctomia interfixa*	rust-brown tiny rosette lichen	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Cladonia digitata*	finger pixie-cup	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Cladonia thomsonii*	blue pork pixie lichen	Sensitive	S1S3	-	-	Taiga Cordillera
Lichen	*Collema furfuraceum*	effervescent tarpaper lichen	Sensitive	S2S4	-	-	Taiga Cordillera
Lichen	*Enchylium bachmanianum*	Caesar's tarpaper lichen	Sensitive	S2S4	-	-	Taiga Cordillera
Lichen	*Enchylium polycarpon*	gilled tarpaper lichen	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Nephroma helveticum*	fringed kidney lichen	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Pannaria conoplea*	mealy-rimmed shingle lichen	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Peltigera didactyla*	temporary pelt lichen	Sensitive	S2S4	-	-	Taiga Cordillera
Lichen	*Peltigera neckeri*	black-saddle pelt lichen	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Physcia phaea*	black-eyed rosette lichen	Sensitive	S2S4	-	-	Taiga Cordillera
Lichen	*Placynthium asperellum*	Lilliput Ink lichen	Sensitive	S2S4	-	-	Taiga Cordillera
Lichen	*Polycauliona polycarpa*	pin-cushion sunburst lichen	Sensitive	S2S4	-	-	Taiga Cordillera
Lichen	*Polychidium muscicola*	eyed mossthorns lichen	Sensitive	S2S3	-	-	Taiga Cordillera,
Lichen	*Solorina spongiosa*	blinking owl lichen	Sensitive	S2S4	-	-	Taiga Cordillera
Lichen	*Stereocaulon arenarium*	sandy foam lichen	May Be At Risk	S2?	-	-	Taiga Cordillera
Lichen	*Stereocaulon botryosum*	cauliflower foam lichen	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Stereocaulon vesuvianum*	variegated foam lichen; variegated coral lichen	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Tholurna dissimilis*	arboreal bottle-collection lichen	May Be At Risk	S1S3	-	-	Boreal Cordillera
Lichen	*Umbilicaria arctica*	arctic rocktripe lichen	Sensitive	S2S4	-	-	Taiga Cordillera
Lichen	*Umbilicaria havaasii*	Havaas's rock tripe	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Umbilicaria polyphylla*	petaled rocktripe lichen	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Umbilicaria virginis*	blushing rocktripe lichen	Sensitive	S2S4	-	-	Taiga Cordillera
Bryophyte (Moss)	*Buxbaumia aphylla*	brown shield moss	May Be At Risk	-	-	-	Taiga Cordillera
Bryophyte (Moss)	*Cynodontium jenneri*	Jenner's dogtooth moss	Sensitive	-	-	-	Taiga Cordillera
Bryophyte (Moss)	*Grimmia torquata*	twisted grimmia moss	May Be At Risk	-	-	-	Taiga Cordillera

Group	Scientific Name[1]	Common Name	NWT General Species Rank [1]	NWT S Rank[1]	SARA Status[1]	COSEWIC Status[1]	Ecoregion[2]
Bryophyte (Moss)	*Hilpertia velenovskyi*	Velenovsky's moss	May Be At Risk	-	-	-	Taiga Cordillera
Bryophyte (Moss)	*Hypnum callichroum*	downy plait moss	Sensitive	-	-	-	Taiga Cordillera
Bryophyte (Moss)	*Seligeria oelandica*	Irish bristle moss	May Be At Risk	-	-	-	Taiga Cordillera

Notes:

[1] Species scientific names, common names and species ranks from GNWT (2016a).

[2] Rare Species List For Boreal Cordillera and Taiga Cordillera From GNWT Species Monitoring Infobase (2016c).

A.2 Potential Plant SOCC Occurrences within the RSA in the Sahtu Region

Group	Scientific Name[1]	Common Name	NWT General Species Rank [1]	NWT S Rank[1]	SARA Status[1]	COSEWIC Status[1]	Ecoregion[2]
Vascular Plant	*Agoseris glauca*	pale false dandelion	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Agrostis exarata*	spike bentgrass	Sensitive	S3	-	-	Taiga Plains, Boreal Cordillera
Vascular Plant	*Alisma triviale*	northern water plantain	Sensitive	S3S4	-	-	Taiga Plains
Vascular Plant	*Anaphalis margaritacea*	pearly everlasting	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Angelica lucida*	seaside angelica	May Be At Risk	S2	-	-	Taiga Plains, Boreal Cordillera
Vascular Plant	*Arenaria longipedunculata*	long-stemmed sandwort	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Arethusa bulbosa*	dragon's mouth	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Arnica latifolia*	mountain arnica	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Artemisia alaskana*	Alaska sagebrush	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Artemisia ludoviciana*	white sagebrush	May Be At Risk	S2	-	-	Taiga Plains, Boreal Plains
Vascular Plant	*Asplenium trichomanes-ramosum*	green spleenwort	May Be At Risk	S2	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Astragalus canadensis*	Canadian milk-vetch	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Athyrium filix-femina*	subarctic lady-fern	Sensitive	S2S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Avenula hookeri*	Hooker's alpine oat grass	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Blysmopsis rufa*	red clubrush	Sensitive	S3S4	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Boechera calderi*	Calder's rockcress	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Botrychium minganense*	mingan moonwort	May Be At Risk	S2	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Botrychium pinnatum*	northwestern moonwort	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Botrychium spathulatum*	spatulate moonwort	May Be At Risk	S2	-	-	Boreal Cordillera
Vascular Plant	*Botrypus virginianus*	rattlesnake fern	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains, Boreal Cordillera
Vascular Plant	*Cardamine microphylla*	small-leaved bittercress	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Cardamine pensylvanica*	Pennsylvania bittercress	Sensitive	S3S4	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Cardamine umbellata*	few-seeded bittercress	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Carex bebbii*	Bebb's sedge	Sensitive	S3	-	-	Taiga Plains, Boreal Cordillera
Vascular Plant	*Carex crawfordii*	Crawford's sedge	Sensitive	S3	-	-	Taiga Plains, Boreal Plains
Vascular Plant	*Carex duriuscula (*	needle-leaved sedge	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Carex eleusinoides*	goosegrass sedge	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Carex filifolia*	thread-leaved sedge	Sensitive	S3	-	-	Taiga Plains, Boreal Cordillera
Vascular Plant	*Carex heleonastes*	Hudson Bay sedge	Sensitive	S3S4	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Carex hoodii*	Hood's sedge	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Carex lasiocarpa*	slender sedge	Sensitive	S3	-	-	Taiga Plains, Taiga Shield
Vascular Plant	*Carex laxa*	weak sedge	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Carex livida*	livid sedge	Sensitive	S3S4	-	-	Taiga Plains
Vascular Plant	*Carex loliacea*	rye-grass sedge	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains

Group	Scientific Name[1]	Common Name	NWT General Species Rank [1]	NWT S Rank[1]	SARA Status[1]	COSEWIC Status[1]	Ecoregion[2]
Vascular Plant	*Carex mackenziei*	Mackenzie's sedge	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Carex micropoda*	small-rooted sedge	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Carex peckii*	Peck's sedge	Sensitive	S3	-	-	Boreal Cordillera
Vascular Plant	*Carex prairea*	prairie sedge	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Carex retrorsa*	retrorse sedge	May Be At Risk	S2	-	-	Taiga Plains, Boreal Cordillera
Vascular Plant	*Carex richardsonii*	Richardson's sedge	Sensitive	S3	-	-	Taiga Plains, Taiga Shield
Vascular Plant	*Carex sychnocephala*	many-headed sedge	Sensitive	S3	-	-	Taiga Plains, Boreal Plains
Vascular Plant	*Cerastium maximum*	great chickweed	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Ceratophyllum demersum*	common hornwort	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Chamaerhodos erecta*	rose chamaerhodos	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Chrysosplenium wrightii*	wright golden saxifrage	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Cirsium drummondii*	Drummond thistle	Sensitive	S3	-	-	Taiga Plains, Taiga Shield
Vascular Plant	*Claytonia megarhiza*	alpine spring beauty	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Coleanthus subtilis*	moss grass	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Corispermum hookeri*	Hooker's bugseed	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Cryptogramma sitchensis*	Alaska parsley-fern	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Cryptogramma stelleri*	slender rock-brake	May Be At Risk	S2	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Cystopteris montana*	mountain bladder-fern	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Danthonia spicata*	poverty wild oat grass	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains, Boreal Cordillera
Vascular Plant	*Descurainia pinnata*	pinate tansy mustard	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Draba albertina*	slender whitlow-grass	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Draba incerta*	Yellowstone whitlow-grass	May Be At Risk	S2	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Draba lonchocarpa*	lance-pod whitlow-grass	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Draba ogilviensis*	Ogilvie range whitlow-grass	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Draba porsildii*	Porsild's whitlow-grass	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Drosera linearis*	slenderleaf sundew	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Dryopteris carthusiana*	spinulose wood-fern	May Be At Risk	S2	-	-	Taiga Plains, Boreal Cordillera
Vascular Plant	*Dryopteris expansa*	northern wood-fern	May Be At Risk	S2	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Eleocharis elliptica*	slender spikerush	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Eleocharis uniglumis*	one-glume spikerush	Sensitive	S3	-	-	Taiga Plains, Boreal Cordillera
Vascular Plant	*Elymus canadensis*	Canada nodding wild rye	Sensitive	S3	-	-	Taiga Plains, Boreal Cordillera
Vascular Plant	*Epilobium lactiflorum*	white-flower willowherb	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Erigeron denalii*	Denali fleabane (Mex's fleabane)	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Erigeron yukonensis*	Yukon fleabane	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Eritrichium splendens*	showy forget-me-not	May Be At Risk	S2	-	-	Taiga Plains

Group	Scientific Name[1]	Common Name	NWT General Species Rank [1]	NWT S Rank[1]	SARA Status[1]	COSEWIC Status[1]	Ecoregion[2]
Vascular Plant	*Erythranthe guttata*	common large monkey flower	May Be At Risk	S2	-	-	Taiga Plains, Boreal Cordillera
Vascular Plant	*Festuca auriculata*	lobed fescue	May Be At Risk	S2S3	-	-	Taiga Plains
Vascular Plant	*Festuca brevissima*	Alaska fescue	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Festuca lenensis*	tundra fescue	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Gentiana prostrata*	pygmy gentian	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains, Boreal Cordillera
Vascular Plant	*Gentianopsis virgata*	Macoun's fringed gentian	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Geranium richardsonii*	Richardson geranium	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Geum glaciale*	glacier avens	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Geum triflorum*	prairie-smoke	May Be At Risk	S2	-	-	Taiga Plains, Boreal Plains
Vascular Plant	*Hesperostipa curtiseta*	Canadian needle grass	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Heuchera richardsonii*	Richardson alumroot	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Hieracium albiflorum*	white-flowered hawkweed	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Hippuris tetraphylla*	four-leaved marestail	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Hudsonia tomentosa*	woolly beach-heath (sand heather)	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Isoetes lacustris*	lake quillwort	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Juncus stygius*	moor rush	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Koeleria asiatica*	oriental koeler's grass	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Koeleria macrantha*	prairie koeler's grass	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Koenigia islandica*	Iceland purslane	Sensitive	S3	-	-	Boreal Cordillera
Vascular Plant	*Lathyrus japonicus*	beach pea	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Limosella aquatica*	northern mudwort	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Liparis loeselii*	Loesel's twayblade	May Be At Risk	S2	-	-	Boreal Cordillera
Vascular Plant	*Listera cordata*	heart-leaved twayblade	Sensitive	S2S3	-	-	Taiga Plains, Boreal Cordillera
Vascular Plant	*Luetkea pectinata*	segmented luetkea	May Be At Risk	S2	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Luzula kjellmaniana*	kjellman woodrush	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Luzula rufescens*	rufous wood rush	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Lysimachia europaea*	arctic starflower	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Lysimachia maritima*	sea milkwort	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Malaxis paludosa*	bog adder's-mouth	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Matteuccia struthiopteris*	ostrich fern	Sensitive	S2S3	-	-	Taiga Plains, Boreal Cordillera
Vascular Plant	*Mertensia maritima*	sea bluebell	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Micranthes ferruginea*	rusty-hair saxifrage	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Minuartia michauxii*	bog stitchwort	Sensitive	S3S4	-	-	Taiga Plains
Vascular Plant	*Monarda fistulosa*	wild bergamot	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Myriophyllum alterniflorum*	alternate-flower water milfoil	Sensitive	S3	-	-	Taiga Plains

Group	Scientific Name[1]	Common Name	NWT General Species Rank [1]	NWT S Rank[1]	SARA Status[1]	COSEWIC Status[1]	Ecoregion[2]
Vascular Plant	*Najas flexilis*	slender naiad	Sensitive	S2S3	-	-	Taiga Plains
Vascular Plant	*Nassella viridula*	green tussock grass (feather grass)	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Nuphar polysepala*	Rocky Mountain pond lily	May Be At Risk	S2	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Nymphaea leibergii*	dwarf white waterlily	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Nymphaea tetragona*	pygmy white waterlily (small white water-lily)	Sensitive	S3	-	-	Taiga Plains, Taiga Shield
Vascular Plant	*Oxybasis glauca*	Rocky Mountain goosefoot	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Oxybasis rubra*	red pigweed (coast-blite goosefoot)	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Oxytropis scammaniana*	Scamman's locoweed	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Packera ogoturukensis*	Ogotoruk Creek groundsel	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Packera pauciflora*	alpine groundsel (few-flower ragwort)	Sensitive	S3	-	-	Taiga Cordillera, Boreal Cordillera
Vascular Plant	*Papaver mcconnellii*	McConnell's poppy	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Pedicularis flammea*	red-tip lousewort	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Pedicularis oederi*	Oeder's lousewort	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Pedicularis verticillata*	whorled lousewort	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Pellaea glabella*	smooth cliff-brake	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Penstemon gormanii*	Gorman's beardtongue	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Phegopteris connectilis*	northern beech fern	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Physaria calderi*	Calder's bladderpod	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Plantago maritima*	seaside plantain	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Platanthera dilatata*	white bog orchid	May Be At Risk	S2	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Platanthera orbiculata*	small round-leaved bog orchid	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Poa ammophila*	sand bluegrass	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Poa pseudoabbreviata*	polar bluegrass	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Podistera macounii*	Macoun's podistera	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Potamogeton foliosus*	leafy pondweed	Sensitive	S3S4	-	-	Taiga Plains, Boreal Cordillera
Vascular Plant	*Potamogeton illinoensis*	Illinois pondweed	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Potamogeton natans*	floating pondweed	Sensitive	S3	-	-	Taiga Cordillera
Vascular Plant	*Potamogeton subsibiricus*	Yenisei River pondweed	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Potentilla villosula*	Beringian hairy potentilla	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Primula pumila*	arctic primrose	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Prunus virginiana*	choke cherry	Sensitive	S3	-	-	Taiga Plains, Boreal Cordillera
Vascular Plant	*Pseudocherleria macrocarpa*	long-pod stitchwort	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Ranunculus abortivus*	kidney-leaved buttercup	Sensitive	S3	-	-	Taiga Plains, Boreal Cordillera
Vascular Plant	*Ranunculus grayi*	tundra buttercup	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Ranunculus turneri*	Turner's buttercup	May Be At Risk	S2	-	-	Taiga Cordillera, Taiga Plains

Group	Scientific Name[1]	Common Name	NWT General Species Rank [1]	NWT S Rank[1]	SARA Status[1]	COSEWIC Status[1]	Ecoregion[2]
Vascular Plant	*Rhynchospora alba*	white beakrush	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Rorippa barbareifolia*	hoary yellowcress	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Rorippa crystallina*	Mackenzie River yellowcress (asiatic cress)	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Rumex lapponicus*	Lapland sorrel	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Sagina nodosa*	knotted pearlwort	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Sagina saginoides*	alpine pearlwort	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Salix chamissonis*	Chamisso's willow	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Salix discolor*	pussy willow	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Salix farriae*	Farr's willow	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Salix ovalifolia*	arctic seashore willow	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Salix raupii*	Raup's willow	May Be At Risk	S2	-	-	Taiga Plains, Boreal Cordillera
Vascular Plant	*Salix tyrrellii*	Tyrrell's willow	May Be At Risk	S2	-	Not At Risk	Taiga Plains
Vascular Plant	*Saxifraga bronchialis ssp. Funstonii*	yellowdot saxifrage	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Sceptridium multifidum*	leathery grape-fern	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Schoenoplectus pungens*	three-square bulrush	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Senecio sheldonensis*	Mount Sheldon ragwort	May Be At Risk	S2	-	-	Taiga Cordillera
Vascular Plant	*Smelowskia media*	alpine smelowskia	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains, Boreal Cordillera
Vascular Plant	*Stellaria umbellata*	umbellate stitchwort	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Streptopus amplexifolius*	clasping twisted stalk	Sensitive	S2S3	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Symphyotrichum yukonense*	Yukon aster	May Be At Risk	S2	-	Not At Risk	Taiga Plains
Vascular Plant	*Tanacetum bipinnatum*	floccose tansy	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Tephroseris lindstroemii*	twice-hairy groundsel	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Utricularia ochroleuca*	northern bladderwort	Sensitive	S3	-	-	Taiga Plains
Vascular Plant	*Vaccinium membranaceum*	mountain huckleberry	May Be At Risk	S2	-	-	Boreal Cordillera
Vascular Plant	*Valeriana dioica*	wood valerian	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains
Vascular Plant	*Veronica alaskensis*	Alaska kitten-tail	May Be At Risk	S2	-	-	Taiga Plains
Vascular Plant	*Veronica americana*	American speedwell	Sensitive	S3	-	-	Taiga Cordillera, Taiga Plains, Boreal Cordillera
Vascular Plant	*Zannichellia palustris*	horned pondweed	Sensitive	S3	-	-	Taiga Plains, Boreal Plains
Lichen	*Ahtiana sphaerosporella*	mountain candlewax lichen	Sensitive	S1S3	-	-	Taiga Cordillera
Lichen	*Anaptychia crinalis*	hairy fringe lichen	Sensitive	S2S4	-	-	Taiga Plains
Lichen	*Arctomia interfixa*	rust-brown tiny rosette lichen	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Cetraria kamczatica*	Kamchatka icelandmoss lichen	Sensitive	S2S3	-	-	Taiga Plains
Lichen	*Cladonia digitata*	finger pixie-cup	Sensitive	S2S3	-	-	Taiga Cordillera, Taiga Plains
Lichen	*Cladonia grayi*	Gray's pixie-cup lichen	Sensitive	S2S4	-	-	Taiga Plains
Lichen	*Cladonia scabriuscula*	winged pixie lichen	Sensitive	S1S3	-	-	Taiga Plains

Group	Scientific Name[1]	Common Name	NWT General Species Rank [1]	NWT S Rank[1]	SARA Status[1]	COSEWIC Status[1]	Ecoregion[2]
Lichen	*Cladonia thomsonii*	blue pork pixie lichen	Sensitive	S1S3	-	-	Taiga Cordillera, Taiga Plains
Lichen	*Collema furfuraceum*	effervescent tarpaper lichen	Sensitive	S2S4	-	-	Taiga Cordillera, Taiga Plains
Lichen	*Dermatocarpon intestiniforme*	quilted stippleback lichen	Sensitive	S2S3	-	-	Taiga Plains
Lichen	*Enchylium bachmanianum*	Caesar's tarpaper lichen	Sensitive	S2S4	-	-	Taiga Cordillera
Lichen	*Enchylium polycarpon*	gilled tarpaper lichen	Sensitive	S2S3	-	-	Taiga Cordillera, Taiga Plains
Lichen	*Heterodermia speciosa*	powdered fringe lichen	May Be At Risk	S1S2	-	-	Taiga Plains
Lichen	*Lasallia caroliniana*	origami rocktripe lichen	May Be At Risk	S2S3	-	-	Taiga Plains
Lichen	*Lasallia papulosa*	brown-bellied toadskin lichen	Sensitive	S2S4	-	-	Taiga Plains
Lichen	*Lathagrium undulatum*	jelly flakes lichen	Sensitive	S2S3	-	-	Taiga Plains
Lichen	*Lobaria linita*	cabbage lung lichen	Sensitive	S2S3	-	-	Taiga Plains
Lichen	*Masonhalea inermis*	thornless tumbleweed lichen	Sensitive	S2S4	-	-	Taiga Plains
Lichen	*Nephroma helveticum*	fringed kidney lichen	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Pannaria conoplea*	mealy-rimmed shingle lichen	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Peltigera didactyla*	temporary pelt lichen	Sensitive	S2S4	-	-	Taiga Cordillera, Taiga Plains
Lichen	*Peltigera neckeri*	black-saddle pelt lichen	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Peltigera praetextata*	born-again pelt lichen	Sensitive	S2S4	-	-	Taiga Plains
Lichen	*Physcia phaea*	black-eyed rosette lichen	Sensitive	S2S4	-	-	Taiga Cordillera, Taiga Plains
Lichen	*Pilophorus robustus*	robust matchstick lichen	May Be At Risk	S1	-	-	Taiga Plains
Lichen	*Placynthium asperellum*	Lilliput ink lichen	Sensitive	S2S4	-	-	Taiga Cordillera, Taiga Plains
Lichen	*Polycauliona polycarpa*	pin-cushion sunburst lichen	Sensitive	S2S4	-	-	Taiga Cordillera
Lichen	*Polychidium muscicola*	eyed mossthorns lichen	Sensitive	S2S3	-	-	Taiga Cordillera, Taiga Plains
Lichen	*Scytinium tenuissimum*	birdnest vinyl lichen	Sensitive	S2S4	-	-	Taiga Plains
Lichen	*Solorina spongiosa*	blinking owl lichen	Sensitive	S2S4	-	-	Taiga Cordillera, Taiga Plains
Lichen	*Sphaerophorus fragilis*	cushion coral lichen	Sensitive	S2S4	-	-	Taiga Plains
Lichen	*Stereocaulon arenarium*	sandy foam lichen	May Be At Risk	S2?	-	-	Taiga Cordillera
Lichen	*Stereocaulon botryosum*	cauliflower foam lichen	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Stereocaulon vesuvianum*	variegated foam lichen; variegated coral lichen	Sensitive	S2S3	-	-	Taiga Cordillera
Lichen	*Tholurna dissimilis*	arboreal bottle-collection lichen	May Be At Risk	S1S3	-	-	Boreal Cordillera
Lichen	*Umbilicaria angulata*	starred rocktripe lichen	Sensitive	S2S3	-	-	Taiga Plains
Lichen	*Umbilicaria arctica*	arctic rocktripe lichen	Sensitive	S2S4	-	-	Taiga Cordillera
Lichen	*Umbilicaria decussata*	netted rocktripe lichen	Sensitive	S2S4	-	-	Taiga Plains, Taiga Shield
Lichen	*Umbilicaria havaasii*	Havaas's rock tripe	Sensitive	S2S3	-	-	Taiga Cordillera, Taiga Plains
Lichen	*Umbilicaria polyphylla*	petaled rocktripe lichen	Sensitive	S2S3	-	-	Taiga Cordillera, Taiga Plains
Lichen	*Umbilicaria virginis*	blushing rocktripe lichen	Sensitive	S2S4	-	-	Taiga Cordillera, Taiga Plains
Lichen	*Vestergrenopsis isidiata*	peppered brownette lichen	May Be At Risk	S1S2	-	-	Tundra Cordillera, Taiga Plains

Group	Scientific Name[1]	Common Name	NWT General Species Rank [1]	NWT S Rank[1]	SARA Status[1]	COSEWIC Status[1]	Ecoregion[2]
Bryophyte (Moss)	*Buxbaumia aphylla*	brown shield moss	May Be At Risk	-	-	-	Taiga Plains, Taiga Cordillera
Bryophyte (Moss)	*Cynodontium jenneri*	Jenner's dogtooth moss	Sensitive	-	-	-	Taiga Cordillera
Bryophyte (Moss)	*Grimmia torquata*	twisted grimmia moss	May Be At Risk	-	-	-	Taiga Cordillera
Bryophyte (Moss)	*Hilpertia velenovskyi*	Velenovsky's moss	May Be At Risk	-	-	-	Taiga Cordillera
Bryophyte (Moss)	*Hypnum callichroum*	downy plait moss	Sensitive	-	-	-	Taiga Cordillera, Taiga Plains
Bryophyte (Moss)	*Seligeria oelandica*	Irish bristle moss	May Be At Risk	-	-	-	Taiga Cordillera

Notes:

1 Species scientific names, common names and species ranks from GNWT (2016a).

2 Rare species list for Boreal Cordillera, Taiga Plains and Taiga Cordillera from GNWT Species Monitoring Infobase (2016c).

Appendix B Alien and Invasive Alien Plant Details

B.1 Alien and Invasive Alien Species Occurring and Potentially Occurring within the RSA

Northwest Territories Listing[1]	Scientific Name	Common Name	Occurrence Within RSA[2]	Observed Along Mackenzie Valley Winter Road[3]	Ecoregion with Potential Occurrences[4]
Alien	*Achillea millefolium*	common yarrow	-	-	Taiga Plains, Boreal Cordillera
Alien	*Agropyron cristatum (Agropyron cristatum ssp pectinatum; Agropyron pectiniforme)*	crested wheatgrass	No	No	Taiga Plains
Alien	*Alopecurus arundinaceus*	creeping meadow-foxtail	No	No	Taiga Plains
Alien	*Alopecurus pratensis*	field meadow foxtail	No	Yes	-
Alien	*Ambrosia artemisiifolia*	annual ragweed	No	No	Taiga Plains
Alien	*Artemisia biennis*	biennial wormwood	Yes	Yes	-
Alien	*Atriplex patula*	spreading orache	No	No	Taiga Plains
Alien	*Bellis perennis*	English daisy	No	No	Taiga Plains
Alien	*Brassica rapa*	field mustard	Yes	No	-
Alien	*Capsella bursa-pastoris*	shepherd's purse	Yes	No	-
Alien	*Caragana arborescens*	Siberian pea-tree	No	No	Taiga Plains
Alien	*Carum carvi*	wild caraway	No	No	Taiga Plains
Alien	*Cerastium fontanum (Cerastium glomeratum, Cerastium vulgatum)*	common chickweed	No	No	Taiga Plains
Alien	*Cerastium nutans*	nodding chickweed	No	No	Taiga Plains
Alien	*Chenopodiastrum simplex (Chenopodium simplex; Chenopodium hybridum var gigantospermum)*	maple-leaved goosefoot	Yes	No	Taiga Plains
Alien	*Chenopodium album*	lamb's quarters	Yes	Yes	Taiga Plains
Alien	*Cirsium arvense*	creeping thistle	No	Yes	-

Northwest Territories Listing[1]	Scientific Name	Common Name	Occurrence Within RSA[2]	Observed Along Mackenzie Valley Winter Road[3]	Ecoregion with Potential Occurrences[4]
Alien	*Clematis tangutica*	golden clematis	No	Yes	-
Alien	*Collomia linearis*	narrow-leaved collomia	No	No	Taiga Plains
Alien	*Corispermum villosum*	hairy bugseed	No	No	Taiga Plains
Alien	*Descurainia sophia*	herb Sophia	Yes	Yes	-
Alien	*Dracocephalum thymiflorum*	thyme-leaf dragonhead	No	No	Taiga Plains
Alien	*Elymus repens*	creeping wild rye	No	Yes	-
Alien	*Elymus sibiricus*	Siberian wild rye	No	No	Taiga Plains, Boreal Cordillera
Alien	*Erucastrum gallicum*	common dog mustard	Yes	Yes	-
Alien	*Erysimum cheiranthoides*	worm-seed wallflower	No	No	Taiga Cordillera, Taiga Plains, Boreal Cordillera
Alien	*Festuca trachyphylla*	hard fescue	No	Yes	-
Alien	*Gaillardia aristata*	great blanket-flower	No	No	Taiga Plains
Alien	*Helianthus annuus*	common sunflower	No	No	Taiga Plains
Alien	*Hordeum vulgare*	barley	No	No	Taiga Plains
Alien	*Lactuca serriola*	prickly lettuce	No	No	Taiga Plains
Alien	*Lappula squarrosa*	European stickseed	Yes	Yes	-
Alien	*Lepidium densiflorum*	dense-flowered pepperwort	No	Yes	-
Alien	*Lepidium virginicum*	wild peppergrass	Yes	No	-
Alien	*Leymus cinereus*	great basin lymegrass	No	Yes	-
Alien	*Lolium multiflorum*	annual rye grass	No	No	Taiga Plains
Alien	*Lolium perenne*	perennial rye grass	No	No	Taiga Plains
Alien	*Lonicera tatarica*	Tatarian honeysuckle	No	No	Taiga Plains
Alien	*Lotus corniculatus*	Bird's-foot trefoil	No	No	Taiga Plains
Alien	*Matricaria discoidea*	pineappleweed	Yes	Yes	-

Northwest Territories Listing[1]	Scientific Name	Common Name	Occurrence Within RSA[2]	Observed Along Mackenzie Valley Winter Road[3]	Ecoregion with Potential Occurrences[4]
Alien	*Onobrychis viciifolia*	sainfoin	No	No	Taiga Plains
Alien	*Persicaria lapathifolia (Polygonum lapathifolium, Polygonum scabrum)*	pale smartweed	No	No	Taiga Plains,
Alien	*Phalaris canariensis*	common canary grass	No	No	Taiga Plains
Alien	*Phleum pratense*	common timothy	Yes	Yes	Taiga Cordillera, Taiga Plains
Alien	*Plantago major*	common plantain	Yes	Yes	Taiga Plains
Alien	*Poa compressa*	flat-stem bluegrass	No	No	Taiga Plains
Alien	*Polygonum aviculare*	prostrate knotweed	Yes	Yes	-
Alien	*Puccinellia distans*	spreading alkali grass	No	Yes	-
Alien	*Rheum rhabarbarum*	rhubarb	No	Yes	-
Alien	*Setaria verticillata*	rough bristlegrass	No	No	Taiga Plains
Alien	*Setaria viridis (Seteria viridus)*	green bristle grass	No	No	Taiga Plains
Alien	*Silene csereii*	Balkan catchfly	No	No	Taiga Plains
Alien	*Sonchus oleraceus*	common sow-thistle	No	No	Taiga Plains
Alien	*Taraxacum erythrospermum*	rock dandelion	Yes	No	-
Alien	*Taraxacum officinale*	common dandelion	Yes	Yes	Taiga Cordillera, Taiga Plains, Boreal Cordillera
Alien	*Thinopyrum intermedium*	intermediate quackgrass	No	Yes	Taiga Plains
Alien	*Thlaspi arvense*	field pennycress	Yes	No	-
Alien	*Trifolium repens*	white clover	No	Yes	-
Alien	*Vicia cracca*	tufted vetch	No	Yes	-
Invasive Alien	*Bromus inermis*	awnless brome	No	Yes	-
Invasive Alien	*Crepis tectorum*	narrow-leaf hawksbeard	Yes	Yes	-
Invasive Alien	*Leucanthemum vulgare*	ox-eye daisy	No	Yes	-

Northwest Territories Listing[1]	Scientific Name	Common Name	Occurrence Within RSA[2]	Observed Along Mackenzie Valley Winter Road[3]	Ecoregion with Potential Occurrences[4]
Invasive Alien	*Medicago falcata*	yellow alfalfa	No	Yes	-
Invasive Alien	*Medicago sativa*	alfalfa	No	Yes	-
Invasive Alien	*Melilotus albus*	white sweet-clover	Yes	Yes	-
Invasive Alien	*Melilotus officinalis*	yellow sweet-clover	No	Yes	-
Invasive Alien	*Phalaris arundinacea L. (cultivar)*	reed canarygrass	Yes	No	-
Invasive Alien	*Sonchus arvensis*	perennial sow thistle	No	Yes	-
Invasive Alien	*Tanacetum vulgare*	common tansy	No	Yes	-
Invasive Alien	*Trifolium hybridum*	alsike clover	Yes	Yes	-
Invasive Alien	*Trifolium pratense*	red clover	No	Yes	-
Invasive Alien	*Tripleurospermum inodorum*	scentless chamomile	No	Yes	-

Notes:

1 Invasive alien plant rankings as described in Carriere (2008) as ‘invasive alien’ or occurring as ‘priority invasive plant species’ in Oldham and Delisle-Oldham (2016), others listed as alien as per GNWT (2016a).

2 AKEPIC (2020).

3 Oldham and Delisle-Oldham (2016).

4 Alien and Invasive Alien species list for Taiga Plains, Taiga Cordillera and Boreal Cordillera from Northwest Territories Species Monitoring Infobase (GNWT 2016a).

- indicates occurrence not documented in the Northwest Territories Species Monitoring Infobase for the Taiga Plains, Taiga Cordillera or Boreal Cordillera.

Source: GNWT (2016a).

APPENDIX 18B

Plants of Interest to Indigenous Governments, Indigenous Organizations and Other Affected Parties – Dehcho and Sahtu Regions

Appendix 18B PLANTS OF INTEREST TO INDIGENOUS GOVERNMENTS, INDIGENOUS ORGANIZATIONS AND OTHER AFFECTED PARTIES – DEHCHO AND SAHTU REGIONS

Table 18B.1 Plants of Interest to Indigenous Governments, Indigenous Organizations and Other Affected Parties – Dehcho and Sahtu Regions

Form	Traditionally Used Name	Scientific Name	Provincial Rank	Upland or Wetland Plant	Wetland Status	Upland Landcover Types	Wetland Landcover Types	Region	Identified By
Tree	rocky mountain subalpine fir	*Abies bifolia*	Secure	upland	FACU	Coniferous Forest	None identified	Dehcho	
Tree	alpine fir	*Abies lasiocarpa**	-	upland	UPL	Coniferous Forest	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kı̨ First Nation
Tree	Alaska paper birch, resin birch	*Betula neoalaskana*	Secure	upland	FACU	Coniferous Forest, Deciduous Forest, Mixedwood Forest	Bog - Forested, Fen - Forested, Fen - Shrubby, Fen - Graminoid	Dehcho, Sahtu	
Tree	white birch, paper birch	*Betula papyrifera*	Secure	upland	FACU	Coniferous Forest, Deciduous Forest, Mixedwood Forest	Swamp - Forested	Dehcho, Sahtu	Dehcho First Nations; Pehdzéh Kı̨ First Nation
Tree	tamarack	*Larix laricina*	Secure	wetland	FACW	None identified	Swamp - Forested, Bog - Forested, Fen - Forested, Fen - Shrubby, Fen - Graminoid	Dehcho	Dehcho First Nations; Pehdzéh Kı̨ First Nation
Tree	spruce	*Picea glauca*	Secure	upland	FACU	Coniferous Forest, Deciduous Forest, Mixedwood Forest	None identified	Dehcho, Sahtu	NWRRC; Dehcho First Nations; Pehdzéh Kı̨ First Nation
Tree	spruce	*Picea mariana*	Secure	wetland	FACW	Coniferous Forest, Deciduous Forest, Mixedwood Forest	Swamp - Forested, Bog - Forested, Bog - Shrubby, Bog - Graminoid, Fen - Forested, Fen - Shrubby	Dehcho, Sahtu	Dehcho First Nations; Pehdzéh Kı̨ First Nation
Tree	jackpine	*Pinus banksiana*	Secure	upland	FACU	Coniferous Forest, Mixedwood Forest	Bog - Graminoid	Dehcho	Dehcho First Nations; Pehdzéh Kı̨ First Nation
Tree	lodgepole pine	*Pinus contorta*	Secure	upland	FAC	Coniferous Forest, Mixedwood Forest	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kı̨ First Nation
Tree	balsam poplar	*Populus balsamifera*	Secure	upland	FACW	Deciduous Forest, Mixedwood Forest	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kı̨ First Nation
Tree	trembling aspen	*Populus tremuloides*	Secure	upland	FACU	Deciduous Forest, Mixedwood Forest	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kı̨ First Nation
Shrub	green alder	*Alnus alnobetula*	Secure	-	-	None identified	None identified	Dehcho	
Shrub	speckled alder (mountain alder, gray alder, hoary alder)	*Alnus incana*	Secure	upland	FAC	None identified	None identified	Dehcho	
Shrub	mountain alder	*Alnus rugosa**	-	-	-	Coniferous Forest, Deciduous Forest, Mixedwood Forest	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kı̨ First Nation

Form	Traditionally Used Name	Scientific Name	Provincial Rank	Upland or Wetland Plant	Wetland Status	Upland Landcover Types	Wetland Landcover Types	Region	Identified By
Shrub	speckled alder, river alder	*Alnus tenuifolia**	-	-	-	Coniferous Forest, Deciduous Forest, Mixedwood Forest	None identified	Dehcho	
Shrub	saskatoon berry, saskatoon	*Amelanchier alnifolia*	Secure	upland	FACU	Coniferous Forest, Deciduous Forest, Native Grassland, Mixedwood Forest	None identified	Dehcho	
Shrub	dwarf bog rosemary	*Andromeda polifolia*	Secure	wetland	FACW	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	alpine bearberry, torpedoberry	*Arctostaphylos alpina**	Secure	-	-	Coniferous Forest	Bog - Forested, Bog - Shrubby, Bog - Graminoid	Dehcho	NWRRC; TRRC; Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	red bearberry	*Arctostaphylos rubra**	Secure	upland	FAC	None identified	Swamp - Forested	Dehcho	
Shrub	alpine bearberry, torpedoberry	*Arctous alpina*	Secure	upland	FACU	Coniferous Forest	Bog - Forested, Bog - Shrubby, Bog - Graminoid	Sahtu	
Shrub	red bearberry	*Arctous rubra*	Secure	upland	FAC	None identified	Swamp - Forested	Sahtu	
Shrub	bog birch	*Betula glandulosa*	Secure	upland	FAC	None identified	Bog - Forested, Bog - Shrubby, Bog - Graminoid	Dehcho, Sahtu	TRRC; Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	water birch	*Betula occidentalis*	Secure	upland	FAC	Coniferous Forest, Deciduous Forest, Mixedwood Forest	Shrubland	Dehcho, Sahtu	Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	dwarf birch	*Betula pumila* var. *glandulifera*	Secure	-	-	None identified	Swamp - Forested, Bog - Forested, Bog - Shrubby, Fen - Forested, Fen - Shrubby	Dehcho, Sahtu	TRRC; Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	leatherleaf	*Chamaedaphne calyculata*	Secure	wetland	FACW	Coniferous Forest	Bog - Forested, Bog - Shrubby, Bog - Graminoid, Fen - Forested, Fen - Shrubby	Dehcho	
Shrub	bunchberry	*Cornus canadensis*	Secure	upland	FACU	Coniferous Forest, Deciduous Forest, Mixedwood Forest	None identified	Dehcho	
Shrub	red osier dogwood	*Cornus sericea*	Secure	upland	-	Deciduous Forest	None identified	Dehcho	
Shrub	silverberry	*Elaeagnus commutata*	Secure	-	-	None identified	None identified	Dehcho	
Shrub	crowberry, black berry	*Empetrum nigrum*	Secure	upland	FAC	Coniferous Forest	Bog - Forested, Bog - Shrubby, Bog - Graminoid	Dehcho, Sahtu	Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	creeping wintergreen, teaberry	*Gaultheria hispidula**	-	wetland	FACW	Coniferous Forest	Swamp - Forested, Bog - Forested, Bog - Shrubby, Bog - Graminoid, Fen - Forested, Fen - Shrubby	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation

Form	Traditionally Used Name	Scientific Name	Provincial Rank	Upland or Wetland Plant	Wetland Status	Upland Landcover Types	Wetland Landcover Types	Region	Identified By
Shrub	sand heather	*Hudsonia tomentosa*	Sensitive	-	-	Mixedwood Forest	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	common juniper	*Juniperus communis*	Secure	upland	UPL	None identified	None identified	Dehcho	NWRRC; Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	creeping juniper	*Juniperus horizontalis*	Secure	upland	UPL	Native Grassland	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	northern bog laurel, pale bog laurel	*Kalmia polifolia*	Secure	wetland	OBL	None identified	Swamp - Forested, Bog - Forested, Bog - Shrubby, Bog - Graminoid	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	twinning/ red honeysuckle	*Lonicera dioica*	Secure	upland	FACU	None identified	None identified	Dehcho	
Shrub	bracted honeysuckle, black twin berry	*Lonicera involucrata**	-	upland	FACU	None identified	None identified	Dehcho	
Shrub	sweet gale	*Myrica gale*	Secure	wetland	OBL	None identified	Bog - Forested, Bog - Shrubby, Bog - Graminoid, Fen - Forested, Fen - Shrubby	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	shrubby cinquefoil	*Potentilla fruticosa**	Secure	upland	FAC	Coniferous Forest, Deciduous Forest	Fen - Forested, Fen - Shrubby	Dehcho	
Shrub	pin cherry	*Prunus pensylvanica*	Secure	upland	FACU	Mixedwood Forest	None identified	Dehcho	
Shrub	choke cherry	*Prunus virginiana*	Sensitive	upland	FACU	Deciduous Forest, Native Grassland, Mixedwood Forest	None identified	Dehcho	
Shrub	Labrador tea, muskeg tea	*Rhododendron groenlandicum* (synonym *Ledum groenlandicum*)	Secure	upland	FACW	Coniferous Forest, Mixedwood Forest	Bog - Forested, Bog - Shrubby, Bog - Graminoid, Fen - Forested, Fen - Shrubby	Dehcho	NWRRC; Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	wild black currant	*Ribes americanum*	-	wetland	FACW	Forests, Shrubland	None identified	Dehcho	
Shrub	skunk currant, wild red currant	*Ribes glandulosum*	Secure	upland	FAC	Coniferous Forest	None identified	Dehcho, Sahtu	
Shrub	northern black current	*Ribes hudsonianum*	Secure	upland	FAC	Coniferous Forest, Deciduous Forest, Mixedwood Forest	Swamp - Forested, Bog - Forested, Bog - Shrubby	Dehcho, Sahtu	Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	bristly black currant	*Ribes lacustre*	Secure	upland	FAC	Coniferous Forest, Deciduous Forest, Mixedwood Forest	Swamp - Forested	Dehcho, Sahtu	
Shrub	blackcurrant	*Ribes nigrum*	Alien	upland	FAC	Anthropogenic habitats	Wet meadows, disturbed streamsides,	Sahtu	NWRRC
Shrub	Canadian gooseberry	*Ribes oxyacanthoides*	Secure	upland	FACU	Coniferous Forest, Deciduous Forest, Mixedwood Forest	None identified	Dehcho	

Form	Traditionally Used Name	Scientific Name	Provincial Rank	Upland or Wetland Plant	Wetland Status	Upland Landcover Types	Wetland Landcover Types	Region	Identified By
Shrub	red currant	*Ribes triste*	Secure	upland	FAC	Deciduous Forest, Mixedwood Forest	None identified	Dehcho, Sahtu	Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	red willow (Alder)	*Salix laevigata*	Undetermined	wetland	FACW	Riparian forests along streams	Seepage areas, springs, subalkaline or brackish lakeshores	Sahtu	NWRRC
Shrub	multiple willow species, including diamond willow and red willow	*Salix* spp.	N/A multiple species	-	-	None identified	None identified	Dehcho, Sahtu	Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	buffaloberry, soopolallie, soapberry	*Shepherdia canadensis*	Secure	upland	FACU	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	western mountain ash	*Sorbus scopulina*	Secure	upland	FACU	Coniferous Forest, Deciduous Forest, Mixedwood Forest	None identified	Dehcho	
Shrub	snowberry	*Symphoricarpos albus*	Undetermined	upland	UPL	Coniferous Forest, Deciduous Forest, Mixedwood Forest	None identified	Dehcho	
Shrub	western snowberry	*Symphoricarpos occidentalis*	Secure	-	-	None identified	None identified	Dehcho	
Shrub	small bog cranberry	*Vaccinium oxycoccos*	Secure	-	-	None identified	Bog - Forested, Bog - Shrubby, Bog - Graminoid, Fen - Forested, Fen - Shrubby	Dehcho, Sahtu	
Shrub	Common Blueberry	*Vaccinium* spp.	N/A multiple species	-	-	None identified	None identified	Dehcho, Sahtu	NWRRC; TRRC; Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	low bush cranberry, mooseberry	*Viburnum edule*	Secure	upland	FACU	None identified	None identified	Dehcho, Sahtu	NWRRC; TRRC; Dehcho First Nations; Pehdzéh Kį First Nation
Shrub	highbush cranberry	*Viburnum opulus*	-	upland	FAC	Deciduous Forest	None identified	Dehcho	
Subshrub	common bearberry, bearberry	*Arctostaphylos uva-ursi*	Secure	upland	UPL	Coniferous Forest, Deciduous Forest, Mixedwood Forest	None identified	Dehcho, Sahtu	
Subshrub	sage	*Artemisia frigida*	Secure	upland	-	Native Grassland	None identified	Dehcho	
Subshrub	wintergreen	*Pyrola asarifolia*	Secure	upland	FACU	Deciduous Forest, Mixedwood Forest	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Subshrub	wild rose	*Rosa acicularis*	Secure	upland	FACU	Coniferous Forest, Deciduous Forest, Mixedwood Forest, Native Grassland	None identified	Dehcho, Sahtu	NWRRC; Dehcho First Nations; Pehdzéh Kį First Nation
Subshrub	raspberry	*Rubus idaeus*	Secure	upland	FACU	Deciduous Forest, Mixedwood Forest	None identified	Dehcho, Sahtu	NWRRC: Dehcho First Nations; Pehdzéh Kį First Nation

Form	Traditionally Used Name	Scientific Name	Provincial Rank	Upland or Wetland Plant	Wetland Status	Upland Landcover Types	Wetland Landcover Types	Region	Identified By
Subshrub	dwarf blueberry	*Vaccinium caespitosum*	Undetermined	upland	FAC	Coniferous Forest	None identified	Dehcho, Sahtu	
Subshrub	dwarf blueberry	*Vaccinium myrtilloides*	Sensitive+	wetland	FACW	Coniferous Forest, Mixedwood Forest, Native Grassland	None identified	Dehcho	
Subshrub	lingonberry, lowbush cranberry, "redberry", Logan berry	*Vaccinium vitis-idaea*	Secure	upland	FAC	Coniferous Forest, Mixedwood Forest	None identified	Dehcho, Sahtu	NWRRC; TRRC; Dehcho First Nations; Pehdzéh Kį First Nation
Forb	yarrow	*Achillea millefolium*	Secure	upland	FACU	Mixedwood Forest, Deciduous Forest, Shrubland, Native Grassland	None identified	Dehcho	NWRRC; Dehcho First Nations; Pehdzéh Kį First Nation
Forb	weke, weekay, wee-case (wihkes), wiike	*Acorus americanus* (*Acorus calamus*)	May Be At Risk+	wetland	OBL	None identified	Marsh, Swamp – Forested, Swamp – Shrubby	Dehcho	NWRRC; Dehcho First Nations; Pehdzéh Kį First Nation
Forb	baneberry	*Actaea rubra*	Secure	upland	FACU	Mixedwood Forest, Deciduous Forest	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	Lily Pad Root	*Aeonium* sp.	Alien	wetland	OBL	None identified	None identified	Sahtu	NWRRC
Forb	giant hyssop	*Agastache foeniculum*	May Be At Risk+	upland	-	Deciduous Forest, Shrubland	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	wild chives	*Allium schoenoprasum*	Secure	upland	FAC	Native Grassland	None identified	Dehcho	
Forb	wild onion and chives	*Allium textile**	-	-	-	Native Grassland	None identified	Dehcho	
Forb	pygmyflower, fairy candelabra	*Androsace septentrionalis*	Secure	upland	UPL	Mixedwood Forest, Deciduous Forest, Shrubland, Native Grassland	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	seaside angelica	*Angelica lucida*	May Be At Risk	upland	FACU	None identified	None identified	Dehcho	
Forb	dogbane	*Apocynum androsaemifolium*	Secure	upland	UPL	Coniferous Forest	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	wild sarsaparilla	*Aralia nudicaulis*	Secure	upland	FACU	Coniferous Forest, Deciduous Forest, Mixedwood Forest	None identified	Dehcho	
Forb	field sagewort	*Artemisia campestris*	Secure	upland	FACU	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	Lindley's aster, fringed aster	*Aster ciliolatus**	Secure	-	-	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	smooth aster	*Aster laevis**	Presence Expected	upland	FACU	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	purple-stemmed aster	*Aster puniceus**	Undetermined	wetland	-	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation

Form	Traditionally Used Name	Scientific Name	Provincial Rank	Upland or Wetland Plant	Wetland Status	Upland Landcover Types	Wetland Landcover Types	Region	Identified By
Forb	flat-topped white aster	*Aster umbellatus**	-	-	-	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	American milk-vetch	*Astragalus americanus*	Secure	upland	FAC	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	northern ground-cone	*Boschniakia rossica*	Secure	upland	FAC	Coniferous Forest, Deciduous Forest, Mixedwood Forest	Bog - Forested, Bog - Shrubby, Bog - Graminoid, Fen - Forested, Fen - Shrubby	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	water calla	*Calla palustris*	Secure	wetland	OBL	None identified	Marsh, Swamp - Forested, Bog - Forested, Bog - Shrubby, Bog - Graminoid, Fen - Forested, Fen - Shrubby,	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	bluebell, Alaska bellflower	*Campanula alaskana*	Undetermined	upland	UPL	Coniferous Forest, Deciduous Forest, Mixedwood Forest	None identified	Dehcho	
Forb	bluebell, Giesecke bellflower	*Campanula gieseckeana*	Undetermined	-	-	None identified	None identified	Dehcho	
Forb	harebell, bluebell	*Campanula rotundifolia*	-	upland	FAC	Coniferous Forest, Deciduous Forest, Mixedwood Forest, Native Grassland	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	lamb's quarters	*Chenopodium album*	Alien	upland	FACU	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	strawberry blite	*Chenopodium capitatum*	Secure	-	-	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	pipsissewa	*Chimaphila umbellata*	May Be At Risk+	-	-	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	water hemlock, spotted water-hemlock	*Cicuta maculata*	Secure	wetland	OBL	None identified	None identified	Dehcho	
Forb	tuberous spring beauty	*Claytonia tuberosa*	Secure	wetland	FACW	None identified	None identified	Dehcho	
Forb	spiney wood fern	*Dryopteris carthusiana*	May Be At Risk	wetland	FACW	Coniferous Forest, Deciduous Forest, Mixedwood Forest	Swamp - Forested	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	fireweed	*Epilobium angustifolium*	Secure	upland	FACU	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	horsetail	*Equisetum arvense*	Secure	upland	FAC	None identified	Marsh	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	strawberry	*Fragaria vesca*	Secure	wetland	UPL	Forest, Shrubland	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	wild strawberry	*Fragaria virginiana*	Secure	upland	FACU	Deciduous Forest, Mixedwood Forest	None identified	Dehcho	
Forb	hemp nettle	*Galeopsis tetrahit*	Alien	upland	FACU	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation

Form	Traditionally Used Name	Scientific Name	Provincial Rank	Upland or Wetland Plant	Wetland Status	Upland Landcover Types	Wetland Landcover Types	Region	Identified By
Forb	northern bedstraw	*Galium boreale*	Secure	upland	FACU	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	northern comandra	*Geocaulon lividum*	Secure	upland	FACU	Coniferous Forest	Bog - Forested, Bog - Shrubby	Dehcho	
Forb	yellow avens	*Geum aleppicum*	Secure	upland	FACU	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	purple avens	*Geum rivale**	-	wetland	FACW	Coniferous Forest, Deciduous Forest, Mixedwood Forest	Marsh Fen - Shrubby, Bog - Forested, Bog - Shrubby, Bog - Graminoid, Fen - Forested	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	gumweed	*Grindelia squarrosa**	-	upland	FACU	Disturbed Areas	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	American alpine sweet-vetch, sweetbroom	*Hedysarum alpinum*	Secure	upland	FACU	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	sneezeweed	*Helenium autumnale**	Secure	wetland	FACW	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	cow parsnip	*Heracleum lanatum**	Secure	upland	FACU	None identified	None identified	Dehcho	
Forb	Alumroot	*Heuchera richardsonii*	May Be At Risk⁺	upland	FACU	Deciduous Forest, Native Grassland	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	ox-eye daisy	*Leucanthemum vulgare*	Invasive Alien	upland	UPL	Disturbed Areas	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	clubmoss	*Lycopodium annotinum*	Secure	upland	FACU	Coniferous Forest, Mixedwood Forest, Native Grassland	Swamp - Forested	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	Canada mayflower	*Maianthemum canadense*	Secure	upland	FACU	Coniferous Forest, Mixedwood Forest	None identified	Dehcho	
Forb	ostrich fern	*Matteuccia struthiopteris**	Sensitive	wetland	FACW	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	wild mint, peppermint	*Mentha arvensis*	Secure	wetland	FACW	None identified	Marsh	Dehcho	NWRRC; Dehcho First Nations; Pehdzéh Kį First Nation
Forb	lungwort, tall bluebells	*Mertensia paniculata*	Secure	upland	FACU	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	mitrewort	*Mitella nuda*	Secure	upland	FAC	Coniferous Forest, Mixedwood Forest	Bog - Forested, Bog - Shrubby	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	yellow pond lily	*Nuphar lutea*	Secure	wetland	OBL	None identified	Marsh	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	rocky mountain pond lily	*Nuphar polysepala*	May Be At Risk	wetland	OBL	None identified	Marsh	Dehcho	
Forb	variegated pond lily	*Nuphar variegata*	Secure⁺	wetland	OBL	None identified	Marsh	Dehcho	
Forb	mountain sorrel	*Oxyria digyna*	Secure	upland	FACU	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation

Form	Traditionally Used Name	Scientific Name	Provincial Rank	Upland or Wetland Plant	Wetland Status	Upland Landcover Types	Wetland Landcover Types	Region	Identified By
Forb	lousewort	*Pedicularis langsdorffii*	Secure	wetland	FACW	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	arrow-leaved coltsfoot	*Petasites sagittatus*	Not Assessed	-	-	Disturbed Areas, Coniferous Forest, Mixedwood Forest, Deciduous Forest	Marsh, Fen - Shrubby, Bog - Forested, Bog - Shrubby, Bog - Graminoid, Fen - Forested	Dehcho	
Forb	broad-leaved plantain	*Plantago major*	Alien	upland	FAC	Disturbed Areas	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	water smartweed	*Polygonum amphibium*	Secure	-	-	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	bistort, serpent grass	*Polygonum viviparum*	Secure	upland	FAC	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	rock polypody fern	*Polypodium vulgare*	Secure	-	-	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	cinquefoil	*Potentilla gracilis**	-	upland	FAC	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	blackberry	*Rubus arcticus*	Secure	wetland	FACW	None identified	Fen - Shrubby	Dehcho, Sahtu	
Forb	cloud berry	*Rubus chamaemorus*	Secure	wetland	FACW	None identified	Bog - Forested, Bog - Shrubby, Bog - Graminoid, Fen - Forested	Dehcho, Sahtu	NWRRC; Dehcho First Nations; Pehdzéh Kį First Nation
Forb	western dock	*Rumex aquaticus*	Secure	-	-	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	arrowhead	*Sagittaria cuneata*	Secure	wetland	OBL	None identified	None identified	Dehcho	
Forb	sage	*Salvia officinalis*	Alien	upland	FACU	None identified	None identified	Dehcho, Sahtu	NWRRC; Dehcho First Nations; Pehdzéh Kį First Nation
Forb	pitcher plant	*Sarracenia purpurea*	Secure	wetland	OBL	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	marsh skullcap	*Scutellaria galericulata*	Secure	wetland	OBL	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	water parsnip	*Sium suave*	Secure	wetland	OBL	None identified	None identified	Dehcho	
Forb	Canada goldenrod	*Solidago canadensis*	Secure	upland	FACU	Tame Pasture, Forest	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	dandelion	*Taraxacum officinale*	Alien	upland	FACU	Deciduous Forest, Mixedwood Forest	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	stinging nettle	*Urtica dioica*	Secure	upland	FACU	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	bladderwort	*Utricularia macrorhiza*	Secure	wetland	OBL	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Forb	false hellebore	*Veratrum viride*	Secure	upland	FAC	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation

Form	Traditionally Used Name	Scientific Name	Provincial Rank	Upland or Wetland Plant	Wetland Status	Upland Landcover Types	Wetland Landcover Types	Region	Identified By
Forb	mountain death camus	*Zigadenus elegans*	Secure	-	-	Coniferous Forest, Native Grassland	Bog - Forested, Bog - Shrubby, Bog - Graminoid	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Graminoid	blue-jointed reed grass, marsh reedgrass	*Calamagrostis canadensis*	Secure	upland	FAC	None identified	None identified	Dehcho	
Graminoid	water sedge	*Carex aquatilis*	Secure	wetland	OBL	None identified	Marsh, Bog – Graminoid, Fen - Graminoid	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Graminoid	sweet-grass	*Hierochloe odorata*	Secure	-	-	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Graminoid	fox-tail barley	*Hordeum jubatum*	Secure	upland	FACU	None identified	None identified	Dehcho	
Graminoid	common reed	*Phragmites australis**	Undetermined	wetland	FACW	None identified	None identified	Dehcho	
Graminoid	bulrush	*Schoenoplectus acutus*	Secure	wetland	OBL	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Graminoid	seaside arrow-grass	*Triglochin maritima*	Secure	wetland	OBL	None identified	Marsh	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
Graminoid	broad-leaf cattail	*Typha latifolia*	Secure	wetland	OBL	None identified	Marsh	Dehcho	
lichen	lichen	Various	N/A multiple species	-	-	None identified	None identified	Dehcho	Dehcho First Nations; Pehdzéh Kį First Nation
fungus	chaga	*Inonotus obliquus*	Undetermined	undetermined	undetermined	None identified	None identified	Sahtu	NWRRC

Notes:
+ Species not expected to occur in the RAA.
Wetland Status Codes:
UPL = Obligate upland, almost never occur in wetlands
FACU = Facultative upland, usually occur in non-wetlands, but may occur in wetlands
FAC = Facultative, occur in wetlands and non-wetlands
FACW = Facultative wetland, usually occur in wetlands, but may occur in non-wetlands
OBL = Obligate wetland, almost always occur in wetlands
Sources: EBA, 2006; IMG-Golder Corporation, 2006; NWRRC, 2023; TRRC, 2022

APPENDIX 19A

Wildlife and Wildlife Habitat Technical Data Report

Mackenzie Valley Highway Project
Technical Data Report—Wildlife and Wildlife Habitat

Prepared for:

Government of the Northwest Territories

Prepared by:

K'alo-Stantec Limited

March 2023

Project No.: 144903025

K'alo-Stantec

Limitations and Sign-off

This document entitled Mackenzie Valley Highway Project Technical Data Report—Wildlife and Wildlife Habitat was prepared by K'alo-Stantec Limited ("K'alo-Stantec") for the account of Government of the Northwest Territories (the "Client") to support the regulatory review process for its Developer's Assessment Report (DAR) (the "Application") for the Mackenzie Valley Highway Project (the "Project"). In connection therewith, this document may be reviewed and used by the Department of Infrastructure (INF) for the Government of the Northwest Territories participating in the review process in the normal course of its duties. Except as set forth in the previous sentence, any reliance on this document by any other party or use of it for any other purpose is strictly prohibited. The material in it reflects K'alo-Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between K'alo-Stantec and the Client. The information and conclusions in the document are based on the conditions existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, K'alo-Stantec did not verify information supplied to it by the Client or others, unless expressly stated otherwise in the document. Any use that another party makes of this document is the responsibility and risk of such party. Such party agrees that K'alo-Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other party as a result of decisions made or actions taken based on this document.

Prepared by Digitally signed by Ebner, Derek Date: 2023.06.23 13:26:05 -04'00' _____
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Executive Summary

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells to replace the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT).

The Regional Study Area (RSA; a 15 km buffer of the proposed Project) has the potential to provide habitat for 43 species of mammal, 2 species of amphibian, and numerous invertebrate species. The RSA is also within the range of four mammal species at risk (SAR), three invertebrate SAR, and one mammal and one invertebrate species of conservation concern (SOCC). The Local Study Area (LSA; a 1 km buffer of the Project) is not expected to provide a key source of habitat for wildlife SAR and SOCC because these species are widely distributed habitat generalists and occur within the RSA at low densities. Historical wildlife SAR and SOCC records within the LSA and RSA include observations of little brown myotis (*Myotis lucifugus*), wolverine (*Gulo gulo*), and all four invertebrate species.

The biophysical characteristics of the LSA are influenced by the Mackenzie River valley that defines the landscape and is dominated by coniferous forest habitats interspersed with wetlands and watercourses. Land cover in the Dehcho Region portion of the LSA is dominated by coniferous forest (43.6%), wetlands (19.8%), and open water (19.3%). The LSA in the Sahtu Region is dominated by coniferous forest (28.7%), wetlands (25.2%), and shrubland (20.6%). Since 1960, 18.5% of the LSA within the Dehcho Region and 75.2% of the LSA within the Sahtu Region has been subject to forest fire.

Along with the existing MVWR and communities along it (e.g., Hamlet of Tulita), the LSA contains disturbances from oil and gas exploration and production infrastructure, borrow sources and quarries, a fibre line, and bridges associated with the MVWR. Notably, the Norman Wells Pipeline, commissioned in 1985, conveys crude oil from Norman Wells south to Alberta and is located in the LSA. The RSA is relatively undisturbed, but oil and gas exploration and production infrastructure does exist on the west side of the Mackenzie River near Norman Wells.

The LSA is located partly within four Important Wildlife Areas (IWAs). Two are designated as important habitat for beaver (*Castor canadensis*) and Canada lynx (*Lynx canadensis*) and two others are Sahtu rivers and a culturally sacred site (Bear Rock - Kweteniʔaá). Sensitive wildlife features relied on by mammal SAR (e.g., denning sites, overwintering hibernacula) are not known to occur within the LSA and the likelihood of them occurring is low given the biophysical conditions present.

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APPENDIX A TABLES

Abbreviations

%	percent
>	greater than
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CZ	Conservation Zone
DLUP	Draft Dehcho Land Use Plan
EOSD NWT	Earth Observation of Sustainable Development of Forests Northwest Territories
GMVFP	Genuine Mackenzie Valley Fur Program
GNWT	Government of the Northwest Territories
GNWT-ENR	Government of the Northwest Territories - Environment and Natural Resources
ha	hectare
INF	Department of Infrastructure
IWA	Important Wildlife Area
km	kilometre
KM	kilometre marker
km^2	square kilometre
LSA	Local Study Area
m	metre
MVH	Mackenzie Valley Highway
MVWR	Mackenzie Valley Winter Road
NT/NWT	Northwest Territories
PDA	Project Development Area
ROW	right-of-way
RSA	Regional Study Area
SAR	Species at Risk
SARA	*Species at Risk Act*
SLUP	Sahtu Land Use Plan
SMZ	Special Management Zone
SOCC	Species of Conservation Concern

TDR ..... Technical Data Report

the Project ..... Mackenzie Valley Highway Project

TK ..... traditional knowledge

TLRU ..... traditional land and resource use

1 Introduction

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells to replace the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT).

The Project is subject to an environmental assessment and the requirements of Part 5 of the *Mackenzie Valley Resource Management Act*. This Technical Data Report (TDR) presents the existing conditions for the Wildlife and Wildlife Habitat valued component to support development of the Developer's Assessment Report as required by the Terms of Reference (MVEIRB, 2015). As part of the environmental assessment process, the Developer's Assessment Report will present the GNWT's assessment of effects of the Project on the environment.

This TDR provides an overview of the existing conditions for wildlife and wildlife habitat and excludes caribou (*Rangifer* spp.) and moose (*Alces alces*; see Caribou and Moose TDR [EDI, 2022]), and birds and bird habitat (see Birds and Bird Habitat TDR [K'alo-Stantec, 2023]), which are separately valued components and not discussed further in this TDR.

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Settlement Area Boundary
- Region Boundary
- Territorial Boundary

0 40 80 Kilometres

(At original document size of 8.5x11)
1:4,500,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/8/2023
TR by AJ on 3/8/2023

Client/Project
144903025-0031 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
1.1

Title
MVH Project Overview

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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2 Study Areas

The Project is in the Mackenzie Valley region of the NT between the current terminus of the existing all-weather highway in Wrigley (Highway #1, kilometre marker [KM] 690) and Prohibition Creek (located approximately 28 km southeast of Norman Wells). The Project alignment parallels the Mackenzie River to its east and passes through the community of Tulita (KM 938 of the MVWR). The Mackenzie Valley region has the potential to provide habitat for a variety of wildlife species, including mammals, amphibians, and invertebrates.

The local study area (LSA) and regional study area (RSA) used in this TDR are areas where data was collected for characterizing the existing environmental conditions for wildlife and wildlife habitat, excluding moose and caribou, in support of the Project-specific effects assessment and the cumulative effects assessment (Figure 2.1).

2.1 Project Development Area (PDA)

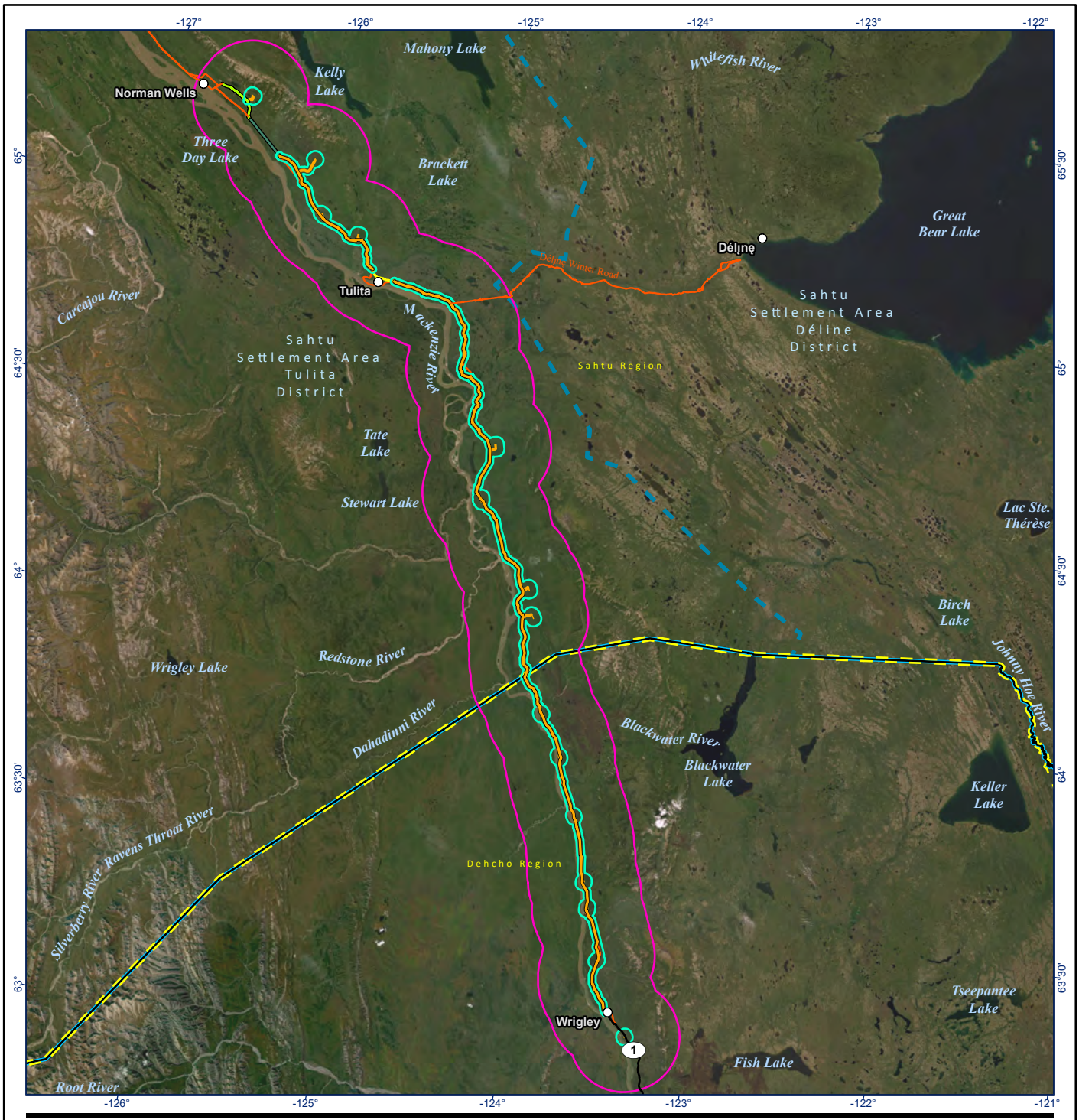
The Project Development Area (PDA) is the area of direct Project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 metres (m) wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps and quarry/borrow sites with access roads on a 30 m ROW.

2.2 Local Study Area

The LSA is a 1 km buffer around the Project highway alignment (i.e., centreline), except around quarries and borrow sources where the LSA increases to a 2 km buffer around the PDA. The size of the buffer is based on measurable effects to mammals (Benitez-Lopez et al., 2010) while also considering recommended setback distances for wildlife and wildlife habitat features (Appendix A, Table A.1; GNWT, 2015a). The size of the LSA is also consistent with guidance provided by Environment and Climate Change Canada (Dufour, 2020, pers. comm.).

2.3 Regional Study Area

The RSA is a 15 km buffer around the proposed road alignment that captures a wide-range of wildlife species and wildlife habitats that could potentially be affected cumulatively by the Project and other past, present, and reasonably foreseeable projects. This RSA is consistent with other highway projects in the NT (e.g., Inuvik to Tuktoyaktuk Highway [Kiggiak - EBA Consulting Ltd., 2011]) and follows recommendations from Environment and Climate Change Canada (Dufour, 2020, pers. comm.).



- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (Permitted)
- Proposed Great Bear River Bridge
- Local Assessment Area
- Regional Assessment Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/8/2023
TR by AJ on 3/8/2023

Client/Project
144903025-0030 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
2.1

Title
Wildlife and Wildlife Habitat Study Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS. Imagery date: 2021

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3 Review of Existing Data

The TDR was developed to address the Project Terms of Reference (MVEIRB, 2015) using a literature review of currently available information.

A review of existing traditional knowledge (TK) and traditional land and resource use (TLRU; Section 3.1) information and a review of relevant wildlife literature (Section 3.2) was completed. Results are used to characterize the existing conditions for wildlife and wildlife habitat within the LSA and RSA.

An overview characterizing the mammal, amphibian, and invertebrate communities is provided in Section 3.2.2, with an emphasis on species at risk (SAR) and species of conservation concern (SOCC; defined in Section 3.2.1.1).

3.1 Traditional Knowledge and Traditional Land and Resource Use

Available TK and TLRU contribute to the description of existing conditions for wildlife and wildlife habitat, particularly as it relates to harvested species, species of cultural importance, and the presence of sensitive habitat features in the RSA.

3.1.1 Methods

Existing TK and TLRU information was obtained through several sources, including Project-specific engagement, land use planning documents and regional research projects for the administrative regions traversed by the Project: the Dehcho Region and the Sahtu Region. An overview of the key TK and TLRU resources used to assist in characterizing the existing condition for wildlife and wildlife habitat are presented below and results are presented by the respective regions.

- ***Respect for the Land: the Dehcho Land Use Plan – Draft (DLUP)*****:** Guidance document that incorporates the cultural, social, and economic factors relating to the management and conservation of natural resources as it relates to development projects within the Dehcho Region (DLUPC, 2006). The DLUP is intended to be a legally binding land use plan that will contain zoning and conformity requirements for all activities requiring an authorization
- ***A Spatial Analysis and Literature Review of Wildlife and Wildlife Habitat in the Dehcho Territory***: A spatial representation of the current knowledge of wildlife and wildlife habitat within the Dehcho Region (EBA Engineering Consultants, 2003).
- ***Project Description Report for the Dehcho Region:*** A preliminary screening document summarizing baseline environmental information, including wildlife and SAR/SOCC, as it relates to the Project in the Dehcho Region (Dessau, 2012).

- ***Tulita Renewable Resources Council Traditional Land and Resource Use Study for Tulita District Mackenzie Highway Project 2022:*** Report prepared for Mackenzie Valley Highway (MVH) Project to describe Traditional Land and Resource use within the Tulita District (TRRC, 2022).
- ***Sahtu Land Use Plan (SLUP)*****:** A document guiding how natural resources will be conserved and developed in the Sahtu Region (SLUPB, 2013). The SLUP is a legally binding land use plan that contains zoning and conformity requirements for all activities requiring an authorization
- ***The Sahtu Atlas – Maps and Stories from the Sahtu Settlement Area in Canada's Northwest Territories:*** A document containing historical TK and TLRU information from the Sahtu Region (Auld and Kershaw, 2005).
- ***Final Report of the Sahtu Harvest Study:*** A survey of Sahtu Dene and Métis hunters that reported wildlife harvest activities in the Sahtu Region between 1998 and 2005 (SRRB, 2021).
- ***Sahtu Dene and Métis Comprehensive Land Claim Agreement:*** A document outlining the species and areas subject to preferential or exclusive rights for Indigenous Peoples of the Sahtu Region (INAC, 1993). A modern treaty that, among other things, addresses wildlife harvesting rights for Sahtu Dene and Metis
- ***Project Description Report for the Sahtu Region:*** A preliminary screening document summarizing baseline environmental information, including wildlife and SAR/SOCC, as it relates to the Project in the Sahtu Region (5658 NWT Ltd. and GNWT, 2011).
- **Other TK and TLRU Resources:** Documents that provided information on the historical or existing condition for birds and bird habitat:
  - *Rakekée Gok'é Godi: Places We Take Care Of* (SHPSJWG, 2000).
  - *Draft Report on Renewable Resource Assessment of the Pehdzeh Ndeh Area of Interest* (IMG-Golder Corporation, 2006).
  - *Traditional Knowledge Study Report Tulita, NT, Great Bear River Bridge* (EBA Engineering Consultants, 2006).
  - Boreal Caribou Traditional Knowledge Collection Study: The Sahtu Settlement Area (McDonald, 2010).
  - Traditional Knowledge Assessment of Boreal Caribou (Mbedzih) in the Dehcho Region (Dehcho First Nation, 2011).
  - *Traditional Knowledge Study for the Great Bear River Bridge Project* (TRRC, 2019).

3.1.2 Results

The results are presented by their respective region and are consistent with information summarized in the Cultural and Traditional Land Use TDR (K'alo-Stantec, 2022a).

3.1.2.1 Dehcho Region

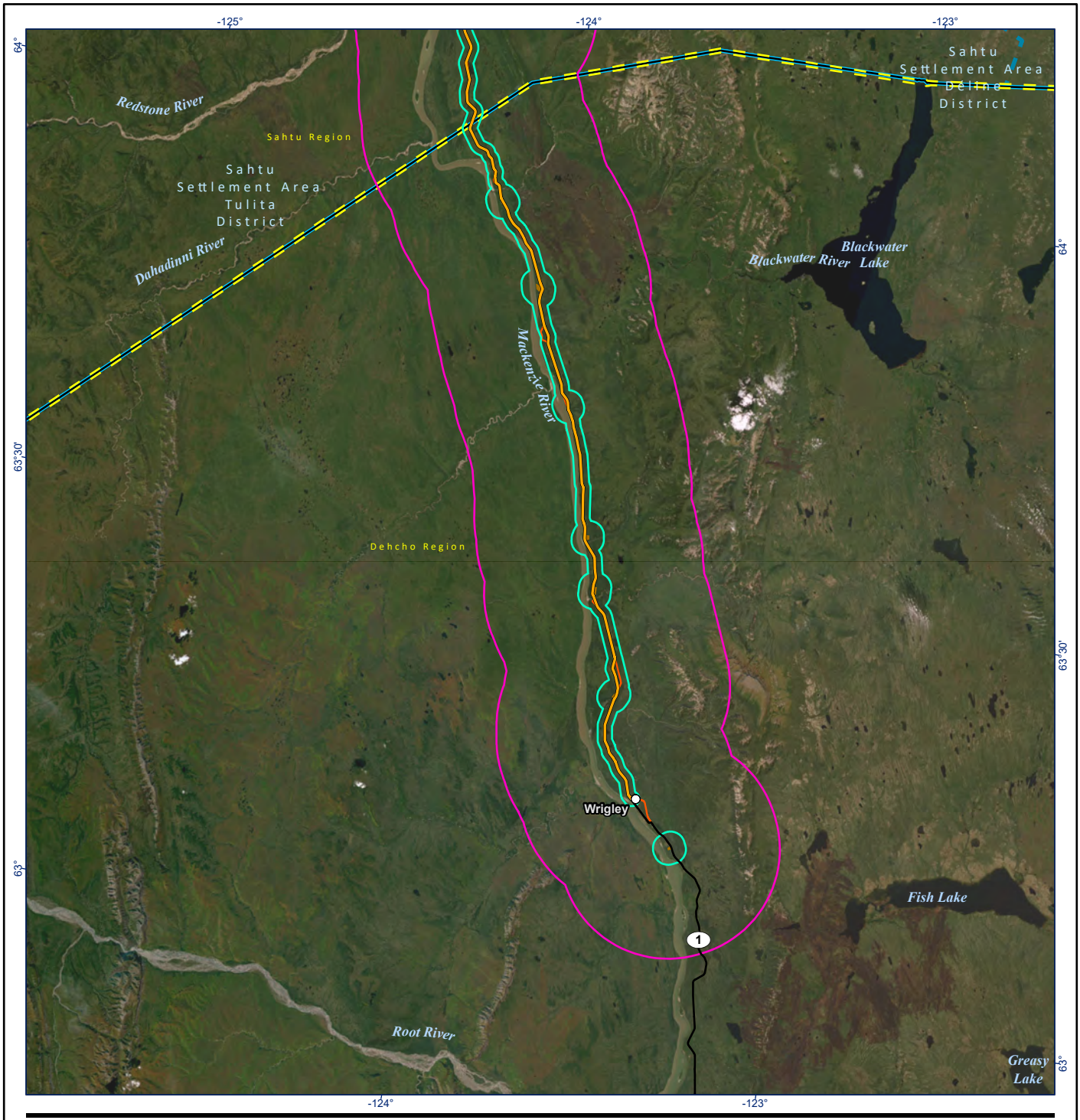
The Project traverses approximately 102 km of the Dehcho Region and includes 26,819.7 hectares (ha) of land within the LSA and 359,038.0 ha within the RSA (Figure 3.1).

The DLUP focuses on protecting Dene culture and traditional land use (e.g., hunting, trapping) as the highest priority for Dehcho First Nation members seeking to maintain existing TLRU opportunities within the territory (DLUPC, 2006). The DLUP identified areas that have significant ecological and cultural values (DLUPC, 2006), which provide habitat for moose, American black bear (*Ursus americanus*), and grey wolf (*Canus lupus*). It is an important cultural area for the community of Wrigley (Desseau, 2012). The Project also traverses the proposed Mackenzie Valley Special Infrastructure Corridor, which has been approved for infrastructure development (primarily the previously proposed Mackenzie Valley Pipeline).

The DLUP also provides guidance for cumulative effects indicators and thresholds for grizzly bear (*Ursus arctos*) and critical lifecycle periods for several sensitive species (e.g., wolverine [*Gulo gulo*]). The activity restrictions presented in Appendix A, Table A.1 are consistent with or more conservative than those proposed in the DLUP. However, the grizzly bear range in the Dehcho Region is limited to montane habitats west and outside the RSA (EBA Engineering Consultants, 2003). Mineral licks are expected to occur throughout the Dehcho Region, particularly to the east of the winter road (IMG-Golder Corporation, 2006), but the locations are kept confidential unless there is a specific threat from development (Dehcho First Nation, 2011). Furbearer habitat exists throughout the Mackenzie Valley, within the LSA (Desseau, 2012), and includes habitat for beaver (*Castor canadensis*), American mink (*Neovision vision*), American marten (*Martes americana*), Canada lynx (*Lynx canadensis*) found in the Blackwater River system (IMG-Golder Corporation, 2006).

Increased populations of large predators have been reported, resulting in impacts on prey species, particularly ungulates. Cougar (*Puma concolor*) have been increasingly seen (directly or through tracks) throughout the Dehcho Region over the past decade, possibly due to the increase in white-tailed deer (*Odocoileus virginianus*) in the region. An increase in American black bear populations has also been reported (Dehcho First Nations, 2011). Grey wolf populations throughout the Dehcho Region appear to be increasing, due in part that fewer of these animals are trapped or hunted today than in the past, for both cultural and socio-economic reasons (Dehcho First Nation, 2011). The presence of development and linear features is also thought to be contributing to these population increases (Dehcho First Nation, 2011).

Wildlife is a key renewable resource for trapping and hunting, and subsistence harvesting, particularly moose, which is an important food resource among residents (IMG-Golder Corporation, 2006; also see the Cultural and Traditional Land Use TDR [K'alo-Stantec, 2022a]). There is no land claim agreement in the Dehcho Region and, thus, no species or areas are subject to preferential or exclusive rights for Indigenous Peoples of the region.



- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 8.5 17 Kilometres

(At original document size of 8.5x11)
1:800,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/8/2023
TR by AJ on 3/8/2023

Client/Project
144903025-0032 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.1

Title
Project Overview within the Dehcho Region

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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3.1.2.2 Sahtu Region

The Project traverses 179 km of the Sahtu Region and includes 48,539.9 ha of land within the LSA and 616,807.0 ha within the RSA (Figure 3.2).

The SLUP focuses on maintaining and/or enhancing ecological and cultural integrity while increasing the decision-making capacity and economic self-sufficiency of the community through sustainable development of natural resources (SLUPB, 2013). A key component of the SLUP is the protection and conservation of species of interest (i.e., species of cultural, conservation, or subsistence importance) and their habitats, and includes recommended activity restriction guidelines for sensitive species. The activity restrictions presented in Appendix A, Table A.1 are consistent with or more conservative than those presented in the SLUP.

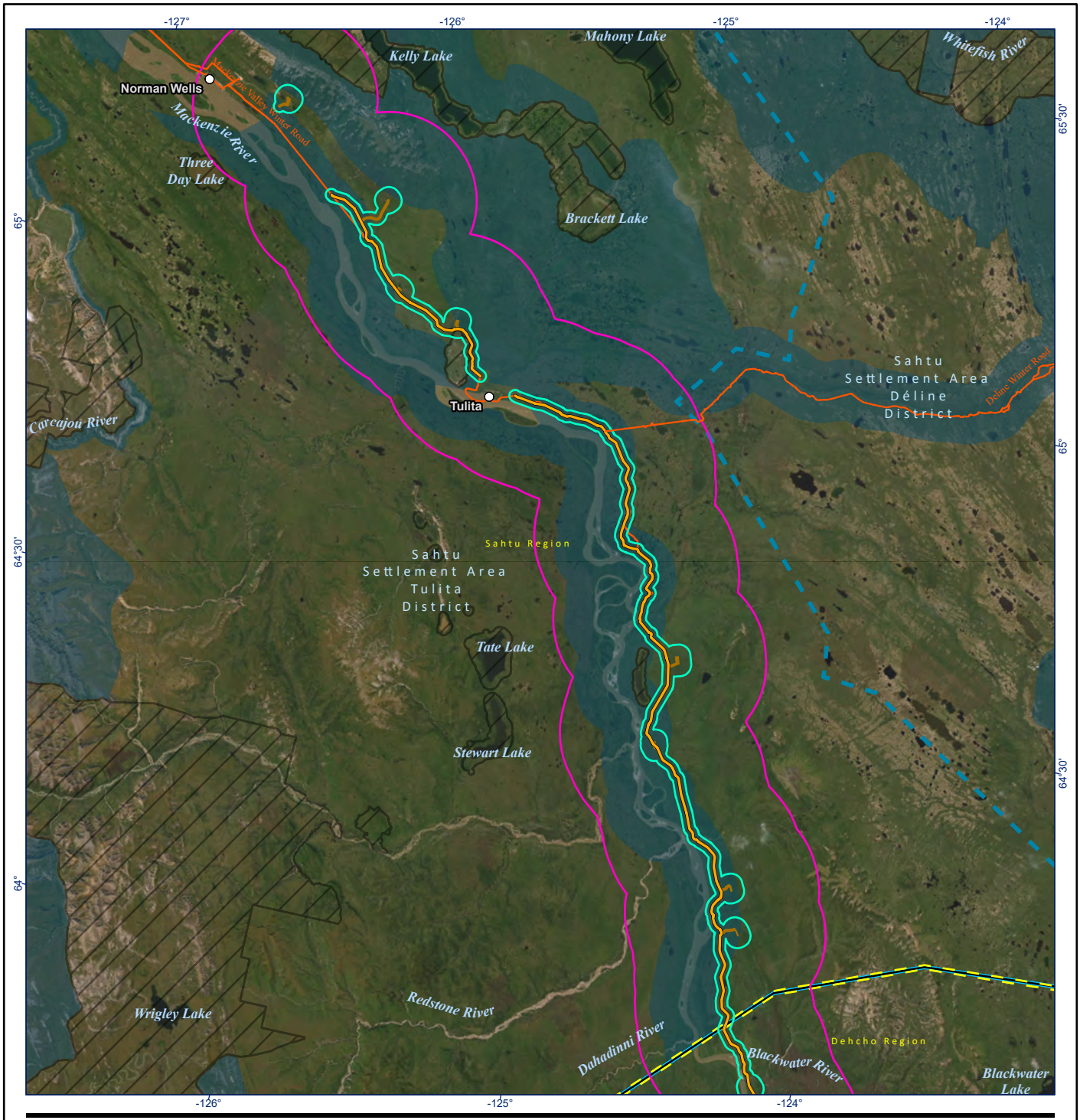
The Project primarily traverses through the Deh Cho (Mackenzie River) SMZ No. 63 of the SLUP (2.2% of Sahtu Region) that is an area designated to protect the water quality, riparian habitat, cultural/heritage sites, and areas that are important for wildlife and wildlife harvesting (SLUPB, 2013). The SMZ allows for the continued use of the areas as a riverine and territorial transportation corridor (e.g., barge traffic, winter road) and bulk water removal is the only prohibited land use.

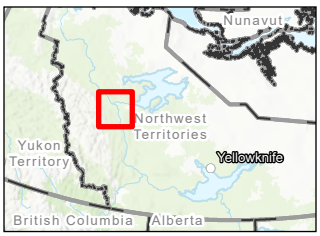
The Bear Rock CZ (No. 32), approximately 4 km northwest of Tulita, is a culturally sacred site located within the LSA (SLUPB, 2013). The CZ is a large karst formation subject to traditional storytelling and provides habitat for a wide variety of wildlife species (see Section 3.2.2.1), including bears and furbearers (SLUPB, 2013).

Mammal species such as American black bear, red fox (*Vulpes vulpes*), Canada lynx, and American marten are common within the Mackenzie River valley and RSA, while grizzly bear (*Ursus actor*), grey wolf, wolverine (*Gulo gulo*), and arctic fox (*Alopex lagopus*) are less common and occur at low densities (Auld and Kershaw, 2005).

The Sahtu Dene and Métis Comprehensive Land Claim Agreement does not identify any wildlife species or areas subject to preferential or exclusive rights for Indigenous Peoples within the Sahtu Region as it relates to species discussed in this TDR (IAAC, 1993).

Important areas for wildlife and wildlife hunting are typically associated with wetlands and watercourses, including the Mackenzie and Great Bear Rivers (SHPSJWG, 2000). According to interviews with Sahtu harvesters, wildlife species commonly found in the area around Tulita include American black bear, American marten, beaver, common muskrat (*Ondatra zibethicus*), North American river otter (*Lontra canadensis*), fox species, rabbit species, grey wolf, wolverine, squirrel species, weasel species, American mink, and Canada lynx (EBA Engineering Consultants, 2006). The area around Brackett Lake supports relatively large populations of wildlife species and the oral tradition records many stories which tell of the importance of this lake (SHPSJWG, 2000).





- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area

Sahtu Land Use Plan Zoning

- Conservation Zone
- Special Management Zone

- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,000,000

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Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/8/2023
TR by AJ on 3/8/2023

Client/Project
144903025-0033 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.2

Title
Project Overview within the Sahtu Settlement Area

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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Increased populations of grey wolf have been reported, which coincides with reduced trapping activity in the Sahtu Region (McDonald, 2010); however, trapping effort is dependent on fur prices and availability of other employment opportunities (SRRB, 2021). Increased grey wolf populations may also be a result of a noted increase in moose and muskox (*Ovibos moschatus*; previously uncommon in the Sahtu Region) populations, which has been suggested to be a result of an abundance of food availability in the region. It is also suggested that the abundance of other ungulates has benefitted species like caribou by reducing predation pressure (McDonald, 2010).

Harvest composition of large mammals in the Sahtu Region is dominated by barren-ground caribou (88%), followed by moose (8%) and woodland caribou (3%) and other species (1%; e.g., muskox; SRRB, 2021).

Through the Project-specific engagement program, participants indicated:

- Concern that construction and operation of the Project will disturb (physical and sensory disturbance) wildlife year-round, including during blasting.
- Concern how the Project will affect furbearers and traplines and result in greater boat traffic (and disturbance) on the Mackenzie River.
- Concern that the Project will facilitate the introduction of invasive species.
- Muskox are becoming more prevalent and are an important food source.
- There are mostly black bears near Norman Wells and grizzly bears are uncommon and typically stay to the west of the Mackenzie River in mountainous areas; bear dens should be protected, and pre-construction surveys should be undertaken. Known bear dens near Bear Rock.
- Some members find it acceptable to trap beavers and destroy lodges or dam while others do not because they are a keystone species. Care needs to be taken and community members should be given trapped beavers to make use of.
- Bats are present in the area.
- There typically no wildlife collisions on the MVWR and most motorists will give wildlife the right of way, but this should be included in Project monitoring.
- Concern that the Project will increase hunting pressure by non-resident hunters and wildlife need to be protected.
- Muskox near Prohibition Creek and Canyon Creek year-round as there are mineral licks present.
- An area called Salt River Creek contains salt deposits used by wildlife and people.
- The creek at KM 776 contains salt deposits used by wildlife and people.
- Concern that aerial surveys disturb wildlife and remote cameras and snowmobile-based surveys using local support is preferable
- Concern for effects on wildlife migration resulting from the Project and recommend using remote cameras to monitor wildlife movement before and after construction.
- Communities are interested in collaborating with GNWT to address uncertainties around monitoring relating to harvest monitoring and stewardship based on Dene laws, for example.

- Lynn Creek areas is used to hunt rabbit.
- Climate change affects food security and many people will fish if wildlife moves away and this should be monitored.

Recent TLRU information (TRRC, 2022) indicates that:

- Many types of wildlife are harvested within the LSA.
- There are a lot of bear dens within the LSA, along the MVWR, near the north side of the airport, and at Four Mile Creek.
- Rabbits are harvested within the LSA.
- More water and wildlife monitoring should be used in the LSA to mitigate potential project effects.
- There are more muskox in the LSA than before as a result or previous road construction and operation.
- Hunting muskox year-round for food and for hides and crafts within the LSA.
- Previous road construction and operation has impacted wildlife and wildlife abundance in the LSA.
- Previous road construction has interfered with small game hunting and undertaking TLRU activities year-round.
- Previous road construction and operation has made it easier to access valued resources.
- Wolves are harvested within the LSA along the MVWR.
- Beaver and muskrat are typically harvested in the spring (April, May, and June).
- A lot of change in the LSA, 'everything is changing; wolves, fox, bears, are all in the community' when they were not coming into the community before that affect undertaking TLRU.
- There is a mineral lick (described as a salt river) near Bear Rock that attracts wildlife and is of interest to the community.
- Plants and wildlife are still needed to undertake TLRU (e.g., food and hides for personal use).
- Hunting occurs along the shores of Bear River year-round and camping and fishing during the summer.
- Signage should be used to promote highway access and to protect wildlife in the area and help letter
- Country food is an important part of community residents' diet and is shared among the community, family members, and friends in all seasons (particularly during spring and winter). The community relies on it and is in constant need of wildlife/country foods for sustenance.
- The MVWR and pipeline ROW has affected valued resources.
- A speed limit should be set on the highway to mitigation potential Project effects (wildlife fatalities).
- Recommended Tulita be a priority (provide feedback and be the lead) when undertaking Project-related TK studies, monitoring and TK-based monitoring for water, land, and wildlife to improve TK-based monitoring, avoid/mitigate potential Project effects and improve safety.

- Construction and operation of roads in the LSA have intersected many known trails into hunting areas around Tulita which have affect the ability to undertake TLRU.
- Previous road construction has caused change to the weather and increased illnesses (illnesses observed in wildlife) around Trout Lake.
- Harvesting and hunting within the LSA are accessed mostly during the wintertime.
- Unable to hunt along the MVWR during the summertime.

3.2 Literature Review

A literature review was used to establish the existing condition for wildlife and wildlife habitat and identify the presence of sensitive features and SAR or SOCC in the RSA.

3.2.1 Methods

Background information was obtained through several sources, including maps and photographs, territorial and federal databases and guidance documents, and not-for-profit publications and data sources. An overview of some of the key resources used during background review to assist in characterizing the existing condition for wildlife and wildlife habitat is presented below.

- **Maps and photographs:** Topographic mapping and orthographic aerial imagery were used to help identify watercourses, lakes and/or wetlands, and to provide an overall indication of site topography (Digital Globe, 2019).
- **Species at risk public registry:** A database containing the status of species assessed and listed under the federal *Species at Risk Act* (SARA) and by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and associated documentation including assessment and status reports, recovery strategies and critical habitat designations, and management strategies (Government of Canada, 2022).
- **GNWT Spatial Data Warehouse Geospatial Portal database:** Online databases used, in part, for screening resource development projects in NT. The databases include information such as SAR ranges and important wildlife areas (e.g., mineral lick areas; GNWT, 2020a).
- **GNWT Species at Risk in the Northwest Territories:** A biennial publication outlining the status and distribution of territorially and federally assessed and listed SAR in NT (GNWT, 2020b).
- **GNWT Species 2016-2020 – General Status Ranks of Wild Species in Northwest Territories:** an overview of the status of the flora and fauna of NT (Working Group on the General Status of NWT Species, 2016).
- **GNWT Wildlife Management Information System (WMIS):** A territorial geo-referenced wildlife database for historical wildlife records (GNWT, 2020c).
- **Important Wildlife Areas in the Western Northwest Territories:** A report outlining the location of known important wildlife areas to help guide development and resource management (Wilson and Haas, 2012).

- **Genuine Mackenzie Valley Fur Program (GMVFP) data:** Data provided by Government of the Northwest Territories - Environment and Natural Resources (GNWT-ENR) summarizing the number of furs and hides that were sold through the GMVFP and excludes the private sale or trading of furs outside of this program (GNWT, 2022a).
- **GNWT aerial bear den survey data:** The Department of Environment and Natural Resources completed an aerial dear den survey within 800 km of the winter road in the Sahtu region in 2022 to identify bear dens that may interact with the Project (GNWT, 2022b).

3.2.1.1 Species at Risk and Species of Conservation Concern

SAR are species listed as special concern, threatened, or endangered under the *Species at Risk (NWT) Act* (GNWT, 2020b) or under Schedule 1 of the federal SARA (Government of Canada, 2021), and SOCC are species assessed as special concern, threatened, or endangered by the NWT Species at Risk Committee (SARC; GNWT, 2020b) or COSEWIC (Government of Canada, 2021).

3.2.1.2 Habitat Identification

Land cover within the LSA and RSA was quantified using Earth Observation of Sustainable Development of Forests Northwest Territories (EOSD NWT) geospatial data (NRCan and GNWT, 2017). This dataset is part of the Multi-source Vegetation Inventory Project (Natural Resources Canada, 2020) and uses an unsupervised classification and cluster analysis to classify land cover.

The EOSD NWT dataset includes cover type and density classes and forest structure height and volume information based on Landsat imagery collected from 2007 to 2013. Mapping was done at a scale of 1:250,000 and was refined through field evaluation by the GNWT (NRCan and GNWT, 2017). Detailed land cover classification methods for this Project are described in the Vegetation and Wetlands TDR (K'alo-Stantec, 2022b).

3.2.2 Results

Results indicate that 42 mammal species, 2 amphibian species, and a number of invertebrate species have the potential to occur in the RSA (Appendix A, Table A.2; GNWT, 2020c), including seven SAR/SOCC (Table 3.1). The results for wildlife and wildlife habitat are presented by taxonomic grouping, with an emphasis placed on harvested species and species of regulatory and/or conservation importance. These are:

- Mammals
- Amphibians
- Invertebrates
- SAR and SOCC – federally and territorially assessed and listed species (see Section 3.2.1.1)

Table 3.1 Wildlife Species at Risk[1] and Species of Conservation Concern (*) with Potential to Occur in the Regional Study Area

Species		Status in NWT[2]		Status in Canada[3]	
Common Name	**Scientific Name**	**SARC Assessment**	**SAR (NWT) Act**	**COSEWIC**	**SARA**
Mammals					
Little brown myotis	*Myotis lucifugus*	Special Concern	Special Concern	Endangered	Endangered
Grizzly bear	*Ursus arctos*	Special Concern	Not Listed	Special Concern	Special Concern
Wolverine	*Gulo gulo*	Not at Risk	Not Listed	Special Concern	Special Concern
Boreal caribou	*Rangifer tarandus caribou*	Threatened	Threatened	Threatened	Threatened
Barren-ground caribou	*Rangifer tarandus groenlandicus*	Threatened	Threatened	Threatened	Not Listed◊
Invertebrates					
Gypsy cuckoo bumble bee	*Bombus bohemicus*	Data deficient	Not Listed	Endangered	Endangered
Suckley's cuckoo bumble bee*	*Bombus suckleyi*	Not Assessed	Not Listed	Threatened	Not Listed◊
Yellow-banded bumble bee	*Bombus terricola*	Not at Risk	Not Listed	Special Concern	Special Concern
Transverse lady beetle	*Coccinella transversoguttata*	Not Assessed	Not Listed	Special Concern	Special Concern

Notes:

1 The existing conditions for caribou species are available in the Caribou and Moose TDR (EDI, 2022)

2 Species at risk in NT assessed by SARC and listed under the territorial *Species at Risk (NWT) Act* (GNWT, 2020b)

3 Species at risk in Canada assessed by COSEWIC and listed under Schedule 1 the federal *Species at Risk Act* (Government of Canada, 2021)

* Species of conservation concern

◊ Under consideration for Schedule 1 status change

3.2.2.1 Overview

Wildlife Habitat

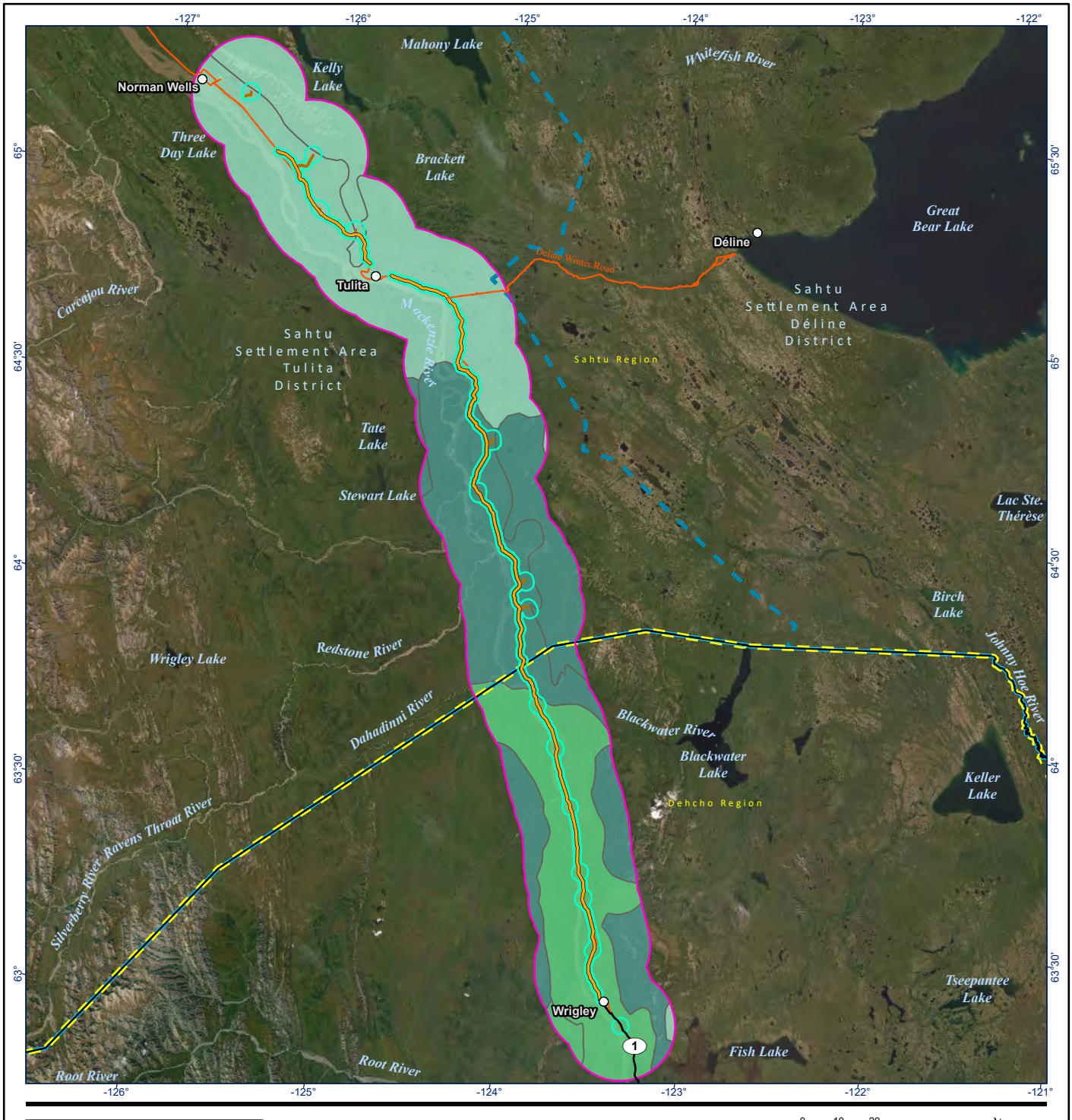
The Project is within the Mackenzie River valley (Mackenzie Valley), a landscape dominated by the Mackenzie River, known as the Deh Cho (meaning Big River) by local Dene First Nations, which is the longest river in Canada (1,738 km) spanning from Great Slave Lake to the Beaufort Sea. The Mackenzie River is a defining feature on the western Canadian landscape and the river basin, at 1.8 million square kilometres (km^2) which is approximately 20% of Canada's landmass, is the second largest in North America, second only to the Mississippi River basin (MRBB, 2020).

The LSA is located primarily within the Mackenzie River valley plain and characterized by relatively subdued topographical relief that gives rise to the Mackenzie Mountains to the west and the Franklin Mountains to the east. Within the Mackenzie Valley, the LSA traverses the Boreal and Taiga Cordillera Ecoregions (Central Makenzie Valley and Central Mackenzie Plains subregions [Level IV]; ECG, 2010) in the south and the Taiga Plains Ecoregion (North Mackenzie Plains Low Subarctic and Norman Range Low Subarctic subregions [Level IV]; ECG, 2007) in the north (Figure 3.3). The Norman Range Low Subarctic subregion, traversed by the Project in a small area, is the only area of notable topographical relief along the LSA and contains the Bear Rock massif, a rock formation rising 400 metres (m) above the Mackenzie River and extending east to join the Franklin Mountains.

Land cover in the Dehcho Region portion of the LSA (26,819.7 ha) is dominated by coniferous forest (43.6%), wetlands (19.8%), and open water (19.3%; e.g., the Mackenzie River; Table 3.2; Figure 3.4), while the LSA that overlaps the Sahtu Region (48,539.9 ha) is dominated by coniferous forest (28.7%), wetlands (25.2%), and shrubland (20.6%; Table 3.2; Figure 3.5). Forest fires within the Dehcho Region have been relatively uncommon and comparably smaller than in the Sahtu Region. From 1960 to 2019, fires within the LSA have burned a total of 4,956.7 ha (18.5%) of land cover in the Dehcho Region and 36,521.7 ha (75.2%) of land cover in the Sahtu Region. However, forest fire prevalence within the RSA has been similar in the Dehcho Region (50.8%) and Sahtu Region (52.8%).

Habitat Disturbance

Except for the existing MVWR and communities along it (e.g., Hamlet of Tulita), the LSA is relatively undisturbed but does contain some disturbance from oil and gas exploration and production infrastructure south of Norman Wells (e.g., Auld and Kershaw, 2005). Notably, the Norman Wells Pipeline conveys crude oil from Norman Wells south to Alberta and is located in the LSA of the Dehcho Region and Sahtu Region. Similarly, the RSA is relatively undisturbed, but oil and gas exploration and production infrastructure exists on the west side of the Mackenzie River near Norman Wells (Auld and Kershaw, 2005). Other existing disturbances include quarries and borrow sources, a fibre line, and bridges associated with the MVWR.



Level III Ecoregion

- Boreal Cordillera, High Boreal
- Taiga Cordillera, Low Subarctic
- Taiga Plains, Low Subarctic
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access

- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0034 REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.3

Title
Ecoregions

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
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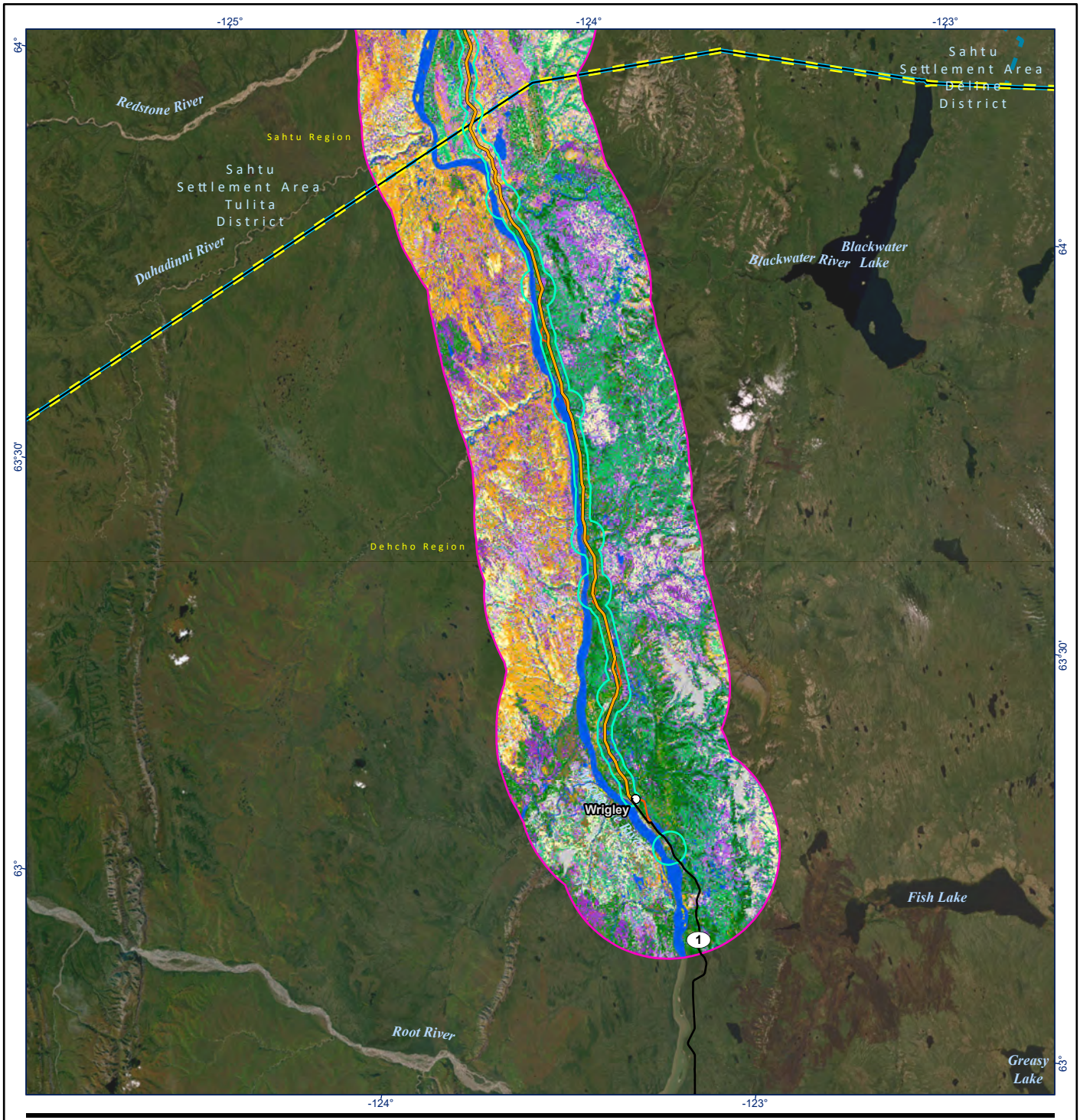
Table 3.2 Land Cover Classes in the LSA and RSA for the Dehcho Region and Sahtu Region

Land Cover Category	Land Cover Class[1]	Dehcho Region		Sahtu Region	
		LSA	RSA	LSA	RSA
		ha (%)	ha (%)	ha (%)	ha (%)
Upland	Broadleaf Dense	1,037.4 (3.9%)	43,781.3 (12.2%)	2,253.1 (5.2%)	34,259.4 (5.3%)
	Broadleaf Open	114.8 (0.4%)	4,154.7 (1.2%)	1,103.9 (2.3%)	14,627.9 (2.2%)
	Broadleaf Sparse	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
	Coniferous Dense	3,374.9 (12.6%)	25,120.5 (7.0%)	917.8 (1.9%)	18,580.5 (2.9%)
	Coniferous Open	4,600.6 (17.2%)	40,034.2 (11.2%)	6,678.1 (13.8%)	113,316.2 (17.4%)
	Coniferous Sparse	3,725.0 (13.9%)	51,491.5 (14.3%)	6,332.6 (13.0%)	71,845.9 (11.0%)
	Mixedwood Dense	1,035.1 (3.9%)	6,786.9 (1.9%)	387.3 (0.8%)	7,494.4 (1.1%)
	Mixedwood Open	117.1 (0.4%)	2,728.5 (0.8%)	2,514.0 (5.2%)	23,834.7 (3.7%)
	Mixedwood Sparse	0.0 (0.0%)	0.0 (0.0%)	6.3 (<0.1%)	11.7 (<0.1%)
	Shrub Low	567.4 (2.1%)	39,005.2 (10.9%)	7,903.4 (16.3%)	72,607.6 (11.1%)
	Shrub Tall	320.6 (1.2%)	1,616.4 (0.5%)	2,091.3 (4.3%)	16,525.8 (2.5%)
	Herbaceous	50.6 (0.2%)	1,300.1 (0.3%)	210.9 (0.4%)	4,093.2 (0.6%)
	Bryoids	7.0 (<0.1%)	20.4 (<0.1%)	6.2 (<0.1%)	137.0 (<0.1%)
	Rock/Rubble	45.1 (0.2%)	4,916.4 (1.4%)	107.3 (0.2%)	10, 285.3 (1.6%)
	Exposed Land	1,338.0 (5.0%)	4,862.2 (1.4%)	1,713.2 (3.5%)	9,897.9 (1.5%)
	Total	16,333.6 (60.9%)	225,848.3 (62.9%)	32,495.5 (66.9%)	397,517.4 (61.0%)

Land Cover Category	Land Cover Class[1]	Dehcho Region		Sahtu Region	
		LSA	RSA	LSA	RSA
		ha (%)	ha (%)	ha (%)	ha (%)
Wetland	Wetland Herbaceous	856.8 (3.2%)	12,668.3 (3.5%)	2,976.9 (6.1%)	44,854.8 (6.9%)
	Wetland Shrub	2,222.9 (8.3%)	44,730.3 (12.5%)	4,503.7 (9.3%)	55,337.6 (8.5%)
	Wetland Treed	2,218.9 (8.3%)	46,859.8 (13.1%)	4,771.6 (9.8%)	64,769.1 (9.9%)
	Total	5,298.5 (19.8%)	104,258.6 (29.0%)	12,252.1 (25.2%)	164,961.5 (25.3%)
Water		5,187.5 (19.3%)	28,835.2 (8.0%)	3,792.3 (7.8%)	89,302.6 (13.7%)
No Data		0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	163.9 (<0.1%)
GRAND TOTAL		**26,819.7 (100%)**	**359,038.0 (100%)**	**48,539.9 (100%)**	**616,807.0 (100%)**

Note:

[1] From EOSD NWT (NRCan and GNWT, 2017; K'alo-Stantec, 2022b)



Notes

1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
   World Imagery: Earthstar Geographics
   World Hillshade: Esri, USGS

Land Cover

- Water
- Rock/Rubble
- Exposed Land
- Bryoids
- Shrub - Tall
- Shrub - Low
- Wetland - Treed
- Wetland - Shrub
- Wetland - Herb
- Herb
- Coniferous - Dense
- Coniferous - Open
- Coniferous - Sparse
- Broadleaf - Dense
- Broadleaf - Open
- Mixedwood - Dense
- Mixedwood - Open
- Mixedwood - Sparse
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 8.5 17 Kilometres

(At original document size of 8.5x11)
1:800,000

N

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Project Location
Wrigley to Norman Wells, NWT

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144903025-0035 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.4

Title
Land Cover in the Dehcho Region

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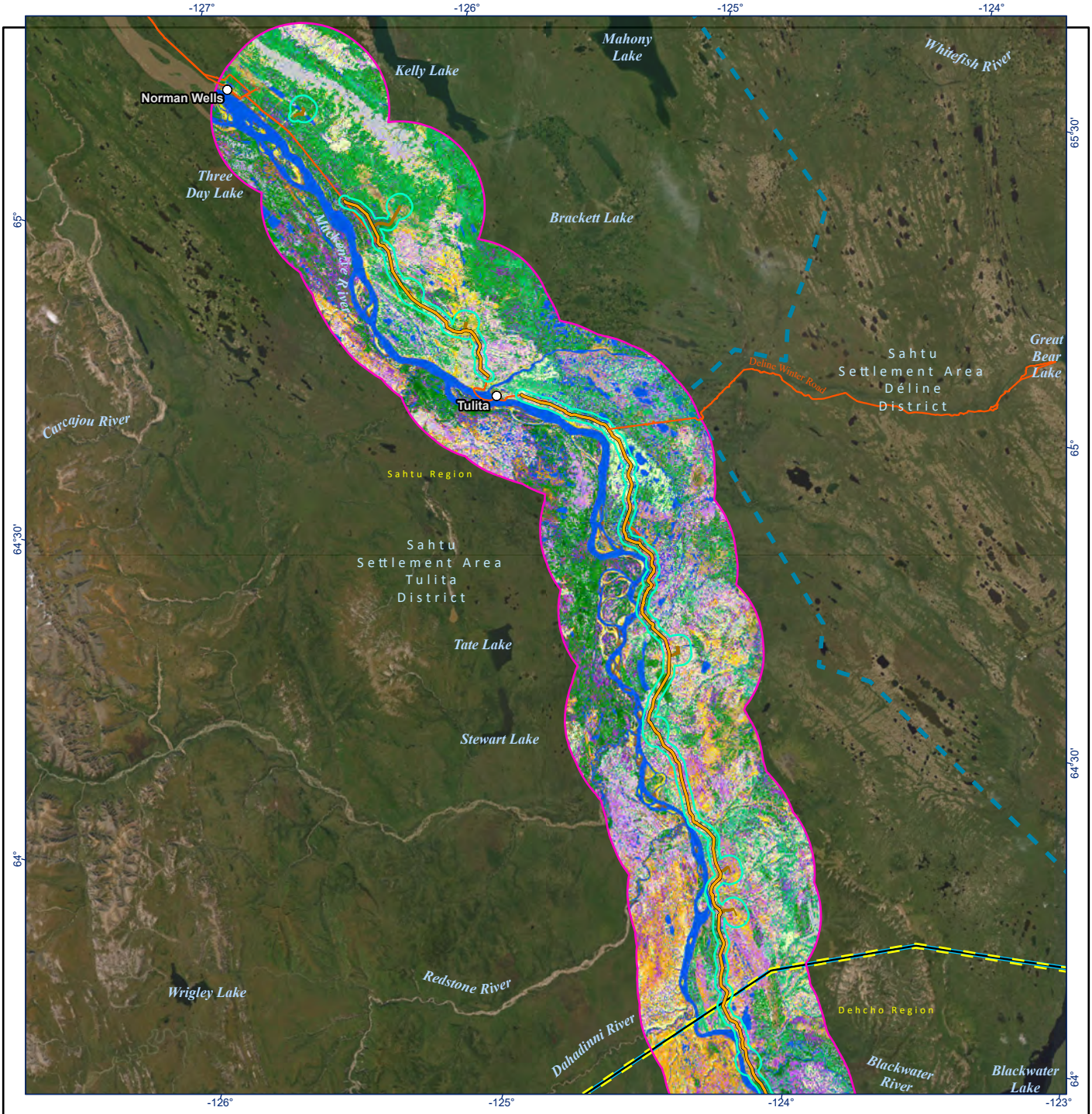

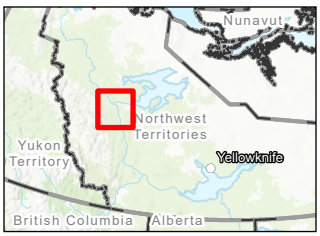

Land Cover

- Water
- Rock/Rubble
- Exposed Land
- Bryoids
- Shrub - Tall
- Shrub - Low
- Wetland - Treed
- Wetland - Shrub
- Wetland - Herb
- Herb
- Coniferous - Dense
- Coniferous - Open
- Coniferous - Sparse
- Broadleaf - Dense
- Broadleaf - Open
- Mixedwood - Dense
- Mixedwood - Open
- Mixedwood - Sparse
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- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

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Project Location
Wrigley to Norman Wells, NWT

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Client/Project
144903025-0036 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.5

Title
Land Cover in the Sahtu Settlement Area

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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Invasive Wildlife Species

The *NWT Species 2016-2020 – General Status Ranks of Wild Species in the Northwest Territories* (Working Group on the General Status of NWT Species, 2016) report identifies 29 invasive alien invertebrate species that inhabit the NT, including 26 beetle species (order Coleoptera), 1 bee species (order Hymenoptera), and 2 moth and butterfly species (order Lepidoptera); however, there are additional species that have yet to be assessed but are also invasive alien species (GNWT n.d.). Some invasive alien species have the potential to threaten ecosystems by altering and degrading native habitats (e.g., forest defoliation).

While there are no mammal or amphibian species that would be considered alien or non-native species that occur within the RSA, there are some mammal species that have exhibited relatively recent range expansion into the RSA. There have been reports suggesting changes to the number and type of prey species that were once absent or uncommon in the RSA, such as white-tailed deer and muskox (Sections 3.1.2.1 and 3.1.2.2; Dehcho First Nation, 2011; GNWT, 2015b). It is believed that the northerly range expansion of white-tailed deer is responsible for the increased number of cougar observations in the Dehcho Region (Section 3.1.2.1; Dehcho First Nation, 2011) but it is not expected to occur within the LSA (GNWT, 2020c; Appendix A, Table A.2).

Wildlife Health

There are several pathogens expected to regularly occur in the RSA that can affect wildlife, including SAR and SOCC. Most pathogens (e.g., lice, ringworm, warbles, winter ticks, liver flukes, trichinosis) typically affect individuals, whereas other pathogens have the potential to result in more significant population effects, particularly in amphibian species (i.e., chytridiomycosis, ranavirus; GNWT, 2017). Many pathogens may be transmitted to people or other animals (e.g., dogs) but, depending on the pathogen, infected individuals are often safe to consume with proper precautions (GNWT, 2017).

The GNWT maintains a chronic wasting disease surveillance program to monitor for the presence of the disease, which affects cervids (e.g., white-tailed deer, moose, caribou), but it has not been detected in any wild species in the NT (GNWT, 2017). White-nose Syndrome is a fungal disease that affects hibernating bat species and can have significant population effects but, to date, the disease has not been detected in the NT (GNWT, 2017; WSNRT, 2021). It is discussed in greater length in Section 3.2.2.5.

Harvested mammals such as beaver, snowshoe hare, and muskox have been shown to have limited environmental contamination because they are lower on the food chain, consuming primarily plants and invertebrates. Therefore, it is not considered a health risk to consume them (GNWT, 2016a, 2016b, 2016c). However, regular consumption of the organs of older muskox is not recommended because contaminants may bioaccumulate in those tissues (GNWT, 2016c).

Wildlife Mortality

Existing wildlife mortality is primarily related to natural predator-prey interactions and by hunting and trapping; there is TK evidence to suggest that both these mortality pathways have changed over time (e.g., reduce trapping activity; Section 3.1.2). While vehicle-related wildlife mortality data is unavailable for the MVWR, it is unlikely to be a notable contributor to mortality because the road has reduced speed limits compared to an all-season road. However, while the MVWR is only open for part of the year, it may provide year-round access opportunities for both predators and humans.

There is no big game outfitting (i.e., commercial guided hunting) in the RSA (GNWT, 2020d).

Important Wildlife Areas

The LSA in the Dehcho Region overlaps two Important Wildlife Areas (IWAs) for beaver and lynx concentration areas, both which include much of the Mackenzie Valley (Table 3.3; Figure 3.6). There is one other IWA for a mineral lick site occurring within the RSA but outside the LSA in the Dehcho Region. The LSA in the Sahtu Region overlaps small portions of the two IWAs describe above for beaver and lynx concentrations above, as well as IWAs for muskox areas, rivers, the Bear Rock formation (Table 3.3), and one additional IWA in the RSA for beaver areas (Willow Lakes Wetlands; Table 3.3; Figure 3.6).

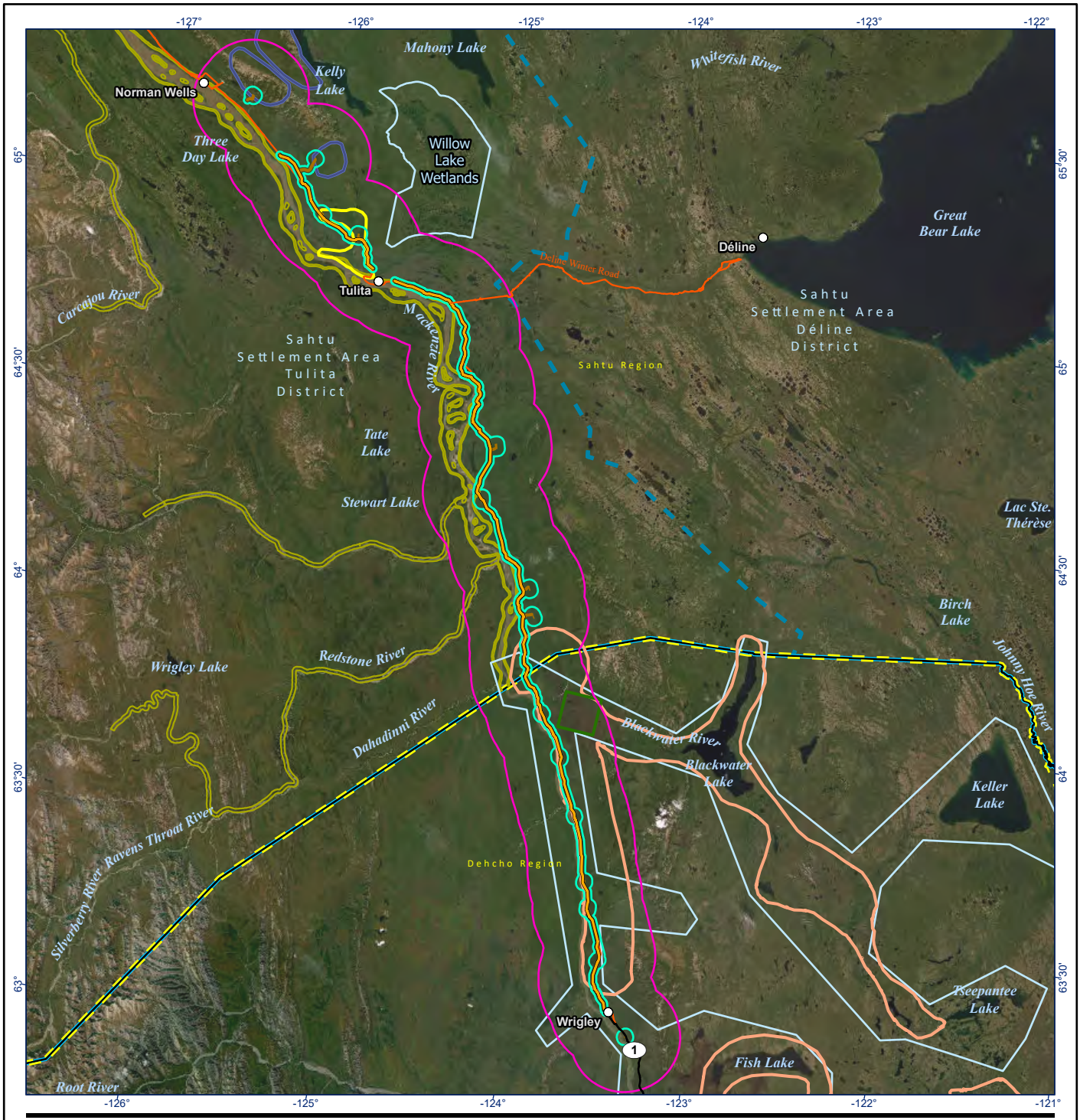
Table 3.3 Important Wildlife Areas in the LSA and RSA for the Dehcho Region and Sahtu Region[1]

Important Wildlife Area	Area within the LSA		Area within the RSA	
	Dehcho Region (ha)	Sahtu Region (ha)	Dehcho Region (ha)	Sahtu Region (ha)
Dehcho beaver concentration areas	26,363.5	1,141.0	184,640.6	7,726.9
Dehcho lynx concentration areas	19,205.6	2,149.5	126,653.2	14,749.9
Mineral lick	-	-	9,884.7	-
Sahtu muskox areas	-	1,999.4	-	28,860.0
Sahtu rivers	-	2,435.6	-	33,125.1
Willow Lake wetlands (beaver)	-	-	-	7,082.9
Bear Rock CZ (culturally sacred site[2])	-	3,143.6	-	13,185.3

Notes:

1 From the GNWT Spatial Data Warehouse Geospatial Portal database (GNWT, 2020a).

2 See Section 3.1.2.2.



Important Wildlife Area
- Bear Rock
- Beaver
- Lynx
- Mineral Lick
- Muskox
- Sahtu River
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres
(At original document size of 8.5x11)
1:1,600,000

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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0045 REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.6

Title
Important Wildlife Areas in the RSA

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
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In general, sensitive wildlife features that wildlife rely on (e.g., mineral licks, overwintering hibernacula, denning sites) are not well documented within the LSA despite information suggesting that the LSA and RSA have the potential to support these features (e.g., mineral licks [see Section 3.1.2.1], overwintering hibernacula [see Section 3.2.2.5]). Additionally, denning sites for American black bear, for example, have the potential to occur in forested habitats within the LSA. There are no notable seasonal wildlife movement patterns for wildlife in the LSA.

There are no known movement corridors or migratory routes for wildlife within the LSA.

3.2.2.2 Mammals

The RSA provides habitat for 42 species of mammal, including 23 rodent and small mammal species (e.g., snowshoe hare [*Lepus americanus*]), 13 carnivore species, 5 ungulate species, and 1 bat species (Appendix A, Table A.2; GNWT, 2020c).

Data suggest that American marten is the most harvested furbearer in both the Dehcho Region and the Sahtu Region (Table 3.4).

Table 3.4 Five-year Average (2017 to 2021) of the Number of Furs and Hides Sold Through the Genuine Mackenzie Valley Fur Program

Common Name	Scientific Name	Average Annual Harvest[1]	
		Dehcho Region	Sahtu Region
Black bear	*Ursus americanus*	1.1	0.3
Gray wolf	*Canis lupus*	3.4	27.1
Muskox (hide)	*Ovibos moschatus*	0.0	2.3
American mink	*Neovison vison*	19.9	14.6
Weasel species	*Mustela* species	26.1	11.7
American marten	*Martes americana*	544.4	902.7
Fisher	*Pekania pennanti*	4.9	0.0
Wolverine	*Gulo gulo*	11.4	16.4
Red fox	-	2.9	19.6
Arctic fox	*Vulpes lagopus*	0.0	8.3
Fox (Cross)	*Vulpes vulpes*	0.4	9.6
Fox (Silver)	-	0.0	3.3
Canada lynx	*Lynx canadensis*	163.3	4.7
Beaver	*Castor canadensis*	117.7	26.3
Muskrat	*Ondatra zibethicus*	23.6	39.6
River otter	*Lontra canadensis*	1.0	0.3
Squirrel species	-	87.4	13.7
Five-year Average Harvest	-	1,007.6	1,100.4
No. of Harvesters	-	80.4	53.2

Note:
[1] Excludes the private sale or trading of furs outside of the GMVFP.

3.2.2.3 Amphibians

The RSA provides habitat for two amphibian species: boreal chorus frog (*Pseudacris maculata*) and wood frog (*Lithobates sylvaticus*; Appendix A, Table A.2; GNWT, 2020c). These species typically occur in or near wetland land cover classes (Table 3.2; Figure 3.4).

3.2.2.4 Invertebrates

The riparian, wetland, and terrestrial habitats in the LSA provide habitat for thousands of invertebrate species. Most invertebrate species play important ecological and economic roles (e.g., pollination) but the number and diversity of species precludes formal assessment and a focus here is placed on SAR and SOCC. The RSA has the potential to provide habitat for three SAR and one SOCC species (Table 3.1) that are discussed in greater detail in Section 3.2.2.5.

3.2.2.5 Species at Risk and Species of Conservation Concern

The RSA is within the range of four mammal SAR (little brown myotis [*Myotis lucifugus*], grizzly bear, wolverine, and boreal caribou [*Rangifer tarandus caribou*]), three invertebrate SAR (gypsy cuckoo bumble bee [*Bombus bohemicus*], yellow-banded bumble bee [*Bombus terricola*], and transverse lady beetle [*Coccinella transversoguttata*]), and one mammal (barren-ground caribou [*Rangifer tarandus groenlandicus*]) and one invertebrate SOCC (Suckley's cuckoo bumble bee [*Bombus suckleyi*] ; Government of Canada, 2021; GNWT, 2020a; Table 3.1). The existing conditions for these species are described in greater detail below. The existing conditions for the caribou species are available in the Caribou and Moose TDR (EDI, 2022).

Little Brown Myotis

Little brown myotis is an aerial insectivore that is federally listed as endangered by SARA (Table 3.1; Government of Canada, 2021), listed as special concern under the *Species at Risk (NWT) Act*, and territorially ranked as at risk (Working Group on the General Status of NWT Species, 2016). Continental bat populations have experienced significant declines, primarily due to the spread of White-nose Syndrome (WNS), a fungal disease that affects hibernating bats and that has resulted in significantly increased mortality rates but has not been detected in the NT (COSEWIC, 2013; GNWT, 2020a; WNSRT, 2021). Other threats to the species include disturbance to, or loss of, overwintering hibernacula, maternal roosting sites, or foraging habitat by anthropogenic activities (e.g., forest harvesting; GNWT, 2020b; CMA, 2020).

Little brown myotis requires different specialized habitats for maternal roosting sites and overwintering hibernacula. Maternal roosting sites include anthropogenic structures or natural features such as tree cavities, which are generally more readily available in the environment, and individuals may travel hundreds of kilometres from overwintering hibernacula to maternal roosting sites for the breeding season (COSEWIC, 2013). Maternal roosting colonies have been documented in both anthropogenic structures (e.g., cabins) and stands of deciduous trees in the NT (Wilson et al., 2014). During the spring, summer, and fall, little brown myotis forage along forest openings, riparian areas, and over waterbodies (COSWEIC, 2013).

Overwintering hibernacula provide prolonged refuge from cold northern winters and are often in limited supply as the internal environmental conditions for hibernacula are relatively restrictive that include natural caves and crevasses and occasionally anthropogenic structures such as abandoned mine shafts or buildings (COSEWIC, 2013; Wilson et al., 2014). There are no known bat hibernacula in the RSA but the relative abundance of karst topography in the NT and presence of known hibernacula outside the RSA (south of Great Slave Lake or in Nahanni National Park Reserve) suggests that hibernacula have the potential to occur within the RSA (Ford, 2009a; CMA, 2020). Additionally, karst features are often remote and there has been relatively little effort to document bat use of those features (Wilson et al., 2014). However, most karst features are generally limited to mountainous areas outside the Mackenzie Valley, such as in the Franklin Mountains and Norman Range, on the eastern edge of the RSA (Ford, 2009b, 2009c). The exception is the Bear Rock formation north of Tulita (i.e., the Bear Rock CZ; see Section 3.1.2.2), which is a notable karst feature in the LSA that has nine documented caves penetrable to 10 m or more (Ford, 2009c) that may provide overwintering habitat for little brown myotis. Additionally, one bat sighting from March 2012 near Tulita was investigated but no landforms suitable for bat hibernation were detected (Critchley and Horne, 2018) but it remains possible for bat hibernacula to exist within the RSA (Wilson et al., 2014; Critchley and Horne, 2018). There are no historical WMIS records for little brown myotis within the LSA or RSA (GNWT, 2020c), but there are reported bat sightings from Wrigley, Tulita, and Norman Wells (CMA, 2020).

Grizzly Bear

Grizzly bear is an omnivorous species that is federally listed as special concern by SARA (Table 3.1; Government of Canada, 2021), is territorially assessed as special concern (SARC, 2017) but has no status under the *Species at Risk (NWT) Act*, and is territorially ranked as sensitive (Working Group on the General Status of NWT Species, 2016). While the species' population is stable to increasing in some areas of the NT, including some northern range expansion, the species generally occurs at low densities throughout the territory with an estimated population of 4,000-5,000 individuals (SARC, 2017). The species' range overlaps the northern portion of the RSA (GNWT, 2020a), where the species is relatively uncommon (Auld and Kershaw, 2005). Threats to grizzly bear in the NT include reduced prey availability (i.e., caribou) and anthropogenic disturbance such as camps and residential and industrial developments that may lead to human-bear conflicts and bear mortality which, combined with their low fecundity rate, results in poor resiliency to population stressors (COSWIC, 2012; SARC, 2017; GNWT, 2020b). The potential for grizzly bear health risks associated with disease or contamination are considered low in the NT (SARC, 2017).

Grizzly bears are habitat generalists, using a wide variety of tundra, alpine, subalpine, and open to semi-forested boreal habitats. Denning site and food availability are key habitat requirements (COSEWIC, 2012; SARC, 2017). Grizzly bears occupy large home ranges (>2,000 km^2) and are sparsely dispersed on the landscape, with densities in NT ranging from 1-20 individuals per 1,000 km^2 (COSEWIC, 2012). Denning sites are sensitive to disturbance and are generally found on well-drained, south-facing slopes where bears may remain in hibernation for over six months (COSEWIC, 2012; SARC, 2017). There are no historical WMIS records for grizzly bear within the LSA or RSA (GNWT, 2020c) and the 2022 aerial bear den survey did not yield any bear den observations (GNWT, 2022b).

The recommended activity restrictions for grizzly bear include a setback of 800 m from general development activities and 1,500 m from blasting activities between October 1 to May 30 (GNWT, 2015a; Appendix A, Table A.1). This is consistent with or more conservative than those presented in the regional land use plans (DLUPC, 2006; SLUPB, 2013).

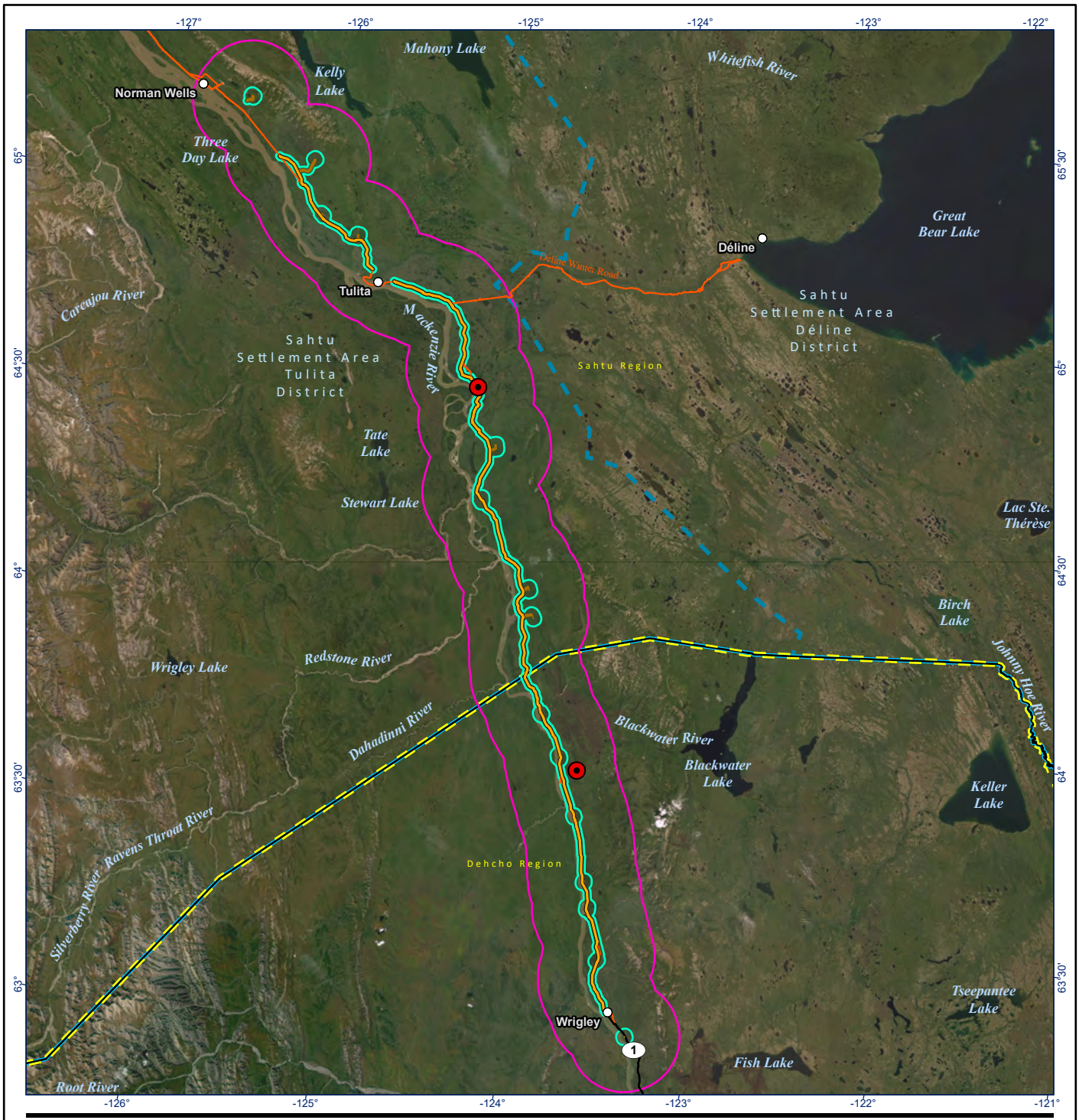
Wolverine

Wolverine is a carnivorous species that is federally listed as special concern by SARA (Table 3.1; Government of Canada, 2021), is territorially assessed as not at risk (SARC, 2014) and has no status under the *Species at Risk (NWT) Act*, and is territorially ranked as sensitive (Working Group on the General Status of NWT Species, 2016). While the species has experienced population declines, primarily in the southern portions of their range in Canada (due in large part to habitat loss and alteration and loss of caribou populations), the species' population has been stable-to=increasing, with reported northward range expansion in the NT (COSEWIC, 2014a; SARC, 2014). The most recent population estimates suggest that there are approximately 3,000-6,000 resident wolverine in NT and an additional 220-470 transient juveniles that may be present in the fall (SARC, 2014). Threats to wolverine in the NT include habitat loss or alteration, maternal den disturbance, and human-related mortality (GNWT, 2020b).

Wolverines are habitat generalists, using a wide variety of boreal and tundra habitats and are typically distributed relative to the availability of a diverse prey base that includes small mammals and large ungulates (e.g., caribou), rather than to the availability of specific habitat types (COSEWIC, 2014a; SARC, 2014). Wolverine occupy large home ranges (50 km^2-1,580 km^2) and are sparsely dispersed on the landscape, with southern arctic ecozone densities ranging from 3.7 to 10.7 individuals per 1,000 km^2 (COSEWIC, 2014a). Denning sites are sensitive to disturbance and are generally found where snow cover persists until late-spring and are generally associated with large boulders or fallen logs in boreal habitats; dens in higher elevations may also be associated with snow tunnels or avalanche debris (COSEWIC, 2014a; SARC, 2014).

There is one historical WMIS observation of wolverine within the LSA from 2019 southeast of Tulita and one observation within the RSA from 2006 north of Wrigley (Figure 3.7). NT produced an average of 107 wolverine pelts between 1992/93 to 2010/11, but because the pelts are valued by Indigenous and local resource users, it is difficult to estimate the number of pelts kept by trappers or sold locally and it is likely that the annual harvest is closer to approximately 200 individuals (COSEWIC, 2014a; GNWT, 2020b). Within the RSA, wolverine harvest is relatively low, with reported annual harvest averages of 6 individuals in the Sahtu Region (Bayha and Snortland, 2002, 2003) and 7 individuals in the Dehcho Region (2000-2005; IMG-Golder Corporation, 2006); however, these values underrepresent actual harvest due to survey participation (SARC, 2014).

The recommended activity restrictions for wolverine include a setback of 800 m from general development activities between October 15 to July 15 (GNWT, 2015a; Appendix A, Table A.1). This is consistent with or more conservative than those presented in the regional land use plans (DLUPC, 2006; SLUPB, 2013).



- Wolverine
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by ZN on 2020-11-19
TR by DR on 2020-11-19

Client/Project
144903025-0046 REVB

Government of Northwest Territories
Mackenzie Valley Highway

Figure No.
3.7

Title
WMIS SAR Observations

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

Invertebrates

Three invertebrate SAR (gypsy cuckoo bumble bee [SARA listed as endangered], yellow-banded bumble bee [SARA listed as special concern], and transverse lady beetle [SARA listed as special concern]), and one SOCC (Suckley's cuckoo bumble bee [COSEWIC listed as threatened]) have the potential to occur throughout the RSA (Table 3.1). Critical habitat for the gypsy cuckoo bumble bee has been identified in the (ECCC, 2022). Areas that contain critical habitat have been identified using a 10 km radius of all known or presumed extant site records. One of the areas that contains critical habitat for gypsy cuckoo bumble bee occurs near Norman Wells, NWT. This critical habitat polygon does not overlap the Project PDA or LSA; however, a portion of critical habitat intersects the RSA near Norman Wells.

Gypsy cuckoo bumble bees are a specialist nest parasite of other bees (*Bombus* spp.). They use a broad range of habitat types including open natural and human-modified habitat features to meet life requisites such as reproduction, foraging, mating and dispersal (ECCC, 2022). Critical habitat has been identified where biophysical features and attributes occur within a critical habitat polygon.

The yellow-banded bumble bee has been territorially assessed as not at risk and the gypsy cuckoo bumble bee has been assessed as data deficient (SARC, 2019). All four invertebrate species have broad distributions in Canada and in western NT and are habitat generalists, occupy a variety of habitats such as meadows, riparian areas, and coniferous forests (COSEWIC, 2014b, 2015, 2016, 2020). There are no historical WMIS records for invertebrate SAR or SOCC within the LSA or RSA (GNWT, 2020c), but collections of Suckley's cuckoo bumble bee have occurred in the RSA near Norman Wells in 1969 (ENR, 2017) and collections of gypsy cuckoo bumble bee, yellow-banded bumble bee, and transverse lady beetle have occurred within the RSA near Norman Wells as recently as 2017 (SARC, 2019).

While habitat conversion may have contributed to bumble bee population declines, primary threats to bees, including in the NT, include pesticide use and pathogen-infected farmed bees (COSEWIC, 2014b, 2015, 2020; GNWT, 2020b). The decline in other bee species has also contributed to the decline of the gypsy cuckoo bumble bee and Suckley's cuckoo bumble bee, which are parasitic species that lay eggs in interspecific bumble bee colonies (COSWIC, 2014a, 2020; GNWT, 2020b). Transverse lady beetle population declines, including in the NT, are thought to be a result of the spread of non-native lady beetles, predation, and the introduction of pathogens (COSEWIC, 2016; GNWT, 2020b).

4 Key Results and Findings

The Project consists of a 281 km all-season highway that largely follows the route of the existing MVWR and includes the construction and operation of temporary and permanent borrow sources. The biophysical characteristics of the LSA are influenced by the Mackenzie River valley that defines the landscape and is dominated by coniferous forest habitats interspersed with wetlands and watercourses. The RSA has the potential to provide habitat for 42 species of mammal, 2 species of amphibian, and a numerous invertebrate species (Appendix A, Table A.2; GNWT, 2020c). The RSA is also within the range of four mammal SAR, two invertebrate SAR, and one mammal and two invertebrate SOCC (GNWT, 2020a, 2020b).

Wildlife habitat in the Dehcho Region portion of the LSA is dominated by coniferous forest (43.6%), wetlands (19.8%), and open water (19.3%), while the LSA that overlaps the Sahtu Region is dominated by coniferous forest (28.7%), wetlands (25.2%), and shrubland (20.6%). Since 1960, 18.5% of the LSA within the Dehcho Region has been subject to forest fire while 75.2% of the LSA within the Sahtu Region has been subject to forest fire.

Other than communities, the Norman Wells Pipeline, and other developments such as borrow sources and quarries, a fibre line, and bridges associated with the MVWR, the LSA and RSA are relatively undisturbed. Oil and gas exploration and production infrastructure in the RSA occurs on the west side of and within the Mackenzie River near Norman Wells (Auld and Kershaw, 2005).

Key results and findings include:

- Many wildlife species are culturally important to local communities (e.g., bears and furbearers), including for trapping (Auld and Kershaw, 2005; DLUPC, 2006; SLUPB, 2013; SRRB, 2021; TRRC, 2022).
- Harvest composition of large mammals in the Sahtu Region is dominated by barren-ground caribou (88%), followed by moose (8%) and woodland caribou (3%) and other species (1%; e.g., muskox; SRRB, 2021).
- The Bear Rock CZ is a large karst formation west of Tulita that is a sacred site and subject to traditional storytelling that also provides habitat for a wide variety of wildlife species (SLUPB, 2013).
- Historical wildlife SAR and SOCC records within the LSA and RSA include observations of little brown myotis, wolverine, and all four invertebrate species.
- The LSA is not expected to provide a notable source of habitat for wildlife SAR and SOCC because these species are widely distributed habitat generalists and occur within the RSA at low densities.

- The LSA is located partly within four IWAs and two are designated as important habitat for beaver and lynx; the others are Sahtu rivers and a culturally sacred site (Bear Rock).
- Sensitive wildlife features that wildlife rely on (e.g., mineral licks, overwintering hibernacula, denning sites) are not well documented within the LSA despite information suggesting that the LSA and RSA have the potential to support these features.

4.1 Additional Studies

It is understood that additional studies are planned to be undertaken to fill the data gaps associated with the limited data availability for sensitive wildlife features in the LSA, including for bear dens and mineral licks prior to Project construction. Additional field-based and TK information will help establish the existing condition and availability of those features within the LSA and support the development of appropriate mitigation measures. The study information will consider the maximum setback distance for the respective feature (GNWT, 2015a; Appendix A, Table A.1).

5 Closure

This TDR was prepared for the sole benefit of GNWT to describe existing conditions related to wildlife and wildlife habitat within the wildlife LSA and RSA. If you have any questions, please do not hesitate to contact the undersigned.

Respectfully submitted,

K'alo-Stantec Limited

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Appendix A Tables

List of Tables

Table A.1 Recommended Activity Restriction Guidelines for Sensitive Wildlife Species[1] A.1
Table A.2 Amphibian and Mammal Species with the Potential to Occupy the Ecoregions in the LSA[1] A.2

Table A.1 Recommended Activity Restriction Guidelines for Sensitive Wildlife Species[1]

Wildlife Species	Feature or Habitat	Specific Conditions	Sensitive Period[2]	Recommended Setback Distance (m)
Ungulates (general)	Mineral/salt lick	General development activities	Year round	1,000
Muskox	Species Presence	Shut down distance if muskox are in the area	Apr 1 – Jun 15	500
Cougar	Den	General development activities	Apr 15 – Jul 15	750
Lynx	Den	General development activities	Apr 1 – Jul 15	250
Grizzly bear, American black bear	Den	If activity is blasting	Oct 1 – May 30	1,500
		General development activities	Oct 1 – May 30	800
	Berry habitat	General development activities when bears are observed foraging	Jul 15 – Sep 15	300
Wolf	Den	General development activities	May 1 – Sep 15	800
Fox	Den	General development activities	May 1 – Jul 15	150
Wolverine	Den	General development activities	Oct 15 – Jul 15	2,000
All other wildlife	Den	Varies with region and species; contact ENR office	Birthing seasons	250

Notes:

1 Modified from DULUPC, 2006, SLUPB, 2013, and GNWT, 2015a

2 Sensitive periods are a general guide and specific timing may vary. Year-round avoidance may not always be feasible, and exceptions will be discussed with NWT Environment and Natural Resources (ENR) to develop appropriate mitigation

Table A.2 Amphibian and Mammal Species with the Potential to Occupy the Ecoregions in the LSA[1]

Group	Common Name	Scientific Name
Amphibians	Boreal chorus frog	*Pseudacris maculata*
	Wood frog	*Lithobates sylvaticus*
Mammals	American black bear	*Ursus americanus*
	Barren-ground caribou	*Rangifer tarandus groenlandicus*
	Boreal caribou	*Rangifer tarandus caribou*
	Grey wolf	*Canis lupus*
	Grizzly bear	*Ursus arctos*
	Moose	*Alces alces*
	Muskox	*Ovibos moschatus*
	White-tailed deer	*Odocoileus virginianus*
	Little brown myotis	*Myotis lucifugus*
	American mink	*Neovison vison*
	Ermine (short-tailed weasel)	*Mustela erminea*
	Least weasel	*Mustela nivalis*
	American marten	*Martes americana*
	Fisher	*Pekania pennanti*
	Wolverine	*Gulo gulo*
	Red fox	*Vulpes vulpes*
	Arctic fox	*Vulpes lagopus*
	Canadian lynx	*Lynx canadensis*
	Coyote	*Canis latrans*
	Red squirrel	*Tamiasciurus hudsonicus*
	Snowshoe hare	*Lepus americanus*
	Beaver	*Castor canadensis*
	Muskrat	*Ondatra zibethicus*
	River otter	*Lontra canadensis*
	American pigmy shrew	*Sorex hoyi*
	Arctic ground squirrel	*Urocitellus parryii*
	Arctic shrew	*Sorex arcticus*
	Bushy-tailed woodrat	*Neotoma cinerea*
	Cinereus shrew	*Sorex cinereus*
	Dusky shrew	*Sorex monticolus*
	Eastern heather vole	*Phenacomys ungava*
	Least chipmunk	*Tamias minimus*

Group	Common Name	Scientific Name
Mammals (cont'd)	Long-tailed vole	*Microtus longicaudus*
	Meadow jumping mouse	*Zapus hudsonius*
	Meadow vole	*Microtus pennsylvanicus*
	Nearctic brown lemming	*Lemmus trimucronatus*
	North American deer mouse	*Peromyscus maniculatus*
	North American porcupine	*Erethizon dorsatum*
	Northern bog lemming	*Synaptomys borealis*
	Northern flying squirrel	*Glaucomys oregonensis*
	Northern red-backed vole	*Myodes rutilus*
	Root vole	*Microtus oeconomus*
	Taiga vole	*Microtus xanthognathus*

Note:

[1] Species within ecoregions 3.3.2.2 North Mackenzie Plain, 3.3.2.3 Norman Range, 3.2.2.11 Central Mackenzie Plain, and 6.1.5.1 Central Mackenzie Valley (GNWT, 2020c).

APPENDIX 19B

Recommended Activity Restriction Guidelines for Sensitive Wildlife Species

Appendix 19B RECOMMENDED ACTIVITY RESTRICTION GUIDELINES FOR SENSITIVE WILDLIFE SPECIES

Table 19B.1 Recommended Activity Restriction Guidelines for Sensitive Wildlife Species[1]

Wildlife Species	Feature or Habitat	Specific Conditions	Sensitive Period / Timing Restriction[2]	Recommended Setback Distance (m)
Ungulates (general)	Mineral/ salt lick	General development activities	Year round	1,000
Muskox	Species Presence	Shut down distance if muskox is in the area	Apr 1 – Jun 15	500
Cougar	Den	General development activities	Apr 15 – Jul 15	750
Lynx	Den	General development activities	Apr 1 – Jul 15	250
Grizzly bear, American black bear	Den	If activity is blasting	Oct 1 – May 30	1,500
		General development activities	Oct 1 – May 30	800
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Wolf	Den	General development activities	May 1 – Sep 15	800
Fox	Den	General development activities	May 1 – Jul 15	150
Wolverine	Den	General development activities	Oct 15 – Jul 15	2,000
All other wildlife	Den	Varies with region and species; contact the GNWT-ECC office	Birthing seasons	250

Notes:

1 Modified from SLUPB (2013) and GNWT (2015); most conservative sensitive period and/or recommended setback distance used.

2 Sensitive periods are a general guide and specific timing may vary. Year-round avoidance may not always be feasible and exceptions will be discussed with the GNWT-ECC to develop appropriate mitigation.

APPENDIX 20A

Birds and Bird Habitat Technical Data Report

Mackenzie Valley Highway Project
Technical Data Report—Birds and Bird Habitat

Prepared for:

Government of the Northwest Territories

Prepared by:

K'alo-Stantec Limited

March 2023

Project No.: 144903025

K'alo-Stantec

Limitations and Sign-off

This document entitled Mackenzie Valley Highway Project Technical Data Report—Birds and Bird Habitat was prepared by K'alo-Stantec Limited ("K'alo-Stantec") for the account of Government of Northwest Territories (the "Client") to support the regulatory review process for its Developers Assessment Report (DAR) (the "Application") for the Mackenzie Valley Highway Project (the "Project"). In connection therewith, this document may be reviewed and used by the Department of Infrastructure (INF) for the Government of Northwest Territories participating in the review process in the normal course of its duties. Except as set forth in the previous sentence, any reliance on this document by any other party or use of it for any other purpose is strictly prohibited. The material in it reflects K'alo-Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between K'alo-Stantec and the Client. The information and conclusions in the document are based on the conditions existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, K'alo-Stantec did not verify information supplied to it by the Client or others, unless expressly stated otherwise in the document. Any use which another party makes of this document is the responsibility and risk of such party. Such party agrees that K'alo-Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other party as a result of decisions made or actions taken based on this document.

Prepared by _____ Digitally signed by Ebner, Derek Date: 2023.06.23 13:25:25 -04'00'
(signature)

Derek Ebner, *on behalf of*
Daniel Routhier, M.Sc.
Senior Wildlife Biologist

Reviewed by _____ Digitally signed by Ebner, Derek Date: 2023.06.23 13:25:36 -04'00'
(signature)

Derek Ebner, B.Sc., M.Sc., P.Biol.
Principal, Environmental Services

Approved by _____ Digitally signed by Bonhomme, Erica
(signature)

Erica Bonhomme, M.Sc., P.Geo.
Principal, Environmental Services

Executive Summary

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells to replace the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT).

The Regional Study Area (RSA), which is a 15 km buffer of the Project has the potential to provide habitat for 213 bird species, including 85 waterbird species, 5 upland gamebird species, 19 bird of prey species, and 104 landbird species. The RSA is also within the breeding range of 10 bird species at risk (SAR) and 2 bird species of conservation concern (SOCC). There are historical records for 11 of the 12 species within the RSA and Local Study Area (LSA), which is a 1 km buffer of the Project. The LSA is not expected to provide a key source of habitat for bird SAR and SOCC when compared to other areas in the RSA or NT as a whole, because these species are generally widely distributed and/or at the northern edge of their range. Data availability is limited for some SAR and targeted surveys for SAR most likely to interact with the Project are planned to be undertaken to fill this remaining data gap.

The biophysical characteristics of the LSA are influenced by the Mackenzie River valley that defines the landscape and is dominated by coniferous forest habitats interspersed with wetlands and watercourses. Land cover in the Dehcho Region portion of the LSA is dominated by coniferous forest (43.6%), wetlands (19.8%), and open water (19.3%), while the LSA that overlaps the Sahtu Region is dominated by coniferous forest (28.7%), wetlands (25.2%), and shrubland (20.6%). Since 1960, 18.5% of the LSA within the Dehcho Region while 75.2% of the LSA within the Sahtu Region has been subject to forest fire.

Along with the existing MVWR and communities along it (e.g., Hamlet of Tulita), the LSA contains disturbances from oil and gas exploration and production infrastructure, borrow sources and quarries, a fibre line, and bridges associated with the MVWR. Notably, the Norman Wells Pipeline, commissioned in 1985, conveys crude oil from Norman Wells south to Alberta and is located in the LSA. The RSA is relatively undisturbed, but oil and gas exploration and production infrastructure does exist on the west side of the Mackenzie River near Norman Wells.

Many bird species are culturally important to local communities (e.g., birds of prey) and for subsistence hunting (e.g., waterbirds, upland gamebirds).

The LSA is partially within the Middle Mackenzie River Important Bird Area (IBA) that provides a significant source of staging and migration habitat for migratory birds, especially waterfowl and other waterbirds. The Brackett Lake IBA provides a similarly significant source of habitat, and is located in the RSA, outside the LSA. Other sensitive wildlife features for birds are nest locations, primarily for raptors, that are located throughout the LSA and RSA. Notable concentrations of raptor nests exist in the Bear Rock Conservation Zone, west of Tulita, which is also a culturally sacred site.

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APPENDIX A TABLES

Abbreviations

ATV	all-terrain vehicle
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CZ	Conservation Zone
DLUP	Dehcho Land Use Plan
ECCC	Environment and Climate Change Canada
EOSD NWT	Earth Observation of Sustainable Development of Forests Northwest Territories
GNWT	Government of the Northwest Territories
ha	hectare
IBA	Important Bird Area
INF	Department of Infrastructure
IWA	Important Wildlife Area
KM	kilometre marker
km	kilometre
LSA	local study area
m	metre
MVH	Mackenzie Valley Highway
MVWR	Mackenzie Valley Winter Road
NT	Northwest Territories
PDA	project development area
RSA	regional study area
SAR	species at risk
SARA	Species at Risk Act
SMZ	Special Management Zone
SLUP	Sahtu Land Use Plan
SOCC	species of conservation concern
TDR	Technical Data Report
TK	traditional knowledge
TLRU	traditional land and resource use

the Project	Mackenzie Valley Highway Project
WMIS	Wildlife Management Information System

1 Introduction

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells to replace the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT; Figure 1.1).

The Project is subject to an environmental assessment and the requirements of Part 5 of the *Mackenzie Valley Resource Management Act*. This Technical Data Report (TDR) presents the existing conditions for the Birds and Bird Habitat valued component to support development of the Developer's Assessment Report, as required by the Terms of Reference (MVEIRB, 2015). As part of the environmental assessment process, the Developer's Assessment Report will present the GNWT's assessment of effects of the Project on the environment.

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Settlement Area Boundary
- Region Boundary
- Territorial Boundary

0 40 80 Kilometres

(At original document size of 8.5x11)
1:4,500,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/8/2023
TR by AJ on 3/8/2023

Client/Project
144903025-0031 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
1.1

Title
MVH Project Overview

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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2 Study Areas

The Project is in the Mackenzie Valley region of the NT between the current terminus of the existing all-weather highway in Wrigley (Highway #1, kilometre marker [KM] 690) and Prohibition Creek (located approximately 28 km southeast of Norman Wells). The Project alignment parallels the Mackenzie River to its east and passes through the community of Tulita (KM 938 of the MVWR). The Mackenzie Valley region has the potential to provide breeding habitat for hundreds of bird species and important staging habitat for more northern migratory species.

The local study area (LSA) and regional study area (RSA) used in this TDR are areas where data was collected to characterize the existing environmental conditions for birds and bird habitat in support of the Project-specific effects assessment and the cumulative effects assessment (Figure 2.1).

2.1 Project Development Area

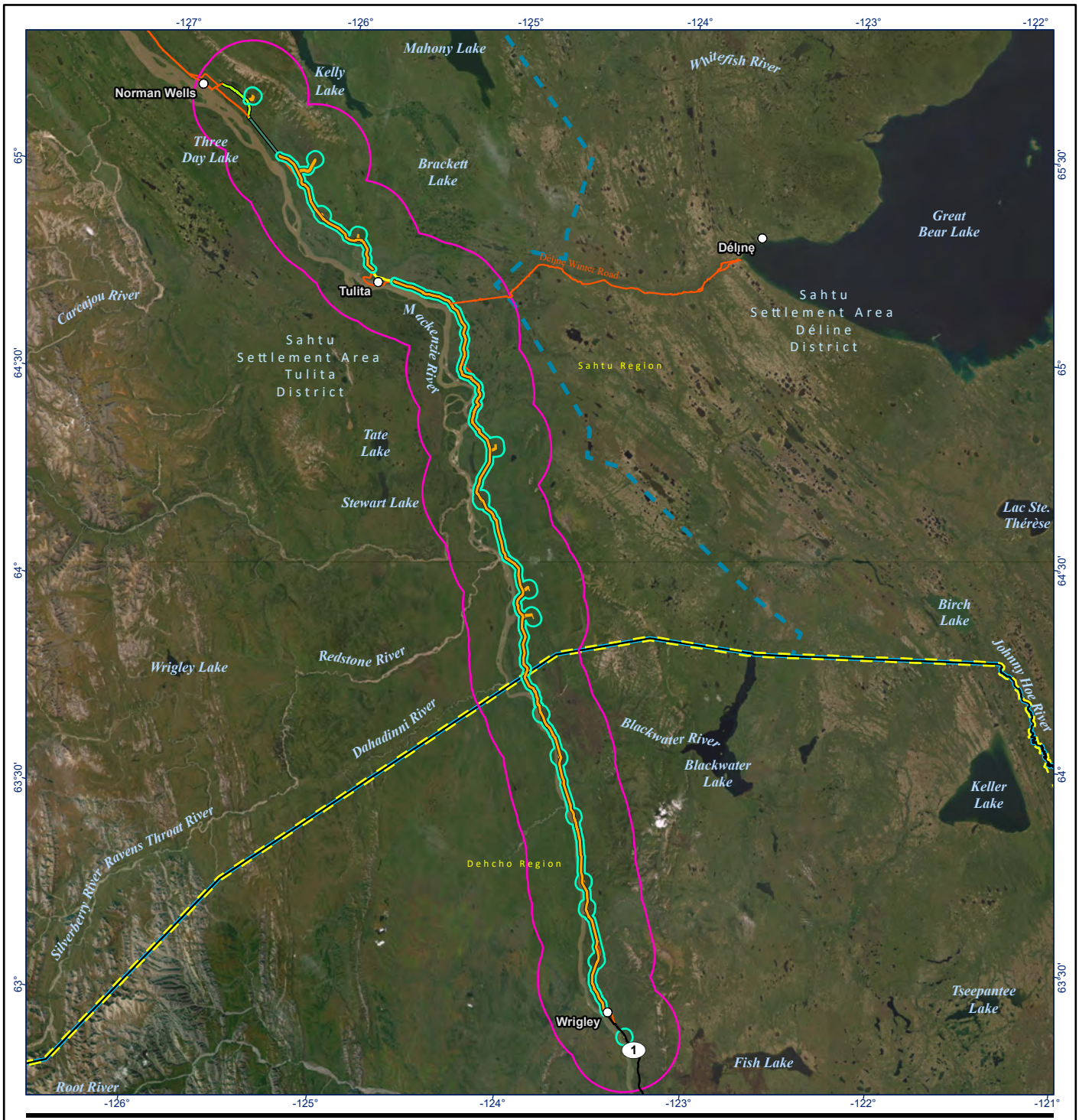
The Project Development Area (PDA) is the area of direct Project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 metre (m) wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps and quarry/borrow sites with access roads on a 30 m ROW.

2.2 Local Study Area

The LSA is a 1 km buffer around the highway alignment component of the Project (i.e., centreline), except around quarries where the LSA increases to a 2 km buffer around the PDA. The size of the buffer is based on measurable effects on migratory birds (e.g., songbirds and waterbirds; Benitez-Lopez et al., 2010; Shannon et al., 2016) while also considering recommended setback distances from bird habitat features (Appendix A, Table A.1; GNWT, 2015a). The size of the LSA is also consistent with guidance provided by Environment and Climate Change Canada (ECCC; Dufour, 2020, pers. comm.).

2.3 Regional Study Area

The RSA is a 15 km buffer around the proposed road alignment that is used to capture a wide range of wildlife species and wildlife habitats that could potentially be affected cumulatively by the Project and other past, present, and reasonably foreseeable projects. This is consistent with other highway projects in the NT (e.g., Inuvik to Tuktoyaktuk Highway [Kiggiak - EBA Consulting Ltd., 2011]) and follows recommendations from ECCC (Dufour, 2020, pers. comm.).



- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (Permitted)
- Proposed Great Bear River Bridge
- Local Assessment Area
- Regional Assessment Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,600,000

N

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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/8/2023
TR by AJ on 3/8/2023

Client/Project
144903025-0030 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
2.1

Title
Wildlife and Wildlife Habitat Study Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS. Imagery date: 2021

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3 Review of Existing Data

The TDR was developed to address the Project Terms of Reference (MVEIRB, 2015) using a literature review of currently available information.

A review of existing traditional knowledge (TK) and traditional land and resource use (TLRU; Section 3.1) and review of relevant literature for birds (Section 3.2) was completed. Results are used to characterize the existing conditions for birds and bird habitat within the LSA and RSA.

An overview characterizing the bird community is provided by general species groups (waterbirds, upland game birds, raptors, and landbirds) and there is an emphasis on species at risk (SAR) and species of conservation concern (SOCC; defined in Section 3.2.2.1).

3.1 Traditional Knowledge and Traditional Land and Resource Use

Available TK and TLRU contributed to the description of existing conditions for birds and bird habitat, particularly as it relates to harvested species, species of cultural importance, and the presence of sensitive habitat features in the RSA.

3.1.1 Methods

Existing TK and TLRU information were obtained through several sources, including land use planning documents and regional research projects for the two administrative regions traversed by the Project: the Dehcho Region and the Sahtu Region. An overview of the key TK and TLRU resources used to assist in characterizing the existing condition for birds and bird habitat are presented below.

- ***Respect for the Land: the Dehcho Land Use Plan – Draft (DLUP)*****:** Guidance document that incorporates the cultural, social, and economic factors relating to the management and conservation of natural resources as it relates to development projects within the Dehcho Region (DLUPC, 2006).
- ***A Spatial Analysis and Literature Review of Wildlife and Wildlife Habitat in the Dehcho Territory***: A spatial representation of the current knowledge of wildlife and wildlife habitat within the Dehcho Region (EBA Engineering Consultants, 2003).
- ***Project Description Report for the Dehcho Region:*** A preliminary screening document summarizing baseline environmental information, including for migratory birds and SAR/SOCC, as it relates to the Project in the Dehcho Region (Dessau, 2012).
- ***Tulita Renewable Resources Council Traditional Land and Resource Use Study for Tulita District Mackenzie Highway Project 2022:*** Report prepared for MVH Project to describe Traditional Land and Resource use within the Tulita District (TRRC, 2022).
- ***Sahtu Land Use Plan (SLUP)*****:** A document guiding how natural resources will be conserved and developed in the Sahtu Region (SLUPB, 2013).

- ***The Sahtu Atlas – Maps and Stories from the Sahtu Settlement Area in Canada's Northwest Territories:*** A document containing historical TK and TU information from the Sahtu Region (Auld and Kershaw, 2005).
- ***Final Report of the Sahtu Harvest Study:*** A survey of Sahtu Dene and Métis hunters that reported wildlife harvest activities in the Sahtu Region between 1998 and 2005 (SRRB, 2021).
- ***Sahtu Dene and Métis Comprehensive Land Claim Agreement:*** A document outlining the species and areas subject to preferential or exclusive rights for Indigenous Peoples of the Sahtu Region (INAC, 1993).
- ***Project Description Report for the Sahtu Region:*** A preliminary screening document summarizing baseline environmental information, including for migratory birds and SAR/SOCC, as it relates to the proposed Project in the Sahtu Region (5658 NWT Ltd. and GNWT, 2011).
- **Other TK and TLRU Resources:** Documents that provided information on the historical or existing condition for birds and bird habitat:
  - *Rakekée Gok'é Godi: Places We Take Care Of* (SHPSJWG, 2000).
  - *Draft Report on Renewable Resource Assessment of the Pehdzeh Ndeh Area of Interest* (IMG-Golder Corporation, 2006).
  - *Traditional Knowledge Study Report Tulita, NT, Great Bear River Bridge* (EBA Engineering Consultants, 2006).
  - *Traditional Knowledge Study for the Great Bear River Bridge Project* (TRRC, 2019).

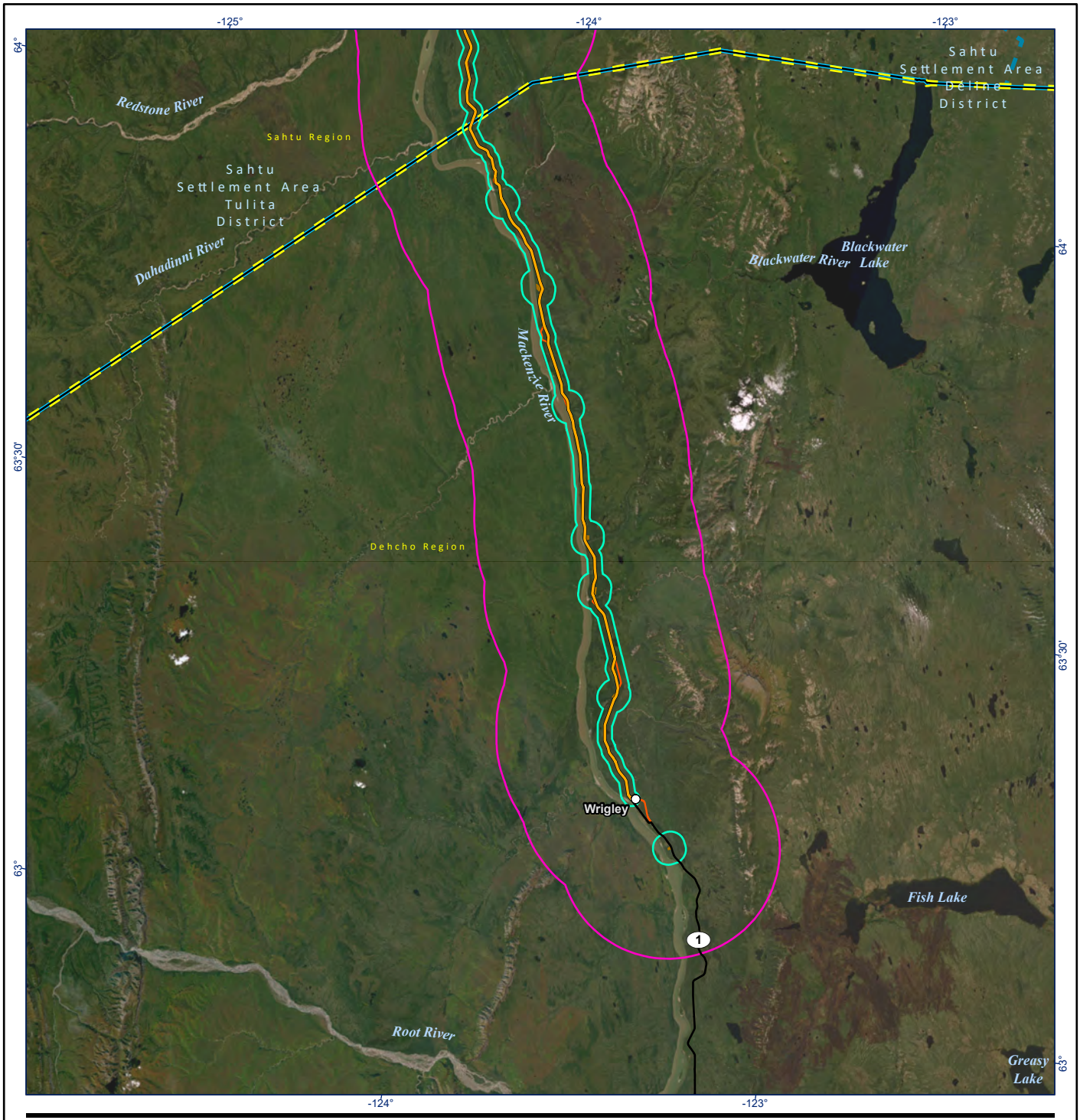
3.1.2 Results

The results are presented by their respective region and are consistent with information summarized in the Cultural and Traditional Land Use TDR (K'alo-Stantec, 2022a).

3.1.2.1 Dehcho Region

The Project traverses approximately 102 km of the Dehcho Region and includes 26,819.7 hectares (ha) of land within the LSA and 359,038.0 ha within the RSA (Figure 3.1).

The DLUP focuses on protecting Dene culture and traditional land use (e.g., hunting, trapping) as the highest priority. Dehcho First Nation members seek to maintain existing TLRU opportunities within the territory (DLUPC, 2006). The DLUP identified areas that have significant ecological and cultural values (DLUPC, 2006) and provides habitat for a wide variety of wildlife species, including migratory birds (Desseau, 2012). The Project also traverses the proposed Mackenzie Valley Special Infrastructure Corridor, which has been approved for infrastructure development (primarily the previously proposed Mackenzie Valley Pipeline).



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0 8.5 17 Kilometres

(At original document size of 8.5x11)
1:800,000

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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/8/2023
TR by AJ on 3/8/2023

Client/Project
144903025-0032 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.1

Title
Project Overview within the Dehcho Region

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
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The DLUP also provides guidance for critical lifecycle periods for several sensitive bird species. The activity restrictions presented in Appendix A, Table A.1 are consistent with or more conservative than those proposed in the DLUP.

There is no land claim agreement in the Dehcho Region and, thus, there are no species or areas subject to preferential or exclusive rights for Indigenous Peoples of the region.

Wetlands and watercourses have been identified as being an important resource for waterfowl in the region and ducks, geese, and swans are harvested by local resource users (Desseau, 2012). Wildlife is a key renewable resource and subsistence harvesting is an important food resource among residents (IMG-Golder Corporation, 2011; also see the Cultural and Traditional Land Use TDR [K'alo-Stantec, 2022a]). The Blackwater River system between Blackwater Lake and the Mackenzie River is an important hunting area for ducks, geese, and swans (Desseau, 2012).

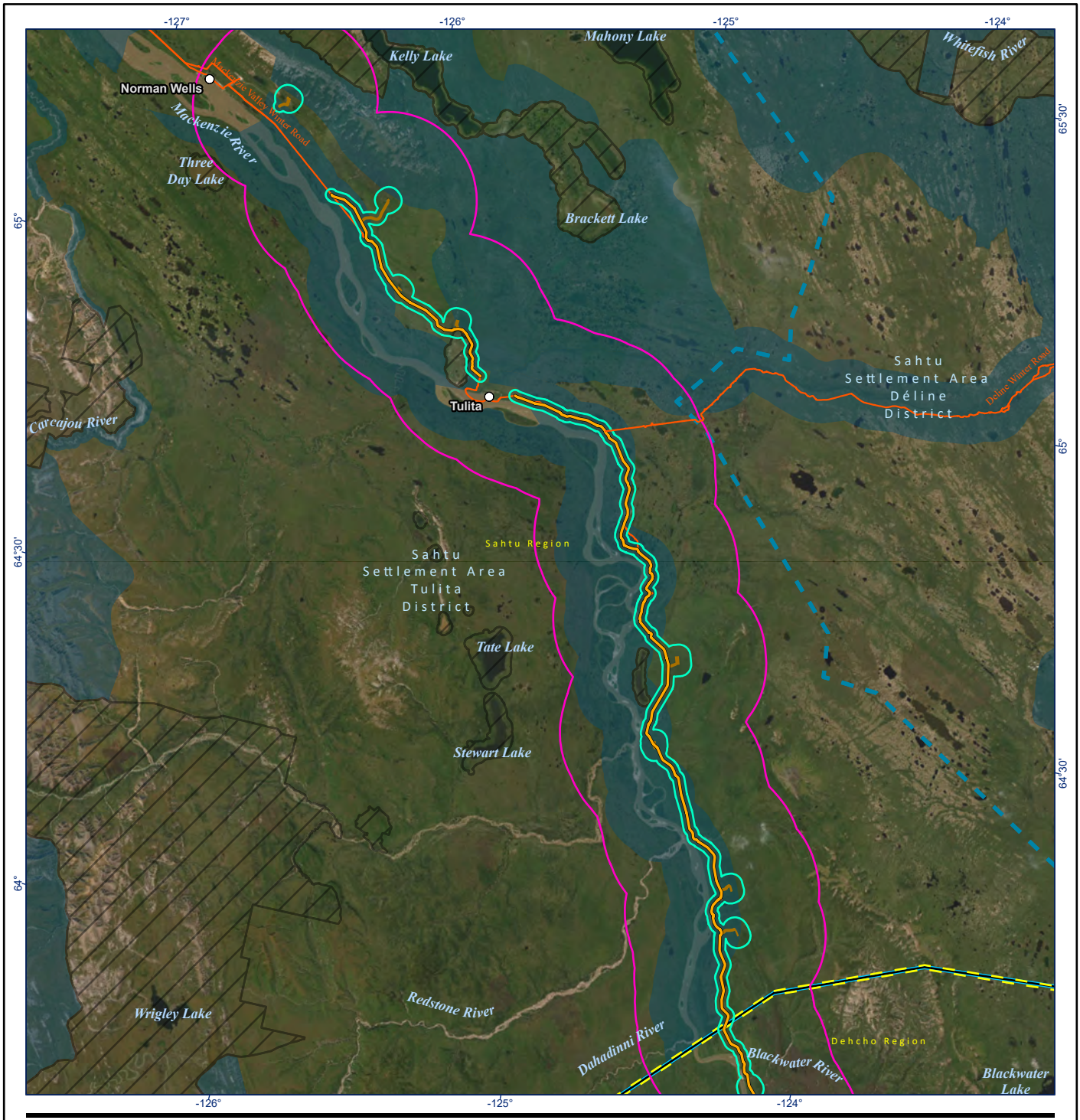
3.1.2.2 Sahtu Settlement Area

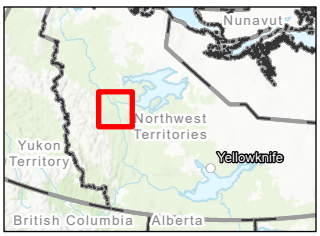
The Project traverses 179 km of the Sahtu Region and includes 48,539.9 ha of land within the LSA and 616,807.0 ha within the RSA (Figure 3.2).

The SLUP focuses on maintaining and/or enhancing ecological and cultural integrity while increasing the decision-making capacity and economic self-sufficiency of the community through sustainable development of natural resources (SLUBP, 2013). A key component of the SLUP is the protection and conservation of species of interest (i.e., species of cultural, conservation, or subsistence importance) and their habitats, and includes recommended activity restriction guidelines for sensitive species. The activity restrictions presented in Appendix A, Table A.1 are consistent with or more conservative than those presented in the SLUP.

The Project primarily traverses through the Deh Cho (Mackenzie River) SMZ No. 63 of the SLUP (2.2% of Sahtu Region) that is an area designated to protect the water quality, riparian habitat, cultural/heritage sites, and areas that are important for wildlife and wildlife harvesting (SHPSJWG, 2000; SLUPB, 2013). The SMZ allows for the continued use of the areas as a riverine and territorial transportation corridor (e.g., barge traffic, MVWR). Bulk water removal is the only prohibited land use.

The Bear Rock CZ (No. 32), approximately 4 km northwest of Tulita, is a culturally sacred site located within the LSA (SLUBP, 2013). The CZ is a large karst formation subject to traditional storytelling and provides habitat for a wide variety of wildlife species (see Section 3.2.2.1), including nesting raptors (SHPSJWG, 2000; EBA Engineering Consultants, 2003; SLUBP, 2013).





- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area

Sahtu Land Use Plan Zoning

- Conservation Zone
- Special Management Zone

- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,000,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/8/2023
TR by AJ on 3/8/2023

Client/Project
144903025-0033 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.2

Title
Project Overview within the Sahtu Settlement Area

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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The Mackenzie Valley is along an important migratory route in the Central Flyway, a path used by a large number of birds migrating between northern breeding grounds and southern overwintering grounds. The RSA contains the northernmost waterfowl banding station at Willow Lake that is jointly operated by the United States Fish and Wildlife Service, the Tulita Renewable Resources Council and the GNWT Department of Environment and Natural Resources (Auld and Kershaw, 2005; SRRB, 2020). The station is within the Brackett Lake Important Bird Area (IBA; IBA Canada, 2020a) and has been in operation since 1995 (25 years), with the primary objective of capturing and banding mallard (*Anas platyrhynchos*) and northern pintail (*Anas acuta*; SRRB, 2020).

Bird species occuring within the RSA that are important to members of the Sahtu Region for subsistence and cultural reasons include Canada goose (*Branta canadensis*), tundra swan (*Cygnus columbianus*), snow goose (*Anser caerulescens*), loon (*Gavia* species), sandhill crane (*Grus canadensis*), peregrine falcon (*Falco peregrinus anatum/tundrius*), short-eared owl (*Asio flammeus*), ptarmigan (*Lagopus* species), common raven (*Corvus corax*), and Canada (gray) jay (*Perisoreus canadensis*; Auld and Kershaw, 2005).

The Sahtu Dene and Métis Comprehensive Land Claim Agreement provides Indigenous Peoples the right to harvest bird species, excluding migratory non-gamebirds and migratory insectivorous birds as defined in the *Migratory Birds Convention Act*, within the settlement area at all seasons of the year (subject to limitations within the Agreement; INAC, 1993). There are no Special Harvest Areas within the LSA, but there are three Special Harvest Areas within the RSA; all are islands in the Mackenzie River (IAAC, 1993).

Important areas for birds and bird hunting are typically associated with wetlands and watercourses, including the Mackenzie River and Great Bear River (SHPSJWG, 2000). Four Mile Island south of Tulita has been identified as an area used for hunting during the migration season (EBA Engineering Consultants, 2006) and, according to interviews with Sahtu harvesters, upland gamebirds can be found around Tulita (EBA Engineering Consultants, 2006; TRRC, 2019). The area around Brackett Lake and wetlands nearby support large populations of animals and the oral tradition records many stories that tell of the importance of this lake (SHPSJWG, 2000).

Harvest composition of birds in the Sahtu Region is dominated by Canada goose (34%), followed by mallard (18%), grouse and ptarmigan species (17%), and other duck (17%) and goose (13%) species (SRRB, 2021).

Through the Project-specific engagement program, participants indicated:

- Concern that construction and operation of the Project will disturb (physical and sensory disturbance) wildlife year-round, including during blasting.
- Concern how the Project will affect result in greater boat traffic (and disturbance) on the Mackenzie River.
- Concern that the Project will facilitate the introduction of invasive species.
- There typically no wildlife collisions on the MVWR and most motorists will give wildlife the right of way, but this should be included in Project monitoring.

- Concern that the Project will increase hunting pressure by non-resident hunters and wildlife need to be protected.
- Communities are interested in collaborating with GNWT to address uncertainties around monitoring relating to harvest monitoring and stewardship based on Dene laws, for example.
- Climate change affects food security and many people will fish if wildlife moves away and this should be monitored.

Recent TLRU information (TRRC, 2022) indicates that:

- Many types of wildlife are harvested within the LSA.
- Ptarmigans are harvested within the LSA.
- There is a travel and migration route for waterfowl overhead of the Bear River Bridge.
- There are fewer waterfowl migrating in the LSA due to changes in weather that effect the ability to undertake TLRU.
- Waterfowl are harvested year-round in the LSA, particularly in spring.
- Changes observed in waterfowl health have affected waterfowl harvesting within the LSA.
- There are different species of birds in the LSA that affect undertaking TLRU.
- Geese and ducks are typically harvested in the spring (April, May, June).
- Plants and wildlife are still needed to undertake TLRU (e.g., food and hides for personal use).
- Hunting occurs along the shores of Bear River year-round and camping and fishing during the summer.
- Signage should be used to promote highway access and to protect wildlife in the area and help mitigate potential Project effects.
- Upland gamebirds are harvested in the summer, especially along the pipeline by Four Mile Creek during the winter.
- Country food is an important part of community residents' diet and is shared among the community, family members, and friends in all seasons (particularly during spring and winter). The community relies on it and is in constant need of wildlife/country foods for sustenance.
- The MVWR and pipeline ROW has affected valued resources.
- Harvesting and hunting within the LSA are accessed mostly during the wintertime.
- Previous road construction and operation has made it easier to access valued resources.

3.2 Literature Review

A literature review was used to establish the existing condition for birds and bird habitat and identify the presence of sensitive features and SAR and SOCC in the RSA.

3.2.1 Methods

Background information was obtained through several sources, including maps and photographs, territorial and federal databases and guidance documents, and not-for-profit publications and data sources. An overview of some of the key resources used during background review to assist in characterizing the existing condition for birds and bird habitat is presented below.

- **Maps and photographs:** Topographic mapping and orthographic aerial imagery were used to help identify watercourses, lakes and/or wetlands, and to provide an overall indication of site topography (Digital Globe, 2019).
- **Species at risk public registry:** An online database containing the status of species assessed and listed under the federal *Species at Risk Act* (SARA) and by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and associated documentation including assessment and status reports, recovery strategies and critical habitat designations, and management strategies (Government of Canada, 2021a).
- **GNWT Spatial Data Warehouse Geospatial Portal database:** Online databases used, in part, for screening resource development projects in NT. The databases include information such as SAR ranges and important wildlife areas (e.g., raptor nesting areas; GNWT, 2020a).
- **GNWT Species at Risk in the Northwest Territories:** A biennial publication outlining the status and distribution of territorially and federally assessed and listed SAR in NT (GNWT, 2020b).
- **GNWT Species 2016-2020 – General Status Ranks of Wild Species in Northwest Territories:** An overview of the status of the flora and fauna of NT (Working Group on the General Status of NWT Species, 2016).
- **GNWT Wildlife Management Information System (WMIS):** A territorial geo-referenced wildlife database for historical wildlife records (GNWT, 2020c).
- **Important Wildlife Areas in the Western Northwest Territories:** A report outlining the location of known important wildlife areas to help guide development and resource management (Wilson and Haas, 2012).
- **North American Breeding Bird Survey databases:** Data from annual surveys of breeding birds in North American used to monitor trends in species abundance and distribution (Pardieck et al., 2019; Smith et al., 2019) were used to identify potential SAR in the study areas and assess local population trends.
- **IBA Canada:** A national database describing the location and characteristics of important bird areas in Canada (IBA Canada, 2020b).

- **eBird:** A database of locational data for bird species within the RSA (including from past projects [e.g., Mackenzie Valley Pipeline Project]; eBird, 2021).
- **ECCC breeding bird survey data:** A dataset of breeding bird observations from 118 locations along the existing MVWR (i.e., within the LSA) and within the RSA using two survey methods (ECCC, 2020a):
  - Autonomous recording unit surveys completed at 53 locations (50 in the LSA) in 2017, primarily along the existing winter road, using multiple 3-minute listening periods over several days between June 1-30. Automated audio recognizers were used to identify common nighthawk and olive-sided flycatcher at all sites and yellow rail at six sites where preferred habitat was present. The data was also summarized to identify the presence, habitat associations, and relative abundance of breeding migratory birds within the LSA.
  - In-field surveys completed by human observers at 65 locations (34 in the LSA) in 2004 and 2006 using a single 10-minute point count survey method. Clustered sampling with point count locations 100-150 m apart. Data was examined for SAR/SOCC detections and used to characterize the breeding bird community.
- **GNWT aerial raptor survey data**: The Department of Environment and Natural Resources completed an aerial raptor survey within 1.5 km of the winter road in the Sahtu region in 2021 to identify raptor stick nests and sensitive breeding habitats that may interact with the Project (GNWT, 2021).

3.2.1.1 Species at Risk and Species of Conservation Concern

SAR are species listed as special concern, threatened, or endangered under the *Species at Risk (NWT) Act* (GNWT, 2020b) or under Schedule 1 of the federal SARA (Government of Canada, 2021a), and SOCC are species assessed as special concern, threatened, or endangered by the NWT Species at Risk Committee (SARC; GNWT, 2020b) or COSEWIC (Government of Canada, 2021a).

3.2.1.2 Habitat Identification

Land cover within the LSA and RSA was quantified using Earth Observation of Sustainable Development of Forests Northwest Territories (EOSD NWT) geospatial data (NRCan and GNWT, 2017). This dataset is part of the Multi-source Vegetation Inventory Project (Natural Resources Canada, 2020) and uses an unsupervised classification and cluster analysis to classify land cover.

The EOSD NWT dataset includes cover type and density classes and forest structure height and volume information based on Landsat imagery collected from 2007 to 2013. Mapping was done at a scale of 1:250,000 and was refined through field evaluation by the GNWT (NRCan and GNWT, 2017). Detailed land cover classification methods for this Project are discussed in the Vegetation and Wetlands TDR (K'alo-Stantec, 2022b).

3.2.2 Results

Results indicate that 213 bird species have the potential to occur in the RSA (Appendix A, Table A.2; GNWT, 2020c), including 12 SAR/SOCC. The results for birds and bird habitat are presented in greater detail by taxonomic grouping, with an emphasis placed on harvested species and species of regulatory and/or conservation importance:

- **Waterbirds** – 85 species of waterfowl (e.g., ducks, geese [family *Anatidae*]), waterbirds (e.g., grebes [family Podicipedidae], loons [family *Gaviidae*]), and shorebirds (e.g., sandpipers [family *Scolopacidae*], terns [family *Sterninae*])
- **Upland gamebirds** – five species of grouse and ptarmigan (family *Phasianidae*)
- **Birds of prey** – 19 species of raptors (e.g., eagles, hawks [family *Accipitridae*]) and owls (family *Strigidae*)
- **Landbirds** – 104 species of passerines (e.g., warbler [family *Parulidae*], sparrows [family *Passerellidae*]) and near-passerines (e.g., woodpeckers [family *Picidae*])
- **SAR and SOCC** – federally and territorially assessed and listed species (see Section 3.2.1.1 and Table 3.1)

Table 3.1 Bird Species at Risk and Species of Conservation Concern (*) with Potential to Occur in the Regional Study Area

Species		Status in NT[1]		Status in Canada[2]	
Common Name	**Scientific Name**	**SARC Assessment**	**SAR (NWT) Act**	**COSEWIC**	**SARA**
Peregrine falcon	*Falco peregrinus anatum/tundrius*	Not Assessed	No Status	Not at Risk	Special Concern◊
Yellow rail	*Coturnicops noveboracensis*	Not Applicable	Not Applicable	Special Concern	Special Concern
Lesser yellowlegs*	*Tringa flavipes*	Not Applicable	Not Applicable	Threatened	Not Listed◊
Red-necked phalarope	*Phalaropus lobatus*	Not Applicable	Not Applicable	Special Concern	Special Concern
Short-eared owl	*Asio flammeus*	Not Assessed	No Status	Threatened	Special Concern◊
Common nighthawk	*Chordeiles minor*	Not Applicable	Not Applicable	Special Concern	Threatened◊
Olive-sided flycatcher	*Contopus cooperi*	Not Applicable	Not Applicable	Special Concern	Threatened◊
Bank swallow	*Riparia riparia*	Not Applicable	Not Applicable	Threatened	Threatened
Barn swallow	*Hirundo rustica*	Not Applicable	Not Applicable	Special Concern	Threatened◊
Harris's sparrow*	*Zonotrichia querula*	Not Applicable	Not Applicable	Special Concern	Not Listed◊

Species		Status in NT[1]		Status in Canada[2]	
Common Name	**Scientific Name**	**SARC Assessment**	**SAR (NWT) Act**	**COSEWIC**	**SARA**
Rusty blackbird	*Euphagus carolinus*	Not Assessed	No Status	Special Concern	Special Concern
Horned grebe	*Podiceps auritus*	Not Applicable	Not Applicable	Special Concern	Special Concern

Notes:

1 Species at risk in NT assessed by SARC and listed under the territorial *Species at Risk (NWT) Act* (GNWT, 2020b). Not applicable: *Species at Risk* (NWT) *Act* does not apply to this species (GNWT, 2020a)

2 Species at risk in Canada assessed by COSEWIC and listed under Schedule 1 the federal *Species at Risk Act* (Government of Canada, 2021a)

* Species of conservation concern

◊ Under consideration for Schedule 1 status change

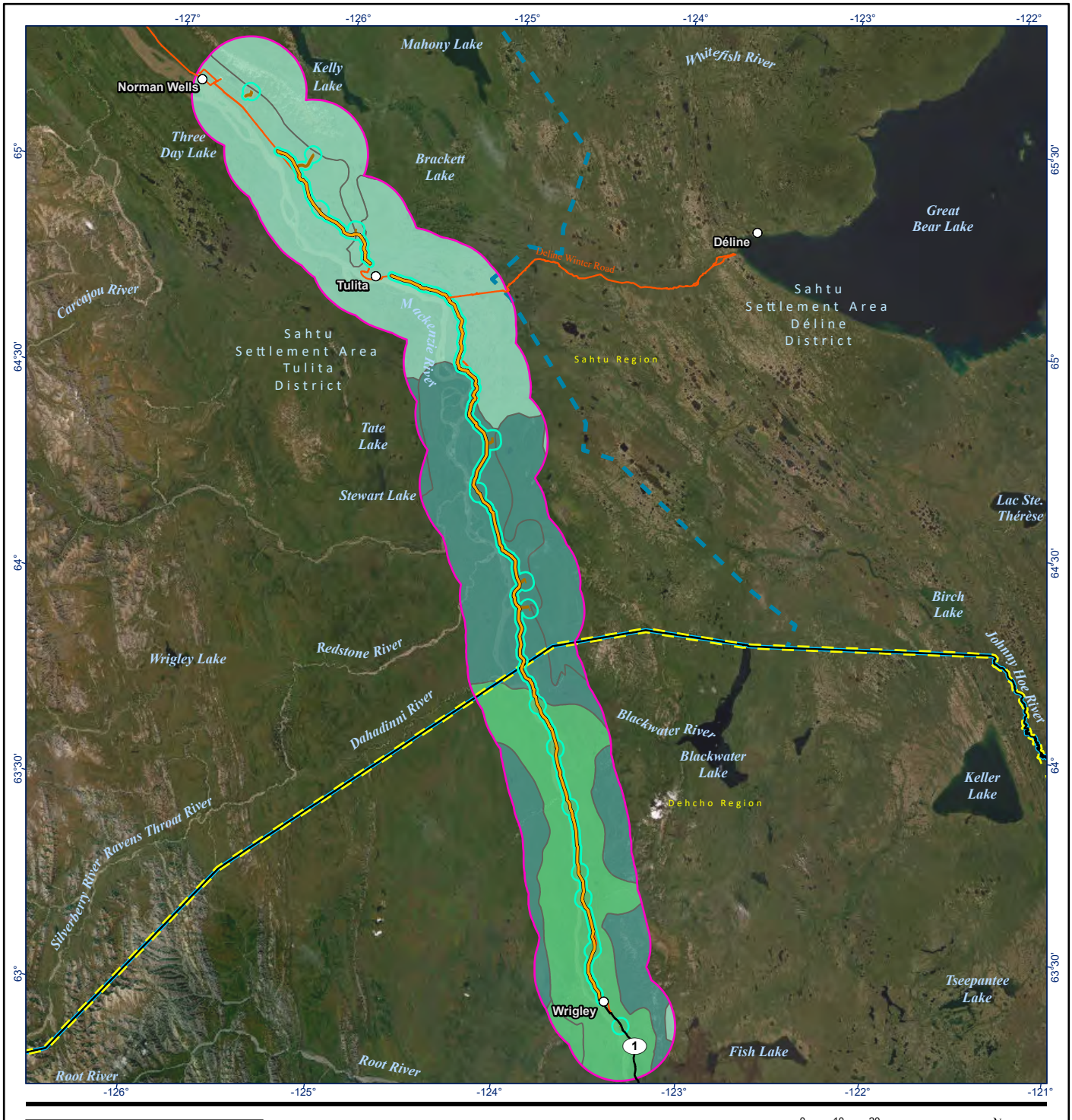
3.2.2.1 Overview

Bird Habitat

The Project is within the Mackenzie River valley (Mackenzie Valley), a landscape dominated by the Mackenzie River, known as the Deh Cho (meaning Big River) by local Dene First Nations, which is the longest river in Canada (1,738 km) spanning from Great Slave Lake to the Beaufort Sea. The Mackenzie River is a defining feature on the western Canadian landscape and the river basin, at 1.8 million km^2 which is approximately 20% of Canada's landmass, is the second largest in North America, second only to the Mississippi River basin (MRBB, 2020).

The LSA is located primarily within the Mackenzie River valley plain and characterized by relatively subdued topographical relief that gives rise to the Mackenzie Mountains to the west and the Franklin Mountains to the east. Within the Mackenzie Valley, the LSA traverses the Boreal and Taiga Cordillera Ecoregions (Central Makenzie Valley and Central Mackenzie Plains subregions [Level IV]; ECG, 2010) in the south and the Taiga Plains Ecoregion (North Mackenzie Plains Low Subarctic and Norman Range Low Subarctic subregions [Level IV]; ECG, 2007) in the north (Figure 3.3). The Norman Range Low Subarctic subregion, traversed by the Project in a small area, is the only area of notable topographical relief along the LSA and contains the Bear Rock massif, a rock formation rising 400 metres (m) above the Mackenzie River and extending east to join the Franklin Mountains.

Land cover in the Dehcho Region portion of the LSA (26,819.7 ha) is dominated by coniferous forest (43.6%), wetlands (19.8%), and open water (19.3%; e.g., the Mackenzie River; Table 3.2; Figure 3.4), while the LSA that overlaps the Sahtu Region (48,539.9 ha) is dominated by coniferous forest (28.7%), wetlands (25.2%), and shrubland (20.6%; Table 3.2; Figure 3.5). Forest fires within the Dehcho Region have been relatively uncommon and comparably smaller than in the Sahtu Region. From 1960 to 2019 fires within the LSA have burned a total of 4,956.7 ha (18.5%) of land cover in the Dehcho Region and 36,521.7 ha (75.2%) of land cover in the Sahtu Region. However, forest fire prevalence within the RSA has been similar in the Dehcho Region (50.8%) and Region (52.8%).



Level III Ecoregion

- Boreal Cordillera, High Boreal
- Taiga Cordillera, Low Subarctic
- Taiga Plains, Low Subarctic
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access

- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0034 REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.3

Title
Ecoregions

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
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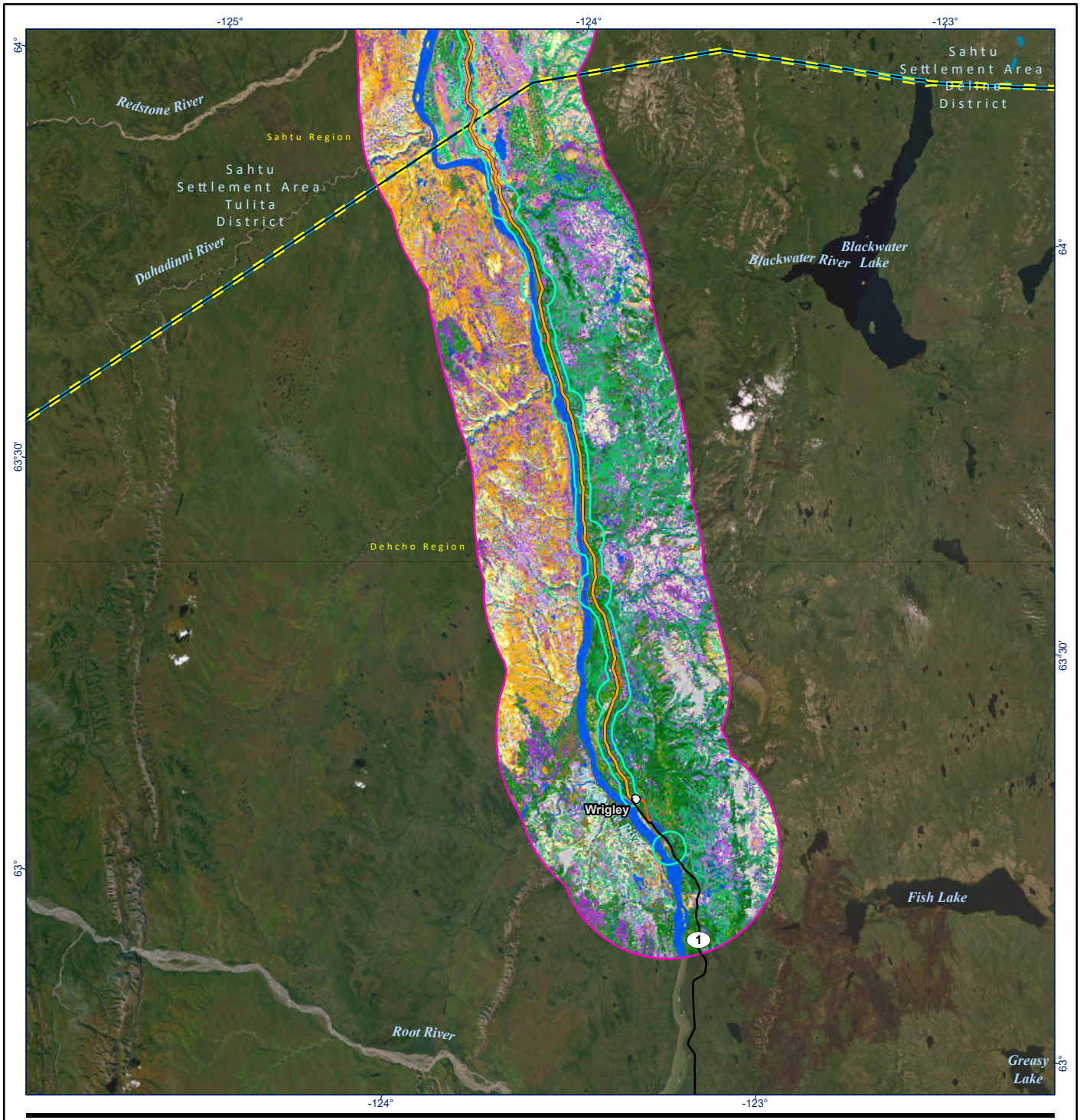
Table 3.2 Land Cover Classes in the LSA and RSA for the Dehcho Region and Sahtu Region

Land Cover Category	Land Cover Class[1]	Dehcho Region		Sahtu Region	
		LSA	RSA	LSA	RSA
		ha (%)	ha (%)	ha (%)	ha (%)
Upland	Broadleaf Dense	1,037.4 (3.9%)	43,781.3 (12.2%)	2,253.1 (5.2%)	34,259.4 (5.3%)
	Broadleaf Open	114.8 (0.4%)	4,154.7 (1.2%)	1,103.9 (2.3%)	14,627.9 (2.2%)
	Broadleaf Sparse	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
	Coniferous Dense	3,374.9 (12.6%)	25,120.5 (7.0%)	917.8 (1.9%)	18,580.5 (2.9%)
	Coniferous Open	4,600.6 (17.2%)	40,034.2 (11.2%)	6,678.1 (13.8%)	113,316.2 (17.4%)
	Coniferous Sparse	3,725.0 (13.9%)	51,491.5 (14.3%)	6,332.6 (13.0%)	71,845.9 (11.0%)
	Mixedwood Dense	1,035.1 (3.9%)	6,786.9 (1.9%)	387.3 (0.8%)	7,494.4 (1.1%)
	Mixedwood Open	117.1 (0.4%)	2,728.5 (0.8%)	2,514.0 (5.2%)	23,834.7 (3.7%)
	Mixedwood Sparse	0.0 (0.0%)	0.0 (0.0%)	6.3 (<0.1%)	11.7 (<0.1%)
	Shrub Low	567.4 (2.1%)	39,005.2 (10.9%)	7,903.4 (16.3%)	72,607.6 (11.1%)
	Shrub Tall	320.6 (1.2%)	1,616.4 (0.5%)	2,091.3 (4.3%)	16,525.8 (2.5%)
	Herbaceous	50.6 (0.2%)	1,300.1 (0.3%)	210.9 (0.4%)	4,093.2 (0.6%)
	Bryoids	7.0 (<0.1%)	20.4 (<0.1%)	6.2 (<0.1%)	137.0 (<0.1%)
	Rock/Rubble	45.1 (0.2%)	4,916.4 (1.4%)	107.3 (0.2%)	10, 285.3 (1.6%)
	Exposed Land	1,338.0 (5.0%)	4,862.2 (1.4%)	1,713.2 (3.5%)	9,897.9 (1.5%)
	Total	16,333.6 (60.9%)	225,848.3 (62.9%)	32,495.5 (66.9%)	397,517.4 (61.0%)

Land Cover Category	Land Cover Class[1]	Dehcho Region		Sahtu Region	
		LSA	RSA	LSA	RSA
		ha (%)	ha (%)	ha (%)	ha (%)
Wetland	Wetland Herbaceous	856.8 (3.2%)	12,668.3 (3.5%)	2,976.9 (6.1%)	44,854.8 (6.9%)
	Wetland Shrub	2,222.9 (8.3%)	44,730.3 (12.5%)	4,503.7 (9.3%)	55,337.6 (8.5%)
	Wetland Treed	2,218.9 (8.3%)	46,859.8 (13.1%)	4,771.6 (9.8%)	64,769.1 (9.9%)
	Total	5,298.5 (19.8%)	104,258.6 (29.0%)	12,252.1 (25.2%)	164,961.5 (25.3%)
Water		5,187.5 (19.3%)	28,835.2 (8.0%)	3,792.3 (7.8%)	89,302.6 (13.7%)
No Data		0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	163.9 (<0.1%)
GRAND TOTAL		**26,819.7 (100%)**	**359,038.0 (100%)**	**48,539.9 (100%)**	**616,807.0 (100%)**

Note:

[1] From EOSD NWT (NRCan and GNWT, 2017; K'alo-Stantec, 2022b)



Notes

1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
   World Imagery: Earthstar Geographics
   World Hillshade: Esri, USGS

Land Cover

- Water
- Rock/Rubble
- Exposed Land
- Bryoids
- Shrub - Tall
- Shrub - Low
- Wetland - Treed
- Wetland - Shrub
- Wetland - Herb
- Herb
- Coniferous - Dense
- Coniferous - Open
- Coniferous - Sparse
- Broadleaf - Dense
- Broadleaf - Open
- Mixedwood - Dense
- Mixedwood - Open
- Mixedwood - Sparse
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
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0 8.5 17 Kilometres

(At original document size of 8.5x11)
1:800,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

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TR by AJ on 3/8/2023

Client/Project
144903025-0035 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.4

Title
Land Cover in the Dehcho Region

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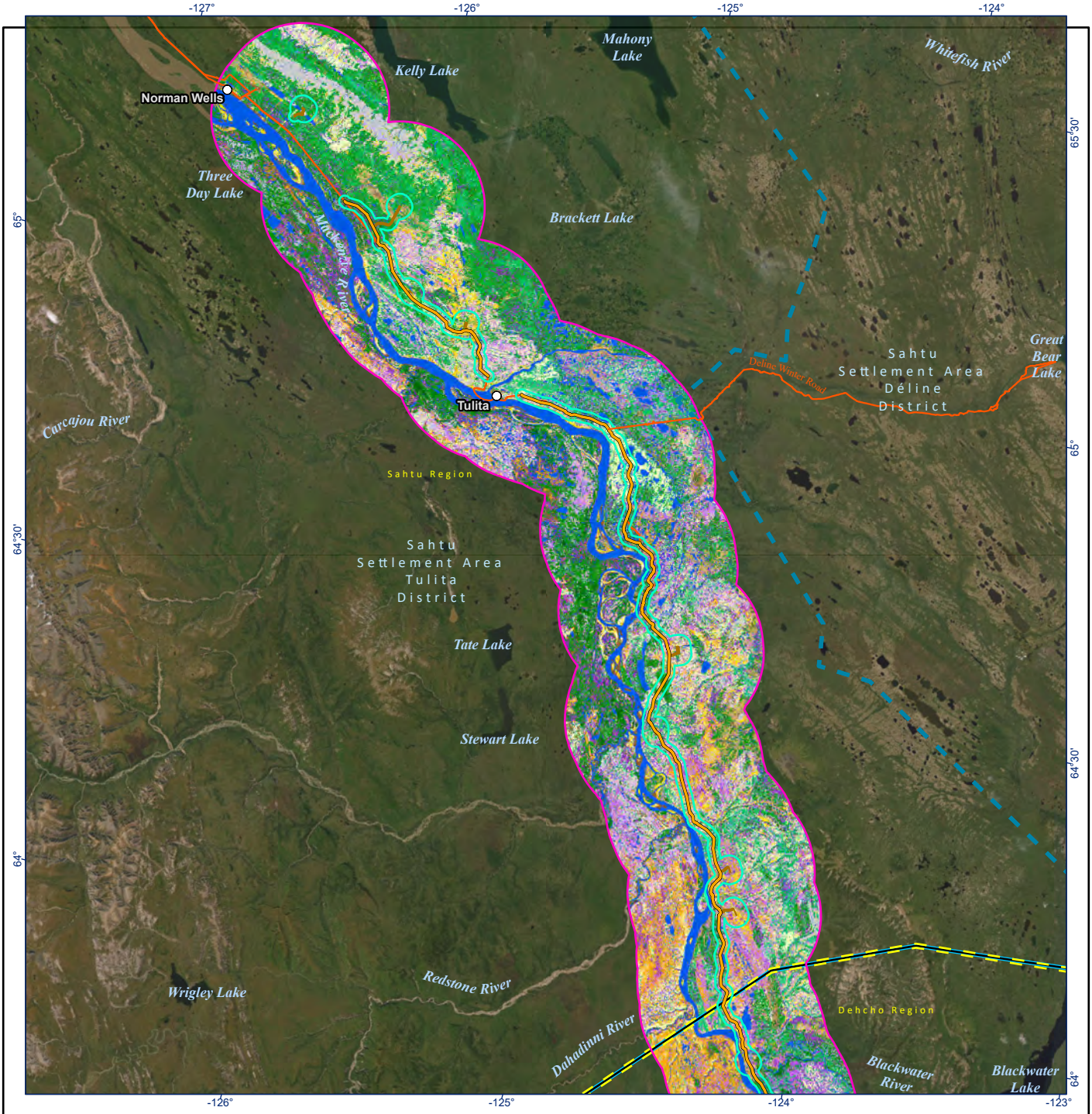

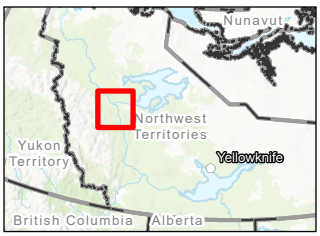

Land Cover

- Water
- Rock/Rubble
- Exposed Land
- Bryoids
- Shrub - Tall
- Shrub - Low
- Wetland - Treed
- Wetland - Shrub
- Wetland - Herb
- Herb
- Coniferous - Dense
- Coniferous - Open
- Coniferous - Sparse
- Broadleaf - Dense
- Broadleaf - Open
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0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,050,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/8/2023
TR by AJ on 3/8/2023

Client/Project
144903025-0036 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.5

Title
Land Cover in the Sahtu Settlement Area

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
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The Mackenzie Valley is situated within the Central Flyway which has long been known to provide a corridor and staging habitat for birds migrating to and from all areas of North America (Cooke, 1915). The RSA overlaps two IBAs that primarily provide important habitat for breeding and migrating waterbirds (IBA Canada, 2020b; Figure 3.6) and are discussed in greater detail in Section 3.2.2.2.

The LSA traverses the Bear Rock CZ (3,143.6 ha; RSA: 13,185.3 ha), a rock formation rising 400 m above the Mackenzie River and extending east to join the Franklin Mountains (Figure 3.6). It is an important nesting area for raptors and is a culturally sacred site (Section 3.1.2.2).

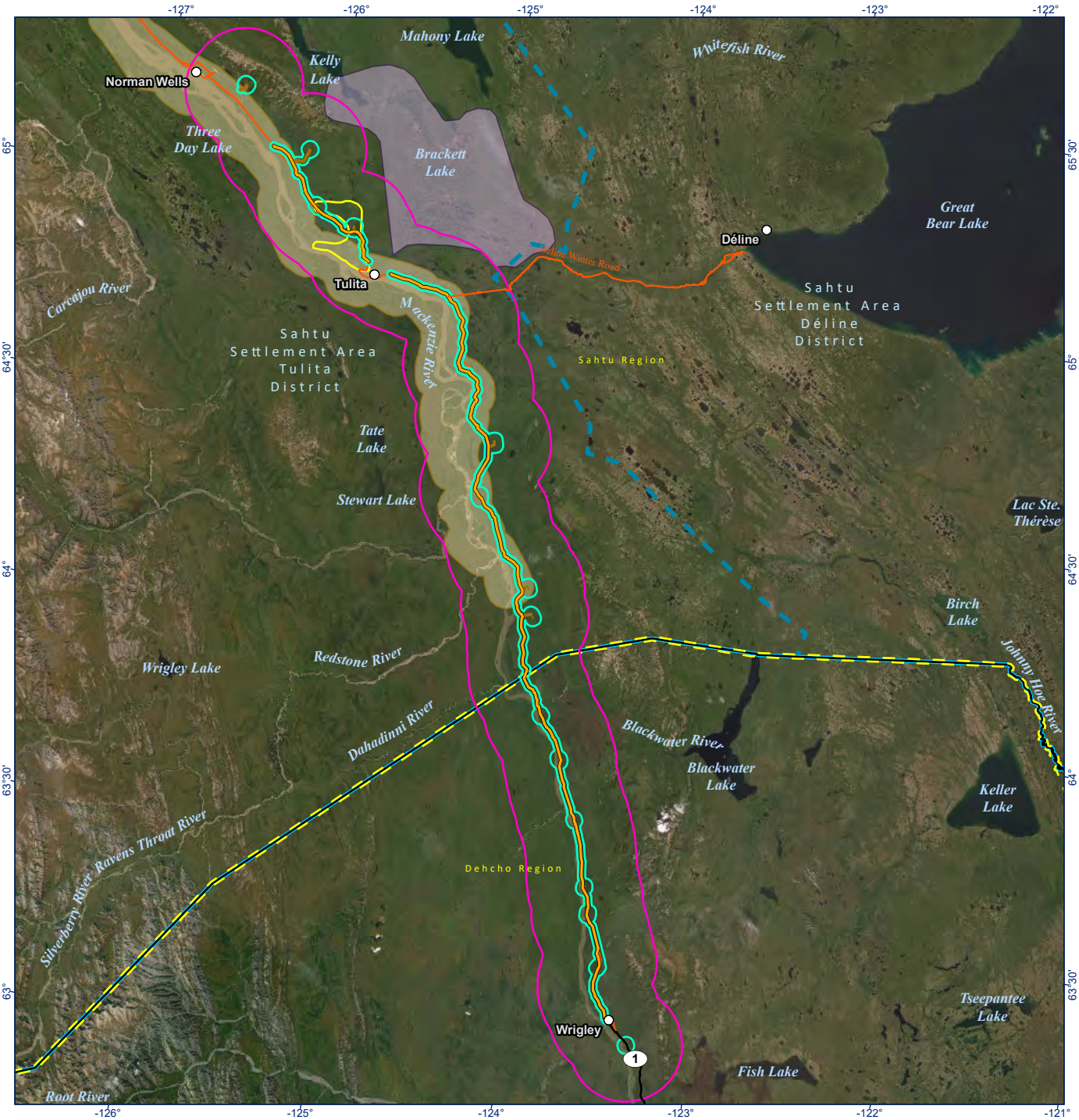
Habitat Disturbance

Except for the existing MVWR and communities along it (e.g., Hamlet of Tulita), the LSA contains disturbances from oil and gas exploration and production infrastructure. Notably, the Norman Wells Pipeline, which conveys crude oil from Norman Wells south to Alberta and is located in the LSA of the Dehcho Region and Sahtu Region. The RSA is relatively undisturbed, but oil and gas exploration and production infrastructure exists on the west side of the Mackenzie River near Norman Wells. Other existing disturbances include borrow sources and quarries, a fibre line, and bridges associated with the MVWR. The Project is in migratory bird nesting zone B8 with a regional nesting period from early-May to late-August (ECCC, 2018a).

The primary nesting period (when >95% of nesting occurs) is May 15 to August 7 for wetland habitat species, May 16 to August 10 for open habitat species, and May 15 to August 8 for forested habitat species (ECCC, 2018a). Raptors typically breed outside the primary nesting periods described above, and, while the critical breeding period for raptors varies by species (see Section 3.2.2.4), their breeding period extends between the first week in April to the second week of September (Shank and Poole, 2016).

Invasive Bird Species

Rock pigeon (*Columba livia*), European starling (*Sturnus vulgaris*), and house sparrow (*Passer domesticus*) are alien / non-native species (i.e., introduced from outside North America) that occur within the LSA (GNWT, 2015b, Working Group on the General Status of NWT Species, 2016; eBird, 2021), but breeding habitats for these species are associated with anthropogenic habitats such as residential areas (Cabe, 2020; Lowther and Cink, 2020; Lowther and Johnson, 2020). However, their presence in these areas may affect native bird species in these altered habitats. Particularly, European starlings aggressively compete for nesting cavities (Cabe, 2020).



Important Widlife Area
- Bear Rock

Important Bird Area
- Brackett Lake
- Mackenzie Middle River Islands

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0037 REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.6

Title
Important Bird & Wildlife Areas in the RSA

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
4. Bird Studies Canada. 2015. Important Bird Areas of Canada Database. Port Rowan, Ontario: Bird Studies Canada. http://www.ibacanada.org

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Bird Health

There are several pathogens expected to regularly occur in the RSA that can affect birds, including SAR and SOCC, including lice, ringworm, aspergillosis, tuberculosis, and avian pox (GNWT, 2017). However, most pathogens typically affect individuals without affecting populations and infected individuals may still be safe to consume depending on the pathogen (GNWT, 2017).

Except for waterfowl and upland gamebirds (see Sections 3.2.2.2 and 3.2.2.3, respectively), there is little information on the health of migratory birds in NT as it relates to environmental contamination. Health risks associated with contamination are most likely to be highest in aquatic habitats where deleterious substances have entered the environment and would affect bird species, including SAR and SOCC, that inhabit or forage in aquatic habitats. Like waterfowl and upland gamebirds, contamination risks to other bird species are generally low because they are generally lower on the food chain and consume primarily plants and invertebrates (GNWT, 2016a, 2016b). However, birds of prey may be at higher risk given that they are higher on the food chain and consume other vertebrates (e.g., fish, small mammals).

Bird Mortality

Existing bird mortality as it relates to harvested waterfowl and upland gamebird species is provided in Sections 3.2.2.2 and 3.2.2.3, respectively. For other bird species, including SAR and SOCC, mortality is primarily related to natural predator-prey interactions with other bird species or with mammal species. While vehicle-related bird mortality data is unavailable for the MVWR, it is unlikely to be a notable contributor to mortality because the road has reduced speed limits compared to an all-season road. Additionally, many migratory bird species will have migrated out of the LSA before the MVWR opens in early winter and have yet to return once the road closes in the spring.

3.2.2.2 Waterbirds

The RSA provides breeding and staging habitat for 85 species of wetland and water dependent birds (hereafter waterbirds), including waterfowl (35 species), waterbirds (8 species), and shorebirds (42 species; Appendix A, Table A.2; GNWT, 2020c). Three waterbird SAR (yellow rail [*Coturnicops noveboracensis*], red-necked phalarope [*Phalaropus lobatus*], and horned grebe [*Podiceps auratus*]; Table 3.1) and one SPCC (lesser yellowlegs [*Tringa flavipes*]) have the potential to inhabit the LSA and are discussed in greater detail in Section 3.2.2.6. The primary nesting period for waterbirds is May 15 to August 7 (Zone B8; ECCC, 2018a).

An annual Waterfowl Breeding Population and Habitat Survey has been conducted jointly by the US Fish & Wildlife Service and Canadian Wildlife Service since 1955 to estimate the population size and trends of breeding inland waterfowl species. The data is primarily used as a harvest management tool. Data from strata 15 (USFWS, 2010) in 2011-2015 indicates that the most abundant waterfowl species breeding in the RSA are greater scaup (*Aythya marila*) and lesser scaup (*Aythya affinis*), green-winged teal (*Anas carolinensis*), mallard, American wigeon (*Mareca americana*), and Canada goose (Table 3.3; USFWS, 2019). However, data suggests that waterfowl breeding densities are low for most species within the LSA compared to other areas within strata 15 or adjacent survey strata in the NT (Fournier and Hines, 2005).

In general, waterfowl populations in Canada have increased 150% between 1970 to 2016 (ECCC, 2019a).

The LSA overlaps the Middle Mackenzie River Islands IBA (28,617.9 ha; RSA: 263,567.1 ha) which is a 250 km section of the Mackenzie River between north of Wrigley to north of Norman Wells that includes the water, shoreline, and islands along the river (IBA Canada, 2020b, 2020c; Figure 3.6). The IBA is an important migratory staging site for many duck and goose species, including greater white-fronted goose (*Anser albifrons*), Canada goose, tundra swan, and snow goose (Latour et al., 2008; IBA Canada, 2020c). The IBA also provides breeding and migration habitat for other waterbird species and SAR (e.g., horned grebe, rusty blackbird [*Euphagus carolinus*]; see Section 3.2.2.6; IBA Canada, 2020c). The Brackett Lake IBA is within the RSA (14,789.8 ha), and is a low-lying area dominated by black spruce (*Picea mariana*) and peat bogs interspersed with open wetland habitats, lakes, and sedge meadows (IBA Canada, 2020b, 2020c). This IBA provides a significant source of breeding habitat for several duck species, particularly scaup, and is an important migratory staging site for waterfowl species such as greater white-fronted geese and tundra swan, and shorebird species such as lesser yellowlegs (*Tringa flavipes*), pectoral sandpiper (*Calidris melanotos*), and long-billed dowitcher (*Limnodromus scolopaceus*; Latour et al., 2008, IBA Canada, 2020a). Both IBAs and the broader Mackenzie Valley are along migratory corridors for migrating tundra swans (Ely et al., 2020) and greater white-fronted geese (Meixell, 2018), further suggesting the RSA provides a notable source of staging habitat for waterfowl. See Section 3.2.2.6 for detailed information on waterbird SAR.

Table 3.3 Mean 5-year Breeding Waterfowl Population Estimates from the Waterfowl Breeding Population and Habitat Survey from 2011 to 2015[1] in Strata 15[2]

Common Name	Scientific Name	Mean Breeding Population
Greater and lesser scaup	*Aythya marila* and *affinis*	277,230
Green-winged teal	*Anas carolinensis*	158,775
Mallard	*Anas platyrhynchos*	124,979
American wigeon	*Mareca americana*	77,062
Canada goose	*Branta canadensis*	63,837
Ring-necked duck	*Aythya collaris*	34,685
Northern pintail	*Anas acuta*	33,282
Bufflehead	*Bucephala albeola*	27,575
Common and Barrow's goldeneye	*Bucephala clangula* and *islandica*	25,805
Northern shoveler	*Spatula clypeata*	7,440
Blue-winged teal	*Anas discors*	1,915
Canvasback	*Aythya valisineria*	1,443
Ruddy duck	*Oxyura jamaicensis*	555

Notes:

1 Survey population data (USFWS, 2019).

2 Survey strata (USFWS, 2010).

Waterfowl are an important subsistence resource for local Indigenous communities (DLUPC, 2006, SLUPB, 2013). Regulated waterfowl (ducks, geese, coots, and snipe) hunting in the NT may occur between September 1 to December 10 under the authorization of a federal Migratory Game Bird Hunting Permit and Canadian Wildlife Habitat Conservation Stamp (ECCC, 2020b). Individuals may also hunt overabundant snow and Ross's geese (*Chen rossii*) between May 1 to May 28.

Waterfowl have been shown to have limited environmental contamination but because some species consume other animals (e.g., fish), some species may experience biomagnification of contaminants, but it is not considered a health risk to consume them, except for regular consumption of organs (GNWT, 2016a).

There are several recommended activity restrictions for waterfowl and other waterbird species nests described in Appendix A, Table A.1 (GNWT, 2015a, 2016a) and there is also a setback of 1,500 m from waterfowl staging areas for general development activities in the spring and fall when concentrations of birds are present. This is consistent with or more conservative than those presented in the regional land use plans (DLUPC, 2006; SLUPB, 2013).

3.2.2.3 Upland Gamebirds

There are five species of upland gamebird that have the potential to occur within the RSA: ruffed grouse (*Bonasa umbellus*), spruce grouse (*Canachites canadensis*), willow ptarmigan (*Lagopus lagopus*), rock ptarmigan (*Lagopus muta*), and sharp-tailed grouse (*Tympanuchus phasianellus*; Appendix A, Table A.2; GNWT, 2020c). There are no upland gamebird SAR or SOCC that have the potential to occur in the LSA (Table 3.1). Upland gamebirds breed in early spring, prior to the primary nesting periods for migratory birds (ECCC, 2018a) and use a wide variety of upland and wetland (e.g., winter forage) habitats throughout the year. There are no documented sharp-tailed grouse leks (traditional mating grounds) within the RSA.

Upland gamebird populations in the NT are naturally cyclical (e.g., Krebs et al., 2001), increasing and decreasing at approximate 10-year intervals in response to broader environmental conditions, including predator populations and climactic conditions (GNWT, 2015c). The most recent population peak was predicted to have occurred in 2016/17 (GNWT, 2015c).

Upland gamebirds are an important subsistence resource for local Indigenous communities (DLUPC, 2006; SLUPB, 2013, SRRB, 2021). Regulated upland gamebird (ptarmigan and grouse) hunting in the NT may occur between September 1 to April 30 under the authorization of a territorial small game hunting permit (GNWT, 2020d). The average annual harvest of upland gamebirds in the NT by resident hunters (i.e., excludes subsistence hunting) between 1998/98 and 2008/09 was approximately 2,000 spruce grouse, 1,700 ptarmigan, 600 ruffed grouse, and 300 sharp-tailed grouse (Carrière, 2012). Harvest data indicates that sharp-tailed grouse, spruce grouse, unidentified grouse species, and ptarmigan species each make up 4% to 5% of the total bird harvest composition within the Sahtu Region (SRRB, 2021).

Upland game birds have been shown to have limited environmental contamination because they are lower on the food chain, consuming primarily plants and invertebrates; it is not considered a health risk to consume them (GNWT, 2016b).

3.2.2.4 Birds of Prey

The RSA provides habitat for 19 bird of prey species, including raptors (13 species) and owls (6 species; Appendix A, Table A.2; GNWT, 2020c). Two bird of prey SAR have the potential to inhabit the LSA (peregrine falcon and short-eared owl; Table 3.1) and are discussed in greater detail in Section 3.2.2.6. In general, bird of prey populations in Canada have increased 110% between 1970 to 2016 (ECCC, 2019a).

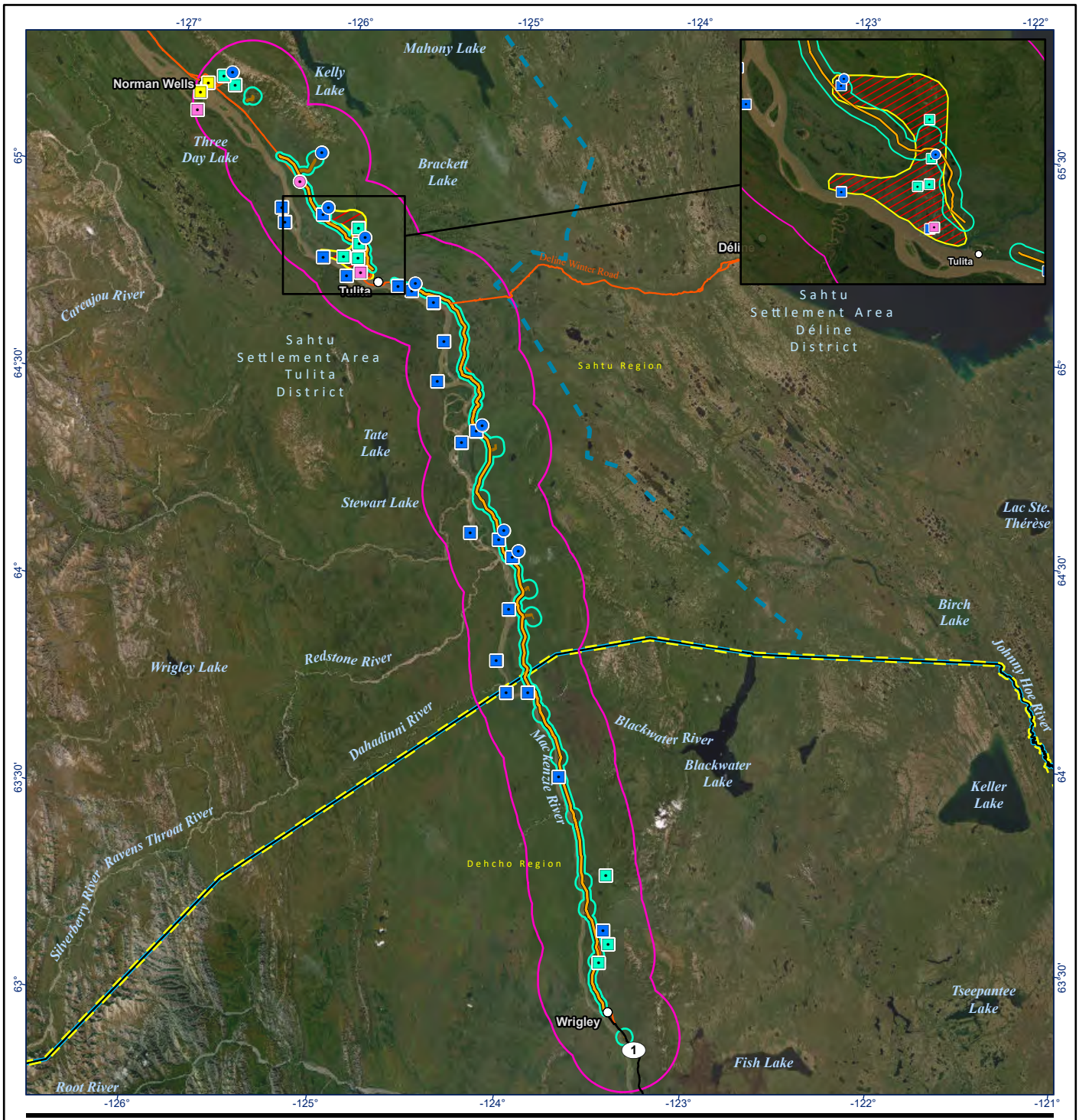
Historical WMIS records indicate that raptor nests within the LSA include two golden eagle (*Aquila chrysaetos*) nests and six peregrine falcon nests (Figure 3.7; GNWT, 2020c). Records within the RSA include 2 bald eagle (*Haliaeetus leucocephalus*) nests, 9 golden eagle nests, 1 American kestrel (*Falco sparverius*) nest, and 21 peregrine falcon nests (Figure 3.7; GNWT, 2020c).

The 2021 aerial raptor survey completed by the GNWT yielded detections of one active bald eagle nest in the LSA, seven active peregrine falcon nests within the LSA (two of which are within or immediately adjacent to proposed quarry locations), and one additional active peregrine falcon nest in the RSA (Figure 3.7). Specialized habitat for raptor species such as peregrine falcon and golden eagle, include steep cliff for nesting, which occur at low densities throughout the LSA and RSA.

Birds of prey breed in early spring, prior to the primary nesting periods for migratory birds (ECCC, 2018a). Published critical nesting periods for raptor species are provided in Table 3.4. In addition to a general year-round setback of 500 m from raptor nests, there are several species-specific recommended activity restrictions for general development activities in the vicinity of active nests (Appendix A, Table A.1; GNWT, 2015a, 2016a):

- Bald eagle – 500 m between April 15 to August 31
- Golden eagle – 800 m between April 15 to August 31
- Osprey (*Pandion haliaetus*) – 1,000 m between May 1 to August 31
- peregrine falcon – 1,500 m between May 1 to August 31

This is consistent with or more conservative than those presented in the regional land use plans (DLUPC, 2006; SLUPB, 2013).



WMIS Observations
- American Kestrel
- Bald Eagle
- Golden Eagle
- Peregrine Falcon

GNWT Observations
- Peregrine Falcon
- Bald Eagle

Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022

- Granular Borrow / Rock Quarry Site and Access
- Bear Rock Important Wildlife Area
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,600,000

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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

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Mackenzie Valley Highway Project

Figure No.
3.7

Title
WMIS and GNWT 2021 Raptor Nest Observations

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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Table 3.4 Critical Breeding Periods for Raptors in the Low Subarctic Ecoregion[1]

Common Name	Scientific Name	Critical Nesting Period
Bald eagle	*Haliaeetus leucocephalus*	3rd wk April – 2nd wk September
Northern harrier	*Circus cyaneus*	3rd wk May – 3rd wk August
Sharp-shinned hawk	*Accipiter striatus*	4th wk May – 2nd wk August
Northern goshawk	*Accipiter gentilis*	4th wk April – 1st wk August
Swainson's hawk	*Buteo swainsoni*	3rd wk May – 4th wk August
Red-tailed hawk	*Buteo jamaicensis*	4th wk April – 1st wk August
Rough-legged hawk	*Buteo lagopus*	2nd wk May – 2nd wk August
Golden eagle	*Aquila chrysaetos*	2nd wk April – 3rd wk August
American kestrel	*Falco sparverius*	3rd wk May – 2nd wk August
Merlin	*Falco columbarius*	1st wk May – 4th wk July
Gyrfalcon	*Falco rusticolus*	1st wk April – 3rd wk July
Peregrine falcon	*Falco peregrinus*	3rd wk May – 3rd wk August
Osprey	*Pandion haliaetus*	3rd wk May – 2nd wk September

Note:

[1] from Shank and Poole (2016)

3.2.2.5 Landbirds

The RSA provides habitat for 85 species of landbirds, including near-passerines (e.g., woodpeckers; 8 species) and passerines (95 species; Appendix A, Table A.2; GNWT, 2020c). Five landbird SAR (common nighthawk [*Chordeiles minor*], olive-sided flycatcher [*Contopus cooperi*], bank swallow [*Riparia riparia*], barn swallow [*Hirundo rustica*], and rusty blackbird) and one SOCC (Harris's sparrow [*Zonotrichia querula*]) have the potential to inhabit the LSA (Table 3.1) and are discussed in greater detail in Section 3.2.2.6. In general, forest-dwelling passerine populations in Canada have increased 7% between 1970 to 2016 (ECCC, 2019a). See Section 3.2.2.6 for detailed information on landbird SAR. The primary nesting period for landbirds is May 15 to August 8 in forested habitats and May 16 to August 10 in open habitats (Zone B8; ECCC, 2018a).

The North American Breeding Bird Survey is a volunteer-based large-scale program used to monitor the population status and trends of bird populations since 1966 (Government of Canada, 2018; USFWS, 2018). The survey is primarily suited to the collection of songbird data but does provide information on a wide range of other species (e.g., waterfowl). Two survey routes are located within the LSA and within the Taiga Plains ecoregion near Norman Wells (route 43012 – Norman Wells) and near Tulita (route 43014 – Bear River; USFWS, 2020) that contain historical data from 1995-2005 and 2004-2005, respectively (Appendix A, Table A.3, Pardieck et al., 2019). The most abundant species recorded on the Norman Wells route included Swainson's thrush (*Catharus ustulatus*), chipping sparrow (*Spizella passerina*), yellow-rumped warbler (*Setophaga coronata*), American robin (*Turdus migratorius*), and white-crowned sparrow (*Zonotrichia leucophrys*). The most abundant species recorded on the Bear River route included white-crowned sparrow (*Zonotrichia leucophrys*), alder flycatcher (*Empidonax alnorum*), hermit thrush

(*Catharus guttatus*), Lincoln's sparrow (*Melospiza lincolnii*), and white-throated sparrow (*Zonotrichia albicollis*; Pardieck et al., 2019).

The general recommended activity restrictions for songbird nests includes a setback of 100 m from general development activities and 30 m for pedestrian or all-terrain vehicle (ATV) activities between May 1 to July 31 (GNWT, 2015a, 2016a; Appendix A, Table A.1).

ECCC Breeding Bird Survey Data

A review of the ECCC breeding bird survey data collected in 2017 using ARUs (ECCC, 2020a) indicates that the spatial distribution of survey locations relative to ecoregion and land cover classes are suitable for satisfying the objective of identifying the presence, habitat associations, and relative abundance of breeding migratory birds within the LSA. Survey locations were evenly distributed along the existing MVWR between Wrigley and Norman Wells (Figure 3.8) and proportionally distributed between the three level III ecoregions traversed by the Project (Table 3.5).

Table 3.5 Distribution of ECCC Breeding Bird Survey Locations by Ecoregion

Ecoregion (Level III)	Area (ha)	Percent of LSA	No. of ARUs	Percent of ARUs
Boreal Cordillera High Boreal	24,925.0	33.1%	15	28.3%
Taiga Cordillera Low Subarctic	25,393.9	33.7%	19	35.8%
Taiga Plains Low Subarctic	25,040.6	33.2%	19	35.8%
Total	75,359.6	100.0%	53	100.0%

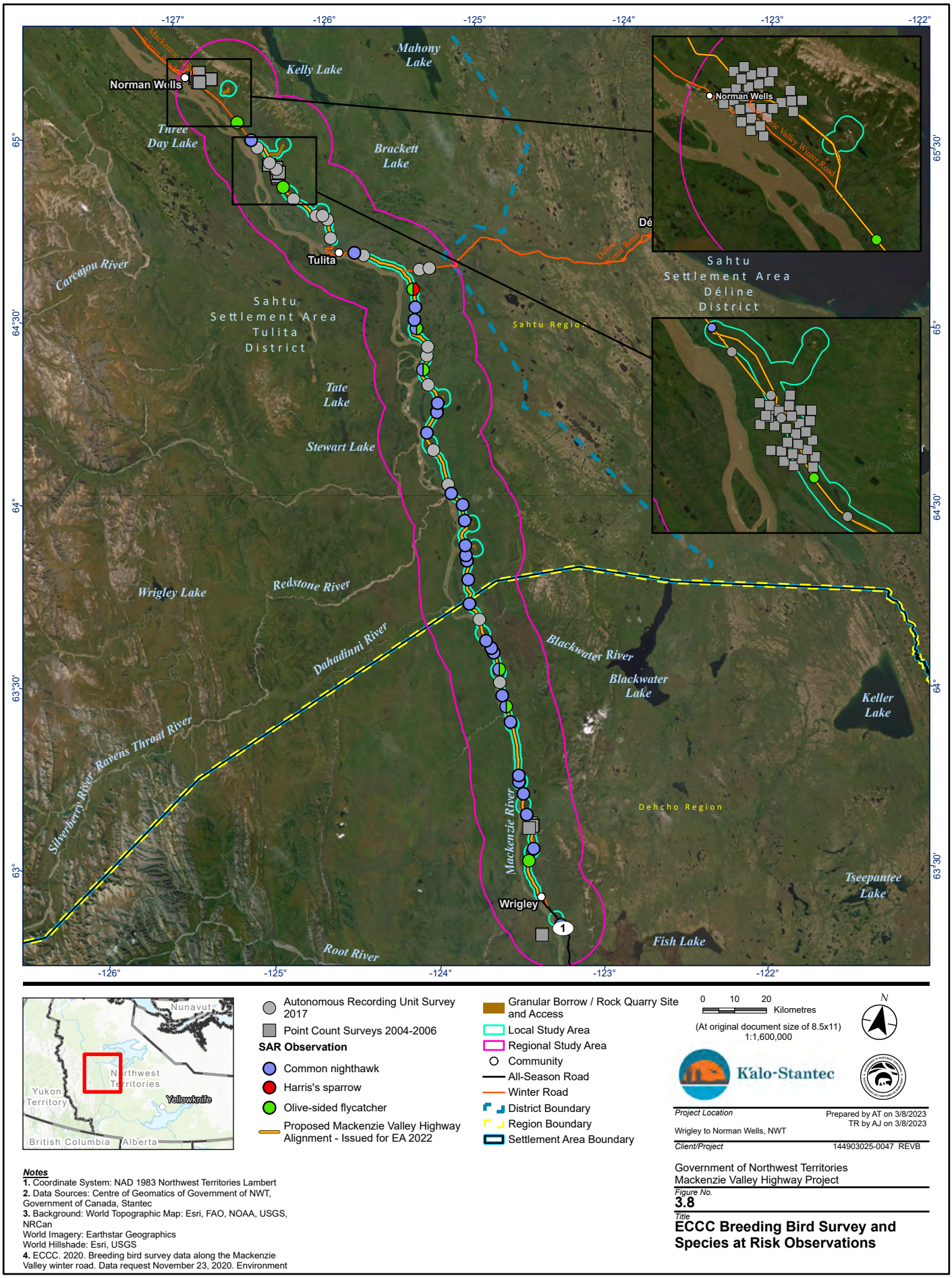
The ARU survey locations were also evenly distributed proportionally relative to the major land cover classes within the LSA (Table 3.6). The land cover composition within a 100 m radius of the survey location was calculated and the dominant land cover class was used to assign a single land cover class for each survey location. However, exposed lands were excluded because most survey locations were along the existing winter road and the dominant habitat for most locations was exposed lands and not indicative of the adjacent breeding habitat for birds.

Table 3.6 Distribution of ECCC Breeding Bird Survey Locations by Land Cover Class

Land Cover Class[1]	Area (ha)	Percent of LSA	No. of ARUs	Percent of ARUs
Broadleaf Forest	4,779.3	6.6%	3	5.7%
Coniferous Forest	25,628.9	35.5%	25	47.2%
Mixedwood Forest	4,059.7	5.6%	3	5.7%
Shrubland	10,882.8	15.1%	6	11.3%
Herbaceous & Unvegetated	261.5	0.4%	2	3.8%
Wetland	17,550.6	24.3%	14	24.5%
Water	8,979.8	12.4%	1	1.9%

Note:

[1] See Table 3.2 for refined land cover classification in the LSA.



- Autonomous Recording Unit Survey 2017
- Point Count Surveys 2004-2006

SAR Observation

- Common nighthawk
- Harris's sparrow
- Olive-sided flycatcher
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
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- District Boundary
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Project Location
Wrigley to Norman Wells, NWT

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Mackenzie Valley Highway Project

Figure No.
3.8

Title
ECCC Breeding Bird Survey and Species at Risk Observations

Notes

1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
4. ECCC. 2020. Breeding bird survey data along the Mackenzie Valley winter road. Data request November 23, 2020. Environment

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At each survey location, ARUs collected daily 3-minute audio recordings and recordings from five to six recordings between June 1-30 were analyzed for species detections; in one case one recording was available for a single ARU while in one other case four recordings were available for a single ARU (ECCC, 2020a). A total of 293 3-minute surveys and 879 minutes of audio were analyzed for species detections.

The detection/non-detection of a species at each ARU survey locations was used to quantify the presence and relative abundance of breeding birds in the LSA and establish habitat associates, which is summarized in Appendix A, Table A.4. Additionally, the mean and standard deviation of the number of detections for each species per Ecoregion is also provided (Appendix A, Table A.5). Only three ARUs were located outside of the LSA, which precludes a comparison of the breeding bird community between the LSA and RSA.

A total of 72 bird species were detected during the ARU survey, with the most common species being Swainson's thrush (at 53 of 53 locations), hermit thrush (at 47 of 53 locations), chipping sparrow (at 42 of 53 locations), Tennessee warbler (*Leiothlypis peregrina*; at 41 of 53 locations), and white-throated sparrow (at 39 of 53 locations).

The most common and total number of species by major land cover classes, excluding water (i.e., a single survey location), were (Appendix A, Table A.4):

- **Broadleaf forest:** Orange-crowned warbler (*Leiothlypis celata*), white-throated sparrow, Tennessee Warbler, Swainson's thrush, and blackpoll warbler (*Setophaga striata*). A total of 24 species.
- **Coniferous forest:** Swainson's thrush, chipping sparrow, hermit thrush, Tennessee warbler, and dark-eyed junco (*Junco hyemalis*). A total of 48 species.
- **Mixedwood forest:** Swainson's thrush, chipping sparrow, hermit thrush, Tennessee warbler, and yellow-rumped warbler. A total of 28 species.
- **Shrubland:** Swainson's thrush, hermit thrush, white-throated sparrow, American robin, and orange-crowned warbler. A total of 39 species.
- **Herbaceous and Unvegetated:** Swainson's thrush, hermit thrush, white-throated sparrow, orange-crowned sparrow, and alder flycatcher. A total of 23 species.
- **Wetland:** Swainson's thrush, hermit thrush, American robin, white-throated sparrow, and Lincoln's sparrow. A total of 51 species.

Relative to Ecoregion, the most common and total number of species were (Appendix A, Table A.5):

- **Boreal Cordillera:** Tennessee warbler, Swainson's thrush, white-throated sparrow, chipping sparrow, and hermit thrush. A total of 36 species.
- **Taiga Cordillera:** Swainson's thrush, hermit thrush, white-throated sparrow, Tennessee warbler, and chipping sparrow. A total of 55 species.
- **Taiga Plains:** Swainson's thrush, hermit thrush, white-throated sparrow, orange-crowned sparrow, Lincoln's sparrow. A total of 58 species.

The ECCC in-field point-count survey data from 2004 and 2006 included point-count surveys (n = 65) in dominant land cover classes that included 29 in coniferous forest, 10 in shrubland, 10 in wetland, 8 in broadleaf forest, 4 in mixedwood forest, and 4 in water. A total of 49 bird species were detected during the point-count survey, with the most common species being Lincoln's sparrow (n = 40), white-crowned sparrow (n = 39), Swainson's thrush (n = 33), dark-eyed junco (n = 30), and chipping sparrow (n = 27) (Appendix A, Table A.6). The survey did not yield any detections of SAR and just one detection of one SOCC: lesser yellowlegs. The most common and total number of species by major land cover classes, excluding the herbaceous and unvegetated (i.e., no survey locations) were (Appendix A, Table A.6):

- **Broadleaf forest:** yellow-rumped warbler, orange-crowned warbler, warbling vireo (*Vireo gilvus*), Swainson's thrush, and Lincoln's sparrow. A total of 13 species.
- **Coniferous forest:** Lincoln's sparrow, white-crowned sparrow, common redpoll (*Acanthis flammea*), dark-eyed junco, and chipping sparrow. A total of 29 species.
- **Mixedwood forest**: Swainson's thrush, orange-crowned warbler, chipping sparrow, Tennessee warbler, boreal chickadee (*Poecile hudsonicus*). A total of 9 species.
- **Shrubland:** white-crowned sparrow, chipping sparrow, Lincoln's sparrow, savannah sparrow (*Passerculus sandwichensis*), and common redpoll. A total of 18 species.
- **Wetland:** dark-eyed junco, Swainson's thrush, Lincoln's sparrow, palm warbler (*Setophaga palmarum*), and blackpoll warbler. A total of 18 species.
- **Water:** Lincoln's sparrow, white-crowned sparrow, northern flicker (*Colaptes auratus*), American robin, and northern waterthrush (*Parkesia noveboracensis*). A total of 28 species.

In general, results of the ECCC breeding bird survey support the results of the North American Breeding Bird Survey (described above) with respect to the presence and relative abundance of species, while also providing insight into habitat associations for breeding species. While the data provides a detailed characterization of the breeding bird community within the LSA, there is limited information on the presence and distribution of most SAR and SOCC.

3.2.2.6 Species at Risk and Species of Conservation Concern

The RSA is within the breeding range of 10 bird SAR (peregrine falcon, yellow rail, red-necked phalarope, short-eared owl, common nighthawk, olive-sided flycatcher, bank swallow, barn swallow, rusty blackbird, and horned grebe) and 2 bird SOCC (lesser yellowlegs, Harris's sparrow; Government of Canada, 2021a; GNWT, 2020a; Table 3.1). There is no SARA-defined critical habitat for any bird SAR within the RSA. The existing conditions for these species are described in greater detail below.

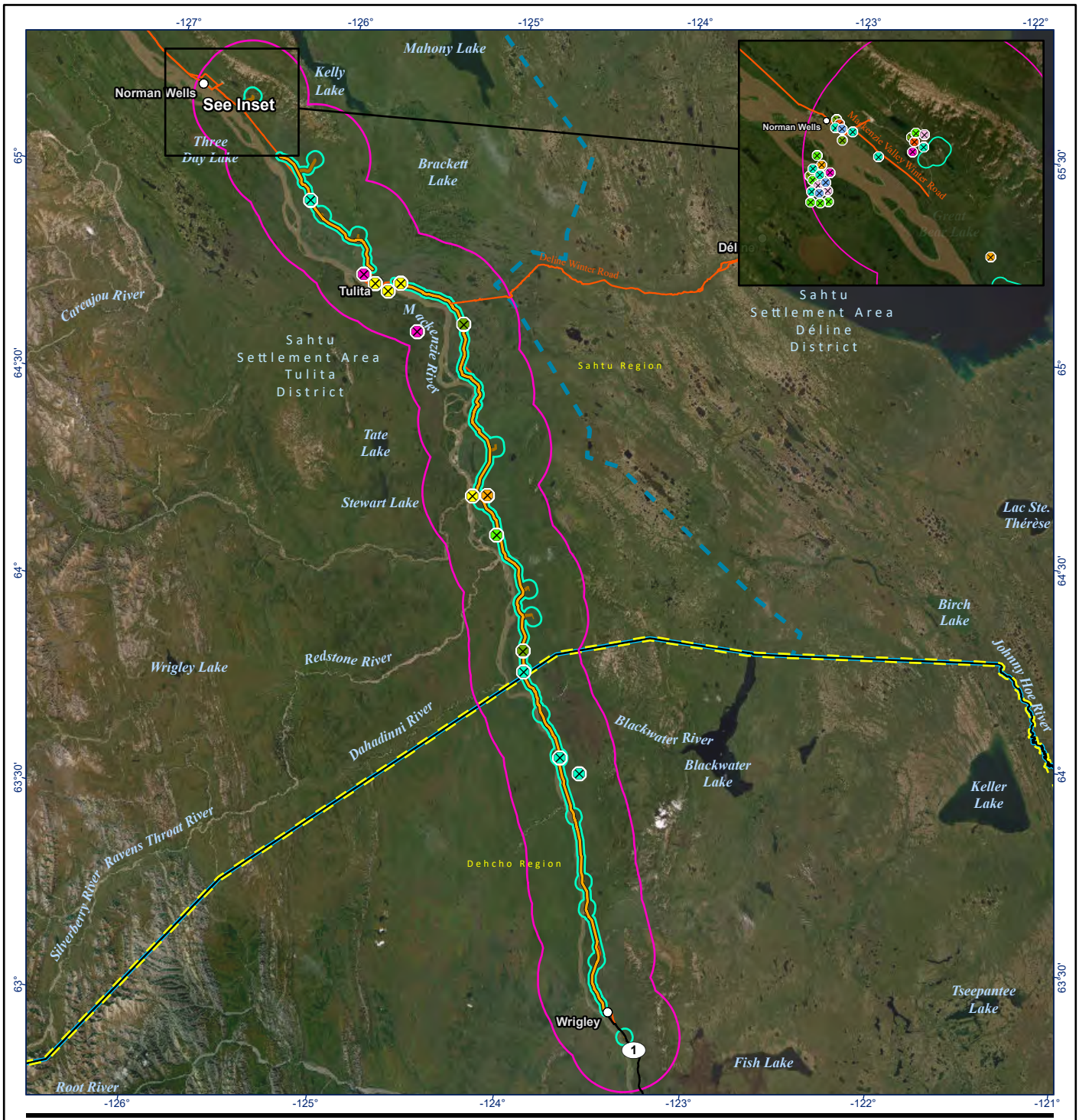
Peregrine Falcon

Peregrine falcon is a raptor species that is federally listed as special concern by SARA (Table 3.1; Government of Canada, 2021a). While not territorially listed under the *Species at Risk (NWT) Act*, it is territorially ranked as sensitive (Working Group on the General Status of NWT Species, 2016). While the species experienced significant population declines throughout Canada in the mid-20th century due largely to now-banned organochlorine pesticide use (e.g., DDT; COSEWIC, 2007a), the species'

population has rebounded and in 2017 was assessed as not at risk by COSEWIC (Government of Canada, 2021a). The species' population increase coincides with a general increase in raptor populations in Canada of 110% between 1970 to 2016 (ECCC, 2019a). Similarly, the population in the Mackenzie Valley has increased dramatically since the late 1960s with the number of successful nesting sites along the river increasing from a low of five in 1972 to a high of 58 in 2011 (Hodson, 2018). Additionally, expanded surveys beyond the Mackenzie Valley have also shown dramatic increases in peregrine falcon occupancy and productivity (Carrière and Matthews, 2013). Threats to peregrine falcon in NT include habitat loss or degradation through anthropogenic disturbance, particularly along the Mackenzie River, disturbance of nest sites, and severe climate-related events that reduce chick survival (GNWT, 2020a). In 2017, a federal management plan was developed for peregrine falcon focusing on stabilizing and increasing the species' declining population trend while increasing the area of occupancy, particularly in southern Canada (ECCC, 2017).

The species' breeding range includes primarily open tundra and coastal habitats throughout the northern NT, but also includes more southern montane habitats and the Mackenzie Valley (COSEWIC, 2007a; GNWT, 2020a). Breeding habitat for peregrine falcon exists throughout the RSA where sheltered cliff ledges or crevices occur near water and/or other areas that congregate prey species, typically other bird species (COSEWIC, 2007a; Carrière and Matthews, 2013; GNWT, 2020a). Historical WMIS records indicate six peregrine falcon nests within the LSA and 21 within the RSA (Figure 3.7; GNWT, 2020c). There are no other WMIS records of peregrine falcon individuals within the LSA, but there are four records within the RSA (Figure 3.9; GNWT, 2020c). There is one historical eBird (2021) record of peregrine falcon within the LSA northwest of Tulita from 2009 and 13 other records of the species occurring within the RSA (Figure 3.10).

The maximal breeding period (i.e., the widest range of potential breeding dates) in nesting zone B8 for peregrine falcon is March 8 to August 30 (Birds Canada, 2020), while the critical nesting period for the species is from the third week in May to the third week in August (Shank and Poole, 2016). The recommended activity restrictions for peregrine falcon nests include a setback of 1,500 m from general development activities between May 1 to August 31 (GNWT, 2015a, 2016a; Appendix A, Table A.1).



SAR Observation

- Bank Swallow
- Horned Grebe
- Lesser Yellowlegs
- Olive-Sided Flycatcher
- Peregrine Falcon
- Rusty Blackbird

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Local Study Area
- Regional Study Area
- Granular Borrow / Rock Quarry Site and Access
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11) 1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0039 REVC

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.9

Title
WMIS SAR Observations

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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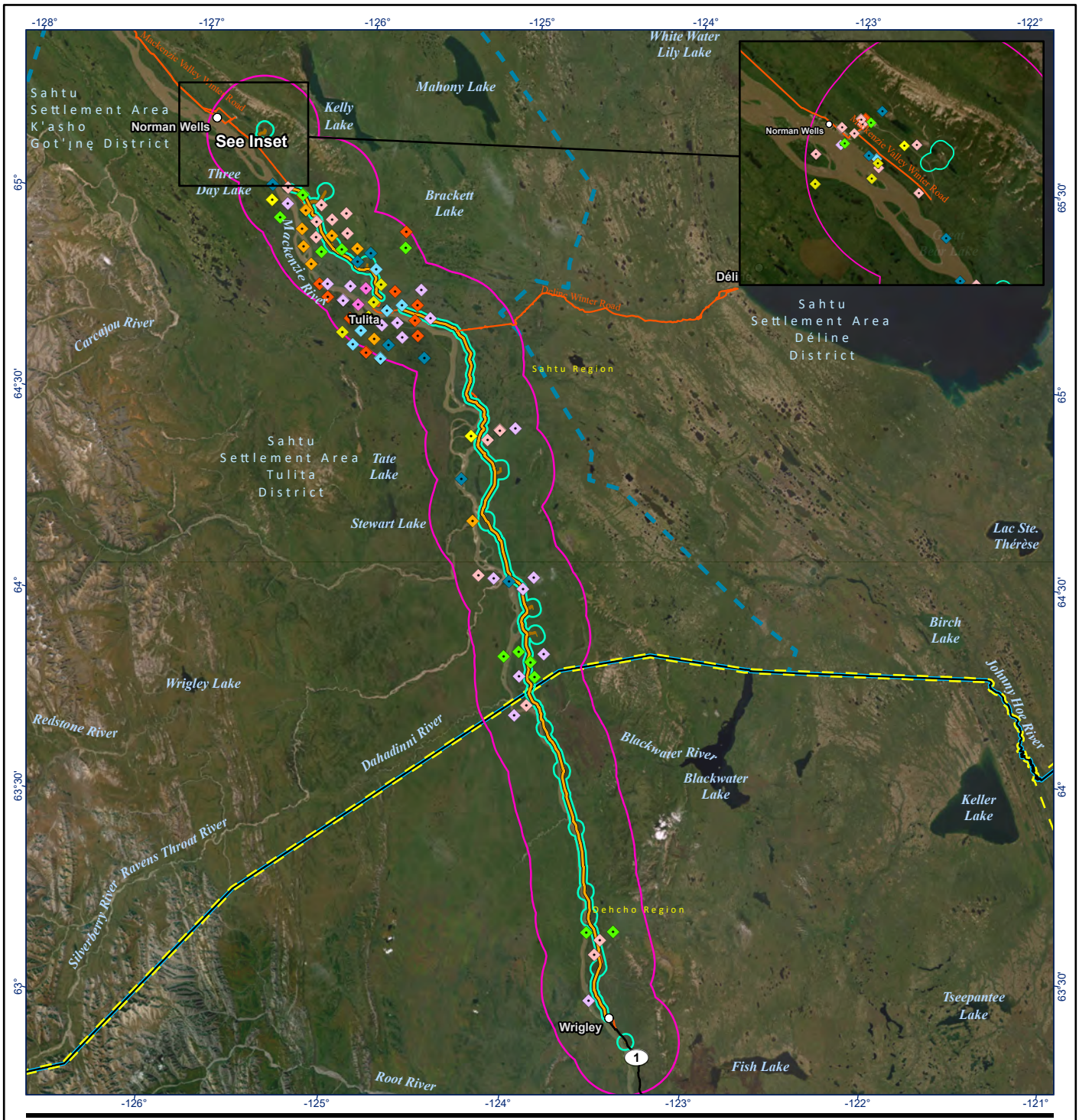

SAR Observation

- Bank Swallow
- Barn Swallow
- Common Nighthawk
- Harris's Sparrow
- Horned Grebe
- Olive-sided Flycatcher
- Peregrine Falcon
- Red-necked Phalarope
- Rusty Blackbird
- Short-eared Owl

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11) 1:1,650,000

N

Kálo-Stantec

Project Location

Wrigley to Norman Wells, NWT

Prepared by AT on 3/8/2023
TR by AJ on 3/8/2023

Client/Project

144903025-0040 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.

3.10

Title

eBird SAR Observations

Notes

1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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Yellow Rail

Yellow rail is a waterbird species that is federally listed as special concern by SARA (Table 3.1; Government of Canada, 2021a) and while not territorially listed under the *Species at Risk (NWT) Act*, is territorially ranked as sensitive (Working Group on the General Status of NWT Species, 2016). Due to the nocturnal and secretive behavior of yellow rails, a population trend is difficult to ascertain but is likely in decline due to habitat loss, primarily in the prairies (COSEWIC, 2001). Threats to yellow rail in NT include habitat loss or degradation through anthropogenic disturbance and climate change (COSEWIC, 2001; GNWT, 2020a).

The species has been traditionally thought to breeding only in the southwestern NT (COSEWIC, 2001; GNWT, 2020a); however, recent evidence indicates that the species has been detected breeding southeast of the RSA near Bulmer Lake and north of the RSA near Fort Good Hope (Dufour, 2020, pers. comm.). Considering recent evidence, habitat for yellow rail may exist for yellow rail throughout the RSA where wet meadow or shallow, sedge-dominated wetlands exist (COSEWIC, 2001; Dufour, 2020, pers. comm.; GNWT, 2020a). There are no historical records of yellow rail within the LSA or RSA (eBird, 2021; ECCC, 2020a; GNWT, 2020c).

The primary nesting period for yellow rail is May 15 to August 7 (ECCC, 2018a). The recommended activity restrictions for yellow rails nests include a setback of 350 m from general development activities between May 15 to August 31 (GNWT, 2015a, 2016a; Appendix A, Table A.1).

Lesser Yellowlegs

Lesser yellowlegs is a shorebird species that has been assessed by COSEWIC as threatened (Table 3.1; Government of Canada, 2021a), but it is not territorially listed under the *Species at Risk (NWT) Act* and is territorially ranked as sensitive (Working Group on the General Status of NWT Species, 2016). While the species has experienced population declines throughout much of Canada, this is primarily attributable to activities outside of Canada such as the loss of staging and wintering habitat and sport and subsistence hunting outside of Canada (Government of Canada, 2021b). Threats to lesser yellowlegs in NT likely include habitat loss or degradation through anthropogenic disturbance and climate change (Government of Canada, 2021b) and contamination of aquatic habitats.

The species' breeding range includes boreal and tundra transition habitats throughout the NT where freshwater shoreline habitats provide foraging opportunities and will nest in anthropogenically disturbed sites, such as cut lines or other clearings (Tibbitts and Moskoff, 2020). Breeding habitat for lesser yellowlegs exists throughout the RSA and ECCC data indicates 6 records of the species within the LSA and 15 within the RSA from 2017 and 1 in the RSA from 2006 (Figure 3.8; ECCC, 2020a). There are 2 historical WMIS records of lesser yellowlegs within the LSA and 10 records within the RSA (Figure 3.9; GNWT, 2020c). There are 6 historical eBird (2020) records of lesser yellowlegs within the LSA and 21 other records of the species occurring within the RSA (Figure 3.10).

The maximal breeding period in nesting zone B8 for lesser yellowlegs is May 21 to July 17 (Birds Canada, 2020). The general recommended activity restrictions for shorebird nests, because there are no species-specific recommendations for lesser yellowlegs, include a setback of 100 m from general

development activities and 50 m from pedestrian or ATV activities between May 1 to July 31 (GNWT, 2015a, 2016a; Appendix A, Table A.1). However, increased setback distances may be considered due to the conservation status of the species (ECCC, 2019b).

Red-necked Phalarope

Red-necked phalarope is a shorebird species that is federally listed as special concern by SARA (Table 3.1; Government of Canada, 2021a) and, while not territorially listed under the *Species at Risk (NWT) Act*, it is territorially ranked as sensitive (Working Group on the General Status of NWT Species, 2016). While the species has experienced population declines throughout much of Canada, this is primarily attributable to significant declines in key staging areas on the Atlantic coast and the vast expanses of remote habitat in the NT where there are limited data collection and population and trend estimation (COSEWIC, 2014). Threats to red-necked phalarope in NT include habitat loss or degradation through anthropogenic disturbance and climate change (GNWT, 2020a) and contamination of aquatic habitats (COSEWIC, 2014).

The species' breeding range includes low- and sub-arctic tundra and tundra-forest transition habitats near freshwater waterbodies throughout most of the NT (COSEWIC, 2014; GNWT, 2020a). Breeding habitat for red-necked phalarope exists throughout the RSA where open, tree- and shrub-less habitats exist adjacent to freshwater ponds, lakes, and streams (COSEWIC, 2014). There are no historical WMIS records of red-necked phalarope within the LSA, but there are three records within the RSA (Figure 3.9; GNWT, 2020c). There is one historical eBird (2020) record of a red-necked phalarope within the LSA near Tulita in 2007 and eight other records of the species occurring within the RSA (Figure 3.10).

The maximal breeding period in nesting zone B8 for red-necked phalarope is May 21 to July 17 (Birds Canada, 2020). The general recommended activity restrictions for shorebird nests, because there are no species-specific recommendations for red-necked phalarope, include a setback of 100 m from general development activities and 50 m from pedestrian or ATV activities between May 1 to July 31 (GNWT, 2015a, 2016a; Appendix A, Table A.1). However, increased setback distances may be considered due to the conservation status of the species (ECCC, 2019b).

Short-eared Owl

Short-eared owl is a raptor species that is federally listed as special concern by SARA (Table 3.1; Government of Canada, 2021a) and, while not territorially listed under the *Species at Risk (NWT) Act*, it is territorially ranked as sensitive (Working Group on the General Status of NWT Species, 2016). While the species has experienced significant population declines throughout Canada, much of this is attributable to habitat loss and degradation on the wintering grounds and more southern breeding grounds (COSEWIC, 2008). Threats to short-eared owl in NT include habitat loss or degradation through anthropogenic disturbance and alteration of tundra habitats due to climate change (GNWT, 2020a). In 2016, a federal management plan was developed for short-eared owl focusing on stabilizing and increasing the species' declining population tend while increasing the area of occupancy, particularly in southern Canada (ECCC, 2018b).

Although the species' breeding range includes open habitats throughout the continental NT, most breeding is believed to occur in coastal and tundra habitats and there is little available data to provide population estimates or trends (COSEWIC, 2008). However, in general, raptor populations in Canada have increased 110% between 1970 to 2016 (ECCC, 2019a). There are no historical WMIS records of short-eared owl within the LSA, but there are three records within the RSA (Figure 3.9; GNWT, 2020c). There are two historical eBird (2020) records of short-eared owl within the LSA near Tulita in 2015 and six other records of the species occurring within the RSA (Figure 3.10).

The maximal breeding period in nesting zone B8 for short-eared owl is March 15 to July 26 (Birds Canada, 2020). The recommended activity restrictions for short-eared owl nests include a setback of 1,500 m from general development activities between May 1 to July 31 (GNWT, 2015a, 2016a; Appendix A, Table A.1).

Common Nighthawk

Common nighthawk is an aerial insectivore species that is federally listed as threatened by SARA (Table 3.1; Government of Canada, 2021a) and, while not territorially listed under the *Species at Risk (NWT) Act*, it is territorially ranked as at risk (Working Group on the General Status of NWT Species, 2016). The species has experienced population declines throughout Canada (COSEWIC, 2007b) and is experiencing long-term (-4.1% per year; 1987-2017) and short-term (-4.0% per year; 2007-2017) declines in the NT portion of the Boreal Taiga Plains Boreal Conservation Region (hereafter BCR6; Smith et al., 2019). The LSA is on the northern edge of the species range and, while relatively widespread in the southern portion of the NT (GNWT, 2020a), there is little available data to provide precise population estimates or trends (Working Group on the General Status of NWT Species, 2016; Smith et al., 2019). However, in general, aerial insectivore bird populations in Canada have increased 59% between 1970 to 2016 (ECCC, 2019a). Threats to common nighthawk in NT include habitat loss or degradation through anthropogenic disturbance, a long-term decline in insect populations, severe weather events, and collisions with vehicle or aircrafts (GNWT, 2020a). In 2016, a federal recovery strategy was developed that provides guidance aimed at halting and reversing population decline of common nighthawk, but existing data has been inadequate for determining critical habitat for common nighthawk (Environment Canada, 2016a).

Common nighthawks breed in a variety of boreal forest habitats, including forest clearings, burns, clearcuts, rocky outcrops, peat bogs, lakeshores, and disturbed areas (COSEWIC, 2007b). Breeding habitat for common nighthawk exists throughout the RSA and ECCC data indicates 29 records of the species within the LSA and one record in the RSA from 2017 (Figure 3.8; ECCC, 2020a). There are no historical eBird (2020) records of common nighthawk within the LSA, but there are three eBird record of the species occurring within the RSA (Figure 3.10).

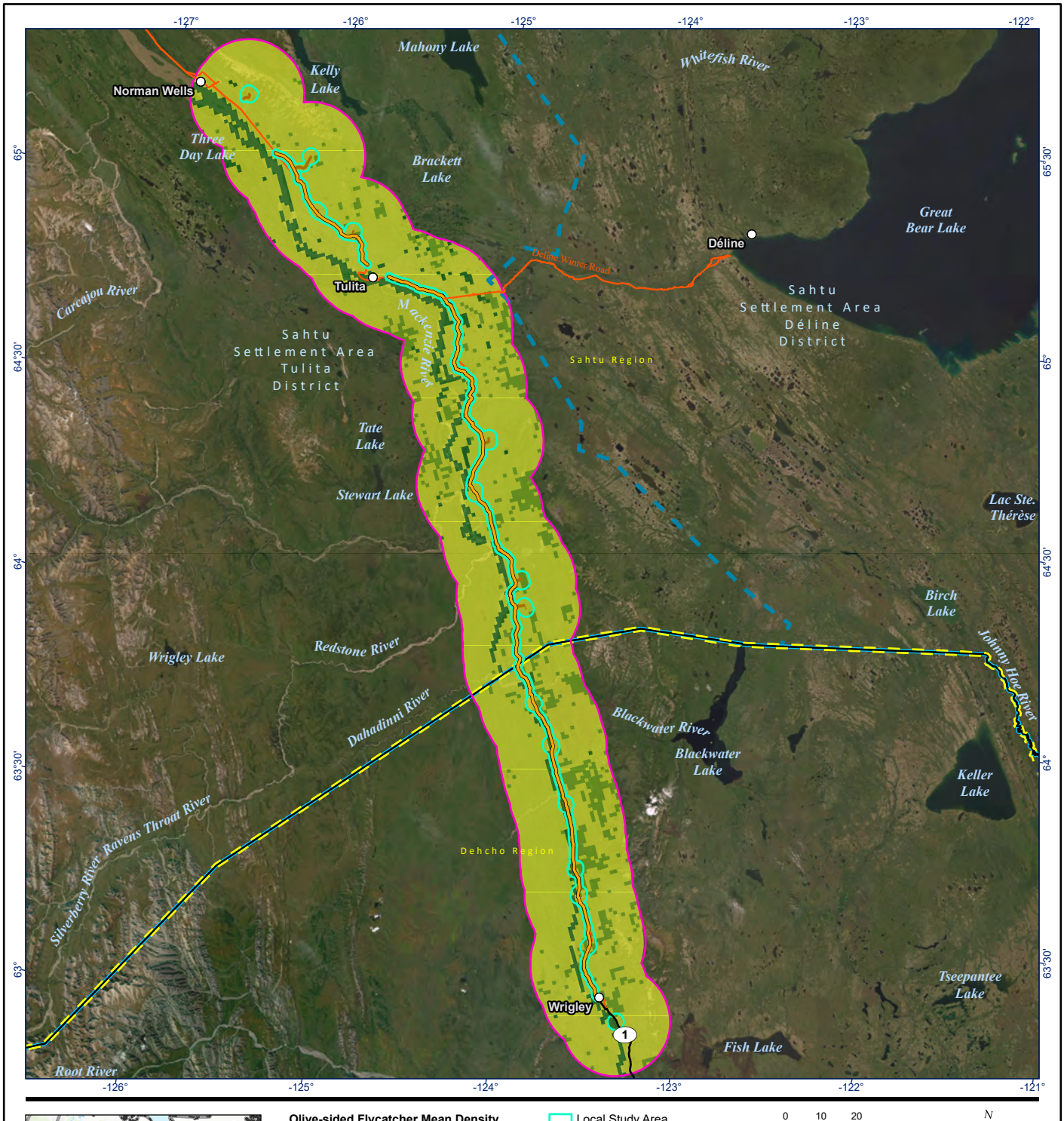
The maximal breeding period in nesting zone B8 for common nighthawk is May 19 to August 2 (Birds Canada, 2020). The recommended activity restrictions for common nighthawk nests include a setback of 200 m from general development activities between May 1 to July 31 (GNWT, 2015a, 2016a; Appendix A, Table A.1).

Olive-sided Flycatcher

Olive-sided flycatcher is an aerial insectivore species that is federally listed as threatened by SARA (Table 3.1; Government of Canada, 2021a) and, while not territorially listed under the *Species at Risk (NWT) Act*, it is territorially ranked as at risk (Working Group on the General Status of NWT Species, 2016). The species has experienced long-term population declines throughout Canada that have slowed in the last decade (COSEWIC, 2018) and is experiencing long-term (-5.8% per year; 1987-2017) and short-term (-10.3% per year; 2007-2017) declines in the NT portion of BCR6 (Smith et al., 2019). The LSA is on the northeastern edge of the species range and while relatively widespread in the southwestern portion of the NT (GNWT, 2020a), there is little available data to provide precise population estimates or trends (Working Group on the General Status of NWT Species, 2016, Smith et al., 2019). However, in general aerial insectivore bird populations in Canada have increased 59% between 1970 to 2016 (ECCC, 2019a). Threats to olive-sided flycatcher in NT include habitat loss or degradation through anthropogenic disturbance and a long-term decline in insect populations (GNWT, 2020a). In 2016, a federal recovery strategy was developed that provides guidance aimed at halting and reversing population decline of olive-sided flycatcher, but existing data has been inadequate for determining critical habitat for olive-sided flycatcher (Environment Canada, 2016b).

Olive-sided flycatcher breeds in a variety of boreal forest habitats, but is typically associated with edge habitats, such as natural (e.g., along riparian areas) and artificial (e.g., tree harvest) clearings and early successional forest (e.g., burns) where tall snags remain (COSEWIC, 2018). Breeding habitat for olive-sided flycatcher exists throughout the RSA and ECCC data indicates eight records of the species within the LSA from 2017 (Figure 3.8; ECCC, 2020a). There is one historical WMIS record of olive-sided flycatcher within the LSA between Wrigley and Tulita from 2003 and an additional three records within the RSA (Figure 3.9; GNWT, 2020c). There are three historical eBird (2020) records of olive-sided flycatcher within the LSA northwest of Tulita from 2004, and seven other records of the species occurring within the RSA (Figure 3.10). Breeding densities of olive-side flycatcher within the RSA are expected to be relatively low (≤ 0.015 males/ha) in comparison to other regions in Canada (BAMP, 2020; Figure 3.11).

The maximal breeding period in nesting zone B8 for olive-sided flycatcher is May 25 to August 14 (Birds Canada, 2020). The recommended activity restrictions for olive-sided flycatcher nests include a setback of 300 m from general development activities between May 1 to July 31 (GNWT, 2015a, 2016a; Appendix A, Table A.1).



Olive-sided Flycatcher Mean Density
- 0-0.00342
- 0.00342-0.00798
- 0.00798-0.015104
- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access

- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres
(At original document size of 8.5x11)
1:1,600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/8/2023
TR by AJ on 3/8/2023

Client/Project
144903025-0041 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.11

Title
Olive-sided Flycatcher Breeding Density

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
4. BAM Modeling Results: https://borealbirds.github.io/species/; © 2020 Boreal Avian Modelling Project under a CC BY-SA 4.0 license

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Bank Swallow

Bank swallow is an aerial insectivore species that is federally listed as threatened by SARA (Table 3.1; Government of Canada, 2021a) and, while not territorially listed under the *Species at Risk (NWT) Act*, it is territorially ranked as at risk (Working Group on the General Status of NWT Species, 2016). The species has experienced population declines throughout Canada and is experiencing long-term (-2.7% per year; 1987-2017) and short-term (-2.5% per year; 2007-2017) declines in the NT portion of BCR6 (Smith et al., 2019). While the species is relatively widespread throughout the western portion of the NT (GNWT, 2020a), there is little available data to provide precise population estimates or trends (Working Group on the General Status of NWT Species, 2016, Smith et al., 2019). However, in general, aerial insectivore bird populations in Canada have increased 59% between 1970 to 2016 (ECCC, 2019a). Threats to bank swallow in NT include natural (e.g., riverbank collapse) and anthropogenic (e.g., aggregate mounds) nesting colony losses, long-term decline in insect populations, and mortality related to severe weather events (GNWT, 2020a).

Bank swallows nest in soft vertical banks (e.g., riverbanks, quarries) adjacent to open boreal forest habitats that are associated with open water and riparian habitats used for foraging on aerial insects (COSEWIC, 2013). Bank swallow can also nest in human-made habitats including aggregate pits, along roadsides as well as piles of sand or gravel that have slopes that are greater than 70 degrees (ECCC, 2020c; ECCC, 2022)

Breeding habitat for bank swallow exists throughout the RSA where suitable banks exist (e.g., Mackenzie River). There are no historical WMIS records of bank swallow within the LSA, but there are four records within the RSA (Figure 3.9; GNWT, 2020c). There are four historical eBird (2020) records of bank swallow within the LSA between Wrigley and Tulita from 1974 and 2017 and there are 15 other records of the species occurring within the RSA (Figure 3.10). Breeding densities of bank swallow within the RSA are expected to be relatively low (≤ 0.003 males/ha) in comparison to other regions in Canada (BAMP, 2020).

The maximal breeding period in nesting zone B8 for bank swallow is May 15 to August 3 (Birds Canada, 2020). The general recommended activity restrictions are the same as for passerine nests because there are no species-specific recommendations for bank swallows This includes a setback of 100 m from general development activities and 30 m from pedestrian or ATV activities between May 1 to July 31 (GNWT, 2015a, 2016a; Appendix A, Table A.1). However, increased setback distances may be considered due to the conservation status of the species (ECCC, 2019b).

Barn Swallow

Barn swallow is an aerial insectivore species that is federally listed as threatened by SARA (Table 3.1; Government of Canada, 2021a) and, while not territorially listed under the *Species at Risk (NWT) Act*, it is territorially ranked as at risk (Working Group on the General Status of NWT Species, 2016). The species has experienced population declines throughout Canada and is experiencing long-term (-1.5% per year; 1987-2017) and short-term (-1.2% per year; 2007-2017) declines in the NT portion of BCR6 (Smith et al., 2019). While the species is widespread throughout the western portion of the NT, the species is reliant on anthropogenic structures for nesting (GNWT, 2020a) and there is little available data to provide precise population estimates or trends (Working Group on the General Status of NWT Species, 2016, Smith et

al., 2019). However, in general, aerial insectivore bird populations in Canada have increased 59% between 1970 to 2016 (ECCC, 2019a). Threats to barn swallow in NT include loss or destruction of anthropogenic structures, long-term decline in insect populations, and mortality related to severe weather events (GNWT, 2020a).

Barn swallows nest on anthropogenic structure (e.g., buildings, bridges) adjacent to open boreal forest habitats that are often associated with meadows or riparian habitats used for foraging on aerial insects (COSEWIC, 2011). Breeding habitat for barn swallow exists throughout the RSA where anthropogenic structures exists but there are no historical WMIS (GNWT, 2020c) of the species occurring within the LSA or RSA (GNWT, 2020c). There are three historical eBird (2021) records of barn swallow within the LSA from the Hamlet of Tulita from 2012 to 2017 and 10 other eBird records of the species occurring within the RSA (Figure 3.10). Breeding densities of barn swallow within the RSA are expected to be relatively low (≤ 0.018 males/ha) in comparison to other regions in Canada (BAMP, 2020).

The maximal breeding period in nesting zone B8 for barn swallow is May 12 to August 22 (Birds Canada, 2020). The general recommended activity restrictions are the same as for passerine nests because there are no species-specific recommendations for barn swallows. These include a setback of 100 m from general development activities and 30 m from pedestrian or ATV activities between May 1 to July 31 (GNWT, 2015a, 2016a; Appendix A, Table A.1). However, increased setback distances may be considered due to the conservation status of the species (ECCC, 2019b).

Harris's Sparrow

Harris's sparrow is a large passerine species that has been assessed by COSEWIC as special concern (Table 3.1; Government of Canada, 2021a), but it is not territorially listed under the *Species at Risk (NWT) Act* and is territorially ranked as undetermined (Working Group on the General Status of NWT, Species, 2016). While the species is relatively widespread throughout the central and eastern portions of the NT (GNWT, 2020a), it is one of the least studied passerine species in North America and its remote northern breeding range is not well captured by existing continental survey programs (COSEWIC, 2017a). As a result, there is no available data to provide population estimates or trends (Working Group on the General Status of NWT Species, 2016; Smith et al., 2019). Threats to Harris's sparrow in NT include the loss and degradation of breeding habitat through anthropogenic disturbance and climate-related habitat alteration (GNWT, 2020a).

Harris's sparrow is a ground-nesting species that inhabits semi-forested tundra, preferably in landscapes with coniferous trees interspersed with short (< 1 m) deciduous shrub understories (COSEWIC, 2017a). Breeding habitat for Harris's sparrow may exist within the RSA where semi-forested tundra habitats exist but the LSA is outside of the species' typical breeding range. ECCC data indicates one record of the species within the LSA southeast of Tulita from 2017 (Figure 3.8; ECCC, 2020a).There are no historical WMIS records of Harris's sparrow within the LSA, but there are two records within the RSA (Figure 3.9; GNWT, 2020c). There are three historical eBird (2021) records of Harris's sparrow within the LSA from the Hamlet of Tulita and six other records of the species occurring within the RSA (Figure 3.10).

The primary nesting period for Harris's sparrow is May 5 to August 21 (ECCC, 2018a). The general recommended activity restrictions as the same as for passerine nests because there are no species-specific recommendations for Harris's sparrow. These include a setback of 100 m from general development activities and 30 m from pedestrian or ATV activities between May 1 to July 31 (GNWT, 2015a, 2016a; Appendix A, Table A.1). However, increased setback distances may be considered due to the conservation status of the species (ECCC, 2019b).

Rusty Blackbird

Rusty blackbird is a songbird species that is federally listed as special concern by SARA (Table 3.1; Government of Canada, 2021a) and, while not territorially listed under the *Species at Risk (NWT) Act*, it is territorially ranked as sensitive (Working Group on the General Status of NWT Species, 2016). The species has experienced long-term population declines throughout Canada (COSEWIC, 2017b) and is experiencing long-term (-1.6% per year; 1987-2017) and short-term (-1.6% per year; 2007-2017) declines in the NT portion of BCR6 (Smith et al., 2019). While the species is widespread throughout most of the continental NT (GNWT, 2020a), there is little available data to provide precise population estimates or trends (Working Group on the General Status of NWT Species, 2016; Smith et al., 2019). Threats to rusty blackbird in NT include habitat loss and alteration of riparian and wetland habitats, including through altered drainage patterns, and through climate-related mercury contamination and wetland degradation (COSEWIC, 2017b; GNWT, 2020a). In 2015, a federal management plan was developed for rusty blackbird focusing on stabilizing and increasing the species' declining population tend while increasing the area of occupancy (Environment Canada, 2015).

Rusty blackbird breeds in a variety of boreal forest habitats typically associated with wetlands, including streams, bogs, and marshes but is typically associated with edge habitats, such as natural (e.g., along riparian areas) and artificial (e.g., tree harvest) clearings and early successional forest (e.g., burns) where tall snags remain (COSEWIC, 2017b). There are three historical WMIS records of rusty blackbird within the LSA from 2004: two north of Wrigley and one south of Norman Wells (Figure 3.9; GNWT, 2020c). There are an additional 11 WMIS records of bank swallow within the RSA (Figure 3.9; GNWT, 2020c). There are four historical eBird (2021) records of rusty blackbird within the LSA: one between Wrigley and Tulita from 1972 and three north of Tulita from 2004 (Figure 3.10). There are also 26 other records of the species occurring within the RSA. Breeding densities of rusty blackbird within the RSA are expected to be relatively low (≤ 0.01 males/ha) in comparison to other regions in Canada (BAMP, 2020).

The maximal breeding period in nesting zone B8 for rusty blackbird is April 30 to July 8 (Birds Canada, 2020). The recommended activity restriction for rusty blackbird nests is a setback of 300 m from general development activities between May 1 to July 31 (GNWT, 2015a, 2016a; Appendix A, Table A.1).

Horned Grebe

Horned grebe is a waterbird species that is federally listed as special concern by SARA (Table 3.1; Government of Canada, 2021a) and, while not territorially listed under the *Species at Risk (NWT) Act*, it is territorially ranked as sensitive (Working Group on the General Status of NWT Species, 2016). The species has experienced long-term population declines throughout Canada (COSEWIC, 2009) and is experiencing long-term (-1.3% per year; 1987-2017) and short-term (-1.9% per year; 2007-2017) declines

in the NT portion of BCR6 (Smith et al., 2019). While the species is widespread throughout most of the central and western NT (GNWT, 2020a), there is little available data to provide precise population estimates or trends (Working Group on the General Status of NWT Species, 2016, Smith et al., 2019). In general, wetland bird populations in Canada have increased 30% between 1970 to 2016 (ECCC, 2019a). Threats to horned grebe in NT include increased predation by mammals, birds, and fish, and climate-related changes to wetland habitats and water quality (GNWT, 2020a).

Horned grebes typically breed in small and open boreal forest wetlands, with emergent vegetation for nesting, but they occasionally breed in shallow, marshy bays of larger lakes (Fournier and Hines, 1999; COSEWIC, 2009). Additionally, borrow pits left following highway construction projects in the northern boreal have been shown to provide suitable breeding habitat for horned grebes (Kuczynski et al., 2012). There is one historical WMIS record of horned grebe within the LSA between Wrigley and Tulita from 2004 and an additional seven records within the RSA (Figure 3.9; GNWT, 2020c). There are three historical eBird (2021) records of horned grebe within the LSA: one between Wrigley and Tulita from 1972 and two north of Tulita from 2002 to 2004 (Figure 3.10). There are also 17 other eBird (2021) records of the species occurring within the RSA.

The maximal breeding period in nesting zone B8 for horned grebe is May 4 to July 29 (Birds Canada, 2020). The recommended activity restriction for horned grebe nests is a setback of 100 m (applied from the edge of the waterbody) for general development activities between May 15 to August 31 (GNWT, 2015a, 2016a; Appendix A, Table A.1).

4 Key Results and Findings

The Project consists of construction of a 281 km all-season highway that largely follows the route of the existing MVWR and includes the construction and operation of temporary and permanent borrow sources and quarries. The biophysical characteristics of the LSA are influenced by the Mackenzie River valley that defines the landscape and is dominated by coniferous forest habitats interspersed with wetlands and watercourses. The RSA has the potential to provide habitat for 201 species of bird, including 84 waterbird species, 5 upland gamebird species, 19 bird of prey species, and 93 landbird species (Appendix A, Table A.2; GNWT, 2020c). The RSA also has the potential to provide habitat for 12 SAR/SOCC.

Bird habitat in the Dehcho Region portion of the LSA is dominated by coniferous forest (43.6%), wetlands (19.8%), and open water (19.3%), while landcover in the LSA in the Sahtu Region is dominated by coniferous forest (28.7%), wetlands (25.2%), and shrubland (20.6%). Since 1960, 18.5% of the LSA within the Dehcho Region and 75.2% of the LSA within the Sahtu Region has been subject to forest fire.

Other than communities, the Norman Wells Pipeline, and other developments such as borrow sources and quarries, a fibre line, and bridges associated with the MVWR, the LSA and RSA are relatively undisturbed. Oil and gas exploration and production infrastructure in the RSA occurs on the west side of and within the Mackenzie River near Norman Wells (Auld and Kershaw, 2005).

Key results and findings include:

- Many bird species are culturally important to local communities (e.g., birds of prey) and for subsistence hunting (e.g., waterbirds, upland gamebirds; e.g., Auld and Kershaw, 2005; DLUPC, 2006; SLUBP, 2013; SRRB, 2021, TRRC, 2022).
- The Bear Rock CZ is a large karst formation west of Tulita that is a sacred site and subject to traditional storytelling that also provides habitat for a wide variety of wildlife species, including nesting raptors (SLUBP, 2013).
- The RSA is within the breeding range of 10 bird SAR and 2 bird SOCC.
- Historical records exist within the LSA and RSA for 11 of 12 SAR/SOCC (all but yellow rail) with the potential to occur in the RSA (Government of Canada, 2021a; GNWT, 2020a, 2020b, 2020c; eBird, 2021; ECCC, 2020a).
- The LSA is not expected to provide a notable source of habitat for bird SAR and SOCC when compared to other areas in the RSA and NT as these species are generally widely distributed and/or at the northern edge of their range. However, data availability is limited for some SAR.
- The LSA is partially within the Middle Mackenzie River IBA that provides a notable source of staging and migration habitat for migratory birds, especially waterfowl and other waterbird species (IBA Canada, 2020b).
- Brackett Lake IBA also provides a notable source of breeding and migration habitat for waterbird species. It is located in the RSA and outside of the LSA (IBA Canada, 2020c).

- Other sensitive wildlife features for birds such as nests, primarily for raptors, are located throughout the LSA and RSA (GNWT, 2020c).
- Notable concentrations of raptor nests exist in the Bear Rock CZ, within the RSA, which is also a culturally sacred site (SLUBP, 2013; GNWT, 2020c).

4.1 Additional Studies

Targeted SAR surveys are planned to be undertaken to fill the data gap associated with the limited data availability for SAR. The information will help establish the existing condition for those species within the LSA and support the assessment of effects of the Project on the environment in the Developer's Assessment Report. Surveys will focus on SAR most likely to interact with the Project.

5 Closure

This TDR was prepared for the sole benefit of GNWT to describe existing conditions related to birds and bird habitat within the bird LSA and RSA. If you have any questions, please do not hesitate to contact the undersigned.

Respectfully submitted,

K'alo-Stantec Limited

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Table A.1 Recommended Activity Restriction Guidelines for Sensitive Bird Species[1]

Wildlife Species	Feature or Habitat	Specific Conditions	Sensitive Period[2]	Recommended Setback Distance (m)
Species At Risk				
Peregrine falcon	Nest	General development activities	May 1 – Aug 31	1,500
Yellow rail	Edge of waterbody with a nest	General development activities	May 1 – Aug 31	300
Lesser yellowlegs	Nest	General development activities	May 1 – Aug 31	300
Red-necked phalarope	Nest	General development activities	May 1 – Aug 31	300
Short-eared owl	Nest	General development activities	May 1 – Aug 31	1,500
Common nighthawk	Nest	General development activities	May 1 – Aug 31	200
Olive-sided flycatcher	Nest	General development activities	May 1 – Aug 31	200
Bank swallow	Nesting colony	General development activities	May 1 – Aug 31	200
Barn swallow	Nest	General development activities	May 1 – Aug 31	200
Harris's sparrow	Nest	General development activities	May 1 – Aug 31	200
Rusty blackbird	Nest	General development activities	May 1 – Aug 31	300
Horned grebe	Edge of waterbody with a nest	General development activities	May 1 – Aug 31	300
Other Species				
Waterfowl (general)	Staging area	General development activities when large concentrations of birds are present	Spring/Fall	3,000
Swans/Loons/Cranes	Nest	General development activities	May 1 – Aug 31	800
		Pedestrians/ATVs	May 1 – Aug 31	500
Ducks	Nest	General development activities	May 1 – Aug 31	150
		Pedestrians/ATVs	May 1 – Aug 31	50
Geese	Nest	General development activities	May 1 – Aug 31	500
		Pedestrians/ATVs	May 1 – Aug 31	300

Wildlife Species	Feature or Habitat	Specific Conditions	Sensitive Period[2]	Recommended Setback Distance (m)
Shorebirds	Nest	General development activities	May 1 – Aug 31	100
		Pedestrians/ATVs	May 1 – Aug 31	50
Terns/Gulls	Nest	General development activities	May 1 – Aug 31	300
		Pedestrians/ATVs	May 1 – Aug 31	200
Raptors (general)	Nest	General development activities	Mar 1 – Aug 31	1,500
	Nest	General development activities	Sep 1 – Feb 28	500
Songbirds (general)	Nest	General development activities	May 1 – Aug 31	100
		Pedestrians/ATVS	May 1 – Aug 31	30
All other birds	Nest	Varies with region and species; contact GNWT or ECCC office	Breeding / nesting seasons	100

Notes:

1 Modified from DLUPC, 2006; SLUPB, 2013; and GNWT, 2015a.

2 Sensitive periods are a general guide and specific timing may vary. Year-round avoidance may not always be feasible, and exceptions will be discussed with GNWT Environment and Natural Resources to develop appropriate mitigation.

Table A.2 Bird Species with the Potential to Occupy the Ecoregions in the LSA[1]

Group	Order	Common Name	Scientific Name	ECCC Detection[2]
Waterbirds	Waterfowl	Greater white-fronted goose	*Anser albifrons*	
		Brant	*Branta bernicla*	
		Cackling goose	*Branta hutchinsii*	
		Canada goose	*Branta canadensis*	✓
		Trumpeter swan	*Cygnus buccinator*	
		Tundra swan	*Cygnus columbianus*	
		American black duck	*Anas rubripes*	
		Mallard	*Anas platyrhynchos*	✓
		Northern pintail	*Anas acuta*	
		Green-winged teal	*Anas crecca*	
		Canvasback	*Aythya valisineria*	
		Redhead	*Aythya americana*	
		Ring-necked duck	*Aythya collaris*	✓
		Greater scaup	*Aythya marila*	
		Lesser scaup	*Aythya affinis*	✓
		King eider	*Somateria spectabilis*	
		Harlequin duck	*Histrionicus histrionicus*	
		Surf scoter	*Melanitta perspicillata*	✓
		Black scoter	*Melanitta americana*	
		Long-tailed duck	*Clangula hyemalis*	
		Bufflehead	*Bucephala albeola*	✓
		Common goldeneye	*Bucephala clangula*	✓
		Barrow's goldeneye	*Bucephala islandica*	
		Hooded merganser	*Lophodytes cucullatus*	

Group	Order	Common Name	Scientific Name	ECCC Detection[2]
Waterbirds (cont'd)	Waterfowl (cont'd)	Common merganser	*Mergus merganser*	
		Red-breasted merganser	*Mergus serrator*	
		Ruddy duck	*Oxyura jamaicensis*	
		Snow goose	*Anser caerulescens*	
		Ross's goose	*Anser rossii*	
		Blue-winged teal	*Spatula discors*	
		Northern shoveler	*Spatula clypeata*	
		Gadwall	*Mareca strepera*	
		Eurasian wigeon	*Mareca penelope*	
		American wigeon	*Mareca americana*	✓
		White-winged scoter	*Melanitta deglandi*	
	Waterbirds	Red-throated loon	*Gavia stellata*	
		Pacific loon	*Gavia pacifica*	✓
		Common loon	*Gavia immer*	✓
		Yellow-billed loon	*Gavia adamsii*	
		American white pelican	*Pelecanus erythrorhynchos*	
		Yellow rail*	*Coturnicops noveboracensis*	
		Pied-billed grebe*	*Podilymbus podiceps*	✓
		Horned grebe	*Podiceps auritus*	
		Red-necked grebe	*Podiceps grisegena*	✓
	Shorebirds	American bittern	*Botaurus lentiginosus*	✓
		Sora	*Porzana carolina*	✓
		American coot	*Fulica americana*	
		Sandhill crane	*Antigone canadensis*	✓
		Black-bellied plover	*Pluvialis squatarola*	
		American golden-plover	*Pluvialis dominica*	

Group	Order	Common Name	Scientific Name	ECCC Detection[2]
Waterbirds (cont'd)	Shorebirds (cont'd)	Semipalmated plover	*Charadrius semipalmatus*	
		Killdeer	*Charadrius vociferus*	
		Spotted sandpiper	*Actitis macularius*	
		Solitary sandpiper	*Tringa solitaria*	✓
		Greater yellowlegs	*Tringa melanoleuca*	✓
		Lesser yellowlegs	*Tringa flavipes*	✓
		Upland sandpiper	*Bartramia longicauda*	
		Whimbrel	*Numenius phaeopus*	
		Hudsonian godwit	*Limosa haemastica*	
		Marbled godwit	*Limosa fedoa*	
		Ruddy turnstone	*Arenaria interpres*	
		Sanderling	*Calidris alba*	
		Semipalmated sandpiper	*Calidris pusilla*	
		Western sandpiper	*Calidris mauri*	
		Least sandpiper	*Calidris minutilla*	
		Baird's sandpiper	*Calidris bairdii*	
		Pectoral sandpiper	*Calidris melanotos*	
		Dunlin	*Calidris alpina*	
		Stilt sandpiper	*Calidris himantopus*	
		Short-billed dowitcher	*Limnodromus griseus*	
		Long-billed dowitcher	*Limnodromus scolopaceus*	
		Wilson's snipe	*Gallinago delicata*	✓
		Wilson's phalarope	*Phalaropus tricolor*	
		Red-necked phalarope	*Phalaropus lobatus*	
		Mew gull	*Larus canus*	✓
		Ring-billed gull	*Larus delawarensis*	✓

Group	Order	Common Name	Scientific Name	ECCC Detection[2]
Waterbirds (cont'd)	Shorebirds (cont'd)	Herring gull	*Larus argentatus*	
		Glaucous gull	*Larus hyperboreus*	
		Black tern	*Chlidonias niger*	
		Common tern	*Sterna hirundo*	
		Arctic tern	*Sterna paradisaea*	
		Parasitic jaeger	*Stercorarius parasiticus*	
		Long-tailed jaeger	*Stercorarius longicaudus*	
		Bonaparte's gull	*Chroicocephalus philadelphia*	
		Buff-breasted sandpiper	*Calidris subruficollis*	
Birds of Prey	Raptors	Bald eagle	*Haliaeetus leucocephalus*	✓
		Northern harrier	*Circus hudsonius*	
		Sharp-shinned hawk	*Accipiter striatus*	
		Northern goshawk	*Accipiter gentilis*	
		Swainson's hawk	*Buteo swainsoni*	
		Red-tailed hawk	*Buteo jamaicensis*	
		Rough-legged hawk	*Buteo lagopus*	
		Golden eagle	*Aquila chrysaetos*	
		American kestrel	*Falco sparverius*	
		Merlin	*Falco columbarius*	
		Gyrfalcon	*Falco rusticolus*	
		Peregrine falcon	*Falco peregrinus*	
		Osprey	*Pandion haliaetus*	
	Owls	Great horned owl	*Bubo virginianus*	✓
		Snowy owl	*Bubo scandiacus*	
		Northern hawk owl	*Surnia ulula*	
		Great grey owl	*Strix nebulosa*	

Group	Order	Common Name	Scientific Name	ECCC Detection[2]
Birds of Prey (cont'd)	Owls (cont'd)	Short-eared owl	*Asio flammeus*	
		Boreal owl	*Aegolius funereus*	
Upland game birds		Ruffed grouse	*Bonasa umbellus*	✓
		Spruce grouse	*Canachites canadensis*	
		Willow ptarmigan	*Lagopus lagopus*	
		Rock ptarmigan	*Lagopus muta*	
		Sharp-tailed grouse	*Tympanuchus phasianellus*	
Landbirds	Near-passerines	Common nighthawk	*Chordeiles minor*	✓
		Belted kingfisher	*Megaceryle alcyon*	
		Yellow-bellied sapsucker	*Sphyrapicus varius*	✓
		Downy woodpecker	*Dryobates pubescens*	
		American three-toed woodpecker	*Picoides dorsalis*	
		Black-backed woodpecker	*Picoides arcticus*	✓
		Northern flicker	*Colaptes auratus*	✓
		Pileated woodpecker	*Dryocopus pileatus*	✓
		Hairy woodpecker	*Dryobates villosus*	
	Passerines	Mourning dove	*Zenaida macroura*	
		Olive-sided flycatcher	*Contopus cooperi*	✓
		Western wood-pewee	*Contopus sordidulus*	✓
		Yellow-bellied flycatcher	*Empidonax flaviventris*	✓
		Alder flycatcher	*Empidonax alnorum*	✓
		Least flycatcher	*Empidonax minimus*	✓
		Hammond's flycatcher	*Empidonax hammondii*	
		Eastern phoebe	*Sayornis phoebe*	
		Say's phoebe	*Sayornis saya*	
		Eastern kingbird	*Tyrannus tyrannus*	✓

Group	Order	Common Name	Scientific Name	ECCC Detection[2]
Landbirds (cont'd)	Passerines (cont'd)	Blue-headed vireo	*Vireo solitarius*	✓
		Warbling vireo	*Vireo gilvus*	✓
		Philadelphia vireo	*Vireo philadelphicus*	
		Red-eyed vireo	*Vireo olivaceus*	✓
		Black-billed magpie	*Pica hudsonia*	
		American crow	*Corvus brachyrhynchos*	
		Common raven	*Corvus corax*	✓
		Horned lark	*Eremophila alpestris*	
		Tree swallow	*Tachycineta bicolor*	✓
		Violet-green swallow	*Tachycineta thalassina*	
		Bank swallow	*Riparia riparia*	
		Cliff swallow	*Petrochelidon pyrrhonota*	
		Barn swallow	*Hirundo rustica*	
		Black-capped chickadee	*Poecile atricapillus*	✓
		Boreal chickadee	*Poecile hudsonicus*	✓
		Red-breasted nuthatch	*Sitta canadensis*	
		American dipper	*Cinclus mexicanus*	
		Golden-crowned kinglet	*Regulus satrapa*	
		Northern wheatear	*Oenanthe oenanthe*	
		Mountain bluebird	*Sialia currucoides*	
		Townsend's solitaire	*Myadestes townsendi*	✓
		Gray-cheeked thrush	*Catharus minimus*	✓
		Swainson's thrush	*Catharus ustulatus*	✓
		Hermit thrush	*Catharus guttatus*	✓
		American robin	*Turdus migratorius*	✓
		Varied thrush	*Ixoreus naevius*	✓

Group	Order	Common Name	Scientific Name	ECCC Detection[2]
Landbirds (cont'd)	Passerines (cont'd)	European starling	*Sturnus vulgaris*	
		American pipit	*Anthus rubescens*	
		Bohemian waxwing	*Bombycilla garrulus*	✓
		Cedar waxwing	*Bombycilla cedrorum*	
		Yellow warbler	*Setophaga petechia*	✓
		Magnolia warbler	*Setophaga magnolia*	✓
		Cape May warbler	*Setophaga tigrina*	✓
		Yellow-rumped warbler	*Setophaga coronata*	✓
		Palm warbler	*Setophaga palmarum*	✓
		Bay-breasted warbler	*Setophaga castanea*	✓
		Blackpoll warbler	*Setophaga striata*	✓
		Black-and-white warbler	*Mniotilta varia*	✓
		American redstart	*Setophaga ruticilla*	✓
		Ovenbird	*Seiurus aurocapilla*	✓
		Northern waterthrush	*Parkesia noveboracensis*	✓
		Mourning warbler	*Geothlypis philadelphia*	✓
		Common yellowthroat	*Geothlypis trichas*	✓
		Wilson's warbler	*Cardellina pusilla*	✓
		Tennessee warbler	*Leiothlypis peregrina*	✓
		Orange-crowned warbler	*Leiothlypis celata*	✓
		Ruby-crowned kinglet	*Corthylio calendula*	✓
		American tree sparrow	*Spizelloides arborea*	✓
		Chipping sparrow	*Spizella passerina*	✓
		Vesper sparrow	*Pooecetes gramineus*	
		Savannah sparrow	*Passerculus sandwichensis*	✓
		Fox sparrow	*Passerella iliaca*	✓

Group	Order	Common Name	Scientific Name	ECCC Detection[2]
Landbirds (cont'd)	Passerines (cont'd)	Song sparrow	*Melospiza melodia*	
		Lincoln's sparrow	*Melospiza lincolnii*	✓
		Swamp sparrow	*Melospiza georgiana*	✓
		White-throated sparrow	*Zonotrichia albicollis*	✓
		Harris's sparrow	*Zonotrichia querula*	✓
		White-crowned sparrow	*Zonotrichia leucophrys*	✓
		Golden-crowned sparrow	*Zonotrichia atricapilla*	
		House sparrow	*Passer domesticus*	
		Clay-colored sparrow	*Spizella pallida*	✓
		Le Conte's sparrow	*Ammospiza leconteii*	✓
		Dark-eyed junco	*Junco hyemalis*	✓
		Lapland longspur	*Calcarius lapponicus*	
		Smith's longspur	*Calcarius pictus*	
		Snow bunting	*Plectrophenax nivalis*	
		Rose-breasted grosbeak	*Pheucticus ludovicianus*	
		Lazuli bunting	*Passerina amoena*	
		Red-winged blackbird	*Agelaius phoeniceus*	✓
		Rusty blackbird	*Euphagus carolinus*	
		Brewer's blackbird	*Euphagus cyanocephalus*	
		Common grackle	*Quiscalus quiscula*	
		Brown-headed cowbird	*Molothrus ater*	
		Pine grosbeak	*Pinicola enucleator*	✓
		Red crossbill	*Loxia curvirostra*	
		White-winged crossbill	*Loxia leucoptera*	✓
		Common redpoll	*Acanthis flammea*	✓
		Hoary redpoll	*Acanthis hornemanni*	

Group	Order	Common Name	Scientific Name	ECCC Detection[2]
Landbirds (cont'd)	Passerines (cont'd)	Pine siskin	*Spinus pinus*	✓
		Evening grosbeak	*Coccothraustes vespertinus*	
		Western tanager	*Piranga ludoviciana*	✓
		Canada jay	*Perisoreus canadensis*	✓
		Winter wren	*Troglodytes hiemalis*	
		Purple finch	*Haemorhous purpureus*	
		Northern shrike	*Lanius borealis*	

Notes:

[1] Species within Level IV ecoregions 3.3.2.2 North Mackenzie Plain, 3.3.2.3 Norman Range, 3.2.2.11 Central Mackenzie Plain, and 6.1.5.1 Central Mackenzie Valley (GNWT, 2020c).

[2] '✓' indicates a historical record from the Environment and Climate Change Canada breeding bird survey data 2004, 2006, and 2017 (ECCC, 2020a).

* As indicated by ECCC (Dufour, 2020, pers. comm.; ECCC, 2020a).

Table A.3 Summary of Historical North American Breeding Bird Survey Data in the RSA (Sahtu Region)[1]

Common Name	Scientific Name	Survey Route and Breeding Abundance[2]			
		Norman Wells		Bear River	
		Mean	Range	Mean	range
Canada goose	*Branta canadensis*	2.5	0-12	-	-
Northern pintail	*Anas acuta*	0.2	0-1	-	-
Green-winged teal	*Anas crecca*	1.5	0-6	-	-
Ring-necked duck	*Aythya collaris*	0.1	0-1	-	-
Greater scaup	*Aythya marila*	0.9	0-6	-	-
Lesser scaup	*Aythya affinis*	5.9	0-20	-	-
Blue-winged teal	*Spatula discors*	0.3	0-1	-	-
Northern shoveler	*Spatula clypeata*	2.1	0-11	-	-
American wigeon	*Mareca americana*	3.5	0-10	-	-
White-winged scoter	*Melanitta deglandi*	0.7	0-8	-	-
Pacific loon	*Gavia pacifica*	0.8	0-2	0.5	0-1
Horned grebe	*Podiceps auritus*	0.6	0-3	-	-
Sora	*Porzana carolina*	2.1	0-5	-	-
American coot	*Fulica americana*	0.2	0-1	-	-
Sandhill crane	*Antigone canadensis*	1.5	0-5	2.0	0-4
Semipalmated plover	*Charadrius semipalmatus*	0.1	0-1	-	-
Killdeer	*Charadrius vociferus*	0.4	0-2	-	-
Spotted sandpiper	*Actitis macularius*	0.1	0-1	-	-
Solitary sandpiper	*Tringa solitaria*	0.5	0-2	-	-
Lesser yellowlegs	*Tringa flavipes*	6.2	0-18	-	-
Wilson's snipe	*Gallinago delicata*	3.6	0-10	1.0	1-1
Mew gull	*Larus canus*	6.6	0-15	-	-
Herring gull	*Larus argentatus*	3.8	1-9	-	-

Common Name	Scientific Name	Survey Route and Breeding Abundance[2]			
		Norman Wells		Bear River	
		Mean	Range	Mean	range
Bonaparte's gull	*Chroicocephalus philadelphia*	0.1	0-1	-	-
Short-eared owl	*Asio flammeus*	0.2	0-2	-	-
Spruce grouse	*Canachites canadensis*	1.1	0-12	-	-
Sharp-tailed grouse	*Tympanuchus phasianellus*	-	-	1.0	1-1
Northern harrier	*Circus hudsonius*	0.4	0-1	-	-
Red-tailed hawk	*Buteo jamaicensis*	0.1	0-1	1.0	1-1
American kestrel	*Falco sparverius*	0.2	0-1	0.5	0-1
Belted kingfisher	*Megaceryle alcyon*	0.1	0-1	-	-
Downy woodpecker	*Dryobates pubescens*	0.1	0-1	-	-
Northern flicker	*Colaptes auratus*	2.7	1-5	5.5	2-9
Olive-sided flycatcher	*Contopus cooperi*	0.6	0-3	1.5	1-2
Western wood-pewee	*Contopus sordidulus*	-	-	0.5	0-1
Alder flycatcher	*Empidonax alnorum*	22.1	9-41	55.5	35-76
Least flycatcher	*Empidonax minimus*	0.4	0-2	3.5	1-6
Eastern kingbird	*Tyrannus tyrannus*	0.5	0-2	-	-
Warbling vireo	*Vireo gilvus*	0.7	0-3	-	-
Red-eyed vireo	*Vireo olivaceus*	0.5	0-2	2.5	2-3
Common raven	*Corvus corax*	0.6	0-2	2.0	1-3
Tree swallow	*Tachycineta bicolor*	2.1	0-13	-	-
Cliff swallow	*Petrochelidon pyrrhonota*	0.4	0-4	-	-
Boreal chickadee	*Poecile hudsonicus*	0.6	0-2	-	-
Gray-cheeked thrush	*Catharus minimus*	0.5	0-2	1.0	1-1
Swainson's thrush	*Catharus ustulatus*	78.9	55-143	10.0	2-18
Hermit thrush	*Catharus guttatus*	16.8	4-32	45.0	11-79

Common Name	Scientific Name	Survey Route and Breeding Abundance[2]			
		Norman Wells		Bear River	
		Mean	Range	Mean	range
American robin	*Turdus migratorius*	30.7	18-45	12.5	7-18
Varied thrush	*Ixoreus naevius*	1.4	0-5	-	-
Bohemian waxwing	*Bombycilla garrulus*	0.5	0-3	0.5	0-1
Yellow warbler	*Setophaga petechia*	4.5	0-10	9.5	4-15
Magnolia warbler	*Setophaga magnolia*	0.7	0-3	0.5	0-1
Yellow-rumped warbler	*Setophaga coronata*	34.6	6-63	0.5	0-1
Palm warbler	*Setophaga palmarum*	9.5	0-27	1.5	0-3
Blackpoll warbler	*Setophaga striata*	8.2	4-13	0.5	0-1
Northern waterthrush	*Parkesia noveboracensis*	0.7	0-3	-	-
Common yellowthroat	*Geothlypis trichas*	1.5	0-4	-	-
Wilson's warbler	*Cardellina pusilla*	0.2	0-1	0.5	0-1
Ruby-crowned kinglet	*Corthylio calendula*	14.8	4-29	-	-
Chipping sparrow	*Spizella passerina*	35.9	15-45	5.0	4-6
Savannah sparrow	*Passerculus sandwichensis*	4.2	1-8	13.5	9-18
Fox sparrow	*Passerella iliaca*	11.8	1-21	18.0	16-20
Song sparrow	*Melospiza melodia*	0.1	0-1	-	-
Lincoln's sparrow	*Melospiza lincolnii*	26.4	13-42	25.0	22-28
Swamp sparrow	*Melospiza georgiana*	4.4	0-10	-	-
White-throated sparrow	*Zonotrichia albicollis*	12.3	3-25	22.5	19-26
Harris's sparrow	*Zonotrichia querula*	0.1	0-1	-	-
White-crowned sparrow	*Zonotrichia leucophrys*	27.9	8-56	102.0	89-115
Dark-eyed junco	*Junco hyemalis*	19.4	6-37	4.0	1-7
Red-winged blackbird	*Agelaius phoeniceus*	0.5	0-2	-	-
Brown-headed cowbird	*Molothrus ater*	0.1	0-1	-	-

Common Name	Scientific Name	Survey Route and Breeding Abundance[2]			
		Norman Wells		Bear River	
		Mean	Range	Mean	range
Pine grosbeak	*Pinicola enucleator*	2.5	0-7	-	-
White-winged crossbill	*Loxia leucoptera*	7.2	0-34	0.5	0-1
Common redpoll	*Acanthis flammea*	3.8	0-9	13.5	12-15
Pine siskin	*Spinus pinus*	0.1	0-1	-	-
Western tanager	*Piranga ludoviciana*	0.3	0-2	-	-
Canada jay	*Perisoreus canadensis*	11.1	3-18	3.5	3-4
Clay-colored sparrow	*Spizella pallida*	0.2	0-1	0.5	0-1
LeConte's sparrow	*Ammospiza leconteii*	0.2	0-2	-	-
Tennessee warbler	*Leiothlypis peregrina*	5.2	0-20	1.0	1-1
Orange-crowned warbler	*Leiothlypis celata*	19.6	1-29	18.0	10-26

Notes:

[1] Data summarized from (Pardieck et al., 2019)

[2] Historical data (number of individuals detected) from 1995-2005 on the Norman Wells route from 2004-2005 on the Bear River route.

Table A.4 Summary of the Number of Survey Locations with Breeding Bird Species Detections from the ECCC ARU Surveys in 2017

Species		Major Land Cover Class							
Common Name	Scientific Name	Broadleaf Forest	Coniferous Forest	Mixedwood Forest	Shrubland	Herbaceous & Unvegetated	Wetland	Water	Total
Canada goose	*Branta canadensis*	0	1	0	1	0	2	0	4
Pacific loon	*Gavia pacifica*	0	0	0	1	0	0	0	1
Common loon	*Gavia immer*	0	1	0	1	0	0	0	2
Pied-billed grebe	*Podilymbus podiceps*	0	0	0	1	0	0	0	1
Red-necked grebe	*Podiceps grisegena*	0	0	0	1	0	0	0	1
American bittern	*Botaurus lentiginosus*	0	2	0	0	0	0	0	2
Sora	*Porzana carolina*	1	0	0	0	0	2	0	3
Sandhill crane	*Antigone canadensis*	0	0	0	4	1	2	0	7
Solitary sandpiper	*Tringa solitaria*	1	1	0	0	1	0	0	3
Greater yellowlegs	*Tringa melanoleuca*	0	0	0	0	0	1	0	1
Lesser yellowlegs	*Tringa flavipes*	0	2	0	2	0	2	0	6
Wilson's snipe	*Gallinago delicata*	1	7	1	4	0	3	0	16
Ring-billed gull	*Larus delawarensis*	0	0	0	1	0	0	0	1
Great horned owl	*Bubo virginianus*	0	0	0	0	0	1	0	1
Ruffed grouse	*Bonasa umbellus*	0	1	0	2	0	2	1	5
Common nighthawk	*Chordeiles minor*	0	0	0	0	0	1	0	1
Yellow-bellied sapsucker	*Sphyrapicus varius*	0	3	0	1	0	2	1	6
Black-backed woodpecker	*Picoides arcticus*	0	0	1	0	0	0	0	1

Species		Major Land Cover Class							
Common Name	Scientific Name	Broadleaf Forest	Coniferous Forest	Mixedwood Forest	Shrubland	Herbaceous & Unvegetated	Wetland	Water	Total
Northern flicker	*Colaptes auratus*	0	3	0	0	0	1	1	4
Pileated woodpecker	*Dryocopus pileatus*	0	1	0	0	0	0	0	1
Olive-sided flycatcher	*Contopus cooperi*	0	1	0	0	0	0	0	1
Western wood-pewee	*Contopus sordidulus*	0	0	0	0	0	2	0	2
Yellow-bellied flycatcher	*Empidonax flaviventris*	0	2	0	2	0	2	0	6
Alder flycatcher	*Empidonax alnorum*	1	13	1	4	2	8	0	29
Least flycatcher	*Empidonax minimus*	1	1	1	0	0	2	0	5
Blue-headed vireo	*Vireo solitarius*	0	0	1	0	0	0	0	1
Warbling vireo	*Vireo gilvus*	0	3	0	1	1	3	0	8
Red-eyed vireo	*Vireo olivaceus*	0	0	0	0	0	1	0	1
Common raven	*Corvus corax*	0	0	1	1	0	2	0	4
Tree swallow	*Tachycineta bicolor*	0	0	0	0	0	1	0	1
Black-capped chickadee	*Poecile atricapillus*	0	0	0	0	1	0	0	1
Boreal chickadee	*Poecile hudsonicus*	0	3	1	0	0	0	0	4
Townsend's solitaire	*Myadestes townsendi*	0	1	0	0	0	0	0	1
Gray-cheeked thrush	*Catharus minimus*	0	0	1	0	0	2	0	3
Swainson's thrush	*Catharus ustulatus*	3	25	3	6	2	13	1	52
Hermit thrush	*Catharus guttatus*	2	23	3	6	2	11	0	47
American robin	*Turdus migratorius*	1	17	1	5	1	11	1	36
Varied thrush	*Ixoreus naevius*	1	6	0	0	0	3	0	10

Species		Major Land Cover Class							
Common Name	Scientific Name	Broadleaf Forest	Coniferous Forest	Mixedwood Forest	Shrubland	Herbaceous & Unvegetated	Wetland	Water	Total
Bohemian waxwing	*Bombycilla garrulus*	0	0	0	1	0	0	0	1
Yellow warbler	*Setophaga petechia*	0	1	1	1	1	1	0	5
Magnolia warbler	*Setophaga magnolia*	0	4	0	2	0	3	0	9
Cape may warbler	*Setophaga tigrina*	1	1	0	0	0	0	0	2
Yellow-rumped warbler	*Setophaga coronata*	2	16	3	3	0	6	1	30
Palm warbler	*Setophaga palmarum*	1	11	1	4	1	3	0	21
Bay-breasted warbler	*Setophaga castanea*	0	1	0	0	0	0	0	1
Blackpoll warbler	*Setophaga striata*	2	4	0	0	1	2	0	9
Black-and-white warbler	*Mniotilta varia*	0	0	0	0	0	1	0	1
American redstart	*Setophaga ruticilla*	0	1	0	0	0	2	0	3
Ovenbird	*Seiurus aurocapilla*	0	0	0	0	0	4	0	4
Northern waterthrush	*Parkesia noveboracensis*	0	1	1	2	1	2	0	7
Common yellowthroat	*Geothlypis trichas*	0	3	1	0	0	1	0	5
Wilson's warbler	*Cardellina pusilla*	1	1	0	1	1	1	0	5
Tennessee warbler	*Leiothlypis peregrina*	3	21	3	3	1	9	1	40
Orange-crowned warbler	*Leiothlypis celata*	3	9	1	5	2	6	0	26
Ruby-crowned kinglet	*Corthylio calendula*	2	17	2	2	0	5	1	28
American tree sparrow	*Spizelloides arborea*	0	1	0	0	1	0	0	2
Chipping sparrow	*Spizella passerina*	2	23	3	3	2	8	1	41
Savannah sparrow	*Passerculus sandwichensis*	0	0	0	0	0	2	0	2

Species		Major Land Cover Class							
Common Name	**Scientific Name**	**Broadleaf Forest**	**Coniferous Forest**	**Mixedwood Forest**	**Shrubland**	**Herbaceous & Unvegetated**	**Wetland**	**Water**	**Total**
Fox sparrow	*Passerella iliaca*	2	5	0	2	1	5	0	15
Lincoln's sparrow	*Melospiza lincolnii*	2	20	2	4	1	9	0	38
Swamp sparrow	*Melospiza georgiana*	0	3	1	1	0	3	0	8
White-throated sparrow	*Zonotrichia albicollis*	3	15	2	6	2	10	1	38
Harris's sparrow	*Zonotrichia querula*	0	0	0	1	0	0	0	1
White-crowned sparrow	*Zonotrichia leucophrys*	1	2	1	4	2	3	0	13
Clay-colored sparrow	*Spizella pallida*	0	2	1	0	0	0	0	3
LeConte's sparrow	*Ammospiza leconteii*	0	0	0	0	0	1	0	1
Dark-eyed junco	*Junco hyemalis*	2	20	1	3	2	8	1	36
White-winged crossbill	*Loxia leucoptera*	1	11	0	1	0	4	0	17
Common redpoll	*Acanthis flammea*	0	0	0	0	0	2	0	2
Pine siskin	*Spinus pinus*	0	2	1	0	1	0	0	4
Western tanager	*Piranga ludoviciana*	0	5	0	0	0	5	1	10
Canada jay	*Perisoreus canadensis*	0	7	1	2	0	4	0	14
Total	**72 species**	**40**	**324**	**41**	**95**	**31**	**190**	**12**	**721**

Table A.5 Summary of the Number of ARU Species Detections by Ecoregion from the ECCC ARU Surveys in 2017

Common Name	Scientific Name	Number of Detections (Mean and Standard Deviation)					
		Boreal Cordillera		Taiga Cordillera		Taiga Plains	
		Mean	SD	Mean	SD	Mean	SD
Canada goose	*Branta canadensis*	0.00	0.00	0.11	0.46	0.16	0.37
Pacific loon	*Gavia pacifica*	0.00	0.00	0.00	0.00	0.05	0.23
Common loon	*Gavia immer*	0.00	0.00	0.05	0.23	0.05	0.23
Pied-billed grebe	*Podilymbus podiceps*	0.00	0.00	0.00	0.00	0.05	0.23
Red-necked grebe	*Podiceps grisegena*	0.00	0.00	0.00	0.00	0.11	0.46
American bittern	*Botaurus lentiginosus*	0.00	0.00	0.16	0.50	0.00	0.00
Sora	*Porzana carolina*	0.20	0.77	0.05	0.23	0.16	0.69
Sandhill crane	*Antigone canadensis*	0.00	0.00	0.11	0.32	0.47	0.90
Solitary sandpiper	*Tringa solitaria*	0.00	0.00	0.00	0.00	0.21	0.54
Greater yellowlegs	*Tringa melanoleuca*	0.00	0.00	0.00	0.00	0.05	0.23
Lesser yellowlegs	*Tringa flavipes*	0.00	0.00	0.05	0.23	0.32	0.58
Wilson's snipe	*Gallinago delicata*	0.20	0.56	0.63	0.90	1.00	2.03
Ring-billed gull	*Larus delawarensis*	0.00	0.00	0.00	0.00	0.05	0.23
Great horned owl	*Bubo virginianus*	0.00	0.00	0.05	0.23	0.00	0.00
Ruffed grouse	*Bonasa umbellus*	0.13	0.35	0.21	0.54	0.05	0.23
Common nighthawk	*Chordeiles minor*	0.00	0.00	0.05	0.23	0.00	0.00
Yellow-bellied sapsucker	*Sphyrapicus varius*	0.53	0.92	0.11	0.32	0.00	0.00
Black-backed woodpecker	*Picoides arcticus*	0.00	0.00	0.05	0.23	0.00	0.00
Northern flicker	*Colaptes auratus*	0.07	0.26	0.05	0.23	0.16	0.37
Pileated woodpecker	*Dryocopus pileatus*	0.07	0.26	0.00	0.00	0.00	0.00
Olive-sided flycatcher	*Contopus cooperi*	0.00	0.00	0.00	0.00	0.16	0.69

Common Name	Scientific Name	Number of Detections (Mean and Standard Deviation)					
		Boreal Cordillera		Taiga Cordillera		Taiga Plains	
		Mean	SD	Mean	SD	Mean	SD
Western wood-pewee	*Contopus sordidulus*	0.07	0.26	0.00	0.00	0.05	0.23
Yellow-bellied flycatcher	*Empidonax flaviventris*	0.07	0.26	0.42	0.90	0.05	0.23
Alder flycatcher	*Empidonax alnorum*	1.00	1.60	2.21	2.53	2.26	2.70
Least flycatcher	*Empidonax minimus*	0.07	0.26	0.21	0.71	0.11	0.32
Blue-headed vireo	*Vireo solitarius*	0.00	0.00	0.05	0.23	0.00	0.00
Warbling vireo	*Vireo gilvus*	0.20	0.56	0.21	0.42	0.11	0.32
Red-eyed vireo	*Vireo olivaceus*	0.00	0.00	0.05	0.23	0.00	0.00
Common raven	*Corvus corax*	0.00	0.00	0.11	0.46	0.21	0.54
Tree swallow	*Tachycineta bicolor*	0.00	0.00	0.00	0.00	0.05	0.23
Black-capped chickadee	*Poecile atricapillus*	0.00	0.00	0.00	0.00	0.05	0.23
Boreal chickadee	*Poecile hudsonicus*	0.13	0.35	0.05	0.23	0.11	0.46
Townsend's solitaire	*Myadestes townsendi*	0.00	0.00	0.11	0.46	0.00	0.00
Gray-cheeked thrush	*Catharus minimus*	0.00	0.00	0.11	0.32	0.05	0.23
Swainson's thrush	*Catharus ustulatus*	7.40	4.10	10.11	4.25	7.68	4.04
Hermit thrush	*Catharus guttatus*	2.33	1.88	5.68	3.79	5.26	3.28
American robin	*Turdus migratorius*	1.60	1.55	1.68	1.95	1.74	1.37
Varied thrush	*Ixoreus naevius*	0.93	1.10	0.00	0.00	0.05	0.23
Bohemian waxwing	*Bombycilla garrulus*	0.00	0.00	0.05	0.23	0.00	0.00
Yellow warbler	*Setophaga petechia*	0.00	0.00	0.37	1.16	0.21	0.71
Magnolia warbler	*Setophaga magnolia*	0.07	0.26	0.89	1.41	0.00	0.00
Cape may warbler	*Setophaga tigrina*	0.07	0.26	0.00	0.00	0.05	0.23
Yellow-rumped warbler	*Setophaga coronata*	1.67	2.35	1.21	1.87	1.53	2.22
Palm warbler	*Setophaga palmarum*	0.33	0.62	1.26	2.40	0.58	0.96

Common Name	Scientific Name	Number of Detections (Mean and Standard Deviation)					
		Boreal Cordillera		Taiga Cordillera		Taiga Plains	
		Mean	SD	Mean	SD	Mean	SD
Bay-breasted warbler	*Setophaga castanea*	0.00	0.00	0.05	0.23	0.00	0.00
Blackpoll warbler	*Setophaga striata*	0.00	0.00	0.16	0.50	1.05	1.78
Black-and-white warbler	*Mniotilta varia*	0.00	0.00	0.05	0.23	0.00	0.00
American redstart	*Setophaga ruticilla*	0.00	0.00	0.26	1.15	0.11	0.32
Ovenbird	*Seiurus aurocapilla*	0.07	0.26	0.11	0.32	0.05	0.23
Northern waterthrush	*Parkesia noveboracensis*	0.00	0.00	0.89	2.58	0.42	1.39
Common yellowthroat	*Geothlypis trichas*	0.07	0.26	0.32	0.95	0.05	0.23
Wilson's warbler	*Cardellina pusilla*	0.00	0.00	0.05	0.23	0.21	0.42
Tennessee warbler	*Leiothlypis peregrina*	10.07	6.04	4.84	3.27	2.42	3.58
Orange-crowned warbler	*Leiothlypis celata*	0.20	0.56	2.32	3.00	4.16	3.67
Ruby-crowned kinglet	*Corthylio calendula*	1.93	1.62	1.11	1.33	1.11	1.82
American tree sparrow	*Spizelloides arborea*	0.00	0.00	0.05	0.23	0.05	0.23
Chipping sparrow	*Spizella passerina*	2.87	1.60	2.63	2.97	2.79	3.10
Savannah sparrow	*Passerculus sandwichensis*	0.00	0.00	0.00	0.00	0.37	1.12
Fox sparrow	*Passerella iliaca*	0.00	0.00	1.16	1.71	1.05	1.87
Lincoln's sparrow	*Melospiza lincolnii*	2.00	2.30	2.63	2.22	3.47	3.55
Swamp sparrow	*Melospiza georgiana*	0.07	0.26	0.63	1.64	0.37	0.76
White-throated sparrow	*Zonotrichia albicollis*	4.40	3.54	5.05	5.24	4.47	4.85
Harris's sparrow	*Zonotrichia querula*	0.00	0.00	0.00	0.00	0.05	0.23
White-crowned sparrow	*Zonotrichia leucophrys*	0.00	0.00	0.37	0.83	1.58	2.46
Clay-colored sparrow	*Spizella pallida*	0.07	0.26	0.21	0.63	0.00	0.00
LeConte's sparrow	*Ammospiza leconteii*	0.00	0.00	0.00	0.00	0.05	0.23
Dark-eyed junco	*Junco hyemalis*	1.93	1.39	1.16	1.89	2.00	2.03

Common Name	Scientific Name	Number of Detections (Mean and Standard Deviation)					
		Boreal Cordillera		Taiga Cordillera		Taiga Plains	
		Mean	SD	Mean	SD	Mean	SD
White-winged crossbill	*Loxia leucoptera*	0.73	0.88	0.21	0.54	0.37	0.60
Common redpoll	*Acanthis flammea*	0.07	0.26	0.00	0.00	0.05	0.23
Pine siskin	*Spinus pinus*	0.07	0.26	0.11	0.32	0.05	0.23
Western tanager	*Piranga ludoviciana*	1.20	1.21	0.05	0.23	0.05	0.23
Canada jay	*Perisoreus canadensis*	0.40	0.63	0.26	0.45	0.26	0.56

Table A.6 Summary of the Number of Individuals Detected during the ECCC Point-count Surveys in 2004 and 2006

Species		Major Land Cover Class							
Common Name	Scientific Name	Broadleaf Forest	Coniferous Forest	Mixedwood Forest	Shrubland	Herbaceous & Unvegetated	Wetland	Water	Total
Mallard	*Anas platyrhynchos*	0	0	0	0	0	0	2	2
Ring-necked duck	*Aythya collaris*	0	0	0	0	0	1	0	1
Lesser scaup	*Aythya affinis*	0	1	0	0	0	1	1	3
Surf scoter	*Melanitta perspicillata*	0	0	0	0	0	0	2	2
Bufflehead	*Bucephala albeola*	0	0	0	0	0	1	1	2
Common goldeneye	*Bucephala clangula*	0	1	0	0	0	0	0	1
American wigeon	*Mareca americana*	0	0	0	0	0	0	1	1
Pacific loon	*Gavia pacifica*	0	1	0	0	0	0	2	3
Common loon	*Gavia immer*	0	1	0	0	0	0	0	1
Bald eagle	*Haliaeetus leucocephalus*	0	0	0	0	0	0	1	1
Solitary sandpiper	*Tringa solitaria*	0	0	0	0	0	0	3	3
Lesser yellowlegs	*Tringa flavipes*	0	0	0	0	0	0	1	1
Wilson's snipe	*Gallinago delicata*	0	2	0	2	0	0	3	7
Common gull	*Larus canus*	0	0	0	0	0	0	1	1
Northern flicker	*Colaptes auratus*	0	0	0	0	0	1	4	5
Alder flycatcher	*Empidonax alnorum*	0	3	0	4	0	0	0	7
Least flycatcher	*Empidonax minimus*	0	0	0	1	0	0	0	1
Eastern kingbird	*Tyrannus tyrannus*	0	0	0	0	0	0	1	1

Species		Major Land Cover Class							
Common Name	Scientific Name	Broadleaf Forest	Coniferous Forest	Mixedwood Forest	Shrubland	Herbaceous & Unvegetated	Wetland	Water	Total
Warbling vireo	*Vireo gilvus*	6	0	0	0	0	0	0	6
Common raven	*Corvus corax*	0	4	0	1	0	0	0	5
Tree swallow	*Tachycineta bicolor*	0	2	0	0	0	1	1	4
Boreal chickadee	*Poecile hudsonicus*	0	1	2	0	0	0	0	3
Swainson's thrush	*Catharus ustulatus*	5	13	8	0	0	7	0	33
Hermit thrush	*Catharus guttatus*	0	6	0	1	0	1	1	9
American robin	*Turdus migratorius*	0	4	0	3	0	0	4	11
Yellow-rumped warbler	*Setophaga coronata*	7	13	0	0	0	3	3	26
Palm warbler	*Setophaga palmarum*	0	6	0	0	0	5	0	11
Blackpoll warbler	*Setophaga striata*	0	7	1	2	0	4	0	14
Black-and-white warbler	*Mniotilta varia*	1	0	0	0	0	0	0	1
Northern waterthrush	*Parkesia noveboracensis*	0	0	0	1	0	0	4	5
Mourning warbler	*Geothlypis philadelphia*	1	0	0	0	0	0	0	1
Tennessee warbler	*Leiothlypis peregrina*	2	2	2	0	0	1	1	8
Orange-crowned warbler	*Leiothlypis celata*	6	4	4	4	0	0	0	18
Ruby-crowned kinglet	*Corthylio calendula*	1	9	0	0	0	1	2	13
Chipping sparrow	*Spizella passerina*	0	15	2	6	0	2	2	27
Savannah sparrow	*Passerculus sandwichensis*	0	11	0	6	0	0	0	17
Fox sparrow	*Passerella iliaca*	0	1	0	1	0	0	0	2
Lincoln's sparrow	*Melospiza lincolnii*	2	21	0	6	0	6	5	40

Species		Major Land Cover Class							
Common Name	**Scientific Name**	**Broadleaf Forest**	**Coniferous Forest**	**Mixedwood Forest**	**Shrubland**	**Herbaceous & Unvegetated**	**Wetland**	**Water**	**Total**
Swamp sparrow	*Melospiza georgiana*	0	0	0	2	0	0	1	3
White-throated sparrow	*Zonotrichia albicollis*	0	0	0	2	0	1	1	4
White-crowned sparrow	*Zonotrichia leucophrys*	1	20	0	11	0	3	4	39
Dark-eyed junco	*Junco hyemalis*	0	15	1	0	0	12	2	30
Clay-colored sparrow	*Spizella pallida*	1	2	0	5	0	0	0	8
Red-winged blackbird	*Agelaius phoeniceus*	0	0	0	0	0	0	4	4
Pine grosbeak	*Pinicola enucleator*	1	1	0	0	0	0	0	2
White-winged crossbill	*Loxia leucoptera*	0	1	0	0	0	0	1	2
Common redpoll	*Acanthis flammea*	1	16	0	5	0	2	0	24
Western tanager	*Piranga ludoviciana*	0	0	2	0	0	0	0	2
Canada jay	*Perisoreus canadensis*	0	4	1	0	0	0	0	5
Total	**49 species**	**35**	**187**	**23**	**63**	**0**	**53**	**59**	**420**

APPENDIX 20B

Recommended Activity Restriction Guidelines for Sensitive Bird Species

Appendix 20B RECOMMENDED ACTIVITY RESTRICTION GUIDELINES FOR SENSITIVE BIRD SPECIES

Table 20B.1 Recommended Activity Restriction Guidelines for Sensitive Bird Species[1]

Bird Species	Feature or Habitat	Specific Conditions	Sensitive Period / Timing Restriction[2]	Recommended Setback Distance (m)
Species At Risk				
Yellow rail	Edge of waterbody with a nest	General development activities	May 1 – Aug 31	300
Lesser yellowlegs	Nest	General development activities	May 1 – Aug 31	300
Red-necked phalarope	Nest	General development activities	May 1 – Aug 31	300
Short-eared owl	Nest	General development activities	May 1 – Aug 31	1,500
Common nighthawk	Nest	General development activities	May 1 – Aug 31	200
Olive-sided flycatcher	Nest	General development activities	May 1 – Aug 31	200
Bank swallow	Nesting colony	General development activities	May 1 – Aug 31	200
Barn swallow	Nest	General development activities	May 1 – Aug 31	200
Harris's sparrow	Nest	General development activities	May 1 – Aug 31	200
Rusty blackbird	Nest	General development activities	May 1 – Aug 31	300
Horned grebe	Edge of waterbody with a nest	General development activities	May 1 – Aug 31	300
Other Species				
Waterfowl (general)	Staging area	General development activities when large concentrations of birds are present	Spring/Fall	3,000
Swans/Loons/Cranes	Nest	General development activities	May 1 – Aug 31	800
		Pedestrians/ATVs	May 1 – Aug 31	500

Bird Species	Feature or Habitat	Specific Conditions	Sensitive Period / Timing Restriction[2]	Recommended Setback Distance (m)
Ducks	Nest	General development activities	May 1 – Aug 31	150
		Pedestrians/ATVs	May 1 – Aug 31	50
Geese	Nest	General development activities	May 1 – Aug 31	500
		Pedestrians/ATVs	May 1 – Aug 31	300
Shorebirds	Nest	General development activities	May 1 – Aug 31	100
		Pedestrians/ATVs	May 1 – Aug 31	50
Terns/Gulls	Nest	General development activities	May 1 – Aug 31	300
		Pedestrians/ATVs	May 1 – Aug 31	200
Raptors (general)	Nest	General development activities	Mar 1 – Aug 31	1,500
	Nest	General development activities	Sep 1 – Feb 28	500
Songbirds (general)	Nest	General development activities	May 1 – Aug 31	100
		Pedestrians/ATVS	May 1 – Aug 31	30
All other birds	Nest	Varies with region and species; contact the GNWT or ECCC office	Breeding / nesting seasons	100

Notes:

1 Modified from SLUPB (2023) and GNWT (2015); most conservative sensitive period and/or recommended setback distance used.

2 Sensitive periods are a general guide and specific timing may vary. Year-round avoidance may not always be feasible, and exceptions will be discussed with the GNWT-ECC to develop appropriate mitigation.

APPENDIX 20C

2022 Avian Survey Report

Mackenzie Valley Highway Project – 2022 Avian Surveys

FINAL

Prepared for:

Government of the Northwest Territories

Prepared by:

K'alo-Stantec Limited

May 2023

144903265

K'alo-Stantec

Limitations and Sign-off

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K'alo-Stantec

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Abbreviations

%	percent
<	less than
>	greater than
≤	less than or equal to
≥	greater than or equal to
°C	degrees Celsius
ARU	autonomous recording unit
BAMP	Boreal Avian Modelling Project
CEC	Commission for Environmental Cooperation
DAR	Developer's Assessment Report
ECCC	Environment and Climate Change Canada
GNWT	Government of the Northwest Territories
ha	hectare
INF	Department of Infrastructure
K'alo-Stantec	K'alo-Stantec Limited
km	kilometre
km/h	kilometres per hour
LSA	local study area
m	metre
MVEIRB	Mackenzie Valley Environmental Impact Review Board
MVH	Mackenzie Valley Highway
MVWR	Mackenzie Valley Winter Road
NRCan	Natural Resources Canada
RSA	regional study area
SAR	species at risk
the "Project"	Mackenzie Valley Highway Project

1 Introduction

1.1 Background

The Government of the Northwest Territories Department of Infrastructure (GNWT-INF) is advancing work on the proposed Mackenzie Valley Highway (MVH) Project (the "Project"; Appendix A, Figure A.1). The Project involves constructing a new all-season gravel road from Wrigley to approximately 28 km south of Norman Wells, mostly along the alignment of the existing Mackenzie Valley Winter Road (MVWR). The Project will involve clearing of right-of-way, developing temporary and permanent quarry/borrow sources, constructing quarry/borrow access roads, and constructing new highway. The Project is undergoing environmental assessment by the Mackenzie Valley Environmental Impact Review Board (MVEIRB). K'alo-Stantec Limited (K'alo-Stantec) is currently supporting GNWT-INF to prepare the Developer's Assessment Report (DAR) for the Project in accordance with the Terms of Reference as issued by the MVEIRB (MVEIRB 2015).

As an outcome of review of existing information on birds and bird habitat, including species at risk (K'alo-Stantec 2022a), K'alo-Stantec, in discussion with representatives of the GNWT-INF team, GNWT Environment and Natural Resources, and Environment and Climate Change Canada (ECCC), identified the need to obtain additional information to assess the effects of the Project on avian species, particularly species at risk (SAR). As a result, the 2022 Avian Surveys incorporated Project-specific field surveys and additional analyses using publicly available data to address data gaps.

1.2 Purpose

The purpose of the 2022 Avian Surveys is to collect additional field-based information to establish the existing conditions for avian species, including primarily SAR, and support the assessment of effects of the Project on the environment in the DAR.

1.2.1 Objectives

The objectives of the 2022 Avian Surveys were to:

- Establish existing conditions for avian SAR most likely to interact with the Project (e.g., bank swallow [*Riparia riparia*], barn swallow [*Hirundo rustica*]) using in-field surveys.
- Establish existing conditions for avian SAR using autonomous recording units (ARUs) that may not have been adequately captured in the 2017 data (e.g., yellow rail [*Coturnicops noveboracensis*]).
- Supplement existing breeding bird community data using ARUs (i.e., surveys in underrepresented habitats or at quarries and access roads, where practicable).
- Evaluate breeding bird densities relative to the Project to support the assessment of Project effects by using publicly available Boreal Avian Modelling Project (BAMP) data that includes survey data collected by ECCC in 2017 from along the MVWR (BAMP 2020).

2 Methods

The 2022 Avian Surveys were undertaken in the Dehcho and Sahtu regions under the authority of GNWT wildlife research permits WL501066 and WL50105, respectively. This section describes the methods used to complete the surveys within the local study area (LSA) for birds and bird habitat, which is a 1 km buffer around the highway component of the Project, as the centerline of an alignment routing corridor, except around borrow sources and quarries where the LSA increases to a 2 km buffer (K'alo-Stantec 2022a). The size of the LSA is based on measurable effects on migratory birds (e.g., Benitez-Lopez et al. 2010; Shannon et al. 2016). Where appropriate, results are compared the regional study area (RSA) which is a 15 km buffer around the Project (Appendix A, Figure A.1). Incidental observations of birds were also collected in the field.

2.1 Swallow Nesting Survey

A swallow nesting survey was completed from May 26 to 30, 2022, and involved visual inspection by a biologist of nesting habitats that support breeding swallows. For bank swallow, a helicopter was used to survey stream crossings for vertical banks within 300 m of the Project, and existing quarry sites, that may support breeding colonies. For barn swallow, bridges and culverts (diameter ≥1 m) along the existing MVWR were inspected for current or historical signs of nesting activity. Data collected at each survey sites included site attributes (e.g., coordinates, photographs) and where appropriate, species observation data (e.g., coordinates, species, number of nests, photographs), including evidence of nesting activity of other bird species. Surveys were undertaken during periods of suitable weather (i.e., clear visibility, wind ≤20 km/h, temperature >0°C, and precipitation not exceeding a light, intermittent drizzle). Results were summarized by location and mapped relative to the Project.

2.2 Autonomous Recording Unit Surveys

The ARU surveys were developed to supplement existing data collected by ECCC using 53 ARUs in 2017 (ECCC 2020; see K'alo-Stantec 2022a) by deploying 23 additional ARUs in potential yellow rail habitat (n= 3 sites), in under-represented land cover classes and relative to ecoregion as recommended in ECCC guidelines (Hache et al. 2018). Habitat for yellow rail was identified by using species-specific mapping developed for the DAR (i.e., wetland herbaceous habitat patches ≥10 ha) and professional judgment (K'alo-Stantec 2022b). Survey sites were distributed relative to level III ecoregion and land cover class composition (as recommended by ECCC guidelines [Hache et al. 2018]) but the area of some land cover classes in the LSA are too small to support the minimum recommended sample size of 10. The ECCC guidelines recommend using 250 m resolution land cover classification data whereas the Project-specific land cover data used is of 30 m resolution. The distribution of survey sites is compared using the two different classification systems.

The 23 ARUs were deployed in late May 2022 within the LSA and left to record 10-minutes of audio at the beginning of each hour until their retrieval in mid-July.

2.2.1 Species at Risk Survey

Processing the audio recordings for SAR followed ECCC guidance (Hache et al. 2018) whereby all recordings were examined using automated computer software for SAR of interest, including for common nighthawk (*Chordeiles minor*), yellow rail, olive-sided flycatcher (*Contopus cooperi*), Canada warbler (*Cardellina canadensis*), and rusty blackbird (*Euphagus carolinus*). Audio files were analyzed using Kaleidoscope Pro 5.4.8 (Wildlife Acoustics 2021) cluster analysis, which identifies and groups similar acoustic patterns (i.e., bird vocalizations) using custom classifiers. Advanced classifiers were developed using reference vocalizations for each species and an acceptance threshold of 2.0 maximum distance from cluster centre was used to include all detected vocalizations in the analysis. All other settings were set to the manufacturer's defaults. The vocalization with the lowest distance to each classifier's cluster centre was manually classified by a qualified biologist using Kaleidoscope Pro's Viewer software to confirm species detection / non-detection. A total of 23 clusters were analyzed per ARU, totalling 621 manually identified files.

2.2.2 Community Survey

Processing the audio recordings to characterize the breeding bird community followed ECCC guidance (Hache et al. 2018) whereby a biologist completed traditional "point-count surveys" on a subset of the audio recordings. The subset of data was selected to provide representative coverage throughout the breeding season and to avoid periods of inclement weather that might reduce recording quality. Most recordings in the subset were from June 6, 14, and 23, 2022, which rarely varied by one day depending on weather conditions. Within each sampling day, six three-minute audio recordings were sampled from 01:00, 03:00, 04:00, 05:00, 08:00, and 22:00, which represents a manual analytical effort of 18 minutes of audio per day and 54 total minutes per ARU (a total of 20.7 hours for the entire survey). Using this approach, positive species detections were recorded at each date/time sampling period (i.e., 18 sampling periods per ARU).

Previous analyses (K'alo-Stantec 2022a) examined the mean number of detection for each species per land cover class and/or ecoregion (as per ECCC guidelines [Hache et al. 2018]); however, the uneven sampling of audio recordings between survey years described above precludes comparison using the same metric (i.e., 54 minutes of audio examined in 2022 is anticipated to have three times more detections than the 18 minutes examined in 2017). As a result, species presence at each ARU survey site is summed relative to land cover class and ecoregion.

2.3 Breeding Bird Densities

Publicly available data of species-specific breeding bird densities were used to evaluate differences in predicted breeding densities near the Project (i.e., within the LSA) compared to distant from the Project (i.e., within the RSA). The BAMP has developed generalized national models to predict boreal breeding bird densities across Canada relative to a variety of environmental covariates and has produced species-specific breeding densities (males / hectare [ha]) using raster files at a 1 km resolution (BAMP 2020). The models were developed using 296,061 breeding bird point counts across Canada up to 2018, including from local and regional data sources such as the North American Breeding Bird Survey and the 2017 ECCC data described above (BAMP 2020).

The BAMP raster files for 151 species were then processed using a zonal statistics spatial analysis tool (ESRI 2022) to estimate the mean breeding density of each species within the LSA (i.e., affected area; see Section 2) and RSA (i.e., reference area). Results were tabulated for 59 species with predicted breeding densities of ≥0.005 males/ha.

3 Results

3.1 Swallow Nesting Survey

There were no active bank swallow or barn swallow nests detected during the survey; however, two bridge crossings supported inactive (i.e., historical) barn swallow nests including Whitesand Creek Bridge and Blackwater River Bridge (Appendix A, Figure A.2; Appendix B, Table B.1). Barn swallow was not observed at Whitesand Creek Bridge; however, 1 individual was observed at Blackwater River Bridge. In addition, three barn swallow individuals were observed at Vermillion Creek S Bridge where there was no evidence of previous nesting activity (Appendix A, Figure A.2; Appendix B, Table B.1). The survey was undertaken during the early part of the breeding season (eBird 2022), which may have limited the likelihood that swallows would be actively nesting, but because evidence of swallow nesting activity may persist for several years the survey is assumed to provide reliable information on the distribution and relative abundance of breeding swallows that have potential to interact with the Project. The survey also yielded incidental observations of belted kingfisher (*Megaceryle alcyon*), black-billed magpie (*Pica hudsonia*), and common raven (*Corvus corax*; Appendix B, Table B.2).

3.2 Autonomous Recording Unit Surveys

3.2.1 Species at Risk Survey

The 23 ARUs recorded a total of 4,097 hours of audio, with each ARU recording an average of 178.1 hours of audio (range: 83.7 to 195.7 hours). The software-assisted analysis and subsequent manual validation yielded detections of common nighthawk at 10 of 23 survey sites and olive-sided flycatcher at 6 of 23 survey sites (Appendix A, Figure A.3 and Figure A.4; Appendix B, Table B.3). Common nighthawk were detected in all level III ecoregions in the LSA and in four different land cover classes: mixedwood forest (n = 4), shrubland (n = 3), broadleaf forest (n = 2), herbaceous (n = 1). Olive-sided flycatcher were detected in two of the three level III ecoregions in the LSA (Taiga Cordillera and Taiga Plains) and in four different land cover classes: mixedwood forest (n = 2), wetland (n = 2), shrubland forest (n = 1), shrubland (n = 1). There were no detections of yellow rail, Canada warbler, or rusty blackbird in 2017 or 2022.

The ARU data from 2017 yielded detections of common nighthawk at 29 of 53 (58%) survey sites and olive-sided flycatcher at 8 of 53 (15%) survey sites (ECCC 2020; see K'alo-Stantec 2022a). The combined data yielded detections of common nighthawk at 39 of 76 (51%) survey sites and olive-sided flycatcher at 14 of 76 (18%) survey sites.

3.2.2 Community Survey

A review of the ECCC breeding bird survey data collected in 2017 using ARUs (ECCC 2020) and the 2022 ARU survey data suggest that these data are suitable for meeting the objective of identifying the presence, habitat associations, and relative abundance of breeding migratory birds within the LSA because survey locations were distributed evenly relative to ecoregion and land cover class. The distribution of ARUs by land cover class, using both 30 m and 250 m resolution data, is summarized in Table 3.1).

Table 3.1 Distribution of ARUs from 2017 and 2022 by Land Cover Class[1]

Land Cover Class[2,3]	No. of ARUs in 2017		No. of ARUs in 2022		No. of Total ARUs	
	30 m	250 m	30 m	250 m	30 m	250 m
Broadleaf Forest	3	4	4	7	7	11
Coniferous Forest	25	19	0	4	25	23
Mixedwood Forest	3	12	9	5	12	17
Shrubland	6	14	6	4	12	18
Herbaceous & Unvegetated	2	3	2	2	4	5
Wetland	13	1	2	1	15	2
Water	1	0	0	0	1	0
Total	**53**		**23**		**76**	

NOTES:
[1] dominant land cover class within 100 m of the ARU
[2] 30 m resolution from Earth Observation of Sustainable Development of Forests Northwest Territories (NRCan and GNWT 2017; K'alo-Stantec 2022c)
[3] 250 m resolution land cover data (CEC 2010)

Survey locations were also evenly distributed along the LSA between Wrigley and Norman Wells (Appendix A, Figure A.3 and Figure A.4) and proportionally distributed between the three level III ecoregions intersected by the Project (Table 3.2).

Table 3.2 Distribution of ARUs from 2017 and 2022 by Ecoregions Intersected by the Project

Ecoregion (Level III)	Area (ha)	Percent of LSA	No. of ARUs in 2017	No. of ARUs in 2022	No. of Total ARUs	Percent of Total ARUs (n = 76)
Boreal Cordillera High Boreal	24,925.0	33.1%	15	7	22	28.9%
Taiga Cordillera Low Subarctic	25,393.9	33.7%	19	6	25	32.9%
Taiga Plains Low Subarctic	25,040.6	33.2%	19	10	29	38.2%
Total	**75,359.6**	**100.0%**	**53**	**23**	**76**	**100.0%**

Except for mixedwood forest, the ARU survey locations were distributed in relative proportion to the availability of major land cover classes in the LSA (Table 3.3). The land cover composition within a 100 m radius of the survey location was calculated and the dominant land cover class was used to assign a single land cover class for each survey location. However, exposed lands were excluded because most survey locations were near the existing cleared MVWR right-of-way and the dominant habitat for most locations was exposed lands and not indicative of the adjacent breeding habitat for birds.

A total of 84 bird species were detected during the ARU surveys in 2017 and 2022 (72 species in 2017 and 61 species in 2022; Appendix B, Table B.4), with the most common species being Swainson's thrush (*Catharus ustulatus*; at 76 of 76 locations), hermit thrush (*Catharus guttatus*; at 70 of 76 locations), white-throated sparrow (*Zonotrichia albicollis*; at 61 of 76 locations), American robin (*Turdus migratorius*; at 59 of 76 locations), and dark-eyed junco (*Junco hyemalis*; at 57 of 76 locations).

Table 3.3 Distribution of ARUs in 2017 and 2022 Compared to Land Cover Class Composition of the LSA

Land Cover Class[1]	Area (ha)	Percent of LSA	No. of Total ARUs	Percent of ARUs
Broadleaf Forest	4,779.3	6.6%	7	9.2%
Coniferous Forest	25,628.9	35.5%	25	32.9%
Mixedwood Forest	4,059.7	5.6%	12	15.8%
Shrubland	10,882.8	15.1%	12	15.8%
Herbaceous & Unvegetated	261.5	0.4%	4	5.3%
Wetland	17,550.6	24.3%	15	19.7%
Water	8,979.8	12.4%	1	1.3%
Total	**72,142.6**	**100.0%**	**76**	**100.0%**

NOTE:
[1] 30 m resolution from Earth Observation of Sustainable Development of Forests Northwest Territories (NRCan and GNWT 2017; K'alo-Stantec 2022c)

The most common and total number of species by major land cover classes, excluding water (i.e., a single survey location), in 2017 and 2022 combined were (Appendix B, Table B.5):

- **Broadleaf forest:** most common species were Swainson's thrush, white-throated sparrow, hermit thrush, dark-eyed junco, and yellow-rumped warbler (*Setophaga coronata*). A total of 46 species were recorded at 7 sites (24 species at 3 sites in 2017).
- **Coniferous forest:** most common species were Swainson's thrush, hermit thrush, chipping sparrow (*Spizella passerina*), Tennessee warbler (*Leiothlypis peregrina*) and dark-eyed junco. A total of 48 species were recorded at 25 sites in 2017 (no sites added in 2022).
- **Mixedwood forest:** most common species were Swainson's thrush, hermit thrush, yellow-rumped warbler, white-throated sparrow, and Tennessee warbler. A total of 60 species were recorded at 12 sites (28 species at 3 sites in 2017).

- **Shrubland:** most common species were Swainson's thrush, hermit thrush, white-throated sparrow, American robin, and orange-crowned warbler (*Leiothlypis celata*). A total of 56 species were recorded at 12 sites (39 species at 6 sites in 2017).
- **Herbaceous and Unvegetated:** most common species were Swainson's thrush, hermit thrush, white-throated sparrow, alder flycatcher (*Empidonax alnorum*), and dark-eyed junco. A total of 36 species were recorded at 4 sites (23 species at 2 sites in 2017).
- **Wetland:** most common species were Swainson's thrush, hermit thrush, American robin, white-throated sparrow, and dark-eyed junco. A total of 58 species were recorded at 15 sites (51 species at 14 sites in 2014).

Relative to ecoregion, the most common and total number of species were (Appendix B, Table B.6):

- **Boreal Cordillera:** most common species were Swainson's thrush, white-throated sparrow, chipping sparrow, hermit thrush, and Tennessee warbler. A total of 54 species were recorded at 22 sites (36 species at 15 sites in 2017).
- **Taiga Cordillera:** most common species were Swainson's thrush, hermit thrush, Tennessee warbler, Lincoln's sparrow (*Melospiza lincolnii*), and white-throated sparrow. A total of 66 species were recorded at 25 sites (55 species at 19 sites in 2017).
- **Taiga Plains:** most common species were Swainson's thrush, hermit thrush, dark-eyed junco, American robin, and orange-crowned warbler. A total of 70 species were recorded at 29 sites (58 species at 19 sites in 2017).

3.3 Breeding Bird Densities

Most predicted breeding bird densities did not differ between the LSA and RSA; however, there are some species that are expected to breed in greater densities within the LSA, and some expected to breed in lower densities within the LSA (Appendix B, Table B.7). Comparing predicted breeding densities in the LSA to those in the RSA:

- 22 species showed no difference
- 24 species showed a slight reduction (≤ 0.005 males/ha)
- 5 species showed a slight increase (≤ 0.005 males/ha)
- 4 species showed a greater reduction (> 0.005 males/ha): dark-eyed junco (-0.017 males/ha), yellow-rumped warbler (-0.016 males/ha), white-crowned sparrow (-0.015 males/ha), and American robin (-0.010 males/ha)
- 4 species showed a greater increase (> 0.005 males/ha): Tennessee warbler (0.045 males/ha), chipping sparrow (0.012 males/ha), white-throated sparrow (0.009 males/ha), and alder flycatcher (0.007 males/ha)

4 Key Results and Findings

The 2022 Bird Surveys and subsequent data analysis improve confidence in the characterization of the breeding bird community within the LSA and key results and findings include:

- No bank swallow breeding colonies were detected at any of the proposed quarries and borrow sources or stream crossings surveyed within the LSA.
- Most bridge and culvert crossings along the MVWR did not show signs of barn swallow nesting activity, but there are two bridge locations that indicated previous nesting activity and one bridge location that could support the species during the breeding season.
- Common nighthawk are abundant and widespread within the LSA and were detected at 51% of ARU surveys sites in 2017 and 2022.
- Olive-sided flycatcher are relatively common within the LSA and were detected at 18% of ARU survey sites in 2017 and 2022.
- There were no detections of yellow rail, Canada warbler, or rusty blackbird in 2017 or 2022.
- The spatial distribution of survey locations relative to ecoregion and land cover classes are suitable for satisfying the objective of identifying the presence, habitat associations, and relative abundance of breeding migratory birds within the LSA to support requirements and objectives of the DAR.
- ARU surveys in 2022 yielded detections of 12 species not detected in 2017, primarily due to increased sample size in underrepresented land cover classes.
- Notable increases in the number of species were observed in previously underrepresented land cover classes (i.e., broadleaf forest, mixedwood forest, shrubland, herbaceous and unvegetated).
- The predicted breeding densities within the LSA for most bird species did not differ, or differed by a relatively small amount, in comparison to predicted densities within the RSA. However, there are four species expected to breed in notably higher densities (>0.005 males/ha) within the LSA and four species expected to breed in notably lower densities (<0.005 males/ha) within the LSA.
- Incidental bird observations included black-billed magpie and common raven.

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5.2 Personal Communications

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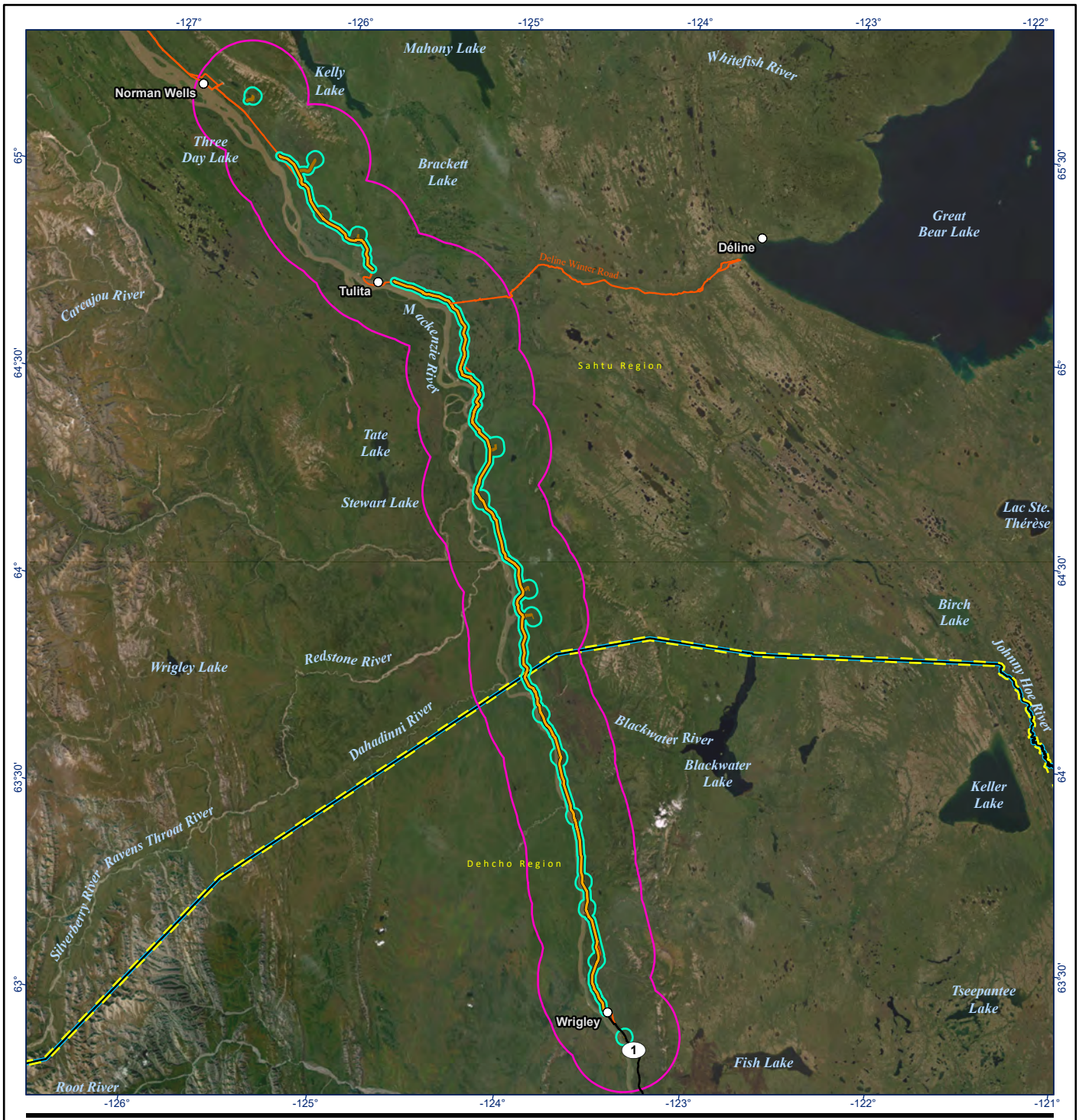
Appendix A Figures



- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Proposed Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area

- Community
- All-Season Road
- Winter Road
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,600,000

N

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Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 3/8/2023
TR by AJ on 3/8/2023

Client/Project
144903025-0055 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.1

Title
Bird Survey Study Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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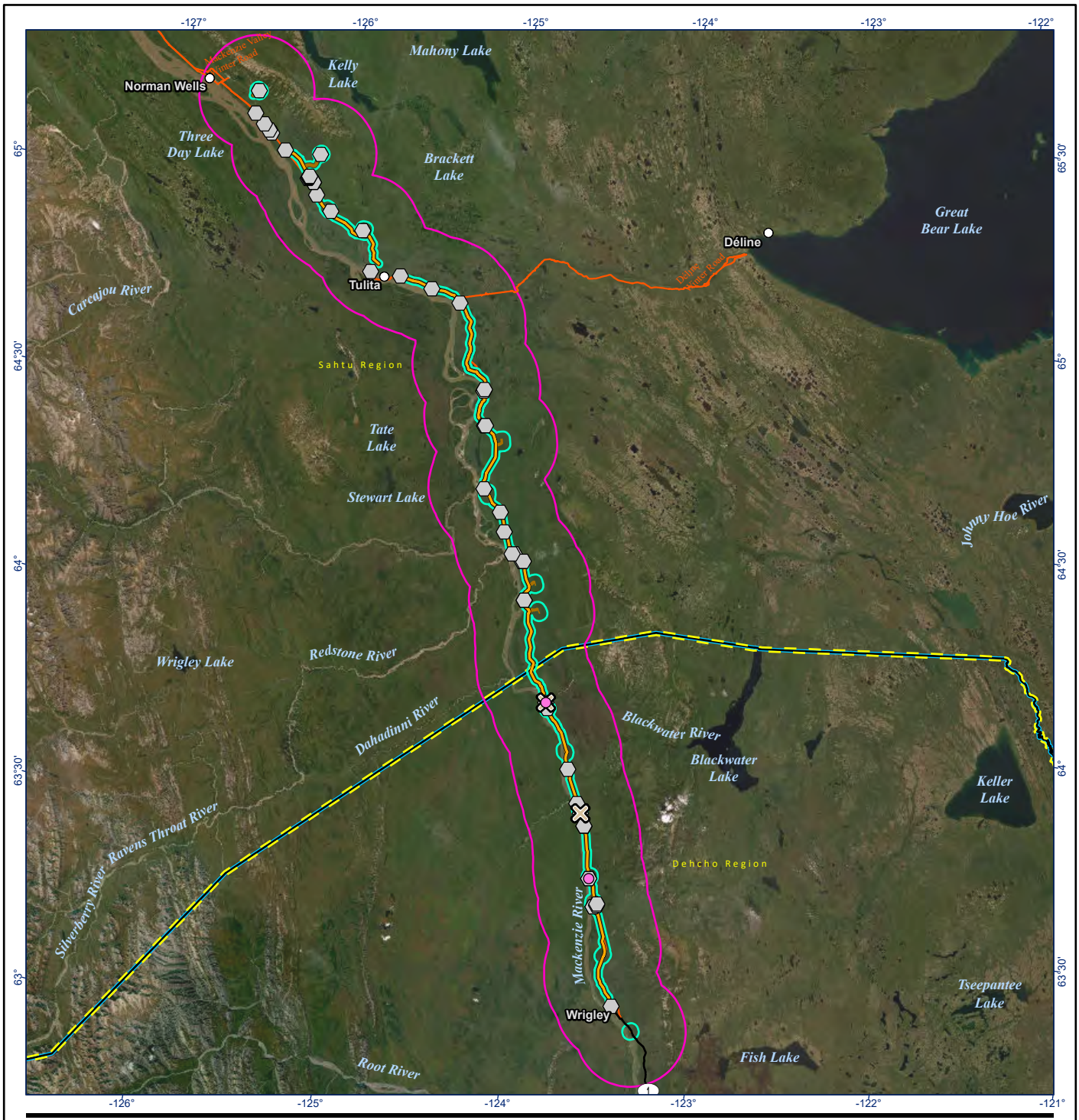

Nesting Activity and Species 2022

- Inactive - Barn Swallow
- Barn Swallow Individuals
- Survey Location

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Proposed Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
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N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by DS on 2023-04-05
TR by DR on 2023-04-05

Client/Project
144903025-0164 REVA

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.2

Title
Swallow Survey Results

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
4. ECCC. 2020. Breeding bird survey data along the Mackenzie Valley winter road. Data request November 23, 2020. Environment and Climate Change Canada, Yellowknife, NT.

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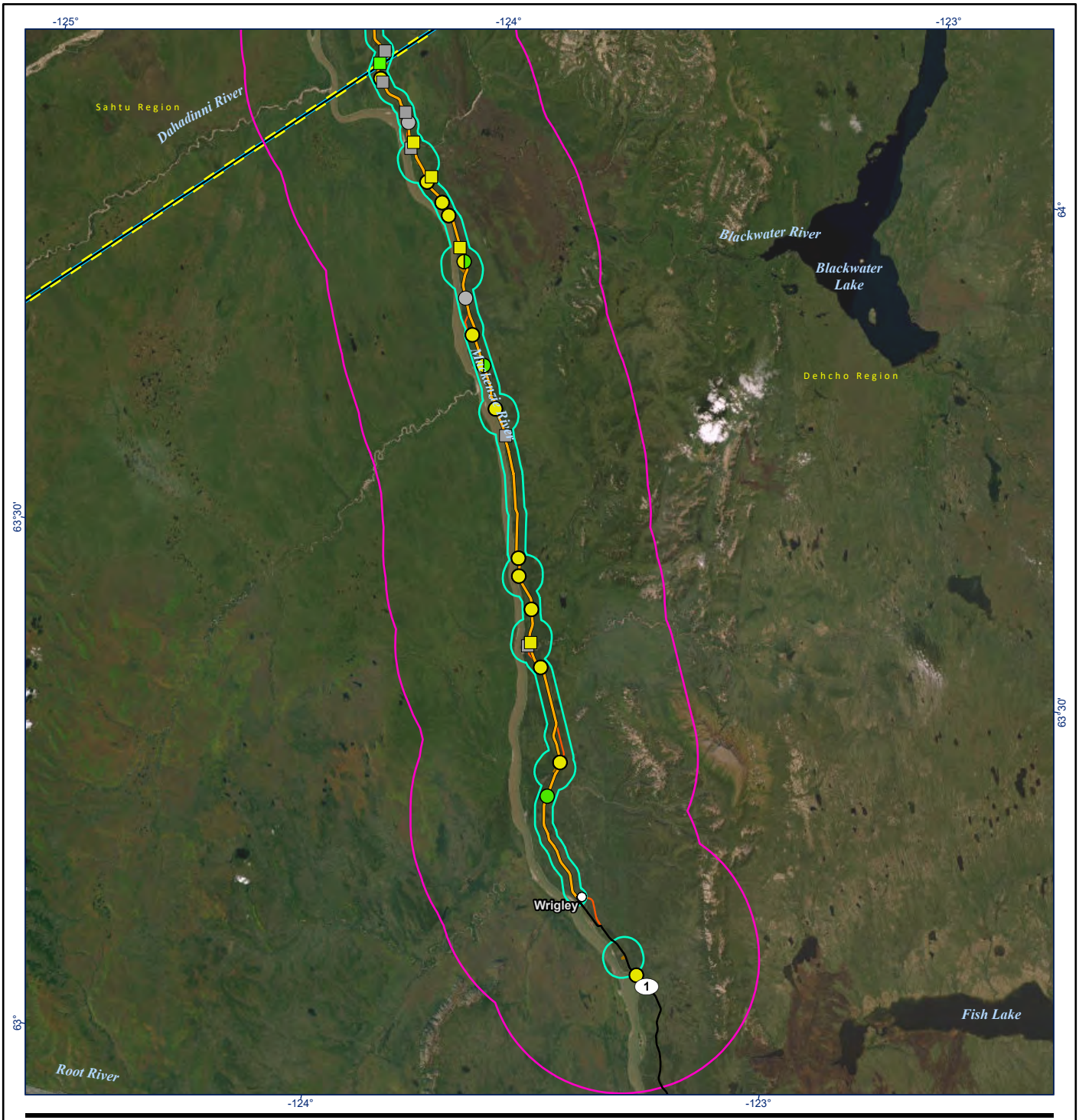

ARU Survey Station 2022
ARU Survey Station 2017

SAR Detection (2022)

Common nighthawk
Olive-sided flycatcher

SAR Detection (2017)[3]

Common nighthawk
Harris's sparrow
Olive-sided flycatcher

Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
Proposed Granular Borrow / Rock Quarry Site and Access
Local Study Area
Regional Study Area
Community
All-Season Road
Winter Road
Region Boundary
Settlement Area Boundary

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(At original document size of 8.5x11)
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N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by DS on 2023-04-05
TR by DR on 2023-04-05

Client/Project
144903025-0170 REVA

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.3

Title
Autonomous Recording Unit Survey Results for Species at Risk in the Dehcho Region

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. ECCC. 2020. Breeding bird survey data along the Mackenzie Valley winter road. Data request November 23, 2020. Environment and Climate Change Canada, Yellowknife, NT.
4. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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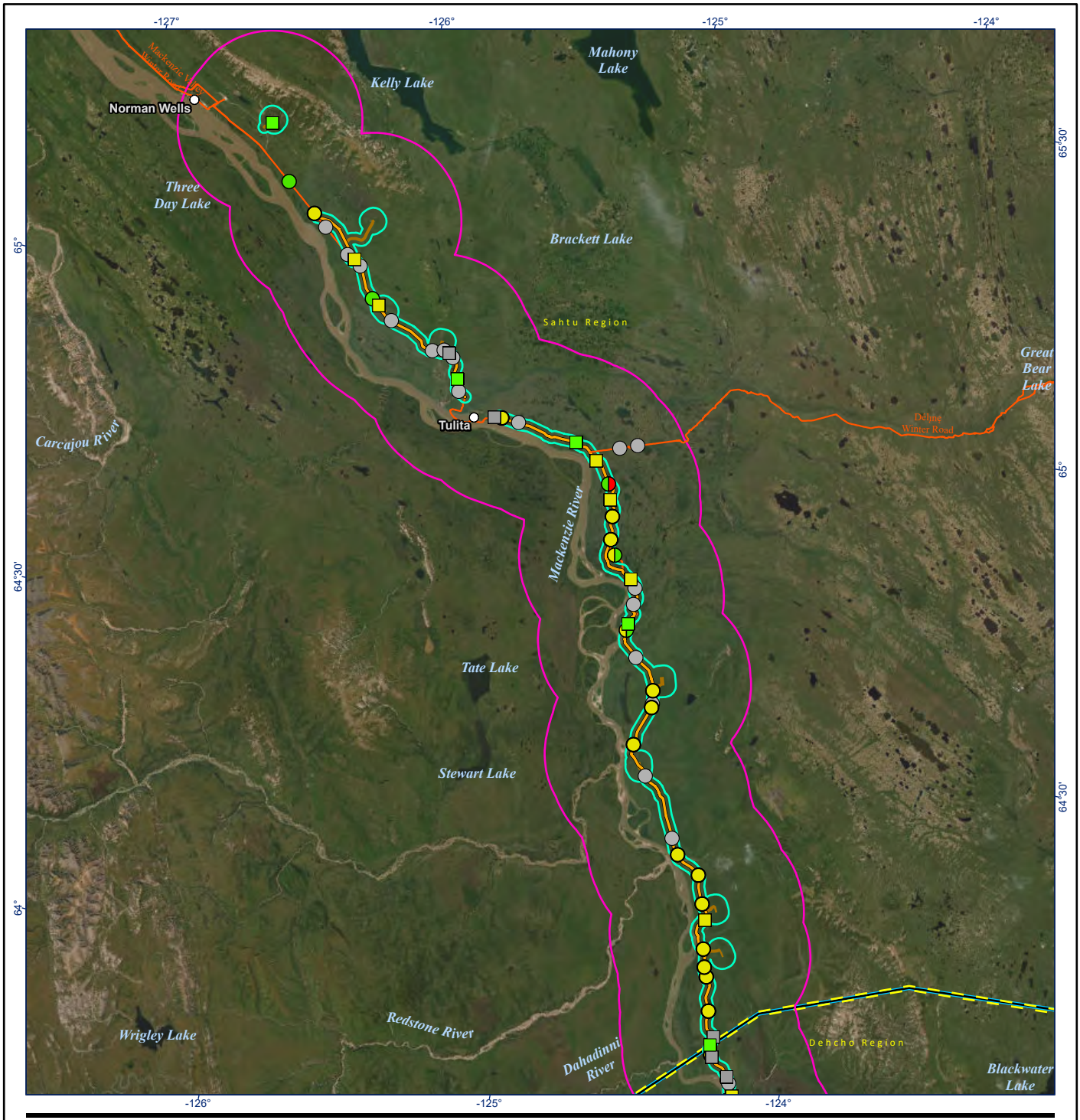

- ARU Survey Station 2022
- ARU Survey Station 2017

SAR Detection (2022)

- Common nighthawk (2022)
- Olive-sided flycatcher (2022)

SAR Detection (2017)[3]

- Common nighthawk
- Harris's sparrow
- Olive-sided flycatcher

- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Proposed Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,000,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by DS on 2023-04-05
TR by DR on 2023-04-05

Client/Project
144903025-0165 REVA

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
A.4

Title
Autonomous Recording Unit Survey Results for Species at Risk in the Sahtu Region

Notes

1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre of Geomatics of Government of NWT, Government of Canada, Stantec
3. ECCC. 2020. Breeding bird survey data along the Mackenzie Valley winter road. Data request November 23, 2020. Environment and Climate Change Canada, Yellowknife, NT.
4. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

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Appendix B Tables

Table B.1 Swallow Nesting Survey Results 2022

Date	Location	Coordinates			Nesting Activity	Common Name	Scientific Name	No. Nests	No. Individuals
		Zone	Easting	Northing					
5/29	Whitesand Creek Bridge	10	463462	7045473	Inactive	Barn swallow	*Hirundo rustica*	7	0
5/29	Vermillion Creek S Bridge	10	458038	7062867	No nests were observed	Barn swallow	*Hirundo rustica*	0	3
5/30	Blackwater River Bridge	10	443232	7091406	Inactive	Barn swallow	*Hirundo rustica*	10	1
5/27	Jungle Ridge Creek Bridge	9	638254	7218536	No nests were observed				
5/27	Beaver dam	9	636486	7221670	No nests were observed				
5/27	Notta Creek Bridge	9	636445	7221681	No nests were observed				
5/27	Vermillion Creek N Bridge	9	634731	7222319	No nests were observed				
5/27	Vertical bank	9	634886	7222566	No nests were observed				
5/27	Vertical bank	9	634923	7222777	No nests were observed				
5/27	Vertical bank	9	634994	7223004	No nests were observed				
5/28	Prohibition Creek Bridge	9	626574	7228215	No nests were observed				
5/28	Vertical bank	9	636307	7229672	No nests were observed				
5/28	Christina Creek Bridge	9	621621	7231757	No nests were observed				
5/28	Hellava Creek Bridge	9	620780	7232385	No nests were observed				
5/28	Francis Creek Bridge	9	619001	7233657	No nests were observed				
5/28	Canyon Creek Bridge	9	615903	7235889	No nests were observed				
5/26	Quarry near mvh_30	9	615188	7242143	No nests were observed				
5/29	Hodgson Creek Bridge	10	475735	7011732	No nests were observed				
5/29	Vertical bank	10	466884	7038547	No nests were observed				
5/29	Vertical bank	10	466899	7038950	No nests were observed				
5/29	Big Strawberry Creek Culvert	10	459639	7059494	No nests were observed				
5/29	Small Strawberry Creek Culvert	10	459599	7059588	No nests were observed				
5/29	Bob's Canyon Creek Culvert	10	456586	7065368	No nests were observed				

Date	Location	Coordinates			Nesting Activity	Common Name	Scientific Name	No. Nests	No. Individuals
		Zone	Easting	Northing					
5/30	Damn Creek Bridge	10	452438	7074266	No nests were observed				
5/30	Borrow	10	443916	7089845	No nests were observed				
5/26	Steep Creek Bridge	10	432369	7118275	No nests were observed				
5/26	Vertical bank	10	429955	7128734	No nests were observed				
5/26	Devil's Canyon Bridge	10	430264	7128862	No nests were observed				
5/26	Vertical bank	10	426820	7130334	No nests were observed				
5/26	Vertical bank	10	423602	7135959	No nests were observed				
5/26	Seagram's Creek Bridge	10	421594	7141121	No nests were observed				
5/26	Little Smith Creek Bridge	10	415994	7146732	No nests were observed				
5/26	Vertical bank	10	413062	7163956	No nests were observed				
5/26	Big Smith Creek Bridge	10	413334	7164040	No nests were observed				
5/26	Vertical bank	10	411191	7173413	No nests were observed				
5/26	Vertical bank	10	411309	7173846	No nests were observed				
5/27	Gotcha Creek Bridge	10	400414	7196261	No nests were observed				
5/27	Twelve Mile Creek Bridge	10	392059	7198785	No nests were observed				
5/27	No Name Creek Bridge	10	374499	7200546	No nests were observed				
5/27	Vertical bank	10	370370	7211313	No nests were observed				
5/27	Vertical bank	10	360704	7215034	No nests were observed				

Table B.2 Summary of Incidental Wildlife Observations

Species		Observation		Coordinates		
Common Name	**Scientific Name**	**Type**	**Count**	**Zone**	**Easting**	**Northing**
Black-billed magpie	*Pica hudsonia*	Individual(s)	1	10	476493	7010871
Belted kingfisher	*Megaceryle alcyon*	Active Nest	1	10	465995	7037999
Common raven	*Corvus corax*	Active Nest	1	10	465995	7037999
Common raven	*Corvus corax*	Active Nest	1	10	463462	7045473
Common raven	*Corvus corax*	Active Nest	1	10	458038	7062867
Common raven	*Corvus corax*	Active Nest	1	10	382841	7200758
Common raven	*Corvus corax*	Inactive Nest	1	10	427371	7130469

Table B.3 2022 Species at Risk Detections using Automated Computer Software

Location ID	Region	Land Cover Class[1]	Coordinates			Species Detections[2]	
			Zone	Easting	Northing	Common Nighthawk	Olive-sided Flycatcher
mvh_01*	Sahtu	Wetland	10	437714	7100010	-	✓
mvh_02	Sahtu	Mixedwood	10	438049	7101479	-	-
mvh_05	Sahtu	Broadleaf	10	433071	7121121	✓	-
mvh_10	Sahtu	Mixedwood	10	410987	7169290	-	✓
mvh_11	Sahtu	Mixedwood	10	410121	7176997	✓	-
mvh_15	Sahtu	Shrub	10	404206	7189906	✓	-
mvh_16	Sahtu	Shrub	10	400630	7196125	✓	✓
mvh_17	Sahtu	Mixedwood	10	396618	7198661	-	✓
mvh_20	Sahtu	Shrub	10	381937	7200463	-	-
mvh_22	Sahtu	Herbaceous	10	374464	7205854	-	✓
mvh_23	Sahtu	Broadleaf	10	372282	7210005	-	-
mvh_25	Sahtu	Broadleaf	10	358835	7216011	✓	-
mvh_27	Sahtu	Mixedwood	9	635137	7222600	✓	-
mvh_30*	Sahtu	Wetland	9	615083	7241552	-	✓
mvh_31	Dehcho	Shrub	10	438392	7097992	-	-
mvh_32	Dehcho	Broadleaf	10	441528	7095096	-	-
mvh_33	Dehcho	Mixedwood	10	443005	7091925	✓	-
mvh_34	Dehcho	Shrub	10	442815	7091213	-	-
mvh_35	Dehcho	Shrub	10	445661	7088461	✓	-
mvh_36	Dehcho	Mixedwood	10	450215	7081177	✓	-
mvh_38	Dehcho	Mixedwood	10	458972	7061249	-	-

Location ID	Region	Land Cover Class[1]	Coordinates			Species Detections[2]	
			Zone	Easting	Northing	Common Nighthawk	Olive-sided Flycatcher
mvh_39	Dehcho	Herbaceous	10	465807	7038834	✓	-
mvh_40	Dehcho	Mixedwood	10	465532	7038408	-	-

NOTES:

* Indicates a location with potential yellow rail habitat.

1 30 m resolution from Earth Observation of Sustainable Development of Forests Northwest Territories (NRCan and GNWT 2017; K'alo-Stantec 2022c)

2 a '✓' indicates a confirmed species detection and a '-' indicates non-detection

Table B.4 Bird Species with the Potential to Occupy the LSA[1]

Group	Order	Common Name	Scientific Name	ECCC Detection[2]	2022 ARU Detection[3]
Waterbirds	Waterfowl	Greater white-fronted goose	*Anser albifrons*	-	-
		Brant	*Branta bernicla*	-	-
		Cackling goose	*Branta hutchinsii*	-	-
		Canada goose	*Branta canadensis*	✓	✓
		Trumpeter swan	*Cygnus buccinator*	-	-
		Tundra swan	*Cygnus columbianus*	-	-
		American black duck	*Anas rubripes*	-	-
		Mallard	*Anas platyrhynchos*	-	✓
		Northern pintail	*Anas acuta*	-	-
		Green-winged teal	*Anas crecca*	-	-
		Canvasback	*Aythya valisineria*	-	-
		Redhead	*Aythya americana*	-	-
		Ring-necked duck	*Aythya collaris*	-	-
		Greater scaup	*Aythya marila*	-	-
		Lesser scaup	*Aythya affinis*	-	-
		King eider	*Somateria spectabilis*	-	-
		Harlequin duck	*Histrionicus histrionicus*	-	-
		Surf scoter	*Melanitta perspicillata*	-	-
		Black scoter	*Melanitta americana*	-	-
		Long-tailed duck	*Clangula hyemalis*	-	-
		Bufflehead	*Bucephala albeola*	-	-
		Common goldeneye	*Bucephala clangula*	-	-
		Barrow's goldeneye	*Bucephala islandica*	-	-
		Hooded merganser	*Lophodytes cucullatus*	-	-

Group	Order	Common Name	Scientific Name	ECCC Detection[2]	2022 ARU Detection[3]
Waterbirds (cont'd)	Waterfowl (cont'd)	Common merganser	*Mergus merganser*	-	-
		Red-breasted merganser	*Mergus serrator*	-	-
		Ruddy duck	*Oxyura jamaicensis*	-	-
		Snow goose	*Anser caerulescens*	-	-
		Ross's goose	*Anser rossii*	-	-
		Blue-winged teal	*Spatula discors*	-	-
		Northern shoveler	*Spatula clypeata*	-	-
		Gadwall	*Mareca strepera*	-	-
		Eurasian wigeon	*Mareca penelope*	-	-
		American wigeon	*Mareca americana*	-	-
		White-winged scoter	*Melanitta deglandi*	-	-
	Waterbirds	Red-throated loon	*Gavia stellata*	-	✓
		Pacific loon	*Gavia pacifica*	✓	-
		Common loon	*Gavia immer*	✓	✓
		Yellow-billed loon	*Gavia adamsii*	-	-
		American white pelican	*Pelecanus erythrorhynchos*	-	-
		Yellow rail*	*Coturnicops noveboracensis*	-	-
		Pied-billed grebe*	*Podilymbus podiceps*	✓	-
		Horned grebe	*Podiceps auritus*	-	-
		Red-necked grebe	*Podiceps grisegena*	✓	-
	Shorebirds	American bittern	*Botaurus lentiginosus*	✓	✓
		Sora	*Porzana carolina*	✓	✓
		American coot	*Fulica americana*	-	✓
		Sandhill crane	*Antigone canadensis*	✓	✓
		Black-bellied plover	*Pluvialis squatarola*	-	-

Group	Order	Common Name	Scientific Name	ECCC Detection[2]	2022 ARU Detection[3]
Waterbirds (cont'd)	Shorebirds (cont'd)	American golden-plover	*Pluvialis dominica*	-	-
		Semipalmated plover	*Charadrius semipalmatus*	-	-
		Killdeer	*Charadrius vociferus*	-	-
		Spotted sandpiper	*Actitis macularius*	-	-
		Solitary sandpiper	*Tringa solitaria*	✓	-
		Greater yellowlegs	*Tringa melanoleuca*	✓	-
		Lesser yellowlegs	*Tringa flavipes*	✓	✓
		Upland sandpiper	*Bartramia longicauda*	-	-
		Whimbrel	*Numenius phaeopus*	-	-
		Hudsonian godwit	*Limosa haemastica*	-	-
		Marbled godwit	*Limosa fedoa*	-	-
		Ruddy turnstone	*Arenaria interpres*	-	-
		Sanderling	*Calidris alba*	-	-
		Semipalmated sandpiper	*Calidris pusilla*	-	-
		Western sandpiper	*Calidris mauri*	-	-
		Least sandpiper	*Calidris minutilla*	-	-
		Baird's sandpiper	*Calidris bairdii*	-	-
		Pectoral sandpiper	*Calidris melanotos*	-	-
		Dunlin	*Calidris alpina*	-	-
		Stilt sandpiper	*Calidris himantopus*	-	-
		Short-billed dowitcher	*Limnodromus griseus*	-	-
		Long-billed dowitcher	*Limnodromus scolopaceus*	-	-
		Wilson's snipe	*Gallinago delicata*	✓	✓
		Wilson's phalarope	*Phalaropus tricolor*	-	-
		Red-necked phalarope	*Phalaropus lobatus*	-	-
		Mew gull	*Larus canus*	-	-

Group	Order	Common Name	Scientific Name	ECCC Detection[2]	2022 ARU Detection[3]
Waterbirds (cont'd)	Shorebirds (cont'd)	Ring-billed gull	*Larus delawarensis*	✓	✓
		Herring gull	*Larus argentatus*	-	-
		Glaucous gull	*Larus hyperboreus*	-	-
		Black tern	*Chlidonias niger*	-	-
		Common tern	*Sterna hirundo*	-	-
		Arctic tern	*Sterna paradisaea*	-	-
		Parasitic jaeger	*Stercorarius parasiticus*	-	-
		Long-tailed jaeger	*Stercorarius longicaudus*	-	-
		Bonaparte's gull	*Chroicocephalus philadelphia*	-	-
		Buff-breasted sandpiper	*Calidris subruficollis*	-	-
Birds of Prey	Raptors	Bald eagle	*Haliaeetus leucocephalus*	-	-
		Northern harrier	*Circus hudsonius*	-	-
		Sharp-shinned hawk	*Accipiter striatus*	-	✓
		Northern goshawk	*Accipiter gentilis*	-	-
		Swainson's hawk	*Buteo swainsoni*	-	-
		Red-tailed hawk	*Buteo jamaicensis*	-	✓
		Rough-legged hawk	*Buteo lagopus*	-	-
		Golden eagle	*Aquila chrysaetos*	-	-
		American kestrel	*Falco sparverius*	-	-
		Merlin	*Falco columbarius*	-	✓
		Gyrfalcon	*Falco rusticolus*	-	-
		Peregrine falcon	*Falco peregrinus*	-	-
		Osprey	*Pandion haliaetus*	-	-
	Owls	Great horned owl	*Bubo virginianus*	✓	-
		Snowy owl	*Bubo scandiacus*	-	-
		Northern hawk owl	*Surnia ulula*	-	-

Group	Order	Common Name	Scientific Name	ECCC Detection[2]	2022 ARU Detection[3]
Birds of Prey (cont'd)	Owls (cont'd)	Great grey owl	*Strix nebulosa*	-	-
		Short-eared owl	*Asio flammeus*	-	-
		Boreal owl	*Aegolius funereus*	-	✓
Upland game birds		Ruffed grouse	*Bonasa umbellus*	✓	✓
		Spruce grouse	*Canachites canadensis*	-	-
		Willow ptarmigan	*Lagopus lagopus*	-	-
		Rock ptarmigan	*Lagopus muta*	-	-
		Sharp-tailed grouse	*Tympanuchus phasianellus*	-	-
Landbirds	Near-passerines	Common nighthawk	*Chordeiles minor*	✓	✓
		Belted kingfisher	*Megaceryle alcyon*	-	-
		Yellow-bellied sapsucker	*Sphyrapicus varius*	✓	✓
		Downy woodpecker	*Dryobates pubescens*	-	-
		American three-toed woodpecker	*Picoides dorsalis*	-	-
		Black-backed woodpecker	*Picoides arcticus*	✓	-
		Northern flicker	*Colaptes auratus*	✓	✓
		Pileated woodpecker	*Dryocopus pileatus*	✓	✓
		Hairy woodpecker	*Dryobates villosus*	-	✓
	Passerines	Mourning dove	*Zenaida macroura*	-	-
		Olive-sided flycatcher	*Contopus cooperi*	✓	✓
		Western wood-pewee	*Contopus sordidulus*	✓	-
		Yellow-bellied flycatcher	*Empidonax flaviventris*	✓	✓
		Alder flycatcher	*Empidonax alnorum*	✓	✓
		Least flycatcher	*Empidonax minimus*	✓	✓
		Hammond's flycatcher	*Empidonax hammondii*	-	-
		Eastern phoebe	*Sayornis phoebe*	-	-
		Say's phoebe	*Sayornis saya*	-	-

Group	Order	Common Name	Scientific Name	ECCC Detection[2]	2022 ARU Detection[3]
Landbirds (cont'd)	Passerines (cont'd)	Eastern kingbird	*Tyrannus tyrannus*	-	-
		Blue-headed vireo	*Vireo solitarius*	✓	✓
		Warbling vireo	*Vireo gilvus*	✓	-
		Philadelphia vireo	*Vireo philadelphicus*	-	-
		Red-eyed vireo	*Vireo olivaceus*	✓	-
		Black-billed magpie	*Pica hudsonia*	-	-
		American crow	*Corvus brachyrhynchos*	-	✓
		Common raven	*Corvus corax*	✓	✓
		Horned lark	*Eremophila alpestris*	-	-
		Tree swallow	*Tachycineta bicolor*	✓	-
		Violet-green swallow	*Tachycineta thalassina*	-	-
		Bank swallow	*Riparia riparia*	-	-
		Cliff swallow	*Petrochelidon pyrrhonota*	-	-
		Barn swallow	*Hirundo rustica*	-	-
		Black-capped chickadee	*Poecile atricapillus*	✓	✓
		Boreal chickadee	*Poecile hudsonicus*	✓	-
		Red-breasted nuthatch	*Sitta canadensis*	-	-
		American dipper	*Cinclus mexicanus*	-	-
		Golden-crowned kinglet	*Regulus satrapa*	-	-
		Northern wheatear	*Oenanthe oenanthe*	-	-
		Mountain bluebird	*Sialia currucoides*	-	-
		Townsend's solitaire	*Myadestes townsendi*	✓	-
		Gray-cheeked thrush	*Catharus minimus*	✓	-
		Swainson's thrush	*Catharus ustulatus*	✓	✓
		Hermit thrush	*Catharus guttatus*	✓	✓
		American robin	*Turdus migratorius*	✓	✓

Group	Order	Common Name	Scientific Name	ECCC Detection[2]	2022 ARU Detection[3]
Landbirds (cont'd)	Passerines (cont'd)	Varied thrush	*Ixoreus naevius*	✓	✓
		European starling	*Sturnus vulgaris*	-	-
		American pipit	*Anthus rubescens*	-	-
		Bohemian waxwing	*Bombycilla garrulus*	✓	✓
		Cedar waxwing	*Bombycilla cedrorum*	-	-
		Yellow warbler	*Setophaga petechia*	✓	✓
		Magnolia warbler	*Setophaga magnolia*	✓	✓
		Cape May warbler	*Setophaga tigrina*	✓	-
		Yellow-rumped warbler	*Setophaga coronata*	✓	✓
		Palm warbler	*Setophaga palmarum*	✓	✓
		Bay-breasted warbler	*Setophaga castanea*	✓	-
		Blackpoll warbler	*Setophaga striata*	✓	✓
		Black-and-white warbler	*Mniotilta varia*	✓	✓
		American redstart	*Setophaga ruticilla*	✓	✓
		Ovenbird	*Seiurus aurocapilla*	✓	✓
		Northern waterthrush	*Parkesia noveboracensis*	✓	✓
		Mourning warbler	*Geothlypis philadelphia*	-	-
		Common yellowthroat	*Geothlypis trichas*	✓	-
		Wilson's warbler	*Cardellina pusilla*	✓	✓
		Tennessee warbler	*Leiothlypis peregrina*	✓	✓
		Orange-crowned warbler	*Leiothlypis celata*	✓	✓
		Ruby-crowned kinglet	*Corthylio calendula*	✓	✓
		American tree sparrow	*Spizelloides arborea*	✓	-
		Chipping sparrow	*Spizella passerina*	✓	✓
		Vesper sparrow	*Pooecetes gramineus*	-	-
		Savannah sparrow	*Passerculus sandwichensis*	✓	✓

Group	Order	Common Name	Scientific Name	ECCC Detection[2]	2022 ARU Detection[3]
Landbirds (cont'd)	Passerines (cont'd)	Fox sparrow	*Passerella iliaca*	✓	✓
		Song sparrow	*Melospiza melodia*	-	-
		Lincoln's sparrow	*Melospiza lincolnii*	✓	✓
		Swamp sparrow	*Melospiza georgiana*	✓	✓
		White-throated sparrow	*Zonotrichia albicollis*	✓	✓
		Harris's sparrow	*Zonotrichia querula*	✓	-
		White-crowned sparrow	*Zonotrichia leucophrys*	✓	✓
		Golden-crowned sparrow	*Zonotrichia atricapilla*	-	-
		House sparrow	*Passer domesticus*	-	-
		Clay-colored sparrow	*Spizella pallida*	✓	-
		Le Conte's sparrow	*Ammospiza leconteii*	✓	-
		Dark-eyed junco	*Junco hyemalis*	✓	✓
		Lapland longspur	*Calcarius lapponicus*	-	-
		Smith's longspur	*Calcarius pictus*	-	-
		Snow bunting	*Plectrophenax nivalis*	-	-
		Rose-breasted grosbeak	*Pheucticus ludovicianus*	-	-
		Lazuli bunting	*Passerina amoena*	-	-
		Red-winged blackbird	*Agelaius phoeniceus*	-	✓
		Rusty blackbird	*Euphagus carolinus*	-	-
		Brewer's blackbird	*Euphagus cyanocephalus*	-	-
		Common grackle	*Quiscalus quiscula*	-	-
		Brown-headed cowbird	*Molothrus ater*	-	-
		Pine grosbeak	*Pinicola enucleator*	-	✓
		Red crossbill	*Loxia curvirostra*	-	-
		White-winged crossbill	*Loxia leucoptera*	✓	✓
		Common redpoll	*Acanthis flammea*	✓	✓

Group	Order	Common Name	Scientific Name	ECCC Detection[2]	2022 ARU Detection[3]
Landbirds (cont'd)	Passerines (cont'd)	Hoary redpoll	*Acanthis hornemanni*	-	-
		Pine siskin	*Spinus pinus*	✓	-
		Evening grosbeak	*Coccothraustes vespertinus*	-	-
		Western tanager	*Piranga ludoviciana*	✓	-
		Canada jay	*Perisoreus canadensis*	✓	✓
		Winter wren	*Troglodytes hiemalis*	-	-
		Purple finch	*Haemorhous purpureus*	-	✓
		Northern shrike	*Lanius borealis*	-	-
Total number of species		214		72	61
Grand total		214		84	

NOTES:

[1] Species within Level IV ecoregions 3.3.2.2 North Mackenzie Plain, 3.3.2.3 Norman Range, 3.2.2.11 Central Mackenzie Plain, and 6.1.5.1 Central Mackenzie Valley (GNWT 2020).

[2] '✓' indicates a historical record from the ECCC 2017 ARU data (ECCC 2020; see K'alo-Stantec 2022a) and a '-' indicates non-detection.

[3] '✓' indicates a positive species detection during the 2022 Avian Surveys and a '-' indicates non-detection.

* Species included as indicated by ECCC (Dufour 2020, pers. comm.; ECCC 2020).

Table B.5 Summary of the Number of Survey Locations with Breeding Bird Species Detections from the ECCC ARU Surveys in 2017 and the 2022 Avian Surveys Relative to Major Land Cover Class

Group	Order	Species		Major Land Cover Class[1]							Total
		Common Name	Scientific Name	Broadleaf Forest	Coniferous Forest	Mixedwood Forest	Shrubland	Herbaceous & Unvegetated	Wetland	Water	
Waterbirds	Waterfowl	Canada goose	*Branta canadensis*	2	1	3	3	0	3	0	12
		Mallard	*Anas platyrhynchos*	0	0	1	0	0	0	0	1
	Waterbirds	Red-throated loon	*Gavia stellata*	0	0	1	0	0	0	0	1
		Pacific loon	*Gavia pacifica*	0	0	0	1	0	0	0	1
		Common loon	*Gavia immer*	2	1	3	6	0	1	0	13
		Pied-billed grebe	*Podilymbus podiceps*	0	0	0	1	0	0	0	1
		Red-necked grebe	*Podiceps grisegena*	0	0	0	1	0	0	0	1
	Shorebirds	American bittern	*Botaurus lentiginosus*	0	2	1	1	0	1	0	5
		Sora	*Porzana carolina*	2	0	1	0	1	2	0	6
		American coot	*Fulica americana*	0	0	0	0	0	1	0	1
		Sandhill crane	*Antigone canadensis*	2	0	4	6	2	3	0	17
		Solitary sandpiper	*Tringa solitaria*	1	1	0	0	1	0	0	3
		Greater yellowlegs	*Tringa melanoleuca*	0	0	0	0	0	1	0	1
		Lesser yellowlegs	*Tringa flavipes*	0	2	1	3	0	3	0	9

Group	Order	Species		Major Land Cover Class[1]							Total
		Common Name	Scientific Name	Broadleaf Forest	Coniferous Forest	Mixedwood Forest	Shrubland	Herbaceous & Unvegetated	Wetland	Water	
Waterbirds (cont'd)	Shorebirds (cont'd)	Wilson's snipe	*Gallinago delicata*	5	7	9	8	0	5	0	34
		Ring-billed gull	*Larus delawarensis*	0	0	0	3	0	1	0	4
Birds of Prey	Raptors	Sharp-shinned hawk	*Accipiter striatus*	0	0	1	0	0	0	0	1
		Red-tailed hawk	*Buteo jamaicensis*	0	0	1	0	0	0	0	1
		Merlin	*Falco columbarius*	0	0	1	2	0	0	0	3
	Owls	Great horned owl	*Bubo virginianus*	0	0	0	0	0	1	0	1
		Boreal owl	*Aegolius funereus*	1	0	0	0	0	0	0	1
Upland Game Birds		Ruffed grouse	*Bonasa umbellus*	0	1	0	5	1	2	1	10
Landbirds	Near-passerines	Common nighthawk	*Chordeiles minor*	0	0	1	2	0	1	0	4
		Yellow-bellied sapsucker	*Sphyrapicus varius*	1	3	5	1	0	2	1	13
		Black-backed woodpecker	*Picoides arcticus*	0	0	1	0	0	0	0	1
		Northern Flicker	*Colaptes auratus*	1	3	2	2	0	2	1	11
		Pileated woodpecker	*Dryocopus pileatus*	0	1	1	2	0	0	0	4
		Hairy woodpecker	*Dryobates villosus*	0	0	1	0	0	0	0	1

Group	Order	Species		Major Land Cover Class[1]							Total
		Common Name	Scientific Name	Broadleaf Forest	Coniferous Forest	Mixedwood Forest	Shrubland	Herbaceous & Unvegetated	Wetland	Water	
Landbirds (cont'd)	Passerines	Olive-sided flycatcher	*Contopus cooperi*	1	1	2	1	0	0	0	5
		Western wood-pewee	*Contopus sordidulus*	0	0	0	0	0	2	0	2
		Yellow-bellied flycatcher	*Empidonax flaviventris*	2	2	4	6	1	3	0	18
		Alder flycatcher	*Empidonax alnorum*	2	13	5	9	4	8	0	41
		Least flycatcher	*Empidonax minimus*	2	1	3	1	2	2	0	11
		Blue-headed vireo	*Vireo solitarius*	0	0	1	1	0	0	0	2
		Warbling vireo	*Vireo gilvus*	0	3	0	1	1	3	0	8
		Red-eyed vireo	*Vireo olivaceus*	0	0	0	0	0	1	0	1
		American crow	*Corvus brachyrhynchos*	0	0	2	1	0	1	0	4
		Common raven	*Corvus corax*	0	0	6	3	1	2	0	12
		Tree swallow	*Tachycineta bicolor*	0	0	0	0	0	1	0	1
		Black-capped chickadee	*Poecile atricapillus*	1	0	3	2	1	1	0	8
		Boreal chickadee	*Poecile hudsonicus*	0	3	1	0	0	0	0	4
		Townsend's solitaire	*Myadestes townsendi*	0	1	0	0	0	0	0	1
		Gray-cheeked thrush	*Catharus minimus*	0	0	1	0	0	2	0	3

Group	Order	Species		Major Land Cover Class[1]							Total
		Common Name	Scientific Name	Broadleaf Forest	Coniferous Forest	Mixedwood Forest	Shrubland	Herbaceous & Unvegetated	Wetland	Water	
Landbirds (cont'd)	Passerines (cont'd)	Swainson's thrush	*Catharus ustulatus*	7	25	12	12	4	15	1	76
		Hermit thrush	*Catharus guttatus*	6	23	12	12	4	13	0	70
		American robin	*Turdus migratorius*	5	17	9	11	3	13	1	59
		Varied thrush	*Ixoreus naevius*	1	6	3	0	1	3	0	14
		Bohemian waxwing	*Bombycilla garrulus*	1	0	2	1	0	0	0	4
		Yellow warbler	*Setophaga petechia*	2	1	4	6	3	1	0	17
		Magnolia warbler	*Setophaga magnolia*	2	4	6	4	0	3	0	19
		Cape May warbler	*Setophaga tigrina*	1	1	0	0	0	0	0	2
		Yellow-rumped warbler	*Setophaga coronata*	6	16	12	8	2	7	1	52
		Palm warbler	*Setophaga palmarum*	2	11	1	6	1	3	0	24
		Bay-breasted warbler	*Setophaga castanea*	0	1	0	0	0	0	0	1
		Blackpoll warbler	*Setophaga striata*	3	4	4	1	2	2	0	16
		Black-and-white warbler	*Mniotilta varia*	1	0	2	2	0	1	0	6
		Tennessee warbler	*Leiothlypis peregrina*	5	21	10	4	3	10	1	54

Group	Order	Species		Major Land Cover Class[1]							Total
		Common Name	Scientific Name	Broadleaf Forest	Coniferous Forest	Mixedwood Forest	Shrubland	Herbaceous & Unvegetated	Wetland	Water	
Landbirds (cont'd)	Passerines (cont'd)	Orange-crowned warbler	*Leiothlypis celata*	6	9	8	11	3	8	0	45
		Ruby-crowned kinglet	*Corthylio calendula*	5	17	10	4	1	6	1	44
		American redstart	*Setophaga ruticilla*	1	1	0	1	0	2	0	5
		Ovenbird	*Seiurus aurocapilla*	1	0	4	1	1	5	0	12
		Northern waterthrush	*Parkesia noveboracensis*	1	1	4	6	1	2	0	15
		Common yellowthroat	*Geothlypis trichas*	0	3	1	0	0	1	0	5
		Wilson's warbler	*Cardellina pusilla*	2	1	0	1	1	1	0	6
		American tree sparrow	*Spizelloides arborea*	0	1	0	0	1	0	0	2
		Chipping sparrow	*Spizella passerina*	2	23	9	5	3	9	1	52
		Savannah sparrow	*Passerculus sandwichensis*	0	0	0	0	0	3	0	3
		Fox sparrow	*Passerella iliaca*	6	5	5	8	2	6	0	32
		Lincoln's sparrow	*Melospiza lincolnii*	5	20	7	10	3	10	0	55
		Swamp sparrow	*Melospiza georgiana*	1	3	7	3	1	4	0	19
		White-throated sparrow	*Zonotrichia albicollis*	7	15	11	12	4	11	1	61

Group	Order	Species		Major Land Cover Class[1]							Total
		Common Name	Scientific Name	Broadleaf Forest	Coniferous Forest	Mixedwood Forest	Shrubland	Herbaceous & Unvegetated	Wetland	Water	
Landbirds (cont'd)	Passerines (cont'd)	Harris's sparrow	*Zonotrichia querula*	0	0	0	1	0	0	0	1
		White-crowned sparrow	*Zonotrichia leucophrys*	3	2	2	7	4	4	0	22
		Clay-colored sparrow	*Spizella pallida*	0	2	1	0	0	0	0	3
		LeConte's sparrow	*Ammospiza leconteii*	0	0	0	0	0	1	0	1
		Dark-eyed junco	*Junco hyemalis*	6	20	8	8	4	10	1	57
		Purple finch	*Haemorhous purpureus*	1	0	3	1	0	0	0	5
		Red-winged blackbird	*Agelaius phoeniceus*	4	0	7	4	2	2	0	19
		Pine grosbeak	*Pinicola enucleator*	2	0	1	1	0	0	0	4
		White-winged crossbill	*Loxia leucoptera*	3	11	6	5	1	5	0	31
		Common redpoll	*Acanthis flammea*	3	0	7	4	2	3	0	19
		Pine siskin	*Spinus pinus*	0	2	1	0	1	0	0	4
		Western tanager	*Piranga ludoviciana*	0	5	0	0	0	5	1	11
		Canada jay	*Perisoreus canadensis*	1	7	3	2	0	4	0	17
			TOTAL	**127**	**324**	**248**	**234**	**73**	**228**	**12**	**1,246**

Note:
[1] 30 m resolution from Earth Observation of Sustainable Development of Forests Northwest Territories (NRCan and GNWT 2017; K'alo-Stantec 2022c)

Table B.6 Summary of the Number of Survey Locations with Breeding Bird Species Detections from the ECCC ARU Surveys in 2017 and the 2022 Avian Surveys Relative to Level III Ecoregion

Group	Order	Species		Level III Ecoregion			Total
		Common Name	Scientific Name	Boreal Cordillera	Taiga Cordillera	Taiga Plains	
Waterbirds	Waterfowl	Canada goose	*Branta canadensis*	0	3	9	12
		Mallard	*Anas platyrhynchos*	0	1	0	1
	Waterbirds	Red-throated loon	*Gavia stellata*	0	1	0	1
		Pacific loon	*Gavia pacifica*	0	0	1	1
		Common loon	*Gavia immer*	1	5	7	13
		Pied-billed grebe	*Podilymbus podiceps*	0	0	1	1
	Shorebirds	American bittern	*Botaurus lentiginosus*	0	5	0	5
		Sora	*Porzana carolina*	1	3	2	6
		American coot	*Fulica americana*	0	1	0	1
		Sandhill crane	*Antigone canadensis*	2	5	10	17
		Solitary sandpiper	*Tringa solitaria*	0	0	3	3
		Greater yellowlegs	*Tringa melanoleuca*	0	0	1	1
		Lesser yellowlegs	*Tringa flavipes*	0	1	8	9
		Wilson's snipe	*Gallinago delicata*	6	14	14	34
		Ring-billed gull	*Larus delawarensis*	1	0	3	4
		Red-necked grebe	*Podiceps grisegena*	0	0	1	1
Birds of Prey	Raptors	Sharp-shinned hawk	*Accipiter striatus*	1	0	0	1
		Red-tailed hawk	*Buteo jamaicensis*	0	0	1	1
		Merlin	*Falco columbarius*	2	0	1	3
	Owls	Great horned owl	*Bubo virginianus*	0	1	0	1
		Boreal owl	*Aegolius funereus*	0	1	0	1
Upland Game Birds		Ruffed grouse	*Bonasa umbellus*	5	4	1	10

Group	Order	Species		Level III Ecoregion			Total
		Common Name	Scientific Name	Boreal Cordillera	Taiga Cordillera	Taiga Plains	
Landbirds	Near-passerines	Common nighthawk	*Chordeiles minor*	2	1	1	4
		Yellow-bellied sapsucker	*Sphyrapicus varius*	7	4	2	13
		Black-backed woodpecker	*Picoides arcticus*	0	1	0	1
		Northern flicker	*Colaptes auratus*	2	3	6	11
		Pileated woodpecker	*Dryocopus pileatus*	4	0	0	4
		Hairy woodpecker	*Dryobates villosus*	0	0	1	1
	Passerines	Olive-sided flycatcher	*Contopus cooperi*	0	1	4	5
		Western wood-pewee	*Contopus sordidulus*	1	0	1	2
		Yellow-bellied flycatcher	*Empidonax flaviventris*	6	6	6	18
		Alder flycatcher	*Empidonax alnorum*	12	13	16	41
		Least flycatcher	*Empidonax minimus*	4	2	5	11
		Blue-headed vireo	*Vireo solitarius*	1	1	0	2
		Warbling vireo	*Vireo gilvus*	2	4	2	8
		Red-eyed vireo	*Vireo olivaceus*	0	1	0	1
		American crow	*Corvus brachyrhynchos*	0	3	1	4
		Common raven	*Corvus corax*	4	2	6	12
		Tree swallow	*Tachycineta bicolor*	0	0	1	1
		Black-capped chickadee	*Poecile atricapillus*	1	2	5	8
		Boreal chickadee	*Poecile hudsonicus*	2	1	1	4
		Townsend's solitaire	*Myadestes townsendi*	0	1	0	1
		Gray-cheeked thrush	*Catharus minimus*	0	2	1	3
		Swainson's thrush	*Catharus ustulatus*	22	25	29	76
		Hermit thrush	*Catharus guttatus*	19	24	27	70
		American robin	*Turdus migratorius*	18	17	24	59
		Varied thrush	*Ixoreus naevius*	12	0	2	14

Group	Order	Species		Level III Ecoregion			Total
		Common Name	Scientific Name	Boreal Cordillera	Taiga Cordillera	Taiga Plains	
Landbirds (cont'd)	Passerines (cont'd)	Bohemian waxwing	*Bombycilla garrulus*	1	2	1	4
		Yellow warbler	*Setophaga petechia*	5	5	7	17
		Magnolia warbler	*Setophaga magnolia*	5	12	2	19
		Cape May warbler	*Setophaga tigrina*	1	0	1	2
		Yellow-rumped warbler	*Setophaga coronata*	16	16	20	52
		Palm warbler	*Setophaga palmarum*	4	9	11	24
		Bay-breasted warbler	*Setophaga castanea*	0	1	0	1
		Blackpoll warbler	*Setophaga striata*	4	2	10	16
		Black-and-white warbler	*Mniotilta varia*	0	4	2	6
		Tennessee warbler	*Leiothlypis peregrina*	19	22	13	54
		Orange-crowned warbler	*Leiothlypis celata*	7	14	24	45
		Ruby-crowned kinglet	*Corthylio calendula*	18	13	13	44
		American redstart	*Setophaga ruticilla*	0	1	4	5
		Ovenbird	*Seiurus aurocapilla*	5	6	1	12
		Northern waterthrush	*Parkesia noveboracensis*	4	6	5	15
		Common yellowthroat	*Geothlypis trichas*	1	3	1	5
		Wilson's warbler	*Cardellina pusilla*	0	2	4	6
		American tree sparrow	*Spizelloides arborea*	0	1	1	2
		Chipping sparrow	*Spizella passerina*	20	15	17	52
		Savannah sparrow	*Passerculus sandwichensis*	0	0	3	3
		Fox sparrow	*Passerella iliaca*	3	13	16	32
		Lincoln's sparrow	*Melospiza lincolnii*	14	19	22	55
		Swamp sparrow	*Melospiza georgiana*	3	6	10	19
		White-throated sparrow	*Zonotrichia albicollis*	21	18	22	61
		Harris's sparrow	*Zonotrichia querula*	0	0	1	1

Group	Order	Species		Level III Ecoregion			Total
		Common Name	Scientific Name	Boreal Cordillera	Taiga Cordillera	Taiga Plains	
Landbirds (cont'd)	Passerines (cont'd)	White-crowned sparrow	*Zonotrichia leucophrys*	1	5	16	22
		Clay-colored sparrow	*Spizella pallida*	1	2	0	3
		Leconte's sparrow	*Ammospiza leconteii*	0	0	1	1
		Dark-eyed junco	*Junco hyemalis*	18	14	25	57
		Purple finch	*Haemorhous purpureus*	2	1	2	5
		Red-winged blackbird	*Agelaius phoeniceus*	6	5	8	19
		Pine grosbeak	*Pinicola enucleator*	2	1	1	4
		White-winged crossbill	*Loxia leucoptera*	15	8	8	31
		Common redpoll	*Acanthis flammea*	7	3	9	19
		Pine siskin	*Spinus pinus*	1	2	1	4
		Western tanager	*Piranga ludoviciana*	9	1	1	11
		Canada jay	*Perisoreus canadensis*	5	6	6	17
			TOTAL	**356**	**397**	**493**	**1,246**

Table B.7 Difference in Mean Breeding Bird Densities between the Local and Regional Study Areas[1]

Group	Order	Species		Mean Breeding Density (males/ha)		
		Common Name	Scientific Name	LSA	RSA	Difference
Waterbrids	Shorebirds	Wilson's snipe	*Gallinago delicata*	0.021	0.021	0.000
		Solitary sandpiper	*Tringa solitaria*	0.012	0.012	0.000
		Lesser yellowlegs	*Tringa flavipes*	0.011	0.012	0.000
Landbirds	Near-passerines	Yellow-bellied sapsucker	*Sphyrapicus varius*	0.024	0.025	-0.001
		Hairy woodpecker	*Dryobates villosus*	0.006	0.006	0.000
		Northern flicker	*Colaptes auratus*	0.013	0.013	0.000
	Passerines	Olive-sided flycatcher	*Contopus cooperi*	0.008	0.008	0.000
		Yellow-bellied flycatcher	*Empidonax flaviventris*	0.019	0.019	0.000
		Alder flycatcher	*Empidonax alnorum*	0.151	0.144	0.007
		Least flycatcher	*Empidonax minimus*	0.052	0.051	0.001
		Blue-headed vireo	*Vireo solitarius*	0.011	0.012	0.000
		Warbling vireo	*Vireo gilvus*	0.025	0.026	-0.001
		Red-eyed vireo	*Vireo olivaceus*	0.045	0.044	0.001
		Canada jay	*Perisoreus canadensis*	0.139	0.145	-0.005
		Common raven	*Corvus corax*	0.007	0.007	0
		Black-capped chickadee	*Poecile atricapillus*	0.005	0.005	0
		Boreal chickadee	*Poecile hudsonicus*	0.057	0.059	-0.002
		Cliff swallow	*Petrochelidon pyrrhonota*	0.04	0.041	-0.001
		Ruby-crowned kinglet	*Corthylio calendula*	0.094	0.096	-0.002
		Red-breasted nuthatch	*Sitta canadensis*	0.013	0.013	0.000
		Varied thrush	*Ixoreus naevius*	0.005	0.006	0.000
		Gray-cheeked thrush	*Catharus minimus*	0.012	0.014	-0.002
		Swainson's thrush	*Catharus ustulatus*	0.399	0.395	0.004

Group	Order	Species		Mean Breeding Density (males/ha)		
		Common Name	Scientific Name	LSA	RSA	Difference
Landbirds (cont'd)	Passerines (cont'd)	Hermit thrush	*Catharus guttatus*	0.106	0.108	-0.002
		American robin	*Turdus migratorius*	0.15	0.16	-0.01
		Bohemian waxwing	*Bombycilla garrulus*	0.034	0.036	-0.002
		Pine grosbeak	*Pinicola enucleator*	0.006	0.007	0.000
		Red crossbill	*Loxia curvirostra*	0.005	0.005	0.000
		White-winged crossbill	*Loxia leucoptera*	0.111	0.117	-0.005
		Pine siskin	*Spinus pinus*	0.058	0.062	-0.003
		Chipping sparrow	*Spizella passerina*	0.312	0.3	0.012
		Clay-colored sparrow	*Spizella pallida*	0.008	0.008	0.000
		American tree sparrow	*Spizelloides arborea*	0.014	0.015	-0.001
		Fox sparrow	*Passerella iliaca*	0.041	0.045	-0.004
		Dark-eyed junco	*Junco hyemalis*	0.271	0.288	-0.017
		White-crowned sparrow	*Zonotrichia leucophrys*	0.075	0.09	-0.015
		White-throated sparrow	*Zonotrichia albicollis*	0.18	0.171	0.009
		LeConte's sparrow	*Ammospiza leconteii*	0.005	0.005	0.000
		Savannah sparrow	*Passerculus sandwichensis*	0.01	0.011	-0.001
		Lincoln's sparrow	*Melospiza lincolnii*	0.17	0.173	-0.003
		Swamp sparrow	*Melospiza georgiana*	0.026	0.026	0.000
		Ovenbird	*Seiurus aurocapilla*	0.048	0.046	0.001
		Northern waterthrush	*Parkesia noveboracensis*	0.033	0.034	-0.001
		Black-and-white warbler	*Mniotilta varia*	0.022	0.023	-0.001
		Tennessee warbler	*Leiothlypis peregrina*	0.399	0.355	0.045
		Orange-crowned Warbler	*Leiothlypis celata*	0.143	0.142	0.001
		Common yellowthroat	*Geothlypis trichas*	0.016	0.016	-0.001
		American redstart	*Setophaga ruticilla*	0.039	0.04	0.000

Group	Order	Species		Mean Breeding Density (males/ha)		
		Common Name	Scientific Name	LSA	RSA	Difference
Landbirds (cont'd)	Passerines (cont'd)	Cape May warbler	*Setophaga tigrina*	0.031	0.032	-0.001
		Magnolia warbler	*Setophaga magnolia*	0.084	0.085	-0.001
		Bay-breasted warbler	*Setophaga castanea*	0.037	0.037	0.000
		Yellow warbler	*Setophaga petechia*	0.033	0.034	-0.001
		Blackpoll warbler	*Setophaga striata*	0.091	0.095	-0.004
		Palm warbler	*Setophaga palmarum*	0.079	0.08	-0.002
		Yellow-rumped warbler	*Setophaga coronata*	0.38	0.395	-0.016
		Canada warbler	*Cardellina canadensis*	0.005	0.005	0.00
		Wilson's warbler	*Cardellina pusilla*	0.031	0.033	-0.002
		Western tanager	*Piranga ludoviciana*	0.039	0.039	0.000
		Rose-breasted grosbeak	*Pheucticus ludovicianus*	0.006	0.006	0.000

NOTE:
[1] Data from the Boreal Avian Modelling Project (BAMP 2020)

APPENDIX 22A

Heritage Resources Technical Data Report

Mackenzie Valley Highway Project
Technical Data Report—Heritage Resources

Prepared for:

Government of the Northwest Territories

Prepared by:

K'alo-Stantec Limited

December 2022

Project No.: 144903025

K'alo-Stantec

Limitations and Sign-off

This document entitled Mackenzie Valley Highway Project Technical Data Report—Heritage Resources was prepared by K'alo-Stantec Limited ("K'alo-Stantec") for the account of Government of the Northwest Territories (the "Client") to support the regulatory review process for its Developers Assessment Report (DAR) (the "Application") for the Mackenzie Valley Highway Project (the Project"). In connection therewith, this document may be reviewed and used by the Department of Infrastructure (INF) for the Government of the Northwest Territories participating in the review process in the normal course of its duties. Except as set forth in the previous sentence, any reliance on this document by any other party or use of it for any other purpose is strictly prohibited. The material in it reflects K'alo-Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between K'alo-Stantec and the Client. The information and conclusions in the document are based on the conditions existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, K'alo-Stantec did not verify information supplied to it by the Client or others, unless expressly stated otherwise in the document. Any use that another party makes of this document is the responsibility and risk of such party. Such party agrees that K'alo-Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other party as a result of decisions made or actions taken based on this document.

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K'alo-Stantec

Executive Summary

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Valley Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells, replacing the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The Project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT).

This technical data report summarizes information on known archaeological sites and provides an evaluation of archaeological site potential within the Mackenzie Valley Winter Road corridor. The study area is defined by the preliminary project highway alignment with a 100 metres (m), 1 km, and 5 km buffer, intended to encompass the area of anticipated disturbance for the Project.

A total of 133 sites within the Regional Study Area (defined by the 5 km buffer) and 33 areas of high potential have been identified, based on known site data and the results of the 2020 desktop Archaeological Overview Assessment, completed relative to the roadway corridor.

The present study was designed solely to identify and assess evidence of past human activity protected under the *Archaeological Sites Act* (GNWT, 2014a). It is not the intent of this report to evaluate traditional Indigenous use, nor is the intent to address potential impacts on non-protected cultural heritage resources within the study area.

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Abbreviations

AIA	Archaeological Impact Assessment
AOA	Archaeological Overview Assessment
CR#4	Conformity Requirement Number Four
CZ	Conservation Zone
DAR	Developer's Assessment Report
DEM	Digital Elevation Model
DLUP	Draft Dehcho Land Use Plan
GIS	geographic information system
GNWT	Government of the Northwest Territories
GPS	global positioning system
INF	Department of Infrastructure
km	kilometre
KM	kilometre marker
LiDAR	Light Detection and Ranging
LSA	Local Study Area
m	metre
MVH	Mackenzie Valley Highway
MVRMA	*Mackenzie Valley Resource Management Act*
MVWR	Mackenzie Valley Winter Road
NT	Northwest Territories
NTS	National Topographic Series
PDA	Project Development Area
PDR	Project Description Report
Project Area	Mackenzie Valley Highway Project Area
PWNHC	Prince of Wales Northern Heritage Centre
RSA	Regional Study Area
SLUP	Sahtu Land Use Plan
SMZ	Special Management Zone

SON ..... Subject of Note

SSA ..... Sahtu Settlement Area

TDR ..... Technical Data Report

the Project ..... Mackenzie Valley Highway Project

TLRU ..... traditional land and resource use

ToR ..... Terms of Reference

VC ..... Valued Component

Glossary

Local Study Area (LSA)	The area within which some measurable Project-related effects may occur. This is a 2 km wide corridor centred on the Project highway alignment (1 km on both sides of the alignment).
MVH Project Area (Project Area)	The area to be utilized by the Project and includes the project highway alignment of the MVH between Wrigley and Norman Wells and a 100 m buffer on both sides of the alignment. It also includes the temporary and permanent borrow sources and associated access roads.
MVH Archaeological Study Area	A study area consisting of the project highway alignment of the MVH between Wrigley and Norman Wells and a 5 km buffer on either side.
Project Development Area (PDA)	The area of direct Project disturbance within which works and activities will occur (footprint). The Project consists of a 321 km all-season highway located between Wrigley and Norman Wells, NWT. The highway right-of-way will be 60 m in width. The footprint includes laydown and staging areas, construction camp locations, quarry/borrow sites with access roads on a 30 m ROW.
Regional Study Area (RSA)	The area for which resource information is included to provide a context for evaluation of Project effects. This is a 10 km wide corridor centred on the project highway alignment (5 km on both sides of the alignment).

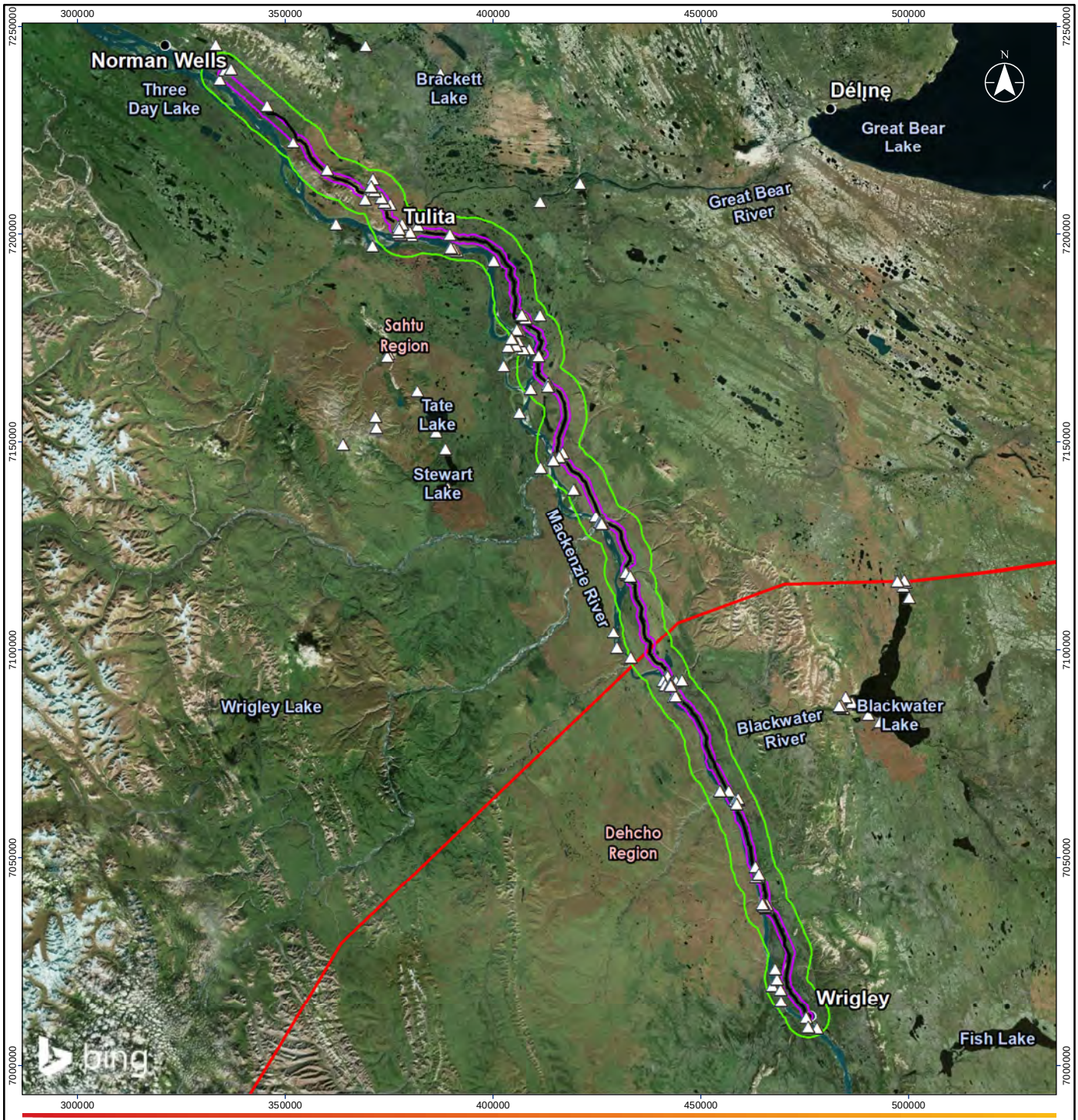
1 Introduction

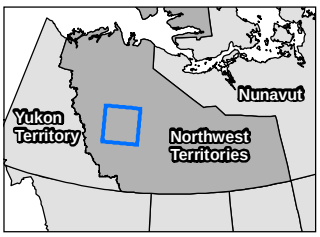
The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells, replacing the Mackenzie Valley Winter Road (MVWR) in this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The Project will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT; Figure 1.1).

The Project is subject to an environmental assessment and the requirements of Part 5 of the *Mackenzie Valley Resource Management Act* (MVRMA). This Technical Data Report (TDR) presents the existing conditions for Heritage Resources to support development of the Developer's Assessment Report (DAR) as required by the Terms of Reference (ToR; MVEIRB, 2015). As part of the environmental assessment process, the DAR will present the GNWT's assessment of effects of the Project on the environment.

Heritage Resources are a Valued Component (VC) and considered to be a Subject of Note (SON) within the Project ToR. Archaeological sites are fragile and non-renewable resources that are susceptible to alteration or removal by development activities. These resources are protected from disturbance by GNWT legislation, regulation, and policy. The Northwest Territories Archaeological Sites Regulations (GNWT, 2014a), pursuant to the *Archaeological Sites Act* (GNWT, 2014b), apply to all lands and waters in NT under territorial control. The legislation is intended to protect archaeological sites from unpermitted disturbances, alterations, or surveys. Heritage Resources are also protected under the *Mackenzie Valley Resource Management Act* (Government of Canada, 1998) and the associated Mackenzie Valley Land Use Regulations, which prohibit unpermitted land use operations within 30 metres (m) of a known or suspected historical or archaeological site or burial site and require suspension of all operations if an archaeological site or burial is encountered. The Mackenzie Valley Land Use Regulations apply to all lands in the NT outside the Inuvialuit Settlement Region.

As noted above, the Project passes through portions of the Dehcho Region and the Sahtu Region. The Land Use Plans for both land claim areas reference Heritage Resources. The Dehcho Land Use Plan (DLUP) (DLUPC, 2006) includes Conformity Requirement #4, indicating the need to "assess the impact … on known heritage, historical, archaeological, cultural and traditional land use and occupancy sites including burial grounds, sacred sites, cabins, and traplines, as identified by the affected Dehcho First Nation(s) and Prince of Wales Northern Heritage Centre" [PWNHC].





- Archaeological Site
- Municipality
- Mackenzie Valley Highway Project
- Mackenzie Valley Highway Project LSA
- Mackenzie Valley Highway Project RSA
- Settlement Region Boundary

0 20 40 Kilometres

1:1,400,000 (at original document size of 8.5x11)

Kálo-Stantec

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Source: © 2022 Microsoft Corporation Earthstar Geographics SIO; LiDAR from Government of Northwest Territories; ArcticDEM
3. Archaeological Site Data provided by the Prince of Wales Northern Heritage Centre; (c) Government of the Northwest Territories, Education, Culture, and Employment

Project Location
Central Northwest Territories

144903025
Prepared by BSorensen on 2021-02-05
Revised by BSorensen on 2021-02-22

Client/Project
Client: Government of the Northwest Territories
Project: Mackenzie Valley Highway Project

Figure No.
1.1

Title
Project Location Showing Alignment, Study Areas, and Recorded Sites

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The Sahtu Land Use Plan (SLUP) (SLUPB, 2013) applies to Sahtu Settlement Area (SSA) lands. Conformity Requirement Number Four (CR#4) of the Sahtu Land Use Plan includes provisions related to archaeological resources, indicating that “land use activities must not be located within 500 m of known or suspected burial sites, or within 150 m of known or suspected archaeological sites, unless measures are developed in cooperation with the PWNHC, affected communities, or in the case of burial sites, with affected families where possible” and “where there is a high risk of impact to known or suspected archaeological sites, as determined by the PWNHC, an archaeological impact assessment must be conducted prior to commencement of the land use activity” (SLUPB, 2013).

This report focuses largely on the known archaeological site data as provided by PWNHC (PWNHC, 2020) through an Archaeological Sites Data Base Access Request, for the Regional Study Area, and the existing permit reports (with associated geographic information system [GIS] data, site forms, and field notes where available). An evaluation of archaeological site potential has been completed (Krahulic, 2020) based largely on landscape attributes drawn from National Topographic Series (NTS) maps, satellite imagery, and the Arctic Digital Elevation Model (DEM) dataset for elevation data. Areas of existing anthropogenic disturbance were used in the evaluation of archaeological site potential, given the importance of site integrity as a key attribute in assessing the likelihood of impacts to sites of high heritage value. Palaeontological locations are identified when recorded within the territorial Archaeological Sites Data Base. Traditional Land and Resource Use (TLRU) information is integrated where available; many of the archaeological sites on record reflect relatively recent local community use. The Land Use Planning management zones are also referenced, where applicable.

2 Study Area

The Project is in the Mackenzie Valley region of the NT between the current terminus of the existing all-weather highway at Hodgson Creek (located approximately 1 km north of Wrigley) and Prohibition Creek (located approximately 28 km southeast of Norman Wells). The project highway alignment parallels the Mackenzie River to its east and passes through the community of Tulita (kilometre marker [KM] 938 of the MVWR). The Project is located within the Taiga Plains Low Subarctic, the Taiga Cordillera Low Subarctic, and the Boreal Cordillera Level III ecoregions.

The Project was reviewed relative to the Mackenzie Valley Highway (MVH) Project Area, the Local Study Area (LSA) and the Regional Study Area (RSA), to evaluate potential Project effects on known Heritage Resources. The project highway alignment and recorded archaeological sites in the study area are illustrated in Figure 1.1.

2.1 MVH Project Area

The MVH Project Area (Project Area) is the area to be utilized by the Project and includes the project highway alignment of the MVH between Wrigley and Norman Wells and a 100 m buffer on either side. It also includes the temporary and permanent borrow sources and associated access roads.

2.2 Local Study Area

The LSA is defined as a 2 km wide corridor, centred on the project highway alignment, with a 1 km buffer on either side, within which some measurable Project-related effects may occur. Following completion of design, the evaluation of Project effects on Heritage Resources can be completed within the Project Development Area (PDA) only. Because the 100 m buffer of the Project Area is nested within the LSA, resource counts for the LSA within this document exclude those within the Project Area.

2.3 Regional Study Area

The RSA is defined as a 10 km wide corridor, centred on the project highway alignment, with a 5 km buffer on either side, to allow for greater contextual information, given that relatively few archaeological sites are on record within the general area. As the Project Area and LSA are nested within the RSA, resource counts for the RSA within this document exclude those within the Project Area and LSA.

2.4 Intersected Ecoregions

Archaeological sites are often found associated with a specific set of landforms (including eskers, valley edges, knolls, rivers, lakeshores, coastlines and channels) which would direct travel, bias routes of communication, and enhance or restrict resource procurement and occupation. Due to this close relationship of human settlement and the environment, a brief overview of the regional and local environments is presented, drawn from the Ecosystem Classification Group descriptions and the Vegetation and Wetlands TDR.

2.4.1 Taiga Plains Low Subarctic

The Taiga Plains Low Subarctic is a Level III ecoregion in the central third of the Taiga Plains (Level II), bordered by the Mackenzie River, Great Bear Lake, and Great Slave Lake. The ecoregion is characterized by undulating plains, upland communities of white and black spruce, and permafrost influenced wetlands (Ecosystem Classification Group, 2007).

The northern section of the Project is located within the North Mackenzie Plain, a Level IV classification within the Taiga Plains Low Subarctic ecoregion. The North Mackenzie Plain parallels the Mackenzie River and consists of level to undulating terrain. Forest vegetation consists of white and black spruce, Alaska paper birch and dwarf birch communities. Occurrences of trembling aspen and jack pine occur on well drained sites south of Tulita. Bogs and fens occupy approximately 15% of the ecoregion (Ecosystem Classification Group, 2007).

A small section of the Project north of Tulita intersects the Norman Range ecoregion, a Level IV classification within the Taiga Plains Low Subarctic ecoregion. The Norman Range ecoregion is located northeast of the North Mackenzie Plain ecoregion and is characterized by more rugged terrain. Southwest portions of this ecoregion are composed of mixedwood deciduous and coniferous forest. Upland deciduous areas typically contain trembling aspen, Alaska paper birch, and coniferous forests (typically containing white and black spruce). Bogs and fens comprise approximately 4% of the ecoregion (Ecosystem Classification Group, 2007).

2.4.2 Taiga Cordillera Low Subarctic

The Taiga Cordillera Low Subarctic ecoregion (Level III) is varied, consisting of mountain ranges, foothills, tundra and spruce woodlands located in the central third of the Taiga Cordillera (Level II). In comparison to the Taiga Plains, the Taiga Cordillera Low Subarctic ecoregion has very few waterbodies and peatland establishment (Ecosystem Classification Group, 2010).

Central sections of the Project intersect the Central Mackenzie Plain ecoregion, a Level IV classification within the Taiga Cordillera Low Subarctic ecoregion. The Central Mackenzie Plain is located between the Dahadinni and Blackwater rivers to the south and the boundary of the Taiga Plains ecoregion to the north. Topography includes level to gently sloping terrain that supports a diverse array of forest types. Almost half the ecoregion has been exposed to fires, leading to widespread shrubby and deciduous community development. Black spruce – shrub – moss woodlands are common and similar in structure to the North Mackenzie Plain ecoregion. Jack pine and trembling aspen occur but are limited to southern sections. Wetlands occupy approximately 10% to 20% of the ecoregion and consist of mainly peatlands (Ecosystem Classification Group, 2010).

2.4.3 Boreal Cordillera High Boreal

The Boreal Cordillera High Boreal ecoregion (Level III) is in the southeast portion of the Taiga Cordillera (Level II), south of the Taiga Cordillera Low Subarctic ecoregion. In comparison to the Taiga Cordillera Low Subarctic, the Boreal Cordillera High Boreal has a milder climate, greater precipitation, and taller, more dense stands of spruce woodlands. Mixedwood forest of trembling aspen, white spruce, paper birch, and balsam poplar are common (Ecosystem Classification Group, 2010).

South portions of the Project intersect the Central Mackenzie Valley ecoregion, a Level IV classification within the Taiga Cordillera High Boreal ecoregion. The Central Mackenzie Valley ecoregion is bordered by the Dahadinni and Blackwater rivers to the north and by higher elevation slopes to the south, east, and west. Topography includes undulating terrain, rolling slopes, and level plains. Northern sections consist of closed black spruce woodlands and peat plateaus. Southern sections near Wrigley are composed of mixedwood stands of trembling aspen and white spruce. Wetlands occupy less than 10% of the entire ecoregion and consist mainly of peat plateaus, sedge fens, northern ribbed fens, and horizontal fens (Ecosystem Classification Group, 2010).

2.5 Land Use Plans

As noted above, the Project passes through lands addressed through the Dehcho Region and a portion of the Tulita District of the Sahtu Region.

Relative to the Dehcho Land Use Plan (DLUPC, 2006), the Project intersects the Pehdzeh Ki Ndeh Conservation Zone, as well as the Community of Wrigley. The Conservation Zones are areas of significant ecological and cultural value and, therefore, limitations are in place for activities other than tourism. The Mackenzie Valley Special Infrastructure Corridor “provides a passage through four Conservation Zones” (DLUPC, 2006: vii).

Relative to the SLUP (SLUPB, 2013), the Project intersects three Special Management Zones (SMZ), the Community of Tulít’a, and one Conservation Zone (CZ). The three SMZ are the Deh Cho/Mackenzie River, the Norman Range, and K’ââlô Tué/Willow Lake Wetlands. The CZ is Petiniʔah/Bear Rock. The latter is “one of the most important sacred sites in Denendeh” (SLUPB, 2013:124), with archaeological sites included as one of the Values to be Protected and traditional trails as one of the Values to Take into Account. Petiniʔah/Bear Rock is a large karst formation at the confluence of the Sahtu Deh/Great Bear River and Deh Cho/Mackenzie River, across from the community of Tulít’a (SLUPB, 2013).

3 Review of Existing Data

3.1 Traditional Knowledge and Traditional Land and Resource Use

As defined in the ToR, traditional land uses include 'traditional lifestyles, values and culture" and "cultural and spiritual sites and activities". Heritage Resources identified within the territorial archaeological sites database often include contemporary and historic land use locations, such as camp sites, cabins, caches, trails, wood harvesting areas, and traps. Spiritual sites such as graves/burials are also recorded within the sites database.

3.1.1 Methods

Traditional Land and Resource Use (TLRU) information is integrated where available; many of the archaeological sites on record reflect relatively recent ("contemporary") and historic local community use. The Land Use Planning management zones have been noted in the section above. The SLUP Conservation Zones in particular are defined as "significant traditional, cultural, heritage and ecological areas" (SLUPB, 2013) within the SLUP, with Conservation Zones in the DLUP defined as "areas having significant ecological and cultural values" (DLUPC, 2006). The archaeological site information provided through PWNHC (PWNHC, 2020) is reviewed relative to community use. Sites that definitively or possibly reflect traditional land and resource use have been highlighted in Table 1, below; sites noted as being Euro-Canadian are excluded from this selection regardless of the site type/activity noted, assuming that they are not associated with Indigenous land use. Sites without a clear affiliation but which include TLRU site types such as cabins, caches, trails, and campsites are included in the selection. Precontact archaeological sites are not included as TLRU sites but rather as Heritage Resources; however, it is evident that the two categories are not mutually exclusive.

3.1.2 Results of Site Information Review relative to TLRU

There are 133 recorded archaeological sites within the RSA. Sixty-three of these recorded archaeological sites may be correlated with TLRU, as highlighted in Table 1, see Section 3.2.2, with one located within the Project Area, 33 within the LSA, and 29 within the RSA.

3.2 Literature Review

3.2.1 Methods

The review of existing data summarizes the known archaeological site data as provided by PWNHC through an Archaeological Sites Data Base Access Request, for the RSA and the existing permit reports (with associated GIS data, site forms, and field notes where available). Palaeontological locations are identified when recorded within the territorial Archaeological Sites Data Base.

The Mackenzie Valley corridor has been subject to archaeological desktop studies (Archaeological Overview Assessments [AOAs]) as well as field assessments (Archaeological Impact Assessments [AIAs]) since the early 1970s. Each of these studies has addressed slightly different footprints related primarily to the proposed roadway expansions, the Mackenzie Gas Project and, more recently, the Mackenzie Valley Fibre Link. In 2020, the GNWT INF contracted Stantec and K'alo-Stantec to complete two AOAs. The first is an AOA of the MVWR upgrades from Prohibition Creek to Mount Gaudet; the study area consisted of the current MVWR alignment, the 1974 Public Works Canada alignment, and the proposed alignments within the 2011 Project Description Report (PDR) for Construction of the Mackenzie Valley Highway Tulita District, Sahtu Settlement Area (EBA, 2011) and the 2012 PDR for the Mackenzie Valley Highway Extension Pehdzeh Ki Ndeh – Dehcho Region (GNWT DOT, 2012), with a 500 m buffer on either side of each alignment (Krahulic 2020). The second is an AOA of 39 proposed granular and bedrock sources, along the project highway alignment (Peach, 2021). These two AOAs involved review of previous AOAs (where available), AIAs, and associated spatial data, field notes, maps, and site forms. These AOAs form the basis of the current assessment because they are recent and comprehensive assessments of the MVWR alignment and corridor.

The evaluations of archaeological site potential are based largely on landscape attributes drawn from NTS maps, satellite imagery, and Arctic DEM elevation data, has been previously completed (Krahulic, 2020). Areas of existing anthropogenic disturbance are used in the evaluation of archaeological site potential, given the importance of site integrity as a key attribute in assessing the likelihood of impacts to sites of high heritage value.

The AOA for the MVH (Krahulic, 2020) and for the proposed granular and bedrock sources (Peach, 2021) are based on the following data sources:

- territorial archaeological site data, provided under licence from the PWNHC (PWNHC, 2020)
- Sahtu Land Use Plan (SLUPB, 2013)
- Draft Dehcho Land Use Plan (DLUPC, 2006): this document is a draft that is useful for understanding current and historic land use; however, it is currently non-binding in regard to regulatory process
- Sahtu Heritage Places and Sites report (Sahtu Heritage Places and Sites Joint Working Group, 2000)

- observations and results of the AIAs for:
  - the Mackenzie Highway System, permit 1973-334 (Millar et al., 1985) (no survey polygons are available for this AIA)
  - the Mackenzie Valley Winter Road Upgrade Programme, permit 1999-892 (Ronaghan, 2000) (no survey polygons are available for this AIA)
  - the Mackenzie Gas Project, permits 2002-916, 2003-933, 2004-956 and 2006-978 (Clarke et al., 2003; Clarke et al., 2004; Clarke and Webster, 2005; Webster et al., 2007)
  - the Mackenzie Valley Fibre Link Project, permits 2014-017 and 2015-002 (Leyden et al., 2016)
  - Granular Supply Source Areas along the Mackenzie (No.1), Liard (No.7) and Proposed Mackenzie Valley Highway, permit 2016-004 (Heffner and Young, 2020)
  - 2004 Mackenzie Valley Air Photo collection provided by the PWNHC
  - surficial geology information from the Geological Survey of Canada (Hanley et al., 1973; Rutter and Boydell, 1980; Rutter et al., 1980)
  - Northwest Territories ecosystem classifications (Ecosystem Classification Group, 2007)
  - Fur Trade Posts of the Northwest Territories, 1870-1970 (Usher, 1971)
  - Bing™ imagery
  - Light Detection and Ranging (LiDAR) imagery provided by the GNWT
  - Arctic DEM Imagery

Areas of high archaeological site potential are evaluated based on terrain features and proximity to watercourses and waterbodies, slope, aspect, and drainage. Areas are selected if they are considered to be possible transportation corridors/routes, visible landmarks/lookouts, resource locations for harvesting fish/game/plant/lithic materials, and/or camp/settlement locations. Areas of prior anthropogenic disturbance are considered to be of low archaeological site potential. Areas previously assessed are also removed from the high potential areas. Previously recorded sites are also included in the evaluation of site potential.

3.2.2 Results - Sites on Record

Table 1 lists the 133 archaeological sites on record with PWNHC within 5 km (the RSA), 1 km (the LSA), and/or 100 m (Project Area) of the project highway alignment and prospective borrows or quarries. Sites that might be TLRU (e.g., historic, contemporary) are highlighted in green. Given that sites in this area have been recorded since at least the 1970s and, in some cases, the 1950s, the site type terminology has not been consistently applied. Hand-held global positioning system (GPS) units have been consistently used for perhaps the last 20 years of field assessment; site locations recorded prior to this time must be viewed as approximate until ground-truthed. The distances provided are from a Project component (highway centreline, quarry, borrow, or quarry/borrow access road) to the site point on record. Because sites can range in size from an isolated find of a single artifact to a large campsite, village, trading post or trail, the distance between a Project component and a site is a very approximate indication

of the likelihood of spatial overlap between a heritage site and the Project and, therefore, the overlap could indicate potential Project effects on known Heritage Resources. Conclusions regarding the likelihood of impact to a known site by Project activities must be considered with caution, given the above noted sources of locational inaccuracy.

However, 13 of the 133 sites are within the Project Area and have a greater likelihood of direct impact from Project construction. An additional 50 sites are within the LSA and 70 sites are within the RSA. Until a final footprint has been defined, the likelihood of impact to the majority of these recorded sites is unknown.

Of the 133 sites that are within the RSA, 34 are recorded as being “contemporary”, and include campsites, cabins, shelters, hearths, tent frames/tent emplacements, trap sites, trails, and associated smaller features (i.e., tripod, doghouse, outhouse, smoking frame). Thirty-five of the sites are considered to be “historic”, “Indigenous historic”, or both. These sites include campsites, cabins, tent frames, hearths, trails, midden/debris scatters, wood harvesting areas, sawmills, caches, villages, trading posts/forts, a barge landing, burials, as well as associated smaller features (e.g., chimney). Fifty-nine sites are considered to be solely of precontact age/association. These include isolated artifact finds, artifact scatters, campsites, hunting lookout/short term campsites, and chipping stations/lithic scatters. Hearths are noted additional features, with one ‘wood scatter’ also recorded. Three additional sites are evidently multicomponent, described as a precontact/Indigenous cabin and grave location, a precontact/contemporary burial, and a precontact/historic trading post. Included as of precontact affiliation is a palaeontological fossil site, the Canyon Creek Fossils. Thirteen sites are recorded with an “undetermined” affiliation, including isolated artifact finds, campsites, caches, and graves.

Five of the sites listed above consist of or include a “grave” or “burial”: KlRm-12, KlRm-16, LbRn-4, LbRn-8, and LfRp-1. Three are within the LSA, and two are within the RSA.

Areas of particular site density are at the confluences of the Mackenzie River/Deh Cho and Ochre River, White Sand Creek, Dam Creek, Blackwater River, Step Creek, Saline River, Little Smith Creek, Big Smith Creek, and Great Bear River.

These results will require review once the Project has been fully designed and a PDA has been established, to determine which of the previously recorded site locations may intersect with the Project.

Table 1 Archaeological Sites on Record within Study Areas (potential TLRU in green)

Archaeological Site (Borden) Number	Site Affiliation; Site Type	Features	Project Study Area (Project Area, LSA, RSA)	Approx. Distance (m) between Project Component and Recorded Site Centre Point
KhRk-1	Precontact; Isolated Find/Campsite	---	RSA	3,434
KhRk-10	Indigenous Historic/Historic; Village/Trading Post	Cabin, cache, artifact scatter	RSA	3,119
KhRk-2	Precontact; Isolated Find	---	RSA	3,559
KhRk-3	Precontact; Isolated Find	---	RSA	1,737
KhRk-4	Indigenous Historic/Historic	Cabin, tent frame	RSA	2,120
KhRk-5	Contemporary; Campsite	---	LSA	518
KhRk-6	Undetermined; Isolated Find	---	RSA	2,549
KhRk-9	Undetermined; Campsite	---	RSA	2,880
KiRl-1	Precontact; Isolated Find	---	LSA	428
KiRl-2	Undetermined	Cache	LSA	411
KiRl-3	Precontact; Chipping station	---	LSA	229
KiRl-4	Indigenous Historic/Historic	Cabin	LSA	231
KiRl-5	Precontact; Chipping station, Campsite	---	LSA	609
KiRl-6	Precontact; Chipping station	---	LSA	428
KiRl-7	Precontact	Lithic scatter	LSA	188
KiRl-8	Historic	Cabin	LSA	549
KiRl-9	Contemporary	Trap	LSA	777
KjRl-1	Precontact	Lithic scatter	LSA	713
KjRl-2	Undetermined; Isolated Find	---	LSA	713
KjRl-3	Precontact	Lithic scatter	LSA	713
KjRl-4	Precontact	Lithic scatter	LSA	713
KjRl-5	Undetermined; Isolated Find	---	LSA	510
KjRl-6	Precontact; Isolated Find	---	LSA	342
KjRl-8	Contemporary; Campsite	Cabin, doghouse, cache	LSA	165
KjRl-9	Contemporary	Trail	LSA	824
KkRl-1	Undetermined; Isolated Find	---	LSA	323
KkRl-2	Contemporary	Trap	LSA	630
KkRl-3	Contemporary; Campsite	---	RSA	1,400
KkRl-4	Contemporary; Campsite	---	RSA	1,413
KkRl-5	Undetermined; Isolated Find	---	LSA	587

Archaeological Site (Borden) Number	Site Affiliation; Site Type	Features	Project Study Area (Project Area, LSA, RSA)	Approx. Distance (m) between Project Component and Recorded Site Centre Point
KkRl-6	Precontact	Lithic scatter	RSA	1,701
KlRm-1	Historic	Cabin	RSA	1,171
KlRm-10	Historic	Cabin	LSA	312
KlRm-11	Historic; Trading Post	---	LSA	542
KlRm-12	Undetermined	Grave/burial	LSA	134
KlRm-13	Precontact	Lithic scatter	LSA	491
KlRm-15	Indigenous historic; campsite	---	RSA	1,056
KlRm-16	Indigenous historic; burial/campsite	Cabin, grave	RSA	1,339
KlRm-17	Historic; Trading Post (?)	Cabin, cache	RSA	1,430
KlRm-18	Precontact; Isolated Find	---	LSA	660
KlRm-19	Contemporary; Cache	Pits	LSA	430
KlRm-2	Contemporary	Cabin	LSA	491
KlRm-3	Contemporary	Hearth	RSA	1,107
KlRm-4	Contemporary; Campsite	Cabin, cache	LSA	109
KlRm-5	Undetermined	Cache	LSA	304
KlRm-6	Contemporary	Cache (pit)	RSA	1,107
KlRm-7	Contemporary	Shelter	LSA	304
KlRm-8	Undetermined; Campsite		RSA	2,495
KlRm-9	Historic; Trading Post	Cabin	LSA	432
LaRn-2	Indigenous Historic; Campsite	Tent frame	RSA	4,585
LbRn-1	Historic, Indigenous Historic; Campsite	Cabin, cache, hearth, tent frame	LSA	302
LbRn-10	Indigenous Historic; Campsite	Tent floor	LSA	382
LbRn-12	Historic, Indigenous Historic; Campsite	Tent frame	LSA	929
LbRn-2	Indigenous Historic; Campsite	Cabin	LSA	198
LbRn-3	Precontact	Lithic scatter	LSA	263
LbRn-4	Undetermined; Burial	Grave	LSA	796
LbRn-5	Historic	Cabin	LSA	547
LbRn-6	Precontact; Isolated Find	---	LSA	387
LbRn-7	Precontact	Hearth	Project Area	40
LbRn-8	Precontact, Indigenous; Burial/campsite	Cabin, grave	LSA	746
LbRn-9	Precontact; Isolated Find	---	LSA	614

Archaeological Site (Borden) Number	Site Affiliation; Site Type	Features	Project Study Area (Project Area, LSA, RSA)	Approx. Distance (m) between Project Component and Recorded Site Centre Point
LcRn-1	Contemporary; Campsite	Tent frame, hearth	RSA	2,967
LcRo-1	Precontact	Lithic scatter	RSA	1,084
LcRo-2	Contemporary; Campsite	Hearth	RSA	3,177
LcRo-3	Indigenous Historic; Campsite	Tent frame, cabin, cache	RSA	1,049
LcRo-5	Indigenous Historic; Campsite		RSA	1,397
LcRo-6	Precontact	Lithic scatter	RSA	1,336
LcRo-7	Precontact	Lithic scatter	LSA	121
LcRo-8	Precontact; Campsite	Hearth	RSA	1,714
LdRo-1	Historic; Fort	Depression, chimney	RSA	2,266
LdRo-11	Historic; Indigenous historic	Cabin	RSA	3,704
LdRo-14	Contemporary	Cabin	RSA	3,660
LdRo-15	Contemporary; Campsite	---	LSA	462
LdRo-2	Precontact	Lithic scatter, hearth	Project Area	12
LdRo-3	Precontact; Isolated Find	---	Project Area	12
LdRo-4	Precontact; Campsite	Lithic and bone scatter	Project Area	42
LdRo-5	Precontact; Isolated Find	---	Project Area	62
LdRo-7	Precontact; Isolated Find	---	LSA	143
LdRo-8	Precontact	Lithic scatter	Project Area	46
LdRo-9	Precontact; Isolated Find	---	LSA	366
LeRo-1	Historic	Cabin	RSA	4,124
LeRo-3	Contemporary; Sawmill	Cabin	RSA	3,741
LeRo-4	Indigenous Historic	Cabin	RSA	1,625
LeRo-5	Contemporary; Spring Campsite	Tent emplacement	RSA	1,712
LeRo-6	Contemporary; Winter trapping campsite	Cabin, outhouse, smoking frame	RSA	3,604
LeRo-7	Contemporary; Campsite	---	RSA	1,568
LeRo-8	Historic; Camp (Fishing Lake?)	Trails, clearings, refuse area, cans/cache	RSA	1,730
LeRp-2	Contemporary	Cabin	RSA	3,975

Archaeological Site (Borden) Number	Site Affiliation; Site Type	Features	Project Study Area (Project Area, LSA, RSA)	Approx. Distance (m) between Project Component and Recorded Site Centre Point
LfRp-1	Precontact; Contemporary; Burial	Grave	RSA	2,820
LfRp-2	Contemporary; Campsite	Tent emplacement	RSA	2,136
LfRp-3	Contemporary; Campsite	Tent frame, cache	RSA	2,525
LfRp-4	Contemporary; Campsite	Tent frame	RSA	2,966
LfRp-5	Historic	Cut wood	RSA	2,526
LfRp-6	Contemporary; Campsite	Tent frame	RSA	2,638
LfRp-7	Indigenous Historic; Campsite	Debris scatter, blazed tree	LSA	323
LfRq-1	Precontact	Lithic scatter	RSA	3,324
LfRq-10	Indigenous Historic	Trail; cut stump	RSA	2,130
LfRq-11	Contemporary; Campsite	Hearth; tent emplacement	RSA	1,880
LfRq-12	Contemporary; Campsite	Hearth	RSA	2,576
LfRq-13	Contemporary; Campsite	Hearth	RSA	1,511
LfRq-14	Contemporary; Campsite	---	RSA	2,563
LfRq-15	Contemporary; Campsite	---	RSA	2,246
LfRq-16	Precontact; Campsite	---	RSA	1,789
LfRq-17	Precontact; Campsite	---	RSA	1,727
LfRq-18	Precontact; Campsite	---	RSA	1,754
LfRq-19	Precontact; Isolated Find	---	RSA	1,667
LfRq-20	Indigenous Historic	Trail	RSA	1,519
LfRq-23	Historic; Camp/Barge Landing	Camp clearing, trail, barge tie-down	RSA	2,736
LfRq-24	Historic; Barge Landing	Wooden structure/barge landing	RSA	2,115
LfRq-25	Precontact; Historic; Campsite, Trading Post, Industrial	Sawmill, cultural depression	RSA	3,412
LfRq-3	Undetermined; Campsite	---	RSA	2,790
LfRq-4	Precontact; Indigenous	Artifact scatter	RSA	3,776
LfRq-6	Precontact; Campsite	Lithic scatter	RSA	1,625
LfRq-7	Precontact	Wood scatter	RSA	3,465
LfRq-8	Precontact; Historic; Trading Post	Hearth	RSA	3,465

Archaeological Site (Borden) Number	Site Affiliation; Site Type	Features	Project Study Area (Project Area, LSA, RSA)	Approx. Distance (m) between Project Component and Recorded Site Centre Point
LfRq-9	Precontact	Lithic scatter	RSA	1,947
LfRr-1	Indigenous Historic; Campsite (Fall Fishing)	Cache, cut wood/stump	Project Area	5
LfRr-2	Undetermined; Campsite	---	LSA	221
LfRr-5	Indigenous Historic	Trail, cut wood/stump	LSA	223
LfRr-6	Precontact	Lithic scatter	Project Area	60
LfRr-7	Precontact; Isolated Find	Lithic core	Project Area	70
LfRr-8	Precontact; Hunting Lookout	---	RSA	1,587
LgRr-1	Historic; Campsite	Debris scatter	Project Area	0 (within quarry)
LgRr-2	Precontact; Hunting Lookout/Campsite	---	Project Area	0 (within quarry)
LgRr-3	Precontact; Hunting Lookout/Campsite	---	Project Area	0 (within quarry)
LgRr-4	Precontact; Hunting Lookout/Campsite	---	RSA	2,793
LgRr-5	Precontact; Hunting Lookout/Campsite	---	Project Area	0 (within quarry)
LgRs-1	Precontact; Isolated Find	---	RSA	1,150
LgRs-2	Contemporary	Tripod	RSA	1,604
LhRt-2	Contemporary	Cabin	LSA (quarry)	625
LhRt-3	Precontact (Palaeontological)	Natural - “Canyon Creek Fossils”	RSA (quarry access)	3,804
LhRt-4	Precontact; Campsite	---	RSA (quarry access)	4,185
LhRt-5	Precontact; Campsite	---	RSA (quarry access)	4,150

3.2.3 Results - Areas of High Heritage Resource Potential

The archaeological sites on record are typically identified during field studies—AIAs relative to proposed development projects. The AIAs are limited to specific footprints and are not, therefore, a comprehensive dataset of archaeological resources within the current Project study areas. As noted in the ToR, the description of Heritage Resources includes consideration of "heritage resource potential."

The Mackenzie River/Deh Cho is a primary focus of human settlement and land use, as well as being a transportation corridor. Despite this focus, much of the study area is a level and featureless landscape. Two recent AOAs have evaluated the Project areas relative to heritage resources. One AOA was completed for the MVH corridor (Krahulic, 2020) and resulted in the definition of 33 target areas, recommended for pre-impact, field-based AIA prior to initiation of development activities. These target areas comprise approximately 14.5% of the AOA study area. The areas of high archaeological site potential are associated with:

- level, well-drained terraces of defined watercourses, particularly tributaries of the Mackenzie River/Deh Cho
- well-drained, level areas in proximity to waterbodies, particularly areas of inlet/outlet stream entry
- landmark features, such as Kwetįnį̀ah/Bear Rock
- confluences of tributary streams, particularly confluences with the Mackenzie River/Deh Cho
- well-defined ridges/linear landforms/lookouts
- previously recorded archaeological and/or Traditional Land Use sites

The 2020 AOA (Krahulic, 2020) was reviewed and approved by the territorial Assessment Archaeologist, Culture and Heritage Division, Department of Education, Culture and Employment.

A second AOA (Peach, 2021) was completed for an inclusive group of borrow and quarry prospects, including preliminary access routes, where needed. Nine areas of high potential within the Project area were identified in the AOA. This AOA was also reviewed and approved by the territorial Assessment Archaeologist, Culture and Heritage Division, Department of Education, Culture and Employment.

An AIA was completed in 2021 for proposed borrows and quarries, with associated access. Additional assessment is outstanding.

These results will require review once a final footprint and PDA have been defined, to establish where the Project overlaps with areas of high archaeological site potential, as identified in the two AOAs.

3.2.4 Regulatory Engagement

Regulatory engagement was initiated early in the Project's conceptual development. Recent engagement with the Culture and Heritage Division, Department of Education, Culture, and Employment includes the review of the two desktop AOAs noted above as well as liaison relative to the 2021 AIA of select borrow and quarry sources. Given the approval of the two AOAs by the territorial Assessment Archaeologist, these results will form the basis for additional field assessments (AIAs) to occur once the Project design has been developed and the PDA defined.

4 Key Results and Findings

Of the 133 archaeological sites have been previously recorded within 5 km of Project components (highway alignment centreline, quarry, borrow, and/or associated access road). Of these, 13 sites are within the Project Area (within 100 m of the project highway alignment or within borrow/quarry), 50 sites are within the LSA (between 100 m and 1,000 m of a Project component), and 70 sites are within the RSA (between 1,000 m and 5,000 m of a Project component).

Of these 133 sites, 63 may reflect traditional land and resource use, based on the available site descriptions. Five of these sites consist of, or include, graves/burials.

A total of 33 areas of high archaeological site potential were identified within the 2020 AOA footprint (Krahulic, 2020). Nine areas of high archaeological site potential were identified within the 2021 AOA footprint for borrows, quarries, and associated access within the Project Area. Additionally, previously unknown sites may be present in these areas of high archaeological site potential following AIA field assessment. These results will require review following better definition of the final Project Development Area.

5 Closure

This TDR was prepared for the sole benefit of GNWT to describe existing conditions related to Heritage Resources within the Project Area, LSA and RSA. If you have any questions, please do not hesitate to contact the undersigned.

Respectfully submitted,

K'alo-Stantec Limited

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