MACKENZIE VALLEY HIGHWAY PROJECT

DEVELOPER'S ASSESSMENT REPORT

October 2023

VOLUME 4

Other Topics Addressed

Government of
Northwest Territories

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23.0 COMPLIANCE AND EFFECTS MONITORING

The Developer's Assessment Report (DAR) identifies and assesses the predicted residual effects of the Mackenzie Valley Highway Project (the Project) on Valued Components (VCs) of the environment after application of mitigation measures and the predicted cumulative effects of the Project. The goals of compliance and effects monitoring are to:

- Verify compliance with conditions of regulatory authorizations and other legal requirements
- Confirm the predictions made in the environmental assessment (EA)
- Confirm mitigation measures are working as intended to reduce adverse effects
- Inform changes that may be required to mitigation measures or monitoring as part of an adaptive management approach

Compliance and effects monitoring is derived from the assessment of potential effects on VCs presented in the DAR and draft environmental and socio-economic management plans. Management plans are guidance documents that outline the Government of the Northwest Territories' (GNWT) commitments to mitigate and monitor effects of the Project on the biophysical and socio-economic environment within regulatory requirements, resource management objectives, and the GNWT's responsibilities as a land and resource manager. The GNWT has committed to developing management plans for the Project. The following draft management plans have been developed to support the environmental assessment. They are included in Volume 5:

- Emergency Response Plan (framework only)
- Draft Erosion and Sedimentation Control Plan
- Draft Fish and Fish Habitat Protection Plan
- Draft Heritage and Sites Protection Plan
- Draft Permafrost Protection Plan
- Quarry Development Plan (framework only)
- Draft Spill Contingency Plan
- Draft Waste Management Plan (including Incinerator Management Plan)
- Draft Wildlife Management and Monitoring Plan (Tier 2)

Additional project-specific management plans will be developed prior to construction, including the following:

- Traffic Management Plan
- Explosives Management Plan
- Safety and Security Plan for Vulnerable Community Members
- Road Safety Plan

- Contractor Training and Employment Plan
- Social Monitoring Plan
- Well-Being Adaptive Management Plan

Management Plans will be developed/updated following the completion of the environmental assessment, and will reflect ongoing input from Indigenous Governments, Indigenous Organizations, and other affected parties as appropriate. Final monitoring plans, as integrated into the respective management plans, will be submitted per regulatory authorities' requirements, considering the outcomes of the EA and updated project information.

The purpose of this chapter is to outline how the GNWT will implement, manage, and report on environmental compliance and effects monitoring undertaken for the Project. Compliance monitoring includes observing, measuring and, if applicable, analyzing parameters to confirm that GNWT's commitments and regulatory requirements are being met. Effects monitoring includes recording observations and taking measurements that can be used to evaluate how environmental conditions may be changing due to the Project.

23.1 Applicable Guidance and Precedents

The environmental compliance and effects monitoring programs are informed by:

- Applicable legislation, regulations, and guidelines
- Compliance and effects monitoring undertaken or underway for other public road/highway projects in the Northwest Territories (NWT), such as:
  - Tłı̨chǫ Highway
  - Canyon Creek All Season Access Road
  - Prohibition Creek Access Road
  - Inuvik to Tuktoyaktuk Highway
- Best practices and professional judgement
- Recommendations of resource managers in NWT

Specific to the areas where the Sahtu Land Use Plan (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 project-specific monitoring. The Sahtu Land and Water Board (SLWB) and/or Mackenzie Valley Land and Water Board (MVLWB) must ensure that: *"Any land use activity requiring a land use permit or water license must include site-specific monitoring, that is sufficient to monitor the effectiveness of the activity's proposed mitigation measures and any impacts to the values in the surrounding area, as defined in the Plan's Background Report, zone descriptions and in discussions with communities."* (SLUPB, 2023). The GNWT's compliance and effects monitoring programs for the Project are anticipated to meet the SLUP conformity requirement related to project-specific monitoring.

23.2 Adaptive Management

The results of compliance and effects monitoring programs should be used in an adaptive management process. Adaptive management is a planned process for responding to uncertainty or to unanticipated or underestimated project effects by changing policies or practices. It follows the steps of:

1. Evaluating monitoring results
2. Comparing results against benchmarks, goals, or predictions
3. Designing and implementing changes to mitigation or management practices, if required
4. Continuing with monitoring

Where a variance between the actual and predicted effects occurs, a determination is made as to whether modifications or other actions are necessary to revise the existing mitigation measures. Reporting and information sharing occurs with regulatory agencies, resource managers, Indigenous Governments, Indigenous Organizations, and other affected parties, which may contribute to modified policies or practices.

Adaptive management is most appropriate when there is uncertainty in predictions about the changes that may occur due to the Project. These uncertainties may arise from:

- Incomplete understanding of existing (baseline) conditions
- Uncertainty of project-related interactions with VCs (how the Project could change VCs)
- Untested or uncertain effectiveness of mitigation measures
- Changing environmental or socio-economic conditions

Adaptive management may also be used when new technologies or new knowledge or information becomes available that can be applied to reducing project-related effects.

23.2.1 Adaptive Management Framework

An adaptive management framework, consisting of a system of thresholds, action levels, and/or management actions, will be implemented for the Project. The framework will provide a formalized approach to monitoring.

Thresholds are pre-determined acceptable limits to changes to the environment. Changes to the environment are detected through monitoring programs, which monitor specific measurable indicators (e.g., turbidity at water crossings) against a threshold. Thresholds are specific to individual monitoring measures and are site-specific (Wek'èezhìı Land and Water Board [WLWB], 2010).

Action levels will be used to identify the appropriate management action commensurate with the magnitude of an environmental change, to avoid reaching a threshold. Monitoring will track the changes for each mitigation measure or indicator and when certain action levels are reached, specific management actions will be implemented. Action levels will be categorized based on levels of environmental change (i.e., low to high) upon which certain actions will then be applied. Action levels are specific to certain monitoring measures and may be site-specific. An exceedance of an action level may necessitate a Response Plan, whereby monitoring activities would be documented, the setting of moderate and high action levels described, and potential mitigative measures identified (WLWB, 2010).

Examples of types of management actions include: notifying appropriate regulatory agencies, Indigenous Governments, Indigenous Organizations, and other affected parties; conducting further investigation of the environmental change; modifying mitigation measures; or, re-evaluating the baseline conditions. For example, if there is measured permafrost degradation and persistent ponding in a specific area, a management action could include changing snow clearing methods.

23.3 Communication Sharing and Reporting

The GNWT is committed to open and transparent engagement throughout the Project's life in accordance with the Engagement Plan (Appendix 2A). The GNWT will also establish a Mackenzie Valley Corridor Working Group (MVHCWG) one year prior to construction, which will provide a forum for information exchange. The MVHCWG will consist of representatives of GNWT departments, Indigenous Governments, Indigenous Organizations, other affected parties, federal government departments, and the contractor. Through the MVHCWG, the GNWT will report at least annually on the Project and review results of management and monitoring plans. The forum will provide advice to GNWT on monitoring and mitigation measures as part of adaptive management.

The objectives of the MVHCWG will be to:

- Review and provide comments to the GNWT on the design of project-specific monitoring programs
- Review project-specific annual and other monitoring reports and provide comments to the GNWT for the following year's project-specific monitoring and mitigation program
- Provide advice to the GNWT on project monitoring and mitigation results that may contribute to adaptive management and/or regional cumulative effects monitoring programs

A communication mechanism will be established to distribute information and accept inquiries from Indigenous Governments, Indigenous Organizations, and other affected parties throughout the life of the Project.

23.3.1 Community and Public Engagement

Project Engagement occurred with Indigenous Governments, Indigenous Organizations, and other affected parties with interests related to areas affected by the Project. Engagement and communication activities will continue throughout all phases of the Project. Feedback from Indigenous Governments, Indigenous Organizations, and other affected parties related to follow-up and monitoring programs will be considered as part of the monitoring process for the Project.

The GNWT will work with Indigenous Governments, Indigenous Organizations, and other affected parties, including other GNWT Departments in the design and implementation of monitoring programs and evaluation of follow-up results and subsequent updates to the program. The GNWT will further work with Indigenous Governments, Indigenous Organizations, and other affected parties in monitoring on a go-forward basis, where applicable.

23.4 Local Social and Economic Monitoring

Monitoring related to socio-economic VCs will be initiated at each phase of the Project. These activities will inform a precautionary approach and contribute to the understanding of changing existing conditions of socio-economic VCs, effects predictions, and the effectiveness of mitigation measures. Potential new or emerging unexpected effects of the Project that were not identified in the DAR will also be identified.

Ongoing engagement activities will identify concerns and adverse trends in the conditions of socio-economic VCs, and will be a key component of the Community Readiness Strategy and work of the MVHCWG, which has been identified as a key component of the socio-economic 'Mitigation Strategies and Associated GNWT Commitments' presented in Section 9.16.1.

The MVHCWG will include three Sub-Working Groups which will have responsibility for a series of associated plans relevant to socio-economic VCs:

- Road Safety and Security Sub-Working Group
  - Safety and Security Plan for Vulnerable Community Members
  - Road Safety Plan
- Training and Employment Sub-Working Group
  - Contractor Training and Employment Plan
- Social Monitoring and Adaptive Management Sub-Working Group
  - Social Monitoring Plan
  - Well-Being Adaptive Management Plan

The Social Monitoring Plan provides the basis for the Social Monitoring and Adaptive Management Sub-Working Group and the MVHCWG to monitor socio-economic and well-being indicators and identify changes and trends. It will track the implementation of the activities identified in the Well-Being Adaptive Management Plan, the Contractor Training and Employment Plan, the Road Safety Plan and the Safety and Security Plan for Vulnerable Community Members. It will consider and apply the follow-up and monitoring framework that is described in Section 9.15.

The Well-Being Adaptive Management Plan will be collaboratively developed by subject matter experts and designated representatives of communities. It will identify actions to be implemented at the community level in affected communities to mitigate negative effects. Activities identified as part of the Well-Being Adaptive Management Plan will be informed by and build on existing GNWT policies and programs related to project effects. Implementation of the Adaptive Management Plan is supported by the GNWT and will be focused in the following areas:

- Community Safety
- Community Wellness
- Community Services
- Substance Abuse and Bootlegging

Adaptive management in response to changing social and economic conditions will be employed by the appropriate authority(s) in an effort to mitigate adverse socio-economic trends, while maximizing potential benefits.

Additional details on the Sub-Working Groups and the plans, which will be developed prior to construction, are provided in Section 9.16.

As described in Section 9.15, the approach to monitoring and follow-up related to socio-economic VCs will consider the development and implementation of the Working Group/Sub-Working Groups and their respective plans (procedural aspects), as well as the understanding of potential project-related effects on the socio-economic environment (substantive aspects).

23.5 Environmental Monitoring

Monitoring is the continuation of observation, measurement, or assessment of environmental conditions surrounding the Project, its components, or activities. As noted in Section 23.1, two types of monitoring are typically undertaken for EAs: compliance monitoring for verification of practices or procedures to meet legislated requirements; and effects monitoring to verify the accuracy of predictions and implemented mitigation measures.

Monitoring may consist of:

- Observations
- Continuous or intermittent data collection using remote methods
- In-field sampling or data collection

Monitoring will be carried out on select effects of concern using environmental indicators and measurable parameters identified in the EA. Components to be monitored will be primarily determined based on regulatory requirements, environmental importance, vulnerability, sensitivity to disturbance, and practicability (for example, relative to action levels). Monitoring plans, where applicable, will describe sampling procedures, quality control and assurance programs, laboratory methods and protocols, laboratory accreditations, and reporting requirements. Results from monitoring will be used through an adaptive management process to adjust mitigation measures and to modify plans on an ongoing basis, if required.

Reports from monitoring programs will be submitted to regulatory authorities as required, and shared with interested Indigenous Governments, Indigenous Organizations, and other affected parties.

The sections that follow describe the preliminary compliance and effects monitoring proposed for the Project. Details of monitoring programs will be developed following the EA and prior to construction, as many of these monitoring programs require approval by regulatory agencies.

23.5.1 Indigenous Participation in Monitoring

Recognizing the important role of Indigenous Governments, Indigenous Organizations, and other affected parties, such as renewable resources councils, the GNWT commits to:

- Incorporating engagement input into the monitoring plans, where appropriate and applicable
- Discussing how best to integrate community-based monitoring into the Project
- Discussing with the Guardian Program to explore how to best implement it for project monitoring
- Employing Environmental Monitors as part of the contracting of the Project

23.5.2 Air Quality Monitoring

Objectives of air quality monitoring may include:

- Verifying and reporting on criteria air contaminant (CAC) emissions
- Verifying compliance with incinerator emissions guidelines (Canadian Council of Ministers of the Environment [CCME], 2000, 2001)

Details of monitoring will be developed prior to construction. If an unexpected deterioration of the environment is observed as a result of monitoring, intervention mechanisms will be addressed by 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 changes in the highway with climate-related parameters.

Monitoring may be initiated on a case-by-case basis should any complaints related to air quality occur from communities because of project activities.

23.5.3 Noise Monitoring

No specific noise monitoring is proposed. 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.

23.5.4 Terrain, Soils, and Permafrost Monitoring

Objectives of permafrost monitoring may include:

- Verifying compliance with terms and conditions of authorizations
- Verifying embankment integrity and performance
- Identifying areas where snow accumulation may be contributing permafrost degradation
- Verifying effectiveness of permafrost protection measures
- Identifying areas of terrain instability in the Project Development Area (PDA)
- Evaluating 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 Erosion and Sedimentation Control Plan (ESCP) and Permafrost Protection Plan (PPP; see Volume 5) will describe sampling, observation and measurement schedule, locations and procedures, quality control, and reporting requirements, where applicable.

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

- 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 practical, 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 a project-specific compliance and effects monitoring plan.

23.5.5 Water Quantity Monitoring

The objectives of water quantity monitoring may include:

- Verifying compliance with terms and conditions of authorizations and commitments
- Verifying effectiveness of mitigation measures
- Verifying effect predictions

Streamflow and lake level monitoring will be undertaken to confirm the Project meets Fisheries and Oceans Canada (DFO) criteria for under-ice withdrawals and other withdrawal-related conditions as may be specified in water licences. This includes confirming the low (< 10%) effect of water withdrawals on stream flows and lake volumes and will require that existing winter under-ice volume are determined for lakes proposed as water sources. This will complement daily monitoring of water volumes withdrawn from each source.

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 and will become part of the project-specific compliance and effects monitoring plan.

The monitoring programs will 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).

A Quarry Development Plan (QDP) will be developed for each borrow source and quarry. This may include the need to assess and mitigate potential residual effects of excavation on groundwater quantity 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.

23.5.6 Water and Sediment Quality Monitoring

The objectives of water and sediment quality monitoring may include:

- Verifying compliance with terms and conditions of authorizations and commitments
- Verifying the effectiveness of mitigation measures to protect water quality, including drinking water sources
- Verifying effect predictions

Surface water quality and, if needed, sediment quality data will be collected as part of construction and compliance monitoring programs. Monitoring sites will include nearfield locations downstream of watercourse crossings, and in water bodies adjacent to borrow sources and quarries. Due to a lack of baseline water and sediment quality monitoring in specific watercourses affected by the Project, suitable upstream reference sites will be sampled to help characterize reference conditions (including the seasonal variability of water quality parameters), where needed to identify potential project-related effects in accordance with the ESCP. At watercourse crossing installation locations in watercourses that are potentially fish-bearing, in-situ physical parameters (e.g., turbidity, pH, dissolved oxygen, and temperature) in surface water will be monitored during construction at upstream and downstream sites when water is present. 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., total suspended solids, total and dissolved metals, nutrients) relevant to specific water uses and guidelines will be monitored in water and sediment. Monitoring of water quality at stream crossing installations is described in the ESCP.

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 for specific sites within the local assessment area (LAA) 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 LAA. Project drinking water quality monitoring will not be required if potable water is to be supplied from municipal sources, as proposed.

To confirm the suitability of quarries for use, additional samples of potential quarry material and other material to be disturbed (such as road cuts) will be collected and analyzed for acid rock drainage (ARD) and metal leaching (ML) potential during the selection and characterization of potential material sources and evaluation of road cuts. As only material with low acid rock drainage (ARD) and metal leaching (ML) potential will be used for the Project, no ARD/ML monitoring is proposed. The need for such monitoring at road cuts will be determined based on the results of additional ARD/ML potential testing once the location of road cuts has been determined through additional design and geotechnical investigations.

A QDP will be developed for each borrow source and quarry. This may include the need to assess and mitigate potential residual effects of excavation on groundwater quality 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 quality or other VCs.

Additional monitoring requirements, if identified as part of the Project's approval and permitting, will be incorporated into a project-specific compliance and effects monitoring plan.

23.5.7 Vegetation and Wetlands Monitoring

The objectives of vegetation and wetlands monitoring may include:

- Verifying compliance with terms and conditions of authorizations and commitments
- Verifying that mitigation measures are effective
- Verifying effects predictions

Targeted vegetation and wetland surveys, including species of conservation concern (SOCC) and plant species of interest to Indigenous Governments, 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. 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 minimum of one inspection per year will occur during construction and one in the year following construction and five years into Project operations. Additional monitoring requirements, if identified as part of the Project's approval and permitting, will be incorporated into a project-specific compliance and effects monitoring plan.

23.5.8 Fish and Fish Habitat Monitoring

Fish and fish habitat monitoring is included within the Fish and Fish Habitat Protection Plan (FFHPP). The objectives of fish and fish habitat monitoring may include:

- Verifying compliance with terms and conditions of authorizations and commitments
- Verifying effectiveness of mitigation measures
- Verifying effects predictions

A draft FFHPP is included in Volume 5. Monitoring of fish and fish habitat will integrate 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 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.

Monitoring of fish harvest in the LAA may be needed to address uncertainties regarding the potential effects of increased access on the sustainability of large-bodied fish populations. The need for such a program will be evaluated in discussion with resource management agencies. Regulation and monitoring of fish harvest falls under the jurisdiction of the GNWT, DFO and co-management boards such as the Sahtu Renewable Resources Board (SRRB). Additional monitoring requirements, if identified as part of the Project's approval and permitting, will be incorporated into the project-specific FFHPP.

23.5.9 Wildlife and Wildlife Habitat Monitoring including Caribou, Moose and Birds

A Tier 2 Wildlife Management and Monitoring Plan (WMMP) is required to be submitted for approval by the Minister of Environment and Climate Change. The WMMP was developed to support the construction, and operations and maintenance of the Project by the GNWT.

The objectives of the WMMP are to:

- Describe the mitigation measures that will be implemented to avoid and/or reduce potential Project effects on wildlife and wildlife habitat
- Describe the monitoring programs that will be implemented to quantify and evaluate the effectiveness of mitigation measures and to confirm the assessment predictions
- Describe the adaptive management approach and action levels that will be used to adjust mitigation measures where necessary to meet management goals

A draft Wildlife Monitoring and Management Plan (WMMP) is included in Volume 5. The responsibility for wildlife management, including harvest management, will continue to be shared between departments of the GNWT and federal government, and co-management boards such as the SRRB.

23.6 Effects Monitoring Table

Table 23.1 provides a summary of the effects monitoring proposed for each VC, and includes the effect of concern, general monitoring parameters, and the basis for the program. Additional pre-construction surveys needed to establish or supplement existing conditions are not included. These are identified in the respective chapters.

Table 23.1 Environmental Assessment Follow-up and Monitoring Program Elements

Targeted Valued Component	Applicable Regulatory or Non-regulatory Monitoring Requirement	Effects Basis	Overview of Proposed Effects Monitoring Programs	Associated Plans
Air quality	Environment and Climate Change Canada (ECCC) National Pollutant Release Inventory (NPRI) reporting thresholds NWT average facility CAC emissions ECCC Greenhouse Gas (GHG) Reporting Program NWT GHG emissions National Inventory Report	Change to CACs Change to GHGs	Emissions tracking, calculation, reporting	N/A
Noise	Health Canada Noise Guidance Alberta Transportation – Noise Attenuation Guidelines for Provincial Highways	Change in noise level	Initiated on case-by-case basis if noise complaints are raised by a community	N/A

Targeted Valued Component	Applicable Regulatory or Non-regulatory Monitoring Requirement	Effects Basis	Overview of Proposed Effects Monitoring Programs	Associated Plans
Terrain, soils, and permafrost	GNWT Land Use Guidelines for Camp and Support Facilities GNWT Land Use Guidelines Pits and Quarries GNWT Land Use Guidelines Access: Roads and Trails Guidelines for Development and Management of Transportation Infrastructure in Permafrost Regions National Guide to Erosion and Sediment Control on Roadway Projects GNWT Erosion and Sediment Control Manual Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health GNWT Quarry Development Plan Template	Change in terrain conditions Change in soils conditions Change in permafrost conditions	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 practical, monitoring of the thermal regimes to assess if the embankment performs as designed	ESCP PPP

Targeted Valued Component	Applicable Regulatory or Non-regulatory Monitoring Requirement	Effects Basis	Overview of Proposed Effects Monitoring Programs	Associated Plans
Water and sediment quality	*Waters Act* and Waters Regulations Federal *Fisheries Act* Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the protection of Freshwater Aquatic Life Canadian Sediment Quality Guidelines for the Protection of Aquatic Life ECCC Federal Environmental Quality Guidelines for the protection of aquatic life in freshwater and sediment Health Canada's Drinking Water Quality Guidelines Health Canada's Recreational Water Quality Guidelines	Change in surface water and/or sediment quality Change in groundwater quality	Monitoring at watercourse crossing installations and in waterbodies adjacent to borrow sources and quarries In-situ physical parameters (turbidity, pH, dissolved oxygen, temperature) monitored in surface water at upstream and downstream sites Additional parameters (total and dissolved metals, nutrients) relevant to specific water uses and guidelines monitored for water and sediment at locations identified for drinking water and fish harvesting Ongoing engagement with affected parties to inform the design of future monitoring programs to account for specific water uses and water-use locations	ESCP QDPs Water licence
Water quantity	*Waters Act* and Waters Regulations DFO Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut	Change in stream flows Change in lake volumes Change in groundwater level	Streamflow monitoring during withdrawal Water withdrawal volumes from lakes and streams Water withdrawal volumes from quarry/borrow sources	QDPs Water Licence

Targeted Valued Component	Applicable Regulatory or Non-regulatory Monitoring Requirement	Effects Basis	Overview of Proposed Effects Monitoring Programs	Associated Plans
Vegetation and wetlands	Federal *Species at Risk Act* Federal Policy on Wetland Conservation NWT *Forest Act* NWT *Species at Risk Act*	Change in landscape diversity Change in community diversity Change in species diversity Change in wetland functions	Observations of changes in drainage patterns Observations of changes in vegetation community, including invasive alien species	N/A
Fish and fish habitat	Federal *Fisheries Act*	Change in fish habitat Change in fish health Change in water quality Change in water quantity	Monitoring of construction practices, mitigation measures employed, and the functionality of those mitigation measures. Turbidity monitoring during instream works. 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. Monitoring of harvest pressure	ESCP FFHPP Water Licence
Wildlife and wildlife habitat	Federal *Species at Risk Act* NWT *Species at Risk Act* NWT *Wildlife Act*	Change in habitat Change in movement Change in mortality risk Change in wildlife health	Non-Indigenous harvest monitoring Monitoring of harvest pressure Collision monitoring	WMMP
Birds and bird habitat	Federal *Species at Risk Act*	Change in habitat Change in mortality risk Change in bird health	Non-Indigenous harvest monitoring	WMMP

Targeted Valued Component	Applicable Regulatory or Non-regulatory Monitoring Requirement	Effects Basis	Overview of Proposed Effects Monitoring Programs	Associated Plans
Caribou and moose	Federal *Species at Risk Act* NWT *Species at Risk Act* NWT *Wildlife Act*	Change in habitat Change in movement Change in mortality risk Change in health	Wildlife sightings, surveillance and reporting will be implemented to support the review of the effectiveness of wildlife protection measures Survey programs, currently completed by the GNWT – Environment and Climate Change (ECC), will continue to collect ongoing information on distribution, abundance, and population trends of moose The boreal caribou collar program, currently completed by the GNWT-ECC, will continue to collect ongoing information on distribution, movements, and mortality. Barren-ground caribou surveys, currently completed by the GNWT-ECC and other organizations, will continue to monitor the distribution, abundance, and population trends of the Bluenose-East herd, subject to periodic assessments and adjustments.	WMMP

Targeted Valued Component	Applicable Regulatory or Non-regulatory Monitoring Requirement	Effects Basis	Overview of Proposed Effects Monitoring Programs	Associated Plans
Caribou and moose (cont'd)			The database for wildlife-vehicle collisions, implemented und maintained by the GNWT-ECC, will be extended to include the Mackenzie Valley Winter Road (MVWR) right-of-way (ROW) and completed sections of the highway during and after construction. Collision locations will be added to the information to determine the necessity of appropriate signage to alert drivers of crossing locations The ongoing collection of annual large game harvest success for all non-Indigenous hunters will be continued to determine if caribou and moose are harvested in proximity of the Project. Indigenous harvest will continue to be monitored by co-management organizations and harvest levels managed in cooperation with the GNWT. Wildlife health will continue to be monitored through local initiatives and collection of specimens from hunters	

Targeted Valued Component	Applicable Regulatory or Non-regulatory Monitoring Requirement	Effects Basis	Overview of Proposed Effects Monitoring Programs	Associated Plans
Non-traditional land and resource use	None currently applicable	Change in non-traditional land use Change in access to non-traditional land use Change in aesthetics Change in non-traditional resource use	Non-Indigenous harvest monitoring Socio-Economic Mitigation Strategy consisting of: Social Monitoring Plan (SMP) Contractor Training and Employment Plan (CTEP)	SMP CTEP WMMP
Culture and traditional land use	None currently applicable	Change in availability of resources for cultural and traditional land use Change in access to resources or areas for cultural and traditional land use Change in sites or areas for cultural and traditional land use	None currently proposed; may be further discussed with Indigenous Governments, Indigenous Organizations, and other affected parties	N/A
Heritage resources	Northwest Territories Archaeological Sites Regulations pursuant to the *Archaeological Sites Act*	Loss of site contents and contexts	Unless required by territorial regulators, there are no commitments for follow-up or monitoring other than implementation of a Heritage and Sites Protection Plan (HSPP)	HSPP

Targeted Valued Component	Applicable Regulatory or Non-regulatory Monitoring Requirement	Effects Basis	Overview of Proposed Effects Monitoring Programs	Associated Plans
Employment and economy	None currently applicable	Change in employment and income Change in gross domestic product (GDP) and government revenues Change in economic opportunities and capacity of local businesses Change in cost of living and consumer prices Change in traditional economy Change in the GNWT operations employment	Socio-Economic Mitigation Strategy consisting of: • SMP • CTEP	SMP CTEP
Infrastructure and services	None currently applicable	Change in housing and accommodation Change in social infrastructure and services Change in public infrastructure and services Change in institutional facilities and services Change in the GNWT operations	Socio-Economic Mitigation Strategy consisting of: • SMP • CTEP • Road Safety Plan (RSP) • Safety and Security Plan for Vulnerable Community Members (SSP)Well-Being Adaptive Management Plan (WBAMP)	SMP CTEP RSP SSP WMP WBAMP

Targeted Valued Component	Applicable Regulatory or Non-regulatory Monitoring Requirement	Effects Basis	Overview of Proposed Effects Monitoring Programs	Associated Plans
Education, training, and skills	No specific territorial education and training legislation and policies	Change in level of education, certification/training, and skills development Change in access to education, certification/training programs Change in capacity to meet demand for education, certification and training programs	Socio-Economic Mitigation Strategy consisting of: • SMP • CTEP • WBAMP	SMP CTEP WBAMP
Human health and community wellness	No regionally specific human health and community wellness legislation or policies	Change in population composition and migration (in/out of communities) Change in population health Change in community/family and social ties Change in food security Change in social pressures Change in nuisance (air quality and noise) Change in drinking and recreational water Change in public safety Change in social determinants of health through changes to youth, young women, Elders, and other vulnerable groups	Socio-Economic Mitigation Strategy consisting of: • SMP • CTEP • RSP • SSP • WBAMP	SMP CTEP RSP SSP WBAMP

23.7 References

CCME (Canadian Council of Ministers of the Environment). 2000. Canada-Wide Standards for Mercury.

CCME. 2001. Canada-Wide Standards for Dioxins and Furans.

SLUPB (Sahtú Land Use Planning Board). 2023. Sahtú Land Use Plan. Government of Northwest Territories. Fort Good Hope. Ratified but not available as of July 19, 2023; see https://sahtulanduseplan.org/plan.

WLWB (Wek'èezhìı Land and Water Board). 2010. Guidelines for adaptive management – A response framework for aquatic effects monitoring (draft). 55 pp.

24.0 ASSESSMENT OF POTENTIAL EFFECTS OF THE ENVIRONMENT ON THE PROJECT

This chapter describes how environmental conditions may affect the Mackenzie Valley Highway Project (the Project). This chapter does not describe how the Project may affect valued components (VCs) and, consequently, does not follow the same assessment approach as most other chapters. Based on the Terms of Reference (ToR; Mackenzie Valley Environmental Impact Review Board [MVEIRB], 2015 [Public Registry {PR}#66]), this chapter focuses on long-term climate changes and associated local changes, such as permafrost degradation and potential associated effects on the project infrastructure.

The environment, and long-term changes in the environment, particularly climate change, may have effects on the Project. These effects include:

- Possible delays and increased costs during construction, including:
  - Delays in receipt of materials and supplies (e.g., construction materials) and in delivering products
  - Changes to the ability of workers to access the site (e.g., if a road were to wash out)
  - Increased structural loading
  - Delays to project schedule
  - Damage to infrastructure
- Increased maintenance needs and associated costs during operations
- Potentially decreased useability of the highway for traffic

These effects are likely to occur but are not likely to threaten the safe construction and operation of the highway. The primary risk results from potential permafrost degradation and resulting erosion, including slumping, sliding, or subsidence. Chapter 14 (terrain, soils, and permafrost) provides more detail on the mechanisms of permafrost degradation and the mitigation measures that will avoid or reduce effects.

24.1 Scope of Assessment

The scope of this assessment is based on Section 8.0 of the ToR, which requires the Government of the Northwest Territories (GNWT) to consider the effects of the environment on the Project (MVEIRB, 2015). This includes a description of how the Project is engineered and designed to integrate into its environmental surroundings and consideration of how physical and biological changes in the environment could have implications for the highway and associated infrastructure during the construction and operations and maintenance phases.

24.1.1 Regulatory and Policy Setting

The GNWT is seeking federal funding under the Investing in Canada Infrastructure Program. A Climate Resilience Assessment (CRA; Appendix 24A, K'alo-Stantec, 2022a; also see Appendix 12A, Air Quality, Greenhouse Gas Emissions and Climate Baseline Technical Data Report [TDR], K'alo-Stantec, 2022b) has been prepared in accordance with Infrastructure Canada requirements and with Infrastructure Canada's Climate Lens General Guidance V.1.2 (Infrastructure Canada, 2019). The assessment covers the infrastructure and systems of the Project. Approaches consistent with International Organization for Standardization 31000:2018 standard Risk Management—Principles and Guidelines were applied. This chapter applies the information provided in the CRA (Appendix 24A, K'alo-Stantec, 2022a) to describe the potential effects of the environment on the Project.

The Project is consistent with and contributes to the GNWT's goals in the 2030 NWT Climate Change Strategic Framework ("Framework"; GNWT, n.d-a) and 2019-2023 Action Plan (GNWT, n.d-b). The Project will contribute to Goal #3 of the Framework by building resilience in the NWT transportation network to adapt to a changing climate.

24.1.2 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 potential effects of the environment on the Project. This feedback has been considered and summarized in Table 24.1 and has been integrated into the assessment of potential effects of the environment on the Project that follows.

Table 24.1 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
Community engagement participants reported that the environment is changing – there is more sloughing, and the permafrost is not the same anymore.	August 2021 Engagement	The GNWT has identified mitigation measures to reduce or eliminate the effects of the environment on the Project, such as: • Project design will avoid ice-rich areas where possible. • 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. • Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns. 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 discussing with Indigenous Governments, Indigenous Organizations and other affected parties how best to integrate community-based monitoring into the Project.	For mitigation measures to reduce or eliminate effects of the environment on the Project, see Section 24.5 (Design Engineering Mitigation Measures). See also: Chapter 5 (Project Description)
Climate change is a concern for community engagement participants. There are concerns with flooding spots. Participant highly recommended looking at lessons learned from other projects in consideration of environmental effects and climate change to stabilize or mitigate erosion and sedimentation washouts.	April to July 2022 Engagement		
Community engagement participants inquired whether there will be enough money to repair the highway because of erosion and climate change.	November to December 2022 Engagement		
Tulita Renewable Resources Council (TRRC) reported that TK-based monitoring will be important and is needed to update the community of Tulita (Tulít'a), hereafter referred to as Tulita, of events and change happening at Four Mile Creek, including effects of smoke and climate change.	TRRC, 2022		

24.1.3 Boundaries

This section describes the geographic area and the timeframe for which effects of the environment on the Project were considered.

24.1.3.1 Spatial Boundaries

While the environmental changes that are likely to affect the Project may cover a much larger area than the Project, the focus of this chapter is on the effects of the environment on the Project itself. The spatial boundary for assessing effects is the Project Development Area (PDA), which is 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. There is no local or regional assessment area associated with the effects of the environment on the Project.

24.1.3.2 Temporal Boundaries

The effects of climate change on the Project are assessed until the 2080s. The highway, as permanent infrastructure, will require rehabilitation from time to time. The temporal boundary for assessing effects on the Project follows the climate change predictions in the CRA (Appendix 24A; K'alo-Stantec, 2022a), which is the climate period from 2071 to 2100. This represents two cycles of the Project's design life.

Within the overall temporal boundary, this assessment distinguishes between the construction phase and the operations and maintenance phase. As described in Section 5.4.1, the Project will 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 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 (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.

The operations and maintenance phase of the Project will commence as construction of each segment has been completed. The operations and maintenance phase is considered indeterminate in duration because the operation of the Project is expected to continue indefinitely. The climate planning horizon is appropriate as it aligns with climate resilience best practice.

24.2 Existing Conditions and Predicted Change

The existing conditions are the environmental conditions prior to the start of construction. These conditions are described for various environmental components throughout this document in relevant chapters and the TDRs. For example, Chapter 14 includes a description of the current conditions for terrain, soils, and permafrost. In accordance with the ToR, the assessment of effects of the environment on the Project included effects caused by changes in the environment, particularly changes in climate and resulting local changes (MVEIRB, 2015). Consequently, this section provides a brief description of anticipated change and details are provided in Appendix 24A (K'alo-Stantec, 2022a).

24.2.1 Overview

Appendix A – Climate Profile to the CRA (Appendix 24A; K'alo-Stantec, 2022a) provides a detailed description of the methods and results of characterizing the existing climate and predicting changes along the proposed highway alignment. The following section provides a brief summary of the existing climate conditions. Two climate zones have been defined for the analysis. These zones correspond with ecological regions in the area, and generally align with different climate and weather patterns. The two climate zones are:

- Norman Wells – Tulita climate zone
- Fort Simpson – Wrigley climate zone

24.2.2 Recording Station Locations

Table 24.2 identifies the available observation stations with long-term records as representative of each climate zone for the purpose of the analysis. For the Norman Wells - Tulita zone, the 'Norman Wells A' station was chosen because of its long record, completeness of dataset, and location in respect to the proposed highway alignment. The Tulita station, despite its long record, has a less complete dataset. For the Wrigley - Fort Simpson zone, the 'Fort Simpson A' station was selected, despite its distance from the proposed highway alignment, because the closer 'Wrigley A' station dataset has a considerable number of days of data missing. A comparison of available data showed that Fort Simpson is generally representative of the zone.

Table 24.2 Recording Station Locations

Climate Zone	Observation Station (ID)	Latitude	Longitude	Record Range (years)
Norman Wells – Tulita	Norman Wells A (ID: 2202800)	65.2813 N	-126.7986 W	1943-2020 (78)
	Tulita A (ID: 2201700)	64.9097 N	-125.5694 W	1903-2020 (118)
Wrigley – Fort Simpson	Wrigley A (ID: 2204000)	63.2094 N	-123.4366 W	1943-2020 (78)
	Fort Simpson A (ID: 2202104)	61.7602 N	-121.2366 W	1895-2020 (126)

24.2.3 Climate Normals

Table 24.3 presents annual averages for the two observation stations from 1981 to 2010 and shows the variation between the two climate zones for temperature and precipitation. This time frame represents the climate baseline for comparison to climate predictions for the 2020s (2010 to 2039), the 2050s (2040 to 2069), and the 2080s (2070 to 2099). Table 24.4 and Table 24.5 present seasonal variations for Norman Wells and Fort Simpson, respectively. Mean, maximum, minimum, and accumulation values are for the respective season averaged over the station's reporting period. A detailed breakdown of seasonal variations for the same parameters, along with predictions of change, is provided in Appendix 24A (K'alo-Stantec, 2022a). Both climate zones are characterized by long cold winters and short cool summers, with the Norman Wells - Tulita zone being overall colder and drier. Both show similar variations.

Table 24.3 Annual Means

Climate Parameter	Norman Wells A (ID: 2202800/1) 1981-2010	Fort Simpson A (ID: 2202104) 1981-2010
Annual Mean Temperature (°C)	-5.1	-2.9
Annual Maximum Temperature (°C)	-0.4	2.7
Annual Minimum Temperature (°C)	-9.9	-8.2
Annual Total Precipitation (mm)	294.4	387.6
# of Days/Year with Tmax >30°C	2.1	4.2
# of Days/Year with Tmin <-30°C	51.0	37.5

Table 24.4 Seasonal Variation Norman Wells

Season	Mean Temperature (°C)[5]	Maximum Temperature (°C)[5]	Minimum Temperature (°C)[5]	Precipitation Accumulation (mm)[5]
Winter[1]	-24.5	-20.4	-28.5	48.7
Spring[2]	-5.7	0.2	-11.6	40.8
Summer[3]	15.3	20.7	9.7	126.3
Fall[4]	-5.6	-1.9	-9.3	78.5

Notes:

1 December, January, February

2 March, April, May

3 June, July, August

4 September, October, November

5 Mean, maximum, minimum, and accumulation values are for the respective season averaged over the station's reporting period (1981-2010)

Table 24.5 Seasonal Variation Fort Simpson

Season	Mean Temperature (°C)[5]	Maximum Temperature (°C)[5]	Minimum Temperature (°C)[5]	Precipitation Accumulation (mm)[5]
Winter[1]	-22.2	-17.5	-26.8	55.6
Spring[2]	-1.6	4.8	-8.1	61.8
Summer[3]	15.8	22.1	9.5	173.8
Fall[4]	-3.1	1.3	-7.6	96.4

Notes:

[1] December, January, February

[2] March, April, May

[3] June, July, August

[4] September, October, November

[5] Mean, maximum, minimum, and accumulation values are for the respective season averaged over the station's reporting period (1981-2010)

Table 24.6 and Table 24.7 present wind speed and direction for Norman Wells and Fort Simpson, respectively. Appendix A to the CRA (Appendix 24A; K'alo-Stantec, 2022a) contains additional information. Both show variable winds with the direction of maximum winds not necessarily correlating with the prevalent wind direction. At both stations, especially at Norman Wells, the maximum measured windspeeds occurred decades ago. Neither station shows a notable number of high wind (≥ 52 kilometres per hour [km/h]) days. While high wind speeds are uncommon, potentially damaging gusts of over 100 km/h have been recorded (see Table 24.6).

Table 24.6 Norman Wells Wind Speed and Direction

Month	Average Speed (km/h)	Most Frequent Direction[1]	Max. Hourly			Max. Gust			Days with Wind ≥52 km/h
			Speed (km/h)	Year	Direction[1]	Speed (km/h)	Year	Direction[1]	
Jan	8.3	SE	80	1962	W	113	1962	W	0.6
Feb	8.9	SE	74	1986	NW	106	1986	NW	0.5
Mar	10.3	W	66	1971	SE	114	1965	NW	0.3
Apr	11	SE	68	1965	W	97	1965	W	0.2
May	11.9	SE	59	1980	NW	85	1979	SE	0.1
Jun	11.7	SE	65	1979	NW	83	1979	NW	0.2
Jul	11	SE	61	1959	NW	100	1967	W	0.2
Aug	10.5	SE	80	1962	W	117	1962	W	0.2
Sep	10.7	SE	70	1988	NW	94	1988	NW	0.1
Oct	10.4	NW	63	1978	NW	93	1990	E	0.2
Nov	8.4	NW	67	1977	NW	101	1962	E	0.3
Dec	8.3	SE	72	1963	E	105	1963	E	0.5
Year	10.1	SE	80	1962	W	117	1962	W	3.3

Note:

[1] cardinal directions (N = north, E = east, S = south, W = west) and ordinal directions (NW = northwest, NE = northeast, SW = southwest, SE = southeast), wind blowing from.

Table 24.7 Fort Simpson Wind Speed and Direction

Month	Average Speed (km/h)	Most Frequent Direction	Max. Hourly			Max. Gust			Days with Wind ≥52 km/h
			Speed (km/h)	Year	Direction[1]	Speed (km/h)	Year	Direction	
Jan	7.2	NW	46	2003	NW	80	1985	SW	0
Feb	8.4	NW	59	1988	NW	89	1988	NW	0.1
Mar	9.8	NW	50	1995	N	79	1967	N	0
Apr	10.1	SE	56	1986	SW	83	1984	SW	0.2
May	10.1	SE	59	1983	N	91	1983	N	0.2
Jun	9.1	SE	46	2002	NW	72	1964	N	0.2
Jul	8.2	NW	48	1964	S	89	1970	S	0.1
Aug	8.5	NW	66	1974	SW	146	2004	N	0.1
Sep	8.5	SE	65	1985	NW	87	1964	N	0.1
Oct	8.7	NW	50	1971	N	77	1971	N	0
Nov	7.9	NW	46	1985	N	78	1985	N	0
Dec	6.8	NW	48	1999	NW	80	1999	SW	0
Year	8.6	SE	66	1974	SW	146	2004	N	1.2

Note:

[1] cardinal directions (N = north, E = east, S = south, W = west) and ordinal directions (NW = northwest, NE = northeast, SW = southwest, SE = southeast), wind blowing from.

24.2.4 Climate and Climate Change

The CRA (Appendix 24A; K'alo-Stantec, 2022a) predicts changes from the climate baseline for the periods of:

- 2020s (2010 to 2039)
- 2050s (2040 to 2069)
- 2080s (2070 to 2099)

The Project will take approximately 10 years to construct, over a timeframe of up to 20 years. With construction starting as early as 2026, the majority of it will occur during the 2020s period, with some construction in the early years of the 2050s. The Project's operations and maintenance phase covers the 2050s to the 2080s period and beyond.

The predicted changes are based on the greenhouse gas emissions scenario, Representative Concentration Pathway (RCP) 8.5, as defined by the Intergovernmental Panel on Climate Change. RCP 8.5 is the internationally recognized high emissions "business as usual" scenario, representing future conditions without policy mitigation. Table 24.8 presents the climate parameters that may pose hazards to the Project and their predicted direction and level of confidence of change.

The CRA (Appendix 24A; K'alo-Stantec, 2022a) identified the following climate trends:

- The geographical region where the project area is located has experienced (and is predicted to continue experiencing) increases for annual mean daily temperature, average maximum daily temperature, and average minimum daily temperature. This trend applies to all seasons. By the 2080s, the annual mean daily temperature is predicted to increase by 5.5 degrees Celsius (°C) under the RCP 8.5 scenario for Norman Wells and 6.2°C for Fort Simpson. This represents an increase in the risk of permafrost thaw.
- The number of extreme heat temperature events, (i.e., days with temperatures greater than 30°C) has averaged around 2.1 days/year from 1981 to 2010 at Norman Wells – Tulita and 4.2 days/year from 1981 to 2010 at Wrigley – Fort Simpson. By the 2080s, the number of days over 30°C is predicted to increase to 14.4 days/year (under RCP 8.5), at Norman Wells – Tulita and 24.8 days/year, at Wrigley – Fort Simpson.
- The number of extreme cold temperature days (i.e., days below minus 30°C), is expected to decline from 51 days per year (1981-2010) to 10.7 days/year by 2080 under RCP 8.5 for Norman Wells – Tulita and from 37.5 days per year (1981-2010) to 6.5 days/year at Wrigley – Fort Simpson. The level of confidence in temperature projections is high (see Table 24.8).

In addition, the TDR—Air Quality, Greenhouse Gas Emissions and Climate Baseline for the project reports an anticipated increase in precipitation from 358 millimetres per year (mm/a) for the 2021-2050 period to 419 for the 2071-2100 time period.

Table 24.8 Climate Change Direction

Parameter	Anticipated Change	Level of Confidence
Mean Seasonal Temperatures	Increase	High
High Temperature Extremes	Increase	High
Low Temperature Extremes	Decrease	High
Precipitation Extremes	Increase	Medium-high
Sustained Rainfall	No change	Medium-low
Dry Spells	No change	Medium -low
Daily Frost	Decrease	Medium high
Freeze-Thaw Days	Decrease	Medium-high
Freezing rain	Increase	Medium

Source: Adapted from Table 1 in the CRA (Appendix 24A; K'alo-Stantec, 2022a); confidence levels are based on data availability and scalability of climate models used)

Figure 10 in Appendix A to the CRA (Appendix 24A; K'alo-Stantec, 2022a) shows a trend towards increased snowfall between 1985 and 2019 for both observation stations. The CRA (Appendix 24A, K'alo-Stantec, 2022a) did not include a similar trend analysis for temperature and used the historic dataset to determine the baseline to compare change predictions against. As the Government of Canada's *Canada's Changing Climate Report* (Government of Canada, 2015) points out, "Over the last half century, the Canadian Arctic has experienced considerable increases in both temperature and precipitation, consistent with trends in other circumpolar regions." The project area is subject to the same or similar temperature and precipitation increases. The CRA (Appendix 24A, K'alo-Stantec, 2022a) includes projections of changes in both parameters.

Similarly, wind and fog occurrences were not subjected to a historical analysis. The wind data suggests that at least the maximum wind speeds have not increased in recent years. There is a higher certainty associated with climate projections of temperature and precipitation, but less certainty with projections of windspeed.

24.2.5 Geological Hazards

The general topography of the region is generally rolling with a variable topography, including ridges reaching 1,040 metres above sea level (m asl). Permafrost conditions are highly variable along the proposed highway route, with continuous to extensive and discontinuous conditions with low to medium ice content (see Chapter 14). The greatest geological hazards to the Project are landslides and ground movement triggered by permafrost degradation. Permafrost degradation may in turn be triggered by the Project itself or by climate change. Chapter 14 provides a detailed description of the Project's interaction with terrain, soil, and permafrost. Climate change will exacerbate any project-caused degradation and may cause degradation on its own. Chapter 14 describes mitigation measures to reduce the effects of the Project on permafrost. These mitigation measures will in turn reduce the effects of degrading permafrost on the Project but are unlikely to eliminate them in the face of a changing climate. Permafrost-related effects are addressed in more detail in Section 24.3.

Publicly available information about seismic activity (Natural Resources Canada, 2015) indicates that earthquake activity in the Northwest Territories (NWT) is largely limited to the mountainous areas in the western portion. Compared to other northern roads, for example the Dempster Highway, the Project is likely to be subjected to few and to relatively small earthquakes. Seismic activity is not expected to cause severe damage to the road. No quantitative assessment is available, however.

24.3 Assessment of Effects of the Environment on the Project

Long term changes in the environment have the potential to affect the Project, during construction and operation. The Project will take approximately 10 years to construct, over a timeframe of up to 20 years. Consequently, climate change effects are likely to be more pronounced during operation, since activities associated with operation are expected to continue for a much longer time.
Table 24.9 summarizes the potential effects of changes in the environment on the Project, how they act on the Project, and what design measures have been taken to minimize them. The remainder of this section describes predicted changes in the environment and how they may affect the Project in more detail, distinguishing between construction and operation.

Table 24.9 Summary of Effects and Mitigations

Potential Effect on Project	Effect Pathway	Mitigation Design Measure
Change in project schedule	Increased temperatures and precipitation may result in delays in project construction (e.g., due to temporary shutdowns) as well as in maintenance activities.	N/A
Change in highway integrity	Permafrost degradation and increased precipitation may lead to differential settling of highway sections, pooling of water, road bank erosion, and rutting of road surface	A project-specific PPP will be developed and implemented.
		The area of direct ground disturbance will be limited by following the pre-existing winter road alignment to the extent possible. Removal of vegetation will be limited to the width of the right-of-way and workspaces.
		Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns.
		Where possible, cleared material will be mulched and spread over cleared areas within the Project footprint to protect the soil and permafrost.

Potential Effect on Project	Effect Pathway	Mitigation Design Measure
Change in highway integrity (cont’d)		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.
		Ice-rich soils or materials that are susceptible to physical erosion encountered during excavation will be covered to reduce permafrost degradation.
		Geotextile and embankment placement will be completed in the winter to limit disturbance to soils and permafrost.
		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.
		Construction equipment will travel on designated winter roads or constructed embankment only.
		Off-road travel will be limited to frozen conditions (December 15 to April 1), where possible.
		Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the right-of-way and approved access roads). To promote the stability of cuts and fills on slopes, fill material will be compacted and the tops of cut slopes will be rounded.
Change in maintenance / rehabilitation effort	The effects listed above of permafrost degradation and increased precipitation will lead to increased needs for maintenance and may require earlier rehabilitation of the highway.	Same as above
Change in highway safety and usability	The effects listed above of permafrost degradation and increased precipitation may lead to a rougher road surface and thus higher accident risk and reduced travel speeds. Increases in temperature may increase the frequency and intensity of wildfires, which may lead to more frequent temporary road closures.	Same as above, plus increased frequency of maintenance

Potential Effect on Project	Effect Pathway	Mitigation Design Measure
Change in culvert flow capacity	Changes to permafrost, temperatures, and precipitation may lead to more frequent freezing of culverts and to more frequent flooding events in spring.	The area of direct ground disturbance will be limited by following the pre-existing winter road alignment to the extent possible. Removal of vegetation will be limited to the width of the right-of-way and workspaces.
		Project design will avoid ice-rich areas where possible.
		Drainage culverts will be installed to accommodate storm events and maintain drainage patterns and in consideration of site-specific icing/glaciation effects.
		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.

24.3.1 During Construction Phase

The following environmental events or changes in the environment have the potential to affect construction:

Permafrost degradation: The greatest risk to the Project is related to the potential degradation of permafrost where present, and subsequent slumping, landslides, subsidence, or erosion locally where ice-rich soils are affected. As Chapter 14 Terrain, Soils, and Permafrost indicates, permafrost conditions in the project area are highly variable. Some locations present stable soil, while more ice-rich, thaw-sensitive permafrost are very unstable and sensitive to change. Construction over these highly sensitive soils can lead to settlement and increased maintenance or regular rehabilitation. Most of the adverse effects from permafrost degradation will take years to develop and are more likely to pose a problem during operation than during construction.

Low temperature extremes: Extreme cold weather will slow down construction and, in a worst-case scenario, may temporarily halt some activities for safety reasons or due to equipment limitations, which will increase costs. The GNWT has experience in cold weather road construction and the Project is designed to be constructed under winter conditions. As Table 24.8 shows, low temperature extremes are predicted to be less frequent with a relatively high degree of certainty. Therefore, changing environmental conditions relating to extreme low temperature events are unlikely to have an adverse effect on the Project.

High temperature extremes: Extreme high temperatures may pose a risk to outdoor workers, pose an increased risk of fires, and may lead to certain activities being curtailed. In a worst-case scenario they may result in a temporary halt to some activities for safety reasons or equipment limitations. Construction will occur year-round and extreme temperature (> 30°C) days will still be measured in days rather than weeks. Even under a worst-case scenario, the effects of extreme high temperature events are anticipated to be minor. For more information about response to fires see Chapter 27.

Dry Spells: The length and frequency of dry spells is not expected to increase and is unlikely to result in an adverse effect. The confidence level for this prediction is medium-low and it may only be applicable for the construction phase. As temperatures rise, droughts may increase in duration and/or frequency and may increase risk of fire and decrease availability of water as a result.

Precipitation Extremes (rain): Extreme rainfall events can lead to erosion or washouts of partially constructed road sections, dangerous working conditions, and indirect effects on the environment from erosion and sedimentation. The frequency of extreme storm events is expected to remain relatively stable while the intensity of storms is expected to increase (Appendix 24A; K'alo-Stantec, 2022a). The possible direct effects on the Project are construction delays (e.g., due to temporary shutdowns), a need to increase sediment control measures, and a possible need for repairs or re-work. Erosion and sedimentation control measures will be in place to reduce indirect effects on the environment (see Chapter 14). Increased rainfall may also indirectly affect the Project by facilitating permafrost degradation.

Precipitation Extremes (snow): Extreme snowfall events, or unusually high snow accumulation in general, will affect the Project by requiring more frequent snow clearing and potentially requiring additional space to store snow. Increased snow loads may also result in a higher flood risk in spring. Potential results are construction delays and increased costs. Snowfall was not included in the Climate Lens Assessment because predictions for snowfall are less confident than those for other parameters. The Developer's Commitments (Chapter 27) include snow removal-related mitigation measures. Examples include blading snow away from the shoulders and clearing snow and ice off the road surface during late winter maintenance.

Freeze Thaw Days: The predicted decrease in daily frost has a potential to adversely affect the Project by shortening the winter construction and winter road season for those activities planned to occur in winter, such as watercourse crossing construction and delivery of materials. As the road is expected to be built within 20 years, the effects are likely small and well within the Project's capability to manage its construction schedule. Once the road is constructed, reliance on frost conditions is likely to decrease, as maintenance activities are largely restricted to the road surface and embankments. The predicted decrease in frost thaw events (i.e., temperatures around 0°C) is not likely to influence construction activities.

Wildfire frequency and intensity: Wildfires in the vicinity of the Project pose a risk to worker safety and to the Project's assets (e.g., machinery). They may also draw resources away from construction activities towards firefighting and may result in evacuations and temporary work stoppages. With an increasing likelihood of extreme temperature events comes an increase in the frequency and intensity of wildfires. Fire prevention and fire response procedures will be included in a project-specific Emergency Response Plan (ERP). A framework for this plan is included in Volume 5.

Wildlife interactions and other environmental components: The Project could be delayed if work is required to stop temporarily to allow wildlife to pass. Sensory disturbance associated with human activity (such as noise and dust) make it unlikely that wildlife will enter a work site. One possible exception is habituated bears near camps. Chapters 10 and 19 describe measures for managing wildlife attractants and preventing wildlife-vehicle collisions. There is too much uncertainty in the predictions of how climate change, along with possible other future development, may alter animal abundance or behavior to predict the direction of effects from changing conditions over the 20-year period.

In summary, during construction, changes in the environment are likely to have adverse effects on the Project by increasing the risk of project delays and increasing project costs. These effects are likely to be small, considering that the entire length of each project phase will not be affected at the same time and because most effects will be of short duration. The effects are generally reversible and can be accommodated within construction schedules. While changes in the environment are likely to result in delays and some cost increases, they are unlikely to pose a substantial risk to the Project.

24.3.2 During Operations and Maintenance Phase

Unlike Construction, the operations and maintenance phase has no end date and is more likely to be subject to long-term changes in the environment. During this phase, the maintenance of the highway may be affected. Appendix 24A (K'alo-Stantec, 2022a), Table 9 provides a description of climate change-related risks to the Project and suggested adaptation measures. The following is a general description of the expected changes.

Permafrost degradation: The greatest risk to the Project during operations and maintenance is associated with higher temperatures and the potential degradation of permafrost and subsequent slumping, landslides, or local erosion in areas of ice-rich soils. The operations and maintenance phase covers a long period of time and long-term climate change effects are likely to occur. Long-term warming can thaw or weaken the permafrost. The thawing of permafrost can affect surface and groundwater flows and the groundwater table. Changes to the groundwater regime could result in differential settlement, erosion, cracking, change in drainage patterns, and flooding of the road surface.

These effects present a safety issue to road users and increased maintenance requirements. These effects will be localized to areas where the highway is built across areas of ice-rich (thaw-susceptible) soils. The design objective is to avoid these soils where possible, and to use a design approach in these areas that reduces potential for thaw-related erosion. Effects of degradation of permafrost on the highway will require material to be used throughout the operations and maintenance phase to repair areas of subsidence, erosion and cracking to maintain public safety. The granular material requirements for the operations and maintenance phase will be estimated during further design advancement.

Thawing of the permafrost in thaw-susceptible areas could result in ponding on the highway surface and effects on drainage (culvert erosion, culvert blockage) and erosion along the side of the highway. Where the highway is constructed on ice-rich permafrost, settlement could be extreme, resulting in surface water ponding and pothole formation. As outlined in Appendix 24A (K'alo-Stantec, 2022a), Table 9, permafrost thawing has the greatest potential to cause environment effects on the Project. Various measures involving increased monitoring and early and more frequent maintenance are available to avoid adverse effects.

Permafrost thawing is likely to cause the following effects on the Project:

- Increased maintenance needs
- More frequent and extensive road rehabilitation needs
- Rougher road surface in some areas (e.g., potholes and ruts)
- Localized temporary road lane or total highway closures

These potential effects are likely to result in increased costs and in adverse effects on highway users including:

- Decreased speed
- Increased vehicle maintenance needs
- Increased accident risk
- Travel delays due to maintenance or rehabilitation activities or short-term closures
- Inability to use highway in case of longer highway closures

The worst-case, but unlikely, scenario is a permanent loss of service. The project design reduces the risks of effects by applying design mitigation measures and addressing erosion and drainage issues promptly. With these measures in place, permafrost-related effects will be unlikely to cause road conditions to deteriorate rapidly, allowing maintenance to be conducted.

Mean Seasonal Temperatures: General warming of the air is likely to result in thawing permafrost, which has adverse effects on the Project. Warmer air also affects snowmelt, which can have an adverse effect on the road and associated drainage structures. Increased temperatures can also lead to more icing on the road surface in winter.

Extreme low temperature events: Extreme cold weather will have similar effects as during construction and are likely to cause delays in maintenance. These will be temporary and, given the low traffic volumes anticipated, can be compensated for relatively easily. Extreme low temperatures can also cause water flowing through culverts to freeze, resulting in a blockage and subsequent flooding issues in the spring.

Extreme high temperature events: Maintenance activities occur only periodically and can be scheduled around extreme temperature events, reducing the likelihood of fires being started by project activities. Wildfires may still be caused by the travelling public, but the project infrastructure is at lower fire risk than during construction because there is notably less equipment involved and fewer activities, such as welding, that could cause a fire. Extreme high temperatures events are likely to contribute to permafrost degradation but are not likely to have immediate, direct effects on the road.

Drought: The length and frequency of dry spells is not expected to increase and hence not likely to add to adverse effects. The confidence level for this prediction is medium-low and it may not hold over the long term. Higher temperatures will likely increase the severity of droughts. If drought conditions increase, maintenance activities will be adversely affected as water (e.g., for dust control) may not be readily available.

Extreme rainfall events: Extreme rainfall events may damage the road surface and/or drainage structures (e.g., culverts), resulting in increased maintenance or more frequent rehabilitation and temporary road closures. While the effects of increased rain on the road are immediate, they can be managed through erosion control and frequent maintenance.

Extreme snowfall events: Extreme snowfall events or increased snow accumulation would require increased maintenance (i.e., snow plowing). No predictions are available. The GNWT's commitments (Chapter 27) include snow removal-related mitigation measures. Recommendations on snow removal to reduce environmental effects on the Project include blading snow away from the shoulders and clearing snow and ice off the road surface during late winter maintenance. Increased snow loads may also increase spring flood risk.

Frost and frost thaw cycles: The predicted decrease in frost days and in frost thaw cycles has the potential to affect road infrastructure because it changes the timing of freeze up and melting. Sustained melting in the spring is more likely to lead to flooding conditions than a more prolonged process where melting stops periodically, allowing meltwater to drain.

Wildfire frequency and intensity: During operations wildfires may pose a risk to the travelling public and may result in road closures. Wildfires are unlikely to cause damage to the road. Increased frequency and intensity of fires is likely to lead to more frequent temporary road closures over time.

Seismic activity: During the operations and maintenance phase, seismic activity could result in damage to the road surface or to culverts. However, the Project is anticipated to be subject to similar levels of seismic activity as other highways the GNWT is currently maintaining without issue (see also Section 24.2.2).

Wildlife interactions: Wildlife interactions are more likely during the operations and maintenance phase than during construction because wildlife are more likely to approach the highway ROW without the effects of construction noise. Given the expected low speed and low traffic level (Section 24.4.1), combined with relatively infrequent maintenance activities, individual interactions may occur occasionally, but the effects are anticipated to be similar to other northern highways projects (Sections 10.4.4, 19.4.4).

24.4 Prediction Confidence

The assessments in Section 24.3.1 and Section 24.3.2 rely on predicted changes in the environment. Such predictions are subject to assumptions as well as gaps and uncertainties in available information.

24.4.1 Assumptions

This effects assessment is based on the following key assumptions:

- The design of the highway anticipates an annual average traffic volume of 50 vehicles per day, including a mix of vehicles such as pickup trucks and truck trailers up to a weight of 64,000 kilograms. The Low Volume Road design allows for annual average daily traffic of up to 200 vehicles per day (see Chapter 5 Detailed Project Description).
- Construction will be completed within a 20-year timeframe.
- The direction of climate change prediction is correct. The assessment does not rely on the predictions about amounts of change to be entirely correct. Predictions refer to mean values only and may not cover the entire range of future climate values.

24.4.2 Gaps and Uncertainties

The assessment of effects of the environment on the Project identified the following information gaps:

- Climate change projections for the project area are not available for some climate variables, including fog and wind. While increased fog is not likely to adversely affect the road infrastructure, it poses a safety risk for the travelling public. Increased wind would have a potential to affect road maintenance and users (e.g., by generating and distributing more dust).
- Current permafrost conditions are known generally but not necessarily at each specific location where the highway will be routed. Additional data will be collected during design advancement specific locations to inform mitigation measures, monitoring, and maintenance (see draft Permafrost Protection Plan [PPP], Volume 5).

- Few evaporation and evapotranspiration data are available within the project area and are unlikely to become available in the short- to medium-term. Predicting changes in evaporation and evapotranspiration is therefore not possible. Given that temperatures are likely to increase, some increase in both measures is likely. Neither are likely to have a direct effect on the Project but may affect other factors, such as availability of water.
- Climate information and predictions are based on a few stations in communities, which are spaced at great distances; local climate and weather conditions may change along the route.
- Section 5.5.5 provides an estimate of the amount of material and borrow/quarry sources required for construction and identified material sources that will be used for construction and for maintenance. An estimate of how gravel requirements may change due to climate change is not currently available. Maintenance needs depend on several factors, including traffic volumes and weight of vehicles, frequency of maintenance, permafrost conditions, weather, and combinations of these factors. There is considerable uncertainty with these factors and a reliable estimate is therefore not possible. Nevertheless, the recommendations made in Section 24.3 include measures to reduce the amount of gravel needed. In general, increased maintenance needs are likely to result in increased volumes of gravel.

The assessment of effects of the environment on the Project includes several uncertainties. The key uncertainties are:

- There is some uncertainty in global climate change projections and the uncertainty increases with time into the future.
- The uncertainty in climate change predictions is compounded by uncertainty in predicting local environmental change (e.g., sensitivity of soils to thaw) and the effect of those changes on the Project.
- There is uncertainty associated with the assumptions presented in Section 24.4.1. For instance, if traffic volumes were to increase considerably (e.g., by a factor of 10) the effects during the operations and maintenance phase are likely to increase proportionally. Similarly, effects during construction may increase if the construction timeframe goes considerably beyond 20 years.
- There is some uncertainty in the effectiveness of engineering or management mitigation against climate change effects, including permafrost degradation. The likely effects of climate change on the Project apply similarly to most roads in the north and there is considerable research under way. For example, Yukon University has partnered with the Government of Yukon to study climate change adaptations along northern highways in the Yukon and NWT (Transport Canada, 2018). The ability to respond and adjust to climate change effects many decades from now is not presently known and may be much better than currently anticipated.

24.5 Mitigation And Follow Up

24.5.1 Design Mitigation Measures

The highway is designed for a northern environment and incorporates various design features to reduce its interaction with terrain, soil, and permafrost. Key design considerations include:

- The area of direct ground disturbance will be limited by following the pre-existing winter road alignment to the extent possible.
- Project design will avoid ice-rich areas where possible.
- Drainage culverts will be installed to accommodate storm events and maintain drainage patterns and in consideration of site-specific icing/glaciation effects.
- Geotextile and embankment placement will be completed in the winter to limit disturbance to soils and permafrost.
- A fill-only construction approach will be used, except at specific locations of road cuts.
- Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the right-of-way and approved access roads). To promote the stability of cuts and fills on slopes, fill material will be compacted and the tops of cut slopes will be rounded.
- Where possible, cleared material will be mulched and spread over cleared areas within the Project footprint.

In addition to these mitigation measures, the following measures will reduce the Project's susceptibility to climate change effects from permafrost degradation:

- A project-specific PPP will be developed and implemented.
- 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.
- Undisturbed areas will be avoided until they are scheduled for clearing/stripping to limit unnecessary soil degradation and compaction. A dust control program using water will be applied during the summer period of the construction phase.

24.5.2 Follow-up and Monitoring

Several follow-up and monitoring requirements have been identified that are designed to reduce the likelihood and severity of effects of the environment on the Project (Appendix 24A; K'alo-Stantec, 2022a). These are:

- Periodic surrounding surface surveys using remote sensing techniques every 5 to 20 years to identify areas where surface features such as ground elevation, vegetation cover, surface water flow, or areas of pond development have changed
- 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)
- 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.
- Engineer inspections after severe events to verify the integrity of roadway and drainage systems
- Frequent inspections of the performance of the infrastructure (e.g., culverts are clear in the spring and the fall)
- Where permafrost is encountered and where practical, monitoring of the thermal regimes to assess if the embankment performs as designed
- Regular monitoring of road maintenance efforts and climate data to better correlate the change in road surface with climate-related parameters and their potential changes
- Develop an adaptative management approach to future maintenance and rehabilitation

24.6 References

GNWT (The Government of the Northwest Territories). No date (a). 2030 NWT Climate Change Strategic Framework. Available at: https://www.enr.gov.nt.ca/sites/enr/files/resources/128-climate_change_strategic_framework_web.pdf. Accessed January 2023.

GNWT. No date (b). 2030 NWT Climate Change Strategic Framework 2019-2023 Action Plan. Available at: https://www.enr.gov.nt.ca/sites/enr/files/resources/128-climate_change_ap_proof.pdf. Accessed January 2023.

Government of Canada. 2015. Canada's Changing Climate Report; Chapter 3 - Northern Canada. Available at: https://www.nrcan.gc.ca/changements-climatiques/impacts-adaptation/chapter-3-northern-canada/10323. Accessed June 2022.

The Government of the Northwest Territories, Department of Transportation. 2013. Erosion And Sediment Control Manual. Available at: https://docslib.org/doc/7948326/erosion-and-sediment-control-manual. Accessed June 2022.

Infrastructure Canada. 2019. Infrastructure Canada's Climate Lens General Guidance. V.1.2.

K'alo-Stantec (K'alo-Stantec Limited). 2022a. Mackenzie Valley Highway Project Climate Lens Part II: Climate Resilience Assessment. Prepared for Government of the Northwest Territories Department of Infrastructure. 71 pp.

K'alo-Stantec. 2022b. Mackenzie Valley Highway Project: Technical Data Report—Air Quality, Greenhouse Gas Emissions and Climate Baseline. Prepared for the Department of Infrastructure, the Government of the Northwest Territories, Yellowknife, Northwest Territories.

MVEIRB (Mackenzie Valley Environmental Impact Review Board). 2015. Terms of Reference EA1213-02 Mackenzie Valley Highway Extension Project Wrigley to Norman Wells Government of Northwest Territories. February 13, 2015. PR#66.

Natural Resources Canada. 2015. Seismic Hazard Maps Available at: https://earthquakescanada.nrcan.gc.ca/hazard-alea/simphaz-en.php. Accessed June 2022.

Transport Canada. 2018. Canada and Yukon governments invest in research projects to address the impacts of climate change on northern transportation infrastructure [News Release] October 10, 2018. Available at: https://www.canada.ca/en/transport-canada/news/2018/10/canada-and-yukon-governments-invest-in-research-projects-to-address-the-impacts-of-climate-change-on-northern-transportation-infrastructure.html. Accessed June 2022.

TRRC (Tulita Renewable Resource Council). 2022. Tulita Renewable Resources Council Traditional Land and Resource Use Study for Tulita District Mackenzie Highway Project. Prepared by K'alo-Stantec Limited. Prepared for Tulita Renewable Resources Council.

25.0 ASSESSMENT OF POTENTIAL EFFECTS OF ACCIDENTS OR MALFUNCTIONS

25.1 Introduction

Accidents or malfunctions resulting from construction or operations and maintenance of the Mackenzie Valley Highway Project (the Project) can adversely affect the environment. Typically, these events occur outside the normal planned function or activity of the Project and can happen during any phase of the Project. Despite rigorous application of mitigation measures and emergency response procedures, accidents and malfunctions may pose risk to Valued Components (VCs) and are therefore analyzed as an aspect of the overall Project.

In accordance with section 9 of the Terms of Reference (ToR; Mackenzie Valley Environmental Impact Review Board [MVEIRB], 2015 [Public Registry {PR}#66]), the environmental assessment (EA) must address environmental effects of accidents or malfunctions that may occur in relation to the Project. Through good planning and design, combined with adoption of safety measures, the risks of accidents or malfunctions can be reduced or controlled. A Spill Contingency Plan (SCP), Waste Management Plan (WMP), Emergency Response Plan (ERP), Explosives Management Plan (ExMP) and a Traffic Management Plan (TMP) will be developed to help mitigate the effects of accidents or malfunctions should they occur and, apart from the TMP and ExMP, are presented in draft in Volume 5 to support the assessment of potential effects of accidents or malfunctions.

On a project of this large spatial and temporal extent, unintended accidents and malfunctions can occur. After taking into consideration project design and safety measures, this chapter will discuss the type and likelihood of accidents and malfunctions, describe mitigation to reduce the likelihood and outcome of the event, and describe the residual effects on different VCs. To present discussion on accidents and malfunctions, the section is organized by regulatory and policy setting, the assessment approach, description of potential accidents or malfunctions, effects pathways, effects assessment, and a description of residual effects. The analysis presented in this chapter relies on the residual effects characterization and significance definitions of project VCs.

25.2 Regulatory & Policy Setting

The regulatory and policy setting for accidents and malfunctions includes acts, regulations, policies, and guidelines relevant to health and safety, environmental protection, and emergency response:

- *Transportation of Dangerous Goods Act* (1992) and regulations
- *Fisheries Act* (1985)
- *Federal Explosives Act* (1985)
- *Northwest Territories Environmental Protection Act* and regulations (including the Spill Contingency Planning and Reporting Regulations) (1988)

- Northwest Territories *Public Highways Act* (1988) and regulations
- Northwest Territories *Safety Act* (1988) and Occupational Health and Safety (OHS) Regulations
- Northwest Territories *Explosives Use Act* (1988) and Explosives Regulations
- *Forest Management Act* (1988)
- *Forest Protection Act* (1988)
- *Mackenzie Valley Resource Management Act* (MVRMA) and Land-Use Regulations
- Northwest Territories *Environmental Rights Act* (2019)
- Northwest Territories *Waters Act* (2014) and Waters Regulations
- Sahtu Land Use Plan (Sahtú Land Use Planning Board, 2023)
- Forest Fire Prevention and Suppression Guidelines For Industrial Activities (Government of the Northwest Territories [GNWT], 2001)
- Guidelines for Spill Contingency Planning (INAC, 2007)
- Guideline for Hazardous Waste Management (GNWT-Environment and Natural Resources [ENR], 2017)
- Standards Council of Canada: Explosives – Quantity Distances CAN/BNQ 2910- 510/2015
- Canadian Council of Ministers of the Environment (CCME). CCME EPC LST PN 1326 – October 2003, Environmental Code of Practice for Aboveground and Underground Storage Tank Systems Containing Petroleum and Allied Petroleum Products
- Northwest Territories Traditional Knowledge Policy (2005)

In addition to these, other regulations related to land use, zoning, and transportation may be applicable to planning for and responding to accidents or malfunctions over the life of the Project.

25.3 Assessment Approach

To assess accidents and malfunctions associated with the Project, the following approach was used to identify and assess potential events:

- Identify potential accidents or malfunctions that could occur during construction phase or operations and maintenance phase as defined below, and their likelihood of occurrence
- Identify the interaction and description of potential effects on VCs (as applicable) for each accident and malfunction scenario. These are potential effects that occur with (and despite) the application of standard mitigation measures applied during normal Project activities.
- Identify the additional safety and design measures and response actions that will be implemented to reduce or control the potential for, and potential outcome of, each accident or malfunction

- Describe the potential residual effects (after additional mitigation measures have been applied) on VCs that would result from each accident or malfunction, taking into consideration factors of external influence such as weather or unpredictable events
- Determine the significance of residual effects on VCs resulting from each accident or malfunction

25.3.1 Definition of Significance

The significance of residual effects on VCs is determined using the definitions presented in each individual VC chapter within the Developer's Assessment Report (DAR), as they relate to the assessment of project environmental effects.

25.3.2 Temporal Boundaries

The assessment of potential effects of accidents or malfunctions is assessed over the following temporal boundaries:

- 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.

25.4 Influence of Engagement

The GNWT has engaged with potentially affected Indigenous Governments and 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 accidents and malfunctions. This feedback has been considered and summarized in Table 25.1 and has been integrated into the assessment of potential accidents and malfunctions that follows.

Table 25.1 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
Community engagement participants expressed concern about spills, including from vehicles, and stated the importance of having spill containment mitigation measures in place. Participants recommended monitoring of spills during construction. Participants also expressed concerns about reporting spills and being able to speak up about things that may seem wrong, stating there was a lack of trust that contractors will do it right.	April to July 2022 Engagement; November to December 2022 Engagement; November 2022 to February 2023 Engagement	The GNWT has identified mitigation measures for prevention, response, and remediation. A WMP, SCP, ERP, ExMP, and a TMP will be developed and implemented to help mitigate the effects of accidents or malfunctions should they occur. 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 discussing with Indigenous Governments, Indigenous Organizations, and other affected parties how best to integrate community-based monitoring into the Project.	See Section 25.7.1for emergency response mitigation measures. See also: Section 25.5 (Description of Potential Accidents or Malfunctions) Volume 5 for management plans
The Tulita Renewable Resources Council (TRRC) noted concerns about potential project effects from vehicle breakdown near open-water sources, specifically near Bear Rock (Petınıʔah), which is of interest to the community, that have potential to contaminate or affect the flow of water.	TRRC, 2022		
Community engagement participants raised concerns about emergency response services and access to those services due to the remoteness of the Project and limited cell phone coverage.	April to July 2022 Engagement; November to December 2022 Engagement; November 2022 to February 2023 Engagement		

Comment	Source	GNWT Response	Where Addressed
Norman Wells Renewable Resources Council (NWRRC) study participants raised concerns about potential contamination to wildlife from vehicle fluid and other contaminants. NWRRC study participants stated that animals can smell the chemicals from the vehicles and will move away from the area or will change their route.	NWRRC, 2023		

25.5 Description of Potential Accidents or Malfunctions

Based on the design and intended use of the Project, professional judgment, and experience with other transportation projects, potential accidents or malfunctions have been identified. These potential accidental event scenarios are described in Table 25.2.

Table 25.2 Potential Accidents or Malfunction Scenarios

Potential Accident or Malfunction	General Description
Spill of fuel or hazardous materials (contaminants)	• Accidental discharge of hazardous material (e.g., diesel fuel, sewage) during storage, handling, or dispensing, resulting in the release of contaminants to the aquatic or terrestrial environment • Vehicle accident or mechanical malfunction involving equipment or transport trucks, resulting in the release of hazardous materials such as hydraulic fluid, fuel, sewage, or oil to the aquatic or terrestrial environment
Explosion or Fire	• A fire or explosion within project infrastructure (e.g., camp or maintenance yard), resulting in the release of contaminants to the atmospheric, aquatic, or terrestrial environment • A fire or explosion within project infrastructure causing injury to people
Transportation, Storage, Manufacture, and use of Explosives	• Accidental discharge of bulk explosive supplies (ammonium nitrate) during transportation or storage, resulting in the release of contaminants to the aquatic or terrestrial environment • Accidental detonation of explosives causing injury to people
Transportation Accidents	• Traffic accident (vehicle collision or rollover) during transport of project supplies and workers from community centers or camp accommodations to construction sites causing injury to people • Traffic accident (vehicle collision) involving project equipment and public user of the Mackenzie Valley Winter Road (MVWR) causing injury to people

The likelihood of an accident or malfunction is characterized relatively as follows:

- **Unlikely:** Event might occur during construction or operations and maintenance but would be infrequent (one event per 10 years)
- **Somewhat likely:** Event could occur during construction or operations and maintenance (one event per year)
- **Very likely:** Event is expected to occur during construction or operations and maintenance (more than one event per year)

25.5.1 Spill of Fuel or Hazardous Material

During project construction and during operations and maintenance, an accidental discharge of fuel (e.g., diesel fuel) could occur during storage, handling, or dispensing. Accidental discharge could be caused by improper storage, human error, or mechanical failure of equipment during filling of tanks or transfer from tanks to vehicles. An accidental discharge of sewage could also occur during transfer of waste from camp infrastructure to truck due to human error or mechanical failure. It is assumed that spills such as these would be relatively small (i.e., less than 100 litres [L]).

Diesel fuel will be delivered in the winter from regional storage hubs to fuel tanks situated at the staging and storage areas, borrow and quarry sources, and camps. A vehicle accident involving equipment, such as a collision or rollover, could result in the release of hazardous materials (e.g., fuel, oil, hydraulic oil) to the aquatic or terrestrial environment. A potential spill involving a fuel truck could result in a release of 1,000 L or more.

During the operations and maintenance phase, vehicles and heavy equipment will be working at quarries and borrow sources and hauling material to maintenance yards. Maintenance yards will be used to store and service vehicles. A vehicle accident or equipment malfunction could result in a release of hazardous materials (e.g., fuel, oil, hydraulic fluid) to the environment. It is anticipated that the volume of release would be comparable to the construction scenario (i.e., less than 100 L).

The use of the highway, once open to the public, will create potential for accidents involving vehicles, and vehicles carrying hazardous materials. As these vehicles are operated under the care and control of third parties, they are not considered project activities and not considered in the assessment.

A spill during storage, handling, or dispensing is considered very likely during construction. The likelihood of a spill will be possible during the operations and maintenance phase due to the activities related to equipment mobilization and operation. A spill due to a project truck rollover is considered somewhat likely.

25.5.2 Explosion or Fire

A fire or explosion in a project facility such as a construction camp or maintenance yard during construction or operations and maintenance could be caused by failures, including equipment or machinery malfunction, combustion of flammable materials, or improper storage or handling of materials. Fires could be caused by careless human activity (e.g., kitchen incidents). A fire may result in the damage or destruction of camp facilities and potential spread to the surrounding environment. A fire or explosion could also be caused by ignition of a pressure vessel, overheating of equipment, or improper handling of chemicals, leading to injury of project personnel. A fire or explosion is considered unlikely; however, should an event occur, fire has potential to spread to the surrounding terrestrial environment.

The risk of fire or explosion due to third party use of the highway is not assessed. This would include risk of fires due to discarded cigarettes and other careless human behavior.

25.5.3 Transportation, Storage, Manufacture and Use of Explosives

The use of explosives during construction (quarries and road cuts) and operations and maintenance (quarries) increases the potential for an accidental release of materials used for explosive manufacture (e.g., ammonium nitrate) or prepared explosives. A vehicle accident or improper storage could result in ammonium nitrate pellets (prill) being spilled during transport to work areas along the constructed embankment, a quarry access road, or within a quarry. This type of event is considered unlikely.

25.5.4 Transportation Accidents

During project construction, project vehicles will be used to transport workers from communities to camps and between camps and worksites. Camps and worksites will be resupplied using project vehicles. A vehicle accident attributable to the Project can cause damage to property and can result in injury to the individuals involved. It could also adversely affect access to communities if the highway were to be closed for a long period of time. Potential project-related accidents could be the result of collisions of project vehicles with other project vehicles, private vehicles using the MVWR, or wildlife. As the MVWR will be open to public traffic during project construction, there is potential for a collision between a project vehicle and a private vehicle, resulting in injury to the public. An accident involving a project vehicle is considered somewhat likely. An accident requiring closure of the highway for more than one day is considered unlikely.

Transportation of materials, cargo, and other supplies to support the Project may also occur by barge. Barge services are anticipated to be provided by licensed third party service providers such as Marine Transportation Services, who have approved SCPs and ERPs. Accidents associated with third party barging services using existing facilities and transportation routes are not assessed.

During the operations and maintenance phase of the Project, the highway will be in use by the public. It is estimated that the road will have 50 vehicles per day, with approximately 15% being heavy trucks.

While the highway is operational and accessed by the public, transportation accidents may occur due to project vehicle/equipment collisions and project vehicle/animal collisions. This type of accident is considered somewhat likely or very likely.

The public is very likely to access the highway while it is operational, and transportation accidents may occur due to private vehicle collisions with other private vehicles and animals (i.e., vehicle accident not attributable to the Project). See Chapter 9 (Socio-economic Impact Assessment) for an assessment of potential effects on human health and community wellness and on infrastructure, services, and institutional capacity as a result of increased risk of traffic accidents year-round due to construction of the Project and presence of the Project during operations.

25.6 Potential Effects Pathways

Table 25.3 identifies the interaction of the accident or malfunction scenarios with the environment as having potential to cause a residual effect on VCs after implementation of mitigation measures, to reduce the consequence if the incident occurred. These interactions are further assessed in Section 25.5. This approach differs from the assessment of potential effects on VCs in other chapters.

A spill of fuel or hazardous material can affect VCs of the terrestrial, aquatic, and human environment. Hazardous liquids, if not properly contained, can flow in an uncontrolled manner to the terrestrial and aquatic environment. Spills of hazardous waste generated during the construction of the Project can include contaminated soil/snow/water, waste fuel, crankcase fluids, solvents, glycol, batteries, and empty fuel drums. Accidental releases of fuel or hazardous materials can affect soils, water, and vegetation.

A spill entering a watercourse can affect water and sediment quality as well as fish habitat and fish health. A spill to land can affect vegetation, soils, wildlife, and birds by directly contaminating soils and vegetation, and potentially affecting the health of wildlife (including caribou and moose) and birds. A spill to land or water can affect traditional land and resource use and heritage resources as well as non-traditional land and resource use, human health, and community wellness. A spill can adversely affect employment and economy if the incident requires work stoppage; however, it can also generate employment and business opportunities related to response.

A fire or explosion has potential to affect VCs of the atmospheric, terrestrial, aquatic, and human environment. A fire or explosion can release criteria air contaminants (CACs), which can in turn affect wildlife, birds, and human health. A fire or explosion can result in loss of vegetation and can result in injury to people. A serious event can also strain existing emergency and health services. A fire near a watercourse can affect water quality and fish habitat if it causes sediment and contaminants to enter the water. An explosion near a watercourse can affect fish due to excessive pressure.

A spill during transportation or storage of ammonium nitrate prill can affect water and sediment quality and fish and fish habitat if it enters a watercourse. Generally, other pathways are excluded since spills on land are expected to be readily cleaned up.

Table 25.3 Accident or Malfunction Scenarios and Potential Residual Effects on Project Valued Components

Accident or Malfunction Event with the Potential to Cause Residual Effects	Air Quality	Noise	Terrain, Soils, Permafrost	Water Quantity	Water and Sediment Quality	Vegetation and Wetlands	Fish and Fish Habitat	Wildlife and Wildlife Habitat	Birds and Bird Habitat	Caribou and Moose	Biodiversity	Non-traditional Land and Resource Use	Traditional Land and Resource Use and Harvesting	Heritage Resources	Employment and Economy	Infrastructure, Services, and Institutional Capacity	Education, Training and Skills	Human Health and Community Wellness
Spill of Fuel or Hazardous Material	–	–	✓	–	✓	✓	✓	✓	✓	✓	–	✓	✓	✓	–	–	–	✓
Fire/Explosion	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–	✓	✓	✓	–	✓	–	✓
Transportation, Storage, Manufacture, and Use of Explosives	✓	✓	–	–	✓	–	✓	–	–	–	–	–	–	–	–	–	–	–
Transportation Accidents	–	–	–	–	–	–	–	✓	✓	✓	–	–	–	–	–	✓	–	✓

Notes:

✓ potential to affect the VC

– no interaction with VC identified

Transportation accidents can affect wildlife and wildlife habitat, birds and habitat, and caribou and moose through collisions between project vehicles and wildlife. Transportation accidents have the potential to result in injury or loss of human life due to collisions between project vehicles and other vehicles, equipment, or wildlife, which would interact with human health and community wellness. In the event of a collision requiring emergency response services, infrastructure, services, and institutional capacity to respond to other emergency events may be affected.

There are minimal adverse interactions expected between accidents and malfunctions and the VCs of biodiversity, employment and economy and education, training, and skills. In the case of project interactions with biodiversity (wildlife, fish, and vegetation VCs), though there may be an interaction with aspects contributing to biodiversity (such as species at risk, habitats, land use), the effects resulting from these interactions are assessed in this chapter as unlikely, indicating that biodiversity should remain stable in the context of an accident or malfunction. In the case of project effects on employment and economy, it is anticipated that there will be increased localized spending with short-term benefit to nearby communities, including businesses supplying goods and services in support of the emergency response. As a result, the biodiversity, employment and economy, and the education, training, and skills VCs will not be discussed further.

25.7 Assessment of Residual Effects of Potential Accidents or Malfunctions

This section is organized as follows:

- Mitigation applicable to all scenarios describes plans and measures to mitigate effects on the environment from all four accident or malfunction scenarios.
- Emergency measures and capacity describes the GNWT approach to responding to emergencies arising out of project accidents or malfunctions.
- Residual effects assessment describes the effects on environmental VCs from each of the accident/malfunction scenarios remaining after mitigation.

25.7.1 Mitigation Applicable to All Scenarios

The mitigation of effects of spills of fuel or hazardous material relies on measures for prevention, response, and remediation. The following management plans together include mitigation for spills of fuel or hazardous material:

- **Waste Management Plan (WMP):** Includes requirements for proper storage, transfer, handling, and disposal of hazardous and non-hazardous wastes (see Volume 5)
- **Spill Contingency Plan (SCP):** Includes requirements for spill prevention measures, notification, spill response measures and procedures, training, reporting, and remediation (see Volume 5)

To prevent or reduce severity of fuel and hazardous material spills during both the construction and operations and maintenance phases the project design includes protective features to reduce risks of traffic accidents. For example, watercourse crossings have been designed with posted speed limits and adequate signage for road curvatures or upcoming crossings. Project traffic will use existing bridges with guardrails to reduce the risk of vehicles and equipment hauling or containing fuel and hazardous materials from entering the water. Furthermore, a considerable amount of project work is scheduled to occur during the winter; therefore, effects of spills to watercourses will be reduced because clean up would occur on frozen ground and ice. A key design strategy of the highway is to prevent accidents from occurring.

Measures for spill prevention are included in the SCP and include the following based on regulatory requirements, guidelines, and industry best practices:

- Spill contingency measures will be implemented in accordance with the SCP. The SCP includes procedures to prevent and respond to spills.
- Fuel will be stored in containers with secondary containment capable of containing 110% of the largest container at all times.
- Fuel handling and refueling will be in accordance with an Operating Procedure to be included in the SCP.
- 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.
- Material Safety Data Sheets for hazardous substances are to be stored on site.
- Fuels and oils/lubricants must be stored more than 100 metres (m) from the ordinary highwater mark bank of a watercourse or waterbody.
- Equipment such as generators and pumps will have secondary containment installed capable of containing fuel drips or leaks during operations and refueling.
- Mobile equipment will be refueled more than 100 m away from the bank ordinary highwater mark of a watercourse or waterbody.
- Sewage and greywater are to be stored in approved holding tanks for this purpose prior to removal from site or disposed of in accordance with the land use permit.
- All site personnel will receive SCP training and will have awareness of spill prevention.
- All construction workers will have sufficient safety training to reduce potential for severe accidents.
- 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.

- Emergency spill response kits will be kept in vehicles and at fuel storage locations.
- Vehicle speeds will be limited to 50 kilometres per hour (km/h) on unfinished project road surfaces.
- Speed limits will be posted on the highway.
- The GNWT will deliver public education around highway safety, provide proper highway signage, and maintain the ROW to provide clear line of sight for drivers.
- Signage and physical barriers will be used to identify areas of active construction and to provide separation between workspaces and the MVWR for public safety and security.

If a spill at the project sites occurs, the spill would be immediately contained and cleaned up using onsite spill kits and appropriate absorbent materials. In the event of a large spill, prioritization of site resources would be sent to the spill area for response. Small spills would be confined and cleaned up within a reasonable timeframe to reduce the potential for migration of contaminants. During the cleanup of small spills, soils in the affected area would be tested for hydrocarbons and excavated as required. Larger spills will require assessment by a qualified professional to confirm the extent of contamination and receptors and to develop a remedial plan as based on the site assessment.

The Project will implement best management and industry practices as appropriate to prevent or reduce the occurrence of vehicle accidents and driver error that may lead to spills due to vehicle/equipment roll over or loss of control, such as:

- Project vehicles will be driven by trained and competent drivers.
- The project site during construction and operations will rely on traffic control speed limits, weight restrictions, and signage for safe driving conditions.
- Project vehicles and equipment will undergo inspection prior to use by an operator.
- Project vehicles will be required to have beacon lights and flagging.
- Radio communication controls between vehicle and equipment operators.
- Access to construction areas will be limited to project personnel only for safety reasons. A TMP will be developed and implemented.
- All on-site contractors will have industry-compliant and satisfactory Health, Safety and Environmental policies, programs, and manuals to be implemented throughout the Project.

To address potential accidents and malfunctions arising from interactions with the public, the GNWT will require the contractor to develop a TMP that:

- Identifies the sections of the MVWR to be affected by construction
- Illustrates work zones and construction equipment movements
- Illustrates public vehicle detours
- Specifies requirements for escorts, signage, lighting, and speed reductions

- Specifies work times and measures for public safety during non-work times
- Specifies communication protocols between the project construction team and MVWR operations team

25.7.2 Emergency Response Measures and Capacity

The GNWT will require the project contractor to demonstrate their ability to provide emergency response services at the project site that are sufficient in capacity and capability to respond to emergency events. An ERP will be developed to include detail pertaining to event response, investigation, review, and corrective measures in accordance with the findings of the investigations. The measures in the ERP will be combined with an SCP for events that require reaction to emergency spills. The ERP will be developed in accordance with federal and territorial laws and regulations, in addition to the GNWT policies and procedures that are protective of the environment and human health. The ERP will be enforced with subcontractors and workers for the duration of the project construction and operations and maintenance.

The project-specific ERP will include:

- Scope of plan and types of emergencies covered by the plan (e.g., fire, medical, security)
- Responsibilities of the GNWT, contractor, and other responders
- Communications plan for alerting employees and the GNWT during an emergency
- Evacuation and response plan
- Government agencies to be notified
- Training, testing, and reporting

25.8 Description of Residual Effects

25.8.1 Spill of Fuel or Hazardous Material

The severity of environmental effects resulting from a spill of fuel or other hazardous material depends on the amount spilled, location, and the nature of the hazardous material spilled. Generally, a spill less than 100 L of fuel can be managed using best practices if it does not directly enter a waterway. Some hazardous materials are much more toxic in smaller quantities but may also be effectively managed if contained and cleaned up promptly and effectively. Effects of small spills < 100 L are therefore considered not significant.

If a large quantity of material is released to the environment it may result in deposition of the substance into the waterway (e.g., topography and soils conducive to flows). For example, a vehicle malfunction or collision could have a significant effect on surface water and fish and fish habitat should the associated spill occur close to a waterbody.

Likewise, spills on land can still have adverse consequences if not cleaned up properly and in a timely manner. In contrast to spills in or near water, the effects are likely to be small on a local scale. With the GNWT's commitments to prevention and effective response, these events will be contained and cleaned up before the spill can spread into sensitive areas. The effects on these VCs may also therefore affect the use and access of land and water resources for recreational and traditional uses.

The worst probable case for a hazardous material spill would likely be a large spill (> 1,000 L) of fuel into a major watercourse. Due to the properties of the fuel (it is insoluble and lighter than water), fuel may be transported downstream into connecting waterbodies and to riparian areas. Some fuel constituents would likely move from the water to the sediment environment. Clean up efforts would remove accessible fuel, but the contamination may be widespread in the aquatic and terrestrial environment downstream of the discharge. Over time, the contamination will dissipate and be diluted. The severity of effects would depend on the use of the area by human and ecological receptors.

Large volume fuel storage will only be in facilities that are well distanced from watercourses with safeguards and response capacity nearby (i.e., response personnel, equipment). The most likely spills near water would be from operating equipment and thus limited to the amount of fuel or hydraulic fluid contained in the equipment. Larger spills near water could occur during transport of fuel and will be limited to the volume of any tanker truck compartment that is damaged severely enough to spill.

In the event of a spill, hazardous materials will be contained and remediated as part of the ERP and SCP. If a spill entered a waterbody, an assessment would be undertaken and site-specific remedial actions would be developed in collaboration with regulators to restore the affected waterbody, including potential offsetting measures for harmfully affected fish and fish habitat.

25.8.1.1 Terrain, Soils, and Permafrost

If a spill event occurred on land, soil contamination would occur. The spill response procedures require the removal of contaminated soil material from the area and storage or shipping for safe disposal. Using the significant effect definition from the VC assessment (see Chapter 14), 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. The effect from a large spill (> 1,000 L) on soil may affect long-term soil development, as the affected soil would need to be excavated and replaced with clean fill. A large spill (> 1,000 L) is unlikely, but the residual effect on soil could be significant, if located in an area of productive soils.

25.8.1.2 Water and Sediment Quality

If a large spill event (> 1,000 L) occurred near a waterbody, there would be effects on surface water and sediment quality. Measures in the SCP would be used to contain and clean up the spill to the extent possible to reduce the significant effects in the immediate area and downstream; however, it is likely that several water quality parameters would be exceeded in the local area.

Using the significance definition from the water and sediment quality assessment (see Chapter 16), a significant residual effect on water quality and/or sediment quality is one that is likely to result in a measurable change in parameters that exceed relevant water quality and sediment quality guidelines and adversely affect ecological and/or human receptors.

A large spill is unlikely. The significance of the effect of a large spill on water and sediment quality will depend on whether ecological receptors such as wildlife and people may have access to the area before the spill can be mitigated. The residual effects on water and sediment quality of a large spill, though unlikely, would be significant.

25.8.1.3 Fish and Fish Habitat

Localized fish mortality may result from an accident or malfunction that results in a spill of fuel or hazardous material in or near fish habitat. Depending on the location of the event, the size of the spill, and the toxicity of the materials being transported, fish mortality could range from a few fish (not affecting the sustainability and productivity of a fishery) to larger scale levels of fish mortality (which could have a temporary effect on localized fish populations). Changes in fish health, growth, or survival (e.g., number of fish mortalities, fish tissue metal content, fish community composition) can occur as a result of chronic or acute toxicity to fish populations.

Using the definition of significance from the fish and fish habitat assessment (see Chapter 17), the potential effects of the Project would be deemed significant if the productivity and sustainability of fish populations along the highway corridor are negatively affected through habitat alteration or destruction of fish habitat that cannot be mitigated, avoided, or offset; death of fish leading to the loss of productivity or sustainability of a fish population; or blockage of fish passage resulting in loss of productivity and sustainability of a fish population.

By applying mitigation to limit the extent of the spill and cleaning up the spill promptly, the residual effects of a spill (large or small) on fish and fish habitat are considered not significant because they are not expected to affect the productivity or sustainability of the fish population. Large spills are also unlikely to occur.

25.8.1.4 Vegetation and Wetlands

In the unlikely event of a large release of fuel or hazardous materials, there could be an effect on vegetation and wetlands. The immediate road slope embankment and right-of-way (ROW) will be cleared of vegetation; however, depending on the location of the failure and the time elapsed until clean up, spills may reach vegetated areas and/or wetlands adjacent to the ROW. Effects may include direct loss or alteration of native vegetation communities and loss of traditional plant use. There is also potential for vegetation loss due to soil removal for cleanup activities. In the case of a large spill into a wetland, local effects may persist into the long-term but would not be expected to affect wetlands on a regional scale.

Using the definition of a significant effect on vegetation and wetlands presented in Chapter 18, a significant effect would be one that 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. As the residual effect would have limited effect on plants and/or wetlands outside of the cleared ROW, the residual effect of a spill on vegetation and wetlands is considered not significant.

25.8.1.5 Wildlife and Wildlife Habitat and Birds and Bird Habitat

A release of fuel could affect wildlife and wildlife habitat. There are circumstances where wildlife could interact with spilled material, such as material resulting from improper clean-up or material that was released prior to spill intervention. Removal of soils and vegetation will reduce habitat in the immediate area and wildlife may avoid the area even after it is cleaned up. The likelihood of small spills are more common; however, it is expected that soil loss due to spill response measures will not result in loss of habitat due to the minimal amount of soil removal that is associated with small spills.

Using the definition of a significant effect on wildlife and birds, as presented in Chapters 19 and 20, a significant adverse residual effect on wildlife and wildlife habitat would be one that causes or further contributes to the exceedance of a conservation-based threshold or threatens the long-term persistence or viability of species at risk or species of cultural or traditional importance. Small spills are unlikely to cause such effects and large spills are unlikely to occur. Due to the limited local extent of a spill as a result of applying mitigation measures, the Project would not be expected to threaten long-term persistence or viability of wildlife species, including species at risk, species of conservation concern, or those that are of cultural or traditional importance. Residual effects on wildlife and wildlife habitat and birds and bird habitat from a spill are considered not significant.

25.8.1.6 Cultural and Traditional Land and Resource Use

A large spill could affect several VCs contributing to cultural use (as defined in Chapter 11), including pathways to traditionally harvested wildlife, plants and fish, and use of land for cultural practices. The effects on cultural and traditional land and resource use ("cultural use") will, to some extent, be tied to the actual effects on those VCs based on measurable parameters and the cultural value of the area affected.

In the event of a large spill, the ability to access areas for recreation or traditional use (fishing, trapping, hunting) may be affected in the area surrounding the incident location. A large spill or a spill in water has potential to cause effects and both are unlikely to occur given the mitigation in place.

Based on the definition of significance used for cultural use, a significant effect on cultural use would be one where there is a long-term loss of availability of cultural and traditional use resources, or access to lands, cultural use sites, and areas relied on for cultural use practices, such that cultural and traditional use would be critically reduced or eliminated within a regional area.

Based on mitigation measures being effective at restoring lands and resources in the area affected by the spill, the effect on cultural use would be not significant; however, a large spill may change the way individual traditional land users use an area or resources, based on the perceived effects or changes to the value of the affected area or resource.

25.8.1.7 Human Health and Community Wellness

In the case of a spill, contaminants could be present in soil and water for a short time before the spill is cleaned up. The purpose of spill response and remediation would be to address residual contamination to levels that are below criteria for human and ecological health. During the short period of exposure, however, there could be ecological uptake by vegetation, wildlife, and fish. These changes in water and country food quality would be very unlikely and limited due to the short period of exposure, but it could influence the well-being of local people who live in proximity of the Project and who take part in hunting, trapping, traditional, and recreational activities, who may be required to or choose to avoid harvesting of potentially affected resources.

As based on the definition of a significant effect on human health and community wellness presented in Chapter 9, a significant effect on human health and community wellness would be one that causes or further exacerbates adverse health and community wellness conditions that contribute to a decline in physical, mental, and/or social health. The short-term nature and reversibility of the effect of the spills would result in the effect of spills on human health and community wellness to be not significant. In addition, large spills are unlikely.

25.8.2 Fire/Explosion

A fire or explosion could be caused by several failures, including equipment or machinery malfunction, combustion of inflammable materials, building fires, or careless human activity occurring at the project site. The project design and safety measures aim to control human influences on fire ignitions. In cases where small, localized building or equipment fires occur, onsite fire suppression systems, fire response, and firefighting equipment are anticipated to be effective. Explosions are anticipated when fires are in proximity to ignite pressurized vessels, such as propane tanks, or tanks that hold flammable materials, such as fuel tanks. Should fire suppression efforts not extinguish a fire immediately, a small fire or resultant explosion is not likely to reach surrounding woodland due to gravel clearings around buildings and embankment setbacks from vegetation, which create a buffer to prevent spread of fire.

While project activities are a potential cause for fires, in the Northwest Territories (NWT) the most common cause of wildfires is due to lightning strikes (GNWT-ENR, 2022) occurring seasonably between April to October. The worst-case scenario would be for a project-related fire to expand into the nearby woodlands or expand outside of the project area, becoming a wildfire. The potential for adverse environmental effects is dependent on the size of fire/explosion, location, duration, weather conditions (i.e., wind, rain, temperature), and intensity of the burn.

Project mitigation plans will reduce the risk of fire or explosion events. Uncontrolled fire can lead to wildfire, ignition of project buildings/facilities, and explosions of pressurized tanks. To avoid or reduce the potential for fire and explosion, project design features include several controls to limit the spread of fire should one occur and to reduce fire-induced explosions.

The ERP procedures related to fire prevention and management will reduce the likelihood of accidents and potential fires. As part of this plan, fire prevention and suppression systems will be located at work sites during construction, including water trucks, water hoses, pumps, fire extinguishers, and other firefighting equipment. Water for firefighting will be drawn from raw local sources (i.e., nearby ponds, rivers) for emergency use. A cleared buffer will be maintained around project infrastructure and staging areas to limit the spread of fire from a facility fire to the surrounding forest and to protect the facilities from a non-project-related wildfire.

The Project will depend on a network of strategically placed water tanks and pump/hose assemblies designed to deliver water in the event of an emergency. Fire extinguishers will be located indoors in accessible locations. Fire detection, fire alert, and fire protection systems will be installed in various facility areas. First response firefighting activities will be conducted by the project workers trained to use water trucks and emergency response equipment.

Employees will be trained in fuel handling, equipment maintenance, and fire prevention and response measures, and fire prevention and suppression systems will be maintained on-site. Furthermore, emergency response procedures will be in place to provide timely and effective response to fires and containment within the project area. Protocols for communication with local authorities will also be included in these emergency response procedures. In a fire scenario that exceeds suppression and control capacities of the project site, it is likely that the GNWT fire management services or nearby community resources would be required to prevent spread of a large-scale wildfire. These protection measures may include:

- Vegetation will be cleared around buildings and staging areas.
- The highway will use signage, such as wildfire severity ratings and/or fire bans, to raise awareness of wildfire risks and to remind highway users of fire prevention actions.
- Workers will be trained with fire prevention, suppression, and management awareness.
- The GNWT and subcontractors will use an ERP to reduce the spread of fire and will have standardized response practices should a fire emergency occur.
- The Project will use fire prevention and suppression systems at work sites during construction, including water trucks, water hoses, pumps, fire extinguishers, and other firefighting equipment.
- Strategic placement of water tanks and pump/hose assemblies will be used to deliver water in the event of a fire-related emergency.
- Fire extinguishers will be located indoors in tactical locations (buildings, vehicles, equipment), with sprinklers used in building and garage areas. Fire detection and fire protection systems will be installed in various facility areas.
- Emergency exits will have appropriately illuminated exit signs. First response firefighting activities will be conducted by the project workers trained to use emergency response equipment.
- To prevent fires, workers will be trained in fuel handling, equipment maintenance, and fire prevention actions. Employees will be trained on emergency response.
- During construction, fire severity ratings and fire bans will be communicated to workers to raise awareness of fire sensitive periods. During operations, fire severity ratings and fire ban signage will be posted in public areas for local awareness. Signage will also promote correct disposal of cigarettes.

In addition to design features, several safety measures will be implemented to reduce the potential for fire and explosion malfunctions or accidents because of the Project. These include the following:

- The Project will implement and enforce an ERP and procedures that covers protocols and responsibilities of site workers during a fire or explosion emergency.
- The Project will also include a TMP and a WMP, which will generate site awareness of worker interaction with fire, ignition hazards, and flammable substances.
- The Project will implement engineered controls and safe design of holding and storage tanks containing flammable and pressurized substances.
- Explosives will be handled, stored, and used by certified blasters in accordance with an ExMP.
- A licensed contractor will be hired to handle explosives sourcing and handling.

The project area is situated in the boreal forest, which is naturally prone to fire disturbance. In recent years, warmer and dryer summer conditions have increased the severity and risk related to wildfire. A project-induced fire may cause a wildfire to spread, altering vegetation communities, burning away the organic soil layer, and thawing permafrost. Widespread loss of vegetative communities or forest structure will affect birds, mammals, and associated habitat that would in turn affect cultural use of the area. It is further expected that if a project-induced fire were to spread there could be effects to other infrastructure (i.e., pipeline, fibre optic line), which would affect services. While a large fire is possible, it is considered unlikely due to the mitigation measures that will be implemented.

25.8.2.1 Air Quality

During a fire or explosion, releases and dispersions of CACs and other pollutants will occur. A large fire or explosion could result in temporary exceedances of ambient air quality standards and could affect human health through changes in air quality and immediate threats to safety and infrastructure. It could also affect wildlife, native vegetation, wildlife habitat, and land and resource use in the downwind area of the fire. Fire response measures will be in place to manage the spread and severity of fire to reduce potential spread to surrounding forest and lands. As such, fire would be most likely restricted to a small area. On average, fires burn nearly 1% of the forests in the NWT every year (GNWT, 2019).

Using the definition for significance from the assessment on air quality (see Chapter 12), a significant residual effect is one where the Project's CAC emissions are likely to exceed the NWT 2018 to 2020 average facility CAC emissions, as described in Section 12.1.1.1. It is unlikely that a fire caused by the Project will contribute to a considerable increase in the total fire air quality effects experienced regionally within the greater NWT or average annual facility emissions for the whole of NWT. Based on this, residual effects of fire on air quality are expected to be not significant.

25.8.2.2 Noise

Explosions can have effects on aquatic and terrestrial environments by creating noise, pressure changes, and vibrations. Short-term noise resulting from an explosion is likely to affect wildlife movement and birds in the immediate area. They would be expected to return to the area after the dissipation of noise. A large explosion at a camp or maintenance yard may kill or harm fish due to overpressure. As these facilities are likely to be located more than 100 m from watercourses (lake or stream), the potential effects on fish are considered low

As based on the assessment of project effects on noise (see Chapter 13), a significant effect for noise would be one that is high magnitude, lasts for more than one month, occur during a sensitive period for a VC, and is continuous or occurs over multiple or regular frequency for most receptors, including wildlife, humans, and birds. Based on the unlikely and short-term nature of an explosion, residual effects related to noise are considered not significant.

25.8.2.3 Terrain, Soils, Permafrost

Fire can affect permafrost by removing the insulating layer of organic soil and vegetation. Without this layer of protection, the upper layers of permafrost can thaw, and the mineral soils can become exposed, leading to erosion. Firefighting measures may use water, leading to local erosion. The severity of the effect on permafrost from a fire will depend on the geographic extent of the fire, the sensitivity of the terrain and soils, and whether permafrost is present.

As the Project, and particularly camps and maintenance yards, are sited to avoid sensitive terrain where possible and will already apply effective fire response and permafrost protection measures, some of this risk is mitigated. Applying the definition of significance or terrain, soils, and permafrost (see Chapter 14), a significant residual effect on terrain, soils, and permafrost is one that threatens the stability of local terrain, soil development, and/or soil capability, as well as physical and thermal stability of permafrost. Localized erosion due to fire or fire response may not be immediately mitigable. The unlikely residual effect of a fire on soils, terrain, and permafrost could be significant.

25.8.2.4 Water and Sediment Quality and Quantity

In the event of a fire or an explosion, the ERP requires that site personnel extinguish the fire, if possible. Fire response will rely on the emergency usage of raw water from proximal sources. The volume of water taken could exceed permitted thresholds if this water is needed in winter or requires a sustained fire-fighting response. These changes would not be considered permanent. Water quality could be affected by sedimentation caused by erosion from permafrost degradation or firefighting response. Erosion and sedimentation control measures would be expected to be effective at mitigating these effects.

Following the definition of significance for water quantity (see Chapter 15), to be deemed significant a residual effect would need to exceed 10% of the volume and exceed the Project Development Area or Local Assessment Area, or it would have to exceed 20% of the volume and meet additional duration, frequency, and reversibility criteria. The definition for significance for surface water and sediment quality (see Chapter 16) is a significant effect on water quality and/or sediment quality that is likely to result in a measurable change in parameters that exceed relevant water quality and sediment quality guidelines and adversely affect ecological and/or human receptors. In both instances, because of the unlikely potential of large fires or explosions and the local geographic extent, the effects are predicted to be not significant.

25.8.2.5 Fish and Fish Habitat

Localized fish mortality may result from an accident or malfunction that results in a fire or explosion near fish habitat. Depending on the location of the event, the size of the fire or explosion, and water depth, fish mortality could range from a few fish (not affecting the sustainability and productivity of a fishery) to larger scale levels of fish mortality (which could have a temporary effect on localized fish populations). Shallow waterbodies with adjacent fires could affect water temperature, which could result in harm to fish or mortality of spawn. Ash deposition, run-off water, and water temperature changes can contribute to changes in water chemistry and turbidity, creating fish migrations or die off. Changes in fish health, growth, or survival (e.g., number of fish mortalities, fish tissue metal content, fish community composition) can occur from changes to fish habitat. In the event of an explosion near a waterbody, vibrations and pressure changes may harm fish. Changes in fish health, growth, or survival (e.g., number of fish mortalities, fish tissue metal content, fish community composition) can occur because of chronic or acute toxicity to fish populations.

Based on definition of significance for fish and fish habitat (see Chapter 17), a significant residual effect would occur if the productivity and sustainability of fish populations along the Mackenzie Valley Highway corridor are negatively affected. Fish populations that have been affected by fire or explosion are expected to recover and not affect the long-term sustainability of fish populations. Given that large explosions or fires are unlikely and the localized effects of smaller events, residual effects on fish and fish habitat are considered not significant.

25.8.2.6 Vegetation

Fire, if it spreads beyond the project footprint, can affect an adjacent forest, which can affect vegetative communities in addition to the structure and function that forests provide to wildlife. Following a fire event, the presence of certain wildlife (i.e., caribou) can be altered due to burn area avoidance, or deterrence from the area due to changes in the habitat. Alternatively, fire may also create increased browse habitat for several mammals such as moose. Benefits of fire in boreal ecozones include natural regeneration of fire-dependent plant species, natural forest succession, and nutrient cycling. Following fire, human recreation and traditional use may be affected, both visually and functionally, until the forest regenerates back to mature tree stands.

Based on the definition of significance for vegetation (see Chapter 18), a significant adverse residual effect on vegetation and wetlands is one that would threaten the long-term persistence or viability of plant communities or species, including those of cultural or traditional importance, or would threaten the long-term viability of local or regional wetland function. Due to the anticipated limited extent of a project fire or explosion, the residual effect on vegetation is considered not significant. Fires or explosions big enough to cause significant effects outside the project footprint are unlikely.

25.8.2.7 Wildlife and Wildlife Habitat and Birds and Bird Habitat Including Moose and Caribou

Wildfire in the NWT is common and characteristic of boreal forest regeneration dynamics, and the effects on wildlife and wildlife habitat will depend on the size of the fire—primarily whether it spreads to adjacent forest. The sensory disturbance associated with an explosion can cause a change in wildlife movement dependent on the size and location. A large explosion may temporarily cause wildlife and birds to leave the area due to noise, light, and smell, but they would be anticipated to return following the event. Most fires are expected to be contained within the project footprint by applying fire response measures. In the case of a fire that spreads to the surrounding forest becoming a large fire, availability of habitat and food for wildlife over the burned area could be affected over the long term. Such changes would approximate natural changes in the landscape due to fires. As noted in Chapter 10, existing fire disturbance already contributes to the exceedance of a habitat-based conservation threshold for boreal caribou.

For animals in the vicinity of a wildfire, there is potential for injury, entrapment, exhaustion, and mortality if the animal is unable to leave with sufficient time. Burned areas may be avoided by some species due to a lack of functional habitat and food sources; however, early successional vegetation species will return. The definition of significance for caribou and moose (Chapter 10), wildlife and wildlife habitat (Chapter 19), as well as for birds and bird habitat (Chapter 20), is an effect that causes or further contributes to the exceedance of a conservation-based threshold or threatens the long-term persistence or viability of a species at risk, a species of conservation concern, or a species of cultural or traditional importance. A fire or explosion would not be expected to threaten the long-term viability of a species; but would further contribute to an existing exceedance of the conservation-based threshold for boreal caribou. Applying the definition of significance, the residual effects on most wildlife and wildlife habitat and birds and bird habitat is considered not significant. The effects of a project-caused wildfire on caribou would be significant. Given the mitigation in place, a large wildfire caused by the Project is unlikely.

25.8.2.8 Cultural and Traditional Land and Resource Use and Heritage Resources

Fires in the NWT are naturally occurring and common; however, land, resource use, and culture and heritage resources could be affected by a project-related fire or explosion event that spreads beyond the project footprint into areas that may be important for cultural use, by affecting heritage sites, displacing harvested species, or causing fish mortality. The effects on cultural use and heritage resources will depend on the location, extent, and severity of the event. Mitigation measures will be effective at limiting the risk of spread of fire beyond the project footprint. The value of a cultural use area or heritage resources may be affected in the years following a fire. If a fire were to occur due to the Project, the effect would not be markedly different than naturally occurring fires.

The significance of effects on culture and traditional land use (see Chapter 11) is defined as a long-term loss of availability of cultural and traditional use resources, or access to lands, cultural use sites, and areas relied on for cultural use practices, such that cultural and traditional use is critically reduced or eliminated. A general definition of significance does not exist for heritage resources (see Chapter 22) and a site-specific determination is required. As the residual effects from fires and explosions are unlikely, and described as small extent, they will not result in a long-term loss or an elimination of traditional use and are, therefore, considered not significant. A fire or explosion caused by the Project may change the way individual traditional land users use an area or resources, based on the perceived effects or changes to the value of the affected area or resource.

25.8.2.9 Human Health and Community Wellness

Community well-being and health conditions may be affected through changes to the availability of wildlife, fish, and plants that are harvested for country foods and the perceived quality of country foods. Changes to harvested foods or food availability can directly affect health and wellness of people in the local communities. Health can also be affected by changes in local air quality while nearby fires burn.

Community wellness may also be affected by project accidents such as a fire or explosion due to potential for injury. Evacuations of construction camps or even a community may be needed in the event of a serious explosion nearby, or an approaching fire. Fires can also damage or destroy homes or bush camps. Wellness can also be affected by the inability to practice cultural traditions and on the land activities. Community members may be displaced for a period while the risk of injury is addressed. Mitigation measures such as fire prevention and response, training in safe handling, and storage of materials will be effective at reducing the risk of a fire/explosion which adversely affects human health and community wellness.

The definition of a significant adverse effect on human health and community wellness (see Chapter 9) is one that causes or further exacerbates adverse health and community wellness conditions that contributes to a decline in physical, mental, and/or social health. Fires and explosions are singular events that can affect individuals and may contribute, exacerbate, or cause overall trends in community wellness. While explosions or a fire in a camp could affect individuals in a significant way, such events are very unlikely. The effects of fires and explosions on community wellness are, on a conservative basis, considered significant but unlikely.

25.8.2.10 Infrastructure, Services, and Institutional Capacity

In the event of a fire or an explosion, it is anticipated that emergency response capabilities at the project site (e.g., firefighting) will be sufficient for most accidents during construction; however, an accident involving multiple injuries or widespread effect may require support from the surrounding communities or service providers, such as if there is a need for evacuations or additional emergency services. As this type of event is considered unlikely, community services should not experience regular disruption. Effects on community services and infrastructure would be short-term in duration and likely reversible. A significant effect would be one where there is a lack of available capacity or a substantial decrease in the quality of a service provided on a persistent and ongoing basis. On this basis, the residual effect on community services and infrastructure from an accident or malfunction is considered not significant given the expectation of adequacy of available response in addressing potential effects on Infrastructure, Services, and Institutional Capacity.

25.8.3 Transportation, Storage and Manufacture and Use of Explosives

The project design has been developed to prevent accidents and malfunctions related to the transportation, storage, manufacture, and use of explosives. Uncontrolled events involving explosives can lead to environmental contamination from spills of ammonium nitrate prill or manufactured emulsions or an unplanned detonation of explosives. To avoid or reduce accidents and malfunctions associated with explosives, the Project's ExMP will include measures such as pad locations to manufacture explosives that are separated from work and camp sites, secure storage of bulk materials and detonators, and cleared vegetation around isolated storage locations to limit the spread of fire.

In addition to design features, several safety measures will be implemented to reduce the potential for fire and explosion malfunctions or accidents as a result of the Project. These include the following:

- The management of explosives will be in accordance with environmental protection measures, territorial and federal legislation, and guidelines. All blasting activities will be performed by ticket-qualified contractors with strong safety track records. The ExMP will include measures for the safe transportation, storage, manufacture, and use of explosives.
- A licensed contractor will be hired to handle explosives sourcing and handling.
- All project blasting will be conducted as per standard safety procedures and regulations, which includes blast timing and communications, blast radius sweep, road signage, warning alerts, and radio announcement.
- The explosives manufacturing and bulk storage facility will be located using regulation setbacks from other project-specific facility components. The explosives storage area and manufacturing plan will be restricted to authorized employees only and the access road signed per regulations.
- Storage of ammonium nitrate will be kept in a dry location away from rain and runoff to prevent migration of contaminants.
- The Project will apply an ERP, SCP, WMP, Quarry Development Plan (QDP), and an ExMP.
- Fire and safety protection, in addition to climate controls, moisture controls and ventilation, will be applied in the explosives manufacturing and storage facility.
- The licensed explosives contractor will provide measures to address potential effects and health and safety considerations.

- The Project will only apply the necessary amount of explosives during blasting operations to reduce effects of potential accidents.
- The project borrow sources are not located in proximity to fish and fish habitat where pressure changes could cause harm.

In addition, to reduce ground-based transportation accidents during construction, the Project will rely on several control mechanisms and safety practices. Project work areas will be closed to the public during construction, allowing for strong worksite control by the GNWT and subcontractors. By limiting the likelihood of the public from driving into the Project's work areas, accidents are less likely to occur. By restricting public access where and when needed for safety reasons, pedestrians are less likely to also contribute to transportation accidents in these areas.

Accidents or malfunctions associated with the transportation, storage, manufacture, and use of explosives could be caused by failures, including equipment or machinery malfunction, improper use or storage of bulk explosive materials, vehicle accidents involving transport of emulsion or bulk materials, and migration of blast residue contaminants.

Ammonium nitrate is classified as a hazardous substance and will be transported in bulk via truckload shipments for manufacture of blasting emulsion. The safe transport of these bulk shipments is required so that accidents do not result in spills of ammonium nitrate. The substance is shipped in a solid prill form. Should an accident or malfunction occur releasing ammonium nitrate onto land, immediate clean up would result in negligible effects on the environment. The use, manufacture, and handling of explosives during the winter months poses lower environmental risk. Spills during winter will have less likelihood to mix directly with aquatic environments due to many waterbodies being frozen. Spill response procedures would be applied immediately following a spill incident.

Storage of bulk ammonium nitrate prill will occur on-site in a secured location and in accordance with the appropriate legislation and guidelines. Bulk explosive materials, emulsion, and detonators will be stored separately. Routine inspection and monitoring of storage and manufacture areas will be performed so that bulk materials and emulsion are not entering the receiving environment.

Small batch manufacture of blasting emulsion will be conducted to reduce the potential for accidents. Safe transportation of emulsion at low speeds with traffic control protocols is common practice to reduce collisions, accidental charge, or accidental release of emulsion material. The emulsion plant will be operated and maintained in accordance with environmental protection measures, territorial and federal legislation, and guidelines.

Mixing of emulsion will not occur in the vicinity of waterbodies or watercourses, preventing migration of contaminants. Furthermore, drainage from quarries and the project site will be managed via the QDP so that blast residue water is not flowing into surrounding waterbodies or watercourses.

25.8.3.1 Air Quality and Noise

The effects on air quality and noise from an uncontrolled detonation are the same as those for fire and explosion and are characterized as not significant.

25.8.3.2 Terrain, Soils, Permafrost

The effects on terrain, soils, and permafrost from a spill or fire, are the same as those described for a small spill of fuel or hazardous material, since the solid material is not likely to mix with soil. They are characterized as not significant.

25.8.3.3 Surface Water and Sediment Quality

In the rare event of a transportation accident or equipment malfunction involving bulk materials or manufactured explosives near a waterbody, ammonium nitrate, fuel, or manufactured emulsion could spill or dissolve in water and enter the ecosystem. Accidents and malfunctions on dry land allow for cleanup; however, aqueous environments do not provide the same option. In winter, where waterbodies will be frozen, cleanup will be effective per the SCP. If prill enters water, there may be limited opportunity to clean up the spill except to limit how much enters the water. The severity of effects on water and sediment quality of a spill into water will depend on the location and amount spilled. A spill into an interconnected waterbody may change water quality over a greater area, but this may be mitigated by dispersion. A spill contained in a waterbody may affect sediment and water quality in the waterbody but may limit the effect on this area.

Using the significance definition from the water and sediment quality assessment (see Chapter 16), a significant residual effect on water quality and/or sediment quality is one that is likely to result in a measurable change in parameters that exceed relevant water quality and sediment quality guidelines and adversely affect ecological and/or human receptors. Due to the anticipated small amounts of prill to be transported, the residual effect on water and sediment quality is expected to be not significant.

25.8.3.4 Fish and Fish Habitat

An uncontrolled blast that occurs in proximity to fish and fish habitat (within 100 m) would create noise, vibration, and pressures change, which is likely to affect fish depending on the size of blast, size of waterbody, and depth of water. Accidental release of ammonium nitrate or manufactured emulsion has potential to harm waterbodies, fish, and aquatic organisms, as discussed in the section on water quality. It is unlikely that an uncontrolled blast would occur in a location other than one of the existing quarries due to these locations being expected to contain temporary storage of manufactured explosives. Quarries are located more than 100 m from fish-bearing waterbodies. Due to the short-term nature and anticipated distance of an accidental detonation from fish and fish habitat, and its isolated incidence, potential residual effects on fish and fish habitat is considered not significant.

25.8.3.5 Cultural and Traditional Land and Resource Use

If an accident or malfunction results in an accidental release of ammonium nitrate prill, the ability to access areas for recreation or traditional use (fishing, trapping) may be temporarily affected in the vicinity surrounding the incident location, thus temporarily affecting cultural use of the area. Mitigation measures to clean up a spill on land are expected to be effective and the spill will be limited to the project footprint, which may have limited cultural use. An unintended blast would be expected to occur within an existing quarry, which would not incrementally contribute additional effects on cultural use from those of regular project activities. The residual effects on cultural use from an accidental release of ammonium nitrate prill or an accidental detonation are expected to be not significant.

25.8.3.6 Human Health and Community Wellness

In a malfunction scenario, release of emulsion or ammonium nitrate contaminants could migrate to waterbodies with effects on fish. These changes in water and country food quality would be very unlikely and limited but it could influence the well-being of local people who live in proximity of the project site district and who take part in hunting, trapping, traditional, and recreational activities. While fish populations would ultimately return, there is potential for contamination of fish tissue and health due to long-term contamination of bottom sediments where constituents of the blast emulsion may settle. A considerable amount of construction work is scheduled during the winter, making for easier containment and cleanup of spills.

Using the definition of significant adverse effect on human health and community wellness as one that causes or further exacerbates adverse health and community wellness conditions that contributes to a decline in physical, mental, and/or social health, with the application of mitigation, residual effects of malfunctions related to spills associated with the use of explosives on human health and community wellness would be not significant.

In situations where an uncontrolled blast occurred as an aspect of explosive usage, while very unlikely, there is potential for human injury or death. In circumstances where there is injury due to an uncontrolled blast, the event would be considered significant.

25.8.4 Transportation Accidents

The project design has been developed to prevent transportation accidents, particularly where accidents are most likely to occur or in high-risk areas. The highway is designed to support an operating speed of 80 km/h and includes design safety considerations. To reduce potential for accidents between project vehicles and other users of the highway, the highway has been designed with a wide cross section and wide ROW clearances, including posted speed limits and adequate signage for safe driving. The design includes 3:1 slopes and low embankment heights, in addition to optimal horizontal and vertical alignment to meet desired minimums wherever possible. In comparison to the MVWR, the new highway design includes optimized alignments for smoother curves and better visibility. Bridges also include guardrails to reduce accident severity around watercourses.

In addition to design considerations, several safety measures will be implemented to reduce the potential for transportation accidents as a result of the Project. These include:

- Implementation of best management and industry practices, as appropriate, to prevent or reduce the occurrence of vehicle accidents and driver error which may lead to transportation accidents due to collisions, roll over, or loss of control, such as:
  - Project vehicles will be driven by trained and competent drivers.
  - The project site during construction and operations will rely on traffic control speed limits, weight restrictions, and signage for safe driving conditions.
  - Project vehicles and equipment will undergo inspection prior to use by an operator.
  - Project vehicles will be required to have beacon lights and flagging.
  - Radio communication controls between project vehicle and equipment operators
  - Zero access policy for members of the public during construction
  - Regular updates on road changes during construction and operations and maintenance
- All on-site contractors will have industry-compliant and satisfactory Health, Safety and Environmental policies, programs, and manuals that will be successfully implemented throughout the Project.
- The GNWT and its contractors will follow all management plans and the ERP, which addresses potential transportation accidents and malfunctions for the Project.
- Regular public updates on road conditions and closures via the GNWT Department of Infrastructure website. Road closure signage will be posted at the physical site where appropriate.
- On-going maintenance of the road to repair degraded areas will provide safer driving conditions.
- Operational use of the road will include highway enforcement of speed limits and safe driving laws.
- Signage will be posted to identify known animal crossings or key habitat areas to prevent animal collisions with vehicles.

The GNWT will use emergency response services based at the project site that are sufficient in capacity and capability to respond to emergency events. An ERP and an SCP will be prepared to assist in the reaction to emergency scenarios related to transportation accidents that may arise at the project site, such as collisions with vehicles, equipment, or wildlife. The ERP will be developed in accordance with federal and territorial laws and regulations, in addition to the GNWT policies and procedures that are protective of the environment and human health. Emergency response planning, training, clean up equipment or supplies, and contact and reporting procedures will be enforced with subcontractors and workers for the duration of the project construction and operations/maintenance.

Due to the ability to control project traffic interactions in a closed project site (for example during construction activities), the event of transportation accidents is limited; however, in the event of an accidental collision from the operation of vehicles or heavy equipment, there is potential for human or wildlife mortality or injury, fuel or hazardous material spills, and fire.

Highway design features, such as signs and speed control, will play a key role to prevent accidents. Speed control signage will be posted to communicate safe driving speeds to road users. The posted limit of 80 km/h is low compared to most highways, giving users suitable reaction time to drive defensively during adverse weather conditions or during unexpected animal encounters. The GNWT posts all territorial road conditions and road closures on the Department of Infrastructure website. Signage will be deployed near key animal habitat areas or known crossings where animals frequent to elevate driver awareness. Signage will be posted to limit littering and inadvertent feeding of wildlife to avoid attracting wildlife to the highway.

In the event of a collision from the operation of vehicles or heavy equipment, there is potential for human or wildlife mortality or injury, fuel or hazardous material spills, and fire. Air- and water-based transportation incidents will not be associated with the operations and maintenance phase of the Project.

The project area hosts terrestrial and avian species that may interact with traffic. During construction, the Project will enforce environmental awareness training and speed limits to allow drivers to operate their vehicles in a defensive manner with greater reaction time should wildlife intercept traffic. An accident involving animals may induce injury or death to vehicle operators or the animal. The presence of wildlife will be monitored and communicated to site personnel via radio when wildlife are observed in the area. When wildlife are present on the road or ROW, site staff will be required to stop or idle their vehicle or equipment to allow for safe passage. The most substantial animal interaction will be with large-bodied mammals such as moose and caribou, and large avian species.

Day-to-day use of the road during construction will also use signage and construction updates to be posted or shared daily during toolbox safety meetings. By sharing information about the road conditions, drivers are aided in defensive driving. Furthermore, by providing these updates daily, workers can stay up to date on changes in the road conditions or other temporary site hazards while the road quality changes due to advancement of the construction plan.

In terms of the risk for transportation accidents, those involving animals are a project concern for wildlife and human health VCs. Informal observations of vehicle-wildlife collisions are tracked by the GNWT (Armstrong, 2021, pers. comm.). The data collected at this time does not include Sahtu and Beaufort Delta regions; however, Highways #1 and #7 in the Dehcho and South Slave Regions show comparable data to infer possible effects related to the Project. Based on this dataset from 2009 to 2016, five collisions with boreal caribou were recorded, suggesting that on a comparable highway such as the Mackenzie Valley Highway, the Project might anticipate one collision a year. The traffic volumes estimated for the Project are less than 50 vehicles per day, which is a very low potential for animal-vehicle interactions on the highway.

Human safety is directly affected by collisions, loss of control, or malfunctions which can be associated with driver error, adverse driving conditions, or the presence of wildlife. The presence of vehicles during operations has the potential to increase collision incidences in the region and territory, resulting in temporary delays in road traffic, road closures, damage to property, injury, or death.

Transportation accidents may also pose a risk to wildlife. Collisions with wildlife can lead to injury or mortality of animals that intercept vehicle traffic. Bird species and large mammals such as moose and caribou are the most likely to be involved in a transportation collision.

Transportation accidents can also result in spills of hydraulic fluids, fuel, or release of hazardous substances that may be hauled as delivery cargo. The effects of transportation accidents in relation to fuel or hazardous material spills can be reviewed in Section 25.5.1.

25.8.4.1 Wildlife and Wildlife Habitat, Birds and Bird Habitat and Caribou and Moose

Vehicle interaction with wildlife can cause mortality with likelihood to affect a wide range of species, including non-migratory and migratory birds, species at risk and species of conservation concern, small mammals, and large mammals such as caribou and moose. Posted speed limits and enforcement of safe driving practices will be enforced during both the construction and operations and maintenance phases of the Project to reduce wildlife-related transportation accidents. Residual effects from a vehicle accident on wildlife (direct mortality) are characterized in Chapter 10. Due to low traffic volume, it is not anticipated that there will be a substantial increase in mortality, and therefore is not considered significant.

25.8.4.2 Human Health and Community Wellness

Transportation accidents have the potential to result in injury or loss of human life due to collisions. In 2019, the NWT Bureau of Statistics reported that there were 535 total reported collisions on NWT highways with 12.1% of all collisions resulting in injury or fatality (GNWT, 2019). Of the 535 total reported collisions, 28 involved alcohol impairment. Of these 28 incidents, 10 collisions resulted in injury and 2 resulted in death. In 2019 there were 4 reported fatalities and 61 reported injuries on NWT highways; 2 of the 4 collision fatalities in 2019 were related to alcohol impairment. A serious transportation accident may close the highway for several hours. This type of closure would not likely affect people's ability to access goods or services and is therefore considered not significant.

Injury or fatalities on NWT highways are statistically low and, with respect to the Project, these rates would continue to stay low due to the aforementioned safety measures and design features. In the event of human fatality or injury in the context of small communities where it is common to see interconnected relationships and large families, fatality can have a widespread effect on community wellness due to widespread grief. In the unlikely event of a vehicle collision resulting in serious injury or loss of life, the outcome would be considered significant.

25.9 Summary

The Project is planned and designed to reduce the potential for occurrence of accidents or malfunctions. If an accident or malfunction occurs, emergency response procedures aimed at lessening significant effects on people and the environment will be deployed.

Where accidents and malfunctions have been found to be likely to occur, mitigation measures in management plans are aimed at preventing and reducing the effect of their occurrence. Likely events will be small, contained within work areas, and within the Project's capacity to respond before adverse environmental effects occur, and would not be vulnerable to external events such as climate or weather. For example, events like spills during refueling, small oil spills from equipment, or damage to an ammonium nitrate bag will have site personnel present to identify, report, and correct for the issue at hand. Such events are unlikely to have a significant effect.

Unlikely accidents or malfunctions with increased significant effect may involve residual effects to the following VCs:

- A spill (> 1,000 L) to the environment (e.g., spill into local waterbodies, soils, and other habitats outside the project area), where effects on terrain, soil, and permafrost and surface water and sediment quality could be significant.
- Fire and Explosions, where effects on caribou, and human health and community wellness could be significant.
- Transportation, Storage, Manufacture, and Use of Explosives could have potential to cause serious injury or death and though unlikely, in such cases the effect would be considered significant due to human health and community wellness.
- Transportation Accidents, where an incident could be considered significant in relation to human health and community wellness

On a project of this magnitude, unintended accidents and malfunctions are expected to occur. After taking into consideration project design and safety measures, there is low likelihood of accidents and malfunctions that could lead to significant effects on the assessed VCs.

25.10 References

25.10.1 Literature Cited

Canadian Council of Ministers of the Environment (CCME). CCME EPC LST PN 1326 – October 2003, Environmental Code of Practice for Aboveground and Underground Storage Tank Systems Containing Petroleum and Allied Petroleum Products.

GNWT (The Government of the Northwest Territories). 2001. Forest Fire Prevention And Suppression Guidelines For Industrial Activities. Available at: https://www.enr.gov.nt.ca/sites/enr/files/industrial_guidelines_forest_fire_prevention_suppression.pdf

GNWT-ENR (The Government of the Northwest Territories Environment and Natural Resources). 2017. Guideline for Hazardous Waste Management. Available at: https://www.enr.gov.nt.ca/sites/enr/files/resources/128-hazardous_waste-interactive_web_0.pdf

GNWT-ENR. 2019. Barren-ground Caribou Habitat and Fire. Available at: https://www.enr.gov.nt.ca/sites/enr/files/resources/caribou_fire_fs_en.pdf#:~:text=Fire%20is%20a%20natural%20and%20important%20part%20of,Fires%20do%20not%20burn%20uniformly%20across%20the%20landscape. Accessed May 2022.

GNWT-ENR. 2022. Wildfire Science. Available at: https://www.enr.gov.nt.ca/en/services/wildfire-operations/wildfire-science. Accessed April 2022.

GNWT-NWT Bureau of Statistics. 2019. Reported Collisions, injuries and fatalities by year, 1989-2019. Available at: https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.statsnwt.ca%2FTransportation%2FRoads%2FTable%2520109-Reported%2520Collisions%2C%2520Injuries%2C%2520and%2520Fatalities%2520by%2520Year%2C%25201989%2520to%25202020.xlsx&wdOrigin=BROWSELINK. Accessed April 2022.

INAC (Indian and Northern Affairs Canada). 2007. Guidelines for Spill Contingency Planning. Accessed from: https://www.enr.gov.nt.ca/sites/enr/files/guidelines_for_spill_contingency_planning_2007.pdf.

NWRRC (Norman Wells Renewable Resource Council). 2023. Norman Wells Renewable Resources Council Traditional Land and Resource Use Study for Tulita District Mackenzie Highway Project. Prepared by K'alo-Stantec Limited. Prepared for Norman Wells Renewable Resources Council.

MVEIRB (Mackenzie Valley Environmental Impact Review Board). 2015. Terms of Reference EA1213-02 Mackenzie Valley Highway Extension Project Wrigley to Norman Wells Government of Northwest Territories. February 13, 2015. PR#66.

TRRC (Tulita Renewable Resource Council). 2022. Tulita Renewable Resources Council Traditional Land and Resource Use Study for Tulita District Mackenzie Highway Project. Prepared by: K'alo-Stantec Limited. Prepared for Tulita Renewable Resources Council.

25.10.2 Personal Communications

Armstrong, T. (The Government of the Northwest Territories, Environment and Natural Resources). 2021. Personal communications with J. Krizan (EDI Environmental Dynamics Inc.), April 21 2021 (email).

26.0 CUMULATIVE EFFECTS ASSESSMENT SUMMARY

26.1 Introduction to the Cumulative Effects Assessment Summary

The purpose of Chapter 26 is to present the assessment of the cumulative effects of the Government of the Northwest Territories' (GNWT's) Mackenzie Valley Highway Project (the Project) in combination with past, present, and reasonably foreseeable future developments, as required by the Terms of Reference (ToR) issued for the Project (MVEIRB, 2015 [PR#66]).

This chapter consolidates methods for cumulative effects assessment and assessment of cumulative effects on valued components (VCs) as presented in Volumes 2 and 3.

26.1.1 Purpose of the Project

The Project will include construction of approximately 281 kilometres (km) of new all-season gravel highway between Hodgson Creek (located 1 km north of Wrigley) and Prohibition Creek (located 28 km southeast of Norman Wells). The Project will connect to existing watercourse crossing structures (bridges and culverts) along the Mackenzie Valley Winter Road (MVWR), previously constructed highway between Prohibition Creek and Norman Wells, and the Great Bear River Bridge project in Tulita, which will be advanced as a separate project.

The Project will also include the construction and operation of temporary and permanent quarry and borrow sources, as well as the operations and maintenance of a contiguous total of approximately 321 km of highway between Wrigley, Tulita, and Norman Wells.

The vision of an all-season highway through the Mackenzie Valley to the Arctic Coast has been a strategic priority for Canada since 1958, under the "Roads to Resources" program. This vision is restated in several of the GNWT strategic investment documents, including *Investing in Roads for People and the Economy: A Highway Strategy for the Northwest Territories* (GNWT, 2000); in the successful funding proposals *Corridors for Canada* (GNWT, 2002) and *Corridors for Canada II* (GNWT, 2005); and in *Connecting Us - NWT Transportation Strategy 2015-2040* (DOT, 2015a).

The purpose of the Project is to provide the needed infrastructure to support an improved quality of life and lower cost of living for territorial residents in the Mackenzie Valley and support the expansion and diversification of the territorial economy.

The Project will connect communities via an all-season road that connects the existing highway at Wrigley, to Tulita and Norman Wells providing reliable access that connects isolated communities to the national highway system. Improved access will incentivize resource exploration and development opportunities in the region, while creating social and economic benefits for territorial and Canadian residents.

In 2015, the GNWT prepared a project-specific Business Case to outline the purpose, benefits, and cost of the Project (GNWT, 2015b; Appendix 1A). Each of the Project purposes described in the Business Case are outlined in Section 1.2. Regarding benefits, over the length of the Project, the Business Case estimated that a total of 14,000 direct and indirect jobs will be created during the construction phase, with 160 jobs created once the highway is operational (GNWT, 2015b).

At the time the Business Case was developed, the Project was projected to cost over $700 million to construct (GNWT, 2015b). Similar to infrastructure projects across Canada, it is anticipated that Project costs will have escalated significantly since it was originally estimated. Upon completion of the detailed design for the Project, the Business Case and associated cost estimates will be updated.

26.1.2 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 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 cumulative effects. This feedback has been considered and summarized in Table 26.1 and has been integrated into the summary of cumulative effects that follows.

Table 26.1 Summary of Engagement Feedback

<table>
<tr><th>Comment</th><th>Source</th><th>GNWT Response</th><th>Where Addressed</th></tr>
<tr><td>There is general support to construct an all-season road. Community engagement participants shared that they support the highway but want to see it built in a sustainable way that will support future generations.</td><td>August 2021 Engagement; April to July 2022 Engagement; November to December 2022 Engagement; November 2022 to February 2023 Engagement</td><td rowspan="5">The Project is being proposed to provide the needed infrastructure to support an improved quality of life and lower cost of living for territorial residents in the Mackenzie Valley and support the expansion and diversification of the territorial economy.
The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning.</td><td rowspan="5">Chapter 5, Section 5.2.3 for more information about project design considerations
Chapter 9 (Socio-economic Impact Assessment)
Chapter 10 for more information about caribou and moose
Chapter 17 for more information about fish and fish habitat</td></tr>
<tr><td>Norman Wells engagement participants noted that the road is a necessity and expressed general support for it. The highway is needed to revitalize the town. It is important for economic development. The town is suffering economically with Imperial Oil's production decreasing. They stated that the road will allow all-season access and make it easier for remediation in Norman Wells by Imperial Oil Resources.</td><td>November to December 2022 Engagement</td></tr>
<tr><td>Community engagement participants asked that cultural and social well-being be considered in highway development. Participants want to ensure that the road does not negatively affect future generations.</td><td>August 2021 Engagement; April to July 2022 Engagement; November to December 2022 Engagement; November 2022 to February 2023 Engagement</td></tr>
<tr><td>Community engagement participants expressed eagerness for the opportunity to participate in the construction activities as a community but also had concerns about the vulnerability of local economic activities to the introduction of bigger players. For example, the local firewood vendors versus the more established companies.</td><td>April to July 2022 Engagement</td></tr>
<tr><td>Community engagement participants commented that the Project provides benefits to the Sahtu Region apart from access to the communities, such as access to more resources, and programs like the Guardians' program (tuyetakgf.ca) getting more publicity in the south.</td><td>April to July 2022 Engagement</td></tr>
</table>

Comment	Source	GNWT Response	Where Addressed
Community engagement participants generally noted that the Project would increase opportunities for resource exploration and extraction industries. They noted that this brings with it risk of over-exploitation of minerals due to increased access.	April to July 2022 Engagement; November to December 2022 Engagement		
Community engagement participants generally noted that the Project would increase opportunities for the tourism industry in the Sahtu Region.	August 2021 Engagement; April to July 2022 Engagement; November to December 2022 Engagement; November 2022 to February 2023 Engagement		

26.1.3 Context of Project in Land and Resource Management Planning

26.1.3.1 Land Tenure Agreements

The Project will include activities on Territorial Lands and Commissioner's Lands (public) and Sahtu Settlement Lands as identified in the Sahtu Dene and Métis Comprehensive Land Claim Agreement (SDMCLCA; 1993). Where land tenure or ownership is required for infrastructure on Sahtu Settlement Lands (e.g., quarries, borrow sources, access roads, and new portions of the highway right-of-way [ROW]), the GNWT will negotiate the appropriate terms and conditions with the Tulita District Land Corporation Ltd. The existing MVWR is located on Commissioner's Land, except for several small portions that are located on Sahtu Settlement Lands and authorized through lease with provisions for land exchanges that are at various stages of being completed.

The current project footprint, inclusive of the highway ROW, access roads, and maximum extent of all 15 quarry/borrow sources, conservatively intersects approximately 360 hectares (ha) of Sahtu Settlement Lands in the Tulita District. This area does not take into account the existence of a 60 metre (m) ROW through these Sahtu Settlement Lands for the MVWR, some of which will be shared by the Project. The final highway alignment (and other components of the project footprint) to be constructed will be determined subject to design and safety considerations, the outcome of the environmental assessment, and in consultation with the Sahtu Secretariat Inc, as identified in Schedule XVII of the SDMCLCA.

To prevent future dispositions on those portions of the proposed highway that are on public land, the GNWT-INF will apply for a reservation by notation (reserve) from the GNWT Department of Environment and Climate Change (ECC). A reserve approach is used by the GNWT to preserve and set aside land for a public purpose, as provided for in Section 19(b) of the *Northwest Territories Lands Act* and Section 4 of the *Commissioner's Land Act*. A reserve is not a sale or disposition of land. Once the Project is constructed and formally designated as a public highway under the *Public Highways Act*, the GNWT-INF will apply to have the reserve relinquished.

The Project will also intersect a 30 m wide easement through Territorial Lands for the Norman Wells Pipeline ROW.

26.1.3.2 Sahtu Land Use Plan

The Project is subject to the Sahtu Land Use Plan (SLUP; Sahtú Land Use Planning Board [SLUPB], 2023). The Project is located within six zones of the SLUP:

- General Use Zones
- Petiniʔah (Bear Rock) Conservation Zone (CZ) (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range Special Management Zone (SMZ) (Zone #50)

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

Specific to the areas to which the SLUP applies, the Project must meet the 13 general conformity requirements (CR) of the SLUP (SLUPB, 2023; Section 6.3). An additional CR (CR#14) applies to the CZs and SMZs. The values to be protected, respected, or taken into account in CZs and SMZs under CR#14 is provided in Section 6.3. The Project can demonstrate conformity to these requirements and does not require an exception to these CRs. The SLUP generally recognizes the Mackenzie Valley Highway as a potential future development to be undertaken in the vicinity of the MVWR.

26.1.4 Scope of Project

The Project includes the following physical works and activities, which are presented in more detail in Chapter 5:

- Clearing of intermittent sections of new ROW and widening of the existing MVWR ROW
- Construction of approximately 281 km of new all-season gravel highway embankment (102 km in the Dehcho Region, 179 km in the Sahtu Region) and intermittent pullouts
- Construction of approximately 85 culverts as watercourse crossing structures
- Construction and operation of approximately 15 borrow sources and quarries and associated all-season access roads:
  - 6 of these will be temporary, to be used to support the construction of the Project only
  - 9 of these will be permanent, to be used during construction, and ongoing operations and maintenance of the Project
- Water withdrawal and water use for road construction and maintenance
- Construction and operation of temporary support infrastructure and workspaces, including camps, maintenance yards, laydown and staging areas, and fuel storage areas
- Staging, supply, and resupply of equipment, materials, fuel, and personnel
- Construction and operation of permanent maintenance yards
- Closure and reclamation of temporary borrow sources, quarries, and workspaces
- Demobilization of equipment and materials
- Closure and reclamation of portions of the MVWR ROW not used for the Project
- Operations and maintenance activities including snow clearing, grading, dust control, and bridge and culvert maintenance
- Use of the highway by the public

The Project does not include:

- Construction of the Great Bear River Bridge project, which is being advanced as a separate project
- Operations and maintenance of the MVWR as required for public safety, including repair or upgrades of existing watercourse crossing structures, until such time that segments of the Mackenzie Valley Highway (the Project) are opened to traffic and replace the MVWR. All existing watercourse crossing structures (bridges and culverts) along the MVWR as well as the Great Bear River Bridge (after it is constructed) will be integrated into the operations and maintenance of the Project.
- Use of existing and authorized municipal, commercial, or public infrastructure or services, such as municipal solid waste and wastewater facilities, transportation services and the MVWR

26.1.5 Temporal Boundaries

The Project will take place over the following timeframes, which are used in the assessment:

- 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, as the Project is not likely to be constructed as a single, continuous project. The conceptual schedule assumes the alignment will be constructed in three consecutive segments, beginning in approximately 2026:
  - Segment 1: Wrigley north to the Dehcho–Sahtu border (102 km)
  - Segment 2: Tulita south to the Dehcho–Sahtu border (134 km)
  - Segment 3: 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: Operations and maintenance activities include public use of the highway and activities that are necessary to operating the highway as a public highway under the *Motor Vehicles Act*. The operations and maintenance phase will commence in a staged manner once construction of each segment has been constructed. 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.

26.2 Cumulative Effects Assessment Methods

Cumulative effects assessment requires assessment of residual effects in combination with measurable residual effects from other physical activities (projects) that overlap in time or space. Past, present, and reasonably foreseeable projects whose residual effects may overlap with those of the Project were identified and assessed for each Valued Component (VC) contributing to KLOI and SON and the Project's contribution to the cumulative effect was then evaluated. The approach used for completing the cumulative effects assessment for the Project followed the Mackenzie Valley Environmental Impact Review Board (MVEIRB) guidance (MVEIRB, 2004), best practice, and the ToR (MVEIRB, 2015).

26.2.1 Consideration of Future Projects

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.

As noted in Section 5.5.9.1, and applied throughout the environmental assessment, the Project includes foreseeable use of the highway once constructed. Anticipated traffic volumes on the Wrigley to Tulita to Norman Wells portion of the Mackenzie Valley Highway once constructed will reflect:

- Local traffic travelling between the communities
- Commercial traffic needed for community operations and resupply
- Traffic associated with operating small businesses, such as tourism
- Industrial traffic to support exploration, development, operations, and/or closure and reclamation of natural resource developments such as oil and gas, mining, or forestry

The design of the highway as described in Section 5.2.2 anticipates an average annual traffic volume of 50 vehicles per day, including a mix of vehicles such as pickup trucks and truck trailers up to a weight of 64,000 kilograms (kg). The Low Volume Road design allows for average annual daily traffic of up to 200 vehicles per day.

There are no reasonably foreseeable projects that will increase the number of heavy industrial users, as speculated in the ToR (MVEIRB, 2015 [PR#66]). The highway will accommodate future industrial users up to 200 vehicles per day average daily traffic, within the load limits of the existing bridges. The need to accommodate industrial users or traffic volume beyond the design capacity of the highway and/or address additional maintenance or management actions required will be evaluated if/when these activities are disclosed and will be specific to the type of activity.

The GNWT's Business Case for the Project (GNWT, 2015b; Appendix 1A) promotes the Project as a "link" to connecting Canada's road network and opening new resources to the benefit of Canadians. This suggests that at some time in the future the completed highway may incentivize further development in the Mackenzie Valley that may currently be limited by seasonal access. The location, timing and type of potential future activities cannot be identified even to a conceptual level, particularly given the extended and phased timeframe to construct the Project (up to 20 years). The associated unpredictability of economic, social, political, and technological conditions and trends over this timeframe that might influence such development would lead to predictions of future development that are highly speculative. The existing resource management regime in the NWT is likely equipped to assess the management of cumulative effects from future developments as interest in such development is disclosed. The GNWT, as a land and resource manager, has a key role in the ongoing assessment and management of cumulative effects.

26.2.2 Identifying Potential Cumulative Interactions

Two conditions must be met to initiate an assessment of cumulative effects on a VC:

- The Project is assessed as having measurable adverse residual effects on a VC.
- The adverse residual effects on a VC from the Project might overlap spatially and temporally with measurable residual effects of other physical activities on the same VC.

If either condition was not met, an assessment of cumulative effects was not completed for the VC.

Other projects and physical activities whose effects might act cumulatively with the Project are identified and presented in the project inclusion list ([PIL] see Table 26.2). These projects were identified from:

- Public records available on the Mackenzie Valley Land and Water Board and Sahtu Land and Water Board public registries and geospatial data provided by staff at these boards
- NWT Cumulative Impact Monitoring Program Inventory of Landscape Change Web Viewer
- NWT Centre for Geomatics

These sources were used to help ascertain whether projects could have effects that overlap spatially or temporally within an area of 15 km of the Project Development Area (PDA), which corresponds to the largest assessment area for biophysical VCs.

The PIL identifies known past, present, and reasonably foreseeable human activities whose residual effects could overlap spatially and temporally with the residual effects of the Project on the assessed VCs. Table 26.2 (which is the same as Table 4.2) presents the type of activities, names, proponents, regulatory reference, general location, and timing and duration of these activities. Figure 26.1 and Figure 26.2 present the locations of these existing and known future physical activities. The specific projects and physical activities considered for each environmental effect and their interaction for each VC considered are described further in the VC chapters (Volumes 2 through 4).

Table 26.2 Project Inclusion List

Activity ID[1]	Type of Activity	Project Name/Description	Proponent/ Owners	Regulatory Reference (if available)	Location	Timing and Duration
Past and Present Projects and Physical Activities within 15 km of the PDA						
1	Geotechnical	**Parks Canada Visitor Centre Geotechnical Program:** Four assessments will be conducted on a property located at 30 and 30A Bear Rock Drive within the Hamlet of Tulita prior to construction of a Visitor Centre, office, and warehouse in support of Nááts'ı̨hch'oh National Park Reserve.	Parks Canada	LUP S21S-003	Max Latitude: 64.902044 Max Longitude: -125.586002	August 3, 2021 to August 2, 2026
2	Geotechnical	**Tulita Health Centre Geotechnical Program:** Drilling of boreholes to assess the engineering properties of the soil at the proposed location of the new Health Centre in Tulita	GNWT- Department of Infrastructure (INF) (Sahtu)	LUP S18X-002	Max Latitude: 64.90153 Max Longitude: -125.572583	July 3, 2018 to July 2, 2020
26	Geotechnical	**Prohibition Creek Access Road Geotechnical Program:** A geotechnical drilling program to support engineering design of the road	GNWT - Department of Infrastructure (INF)	LUP S20S-001	Centroid 65° 13' 57" N, -126° 27' 3" W (within the MVWR ROW)	March, 2020

Activity ID[1]	Type of Activity	Project Name/Description	Proponent/ Owners	Regulatory Reference (if available)	Location	Timing and Duration
3	Infrastructure	**Canyon Creek All Season Access Road:** Construction of approximately 14 km of all-season access road from Quarry Road in the Town of Norman Wells to approximately 450 m beyond the existing bridge at Canyon Creek. The project also includes the development of a haul road to a proposed new quarry, upgrades to the access road to Jackfish Lake, and development of a road to proposed camping/recreational areas on Sahtu Lands at Canyon Creek.	GNWT-INF (Sahtu)	LUP S15E-004, WL S15L8-004	Centroid 65° 20' 32" N, -126° 40' 17" W	December 20, 2015 to December 19, 2022
5	Infrastructure	**Délı̨nę Winter Road:** Highway Winter Road Construction & Maintenance Operations, KM 0 to KM 107 of the Délı̨nę Access Road	GNWT -INF	LUP S02E-001	KM 0 to KM 107 of the Délı̨nę Access Road	2002-present (Winter Season)

Activity ID[1]	Type of Activity	Project Name/Description	Proponent/ Owners	Regulatory Reference (if available)	Location	Timing and Duration
6	Infrastructure	**Mackenzie Highway (NWT Highway #1) Operations and Maintenance:** Ongoing highway, airport, marine services, winter roads operations, and maintenance activities	GNWT - Department of Transportation	LUP MV2008E0033 MV2016E0006	Alberta/NWT border to Wrigley	1940 to present
7	Infrastructure	**Mackenzie Valley Winter Road and Délı̨nę Winter Road:** To construct and maintain the Mackenzie Valley Winter Road and the Délı̨nę Winter Road through the Tulita District within the Sahtu Settlement Area	GNWT-INF (Sahtu)	WL S04L8-013	Located from approximately KM 794 to KM 1083 of the Mackenzie Valley Winter Road in the Tulita District	December 23, 2004 to December 22, 2014
8	Infrastructure	**Mackenzie Valley Fibre Link:** Fibre optic cable installation	GNWT-INF	LUP MV2014X0009 WL MV2014L1-0003 LUP MV2014X0027 LUP MV2014L1-0011	Fort Simpson, Wrigley, Délı̨nę, Tulita, Norman Wells, Fort Good Hope(K'asho Got'ine), Colville Lake (K’áhbamítúé), Tsiigehtchic, Inuvik	2014-2016

Activity ID[1]	Type of Activity	Project Name/Description	Proponent/ Owners	Regulatory Reference (if available)	Location	Timing and Duration
9	Infrastructure	**Norman Wells Pipeline Operations and Maintenance:** on and off right-of-way activities to operate and maintain the Norman Wells (Line 21) pipeline from Norman Wells to the Alberta/NWT border. The pipeline was commissioned in 1985. Ongoing permitted activities include use and maintenance of cleared fireguard areas, seasonal trails and shoo flies, all-season roads, campsites, workspaces, borrow source, an airstrip, and application of herbicides. Previously permitted under MV2006P0018 and MV2013P0011. Also included are activities for replacement of a segment of the Line 21 pipeline southeast of KM 158 near Little Smith Creek in the NWT.	Enbridge Pipelines (NW) Inc.	LUP MV2020P0006, WL S20L1-001, LUP S20P-003	From Norman Wells, Tulita, Délı̨nę, Wrigley, Fort Simpson, Fort Liard to halfway to Fort Providence, and all the way to the Alberta/NWT border, see associated map on MVLWB's website.	July 23, 2020 to July 22, 2025

Activity ID[1]	Type of Activity	Project Name/Description	Proponent/ Owners	Regulatory Reference (if available)	Location	Timing and Duration
9	Infrastructure	**Norman Wells Pipeline Operations and Maintenance:** General operations and maintenance of the pipeline, plus support activities: Erosion protection activities on and around Hodgson Creek, near where the creek crosses Enbridge's Line 21 pipeline at KM 305, approximately 10 km northeast of Wrigley; general maintenance; pipeline digs; Great Bear and Mackenzie River Crossing; pipeline construction and operation	Enbridge Pipelines (NW) Inc.	LUP MV2012X0024, LUP MV2002P0009, LUP S99P-009, LUP S17P-005, WL S17L1-004	GPS 63° 20'03" N, 123° 27'30" W	December 18, 2012 to December 17, 2019. October 9, 2002 to October 8, 2007. October 14, 1999 to October 7, 2006. February 7, 2018 to February 6, 2020.
11	Mining Exploration	**Diamond Drilling and Exploration (Wrigley Zinc property):** Near Wrigley	Devonian Metals Ltd.	LUP MV2020C0015, LUP MV2008C0020	Min lat 63°07'00", max lat 63°10'00", min long 123°35'00", max long 123°40'00"	July 2, 2009 to July 1, 2016
12	Oil and Gas	**2D Seismic Acquisition (Tulita):** 60.18 km of 2D seismic acquisition northwest of the Hamlet of Tulita, Tulita District, Sahtu Settlement Area	Explor Geophysical Ltd.	LUP S09B-002	In the area northwest of the Hamlet of Tulita, Tulita District, Sahtu Settlement Area, excluding those portions within the Tulita Block Land Transfer	January 12, 2010 to January 11, 2015

Activity ID[1]	Type of Activity	Project Name/Description	Proponent/ Owners	Regulatory Reference (if available)	Location	Timing and Duration
13	Oil and Gas	**Exploratory Oil and Gas Drilling (Tulita):** 7 to 15 km south of Tulita; proposal to conduct a one to two horizontal fracking operation south of Tulita on exploration licence 466	MGM Energy	LUP S12A-001, WL S12L1-001, LUP S12A-003, WL S12L1-003	Minimum latitude: 64° 40' N Maximum latitude: 65° 00' N Minimum longitude: 125° 35' W Maximum longitude: 126° 00' W	July 23, 2012 to July 22, 2017 & December 19, 2010 to December 18, 2018
14	Oil and Gas	**Exploratory Oil and Gas Drilling (Windy Island):** Approximately 8 km north of Tulita	MGM Energy	WL S10L1-001	Well site windy island J-39 located at latitude 64 ° 58' 42.4" N and longitude 125° 36' 22.8" W; well site windy island contingent wellsite – max latitude 65° 00' N min latitude 64° 53' N and max longitude 125° 47' W min longitude 125° 26' W	December 19, 2010 to December 18, 2018
15	Oil and Gas	**Exploratory Oil and Gas Drilling Project (Summit Creek)**	Husky Oil Operations Ltd.	LUP S05A-007 WL S05L1-004	Summit Creek/Keele River Area approximately 60 km, Southwest of Tulita.	November 3, 2005 to November 2, 2010
16	Oil and Gas	Mackenzie River Dredging (IOLRVL Operations): To facilitate access.	Imperial Oil Resources Ltd.	WL S17L8-005	Max Lat: 65.279236 Max Long: - 126.875789	January 29, 2018 to January 28 2020

Activity ID[1]	Type of Activity	Project Name/Description	Proponent/ Owners	Regulatory Reference (if available)	Location	Timing and Duration
17	Oil and Gas	**Mackenzie River Water Withdrawal (IOLRVL Operations):** 3,500,000 cubic metres (m^3) of water per year for process cooling and injection into the oil reservoir	Imperial Oil Resources Ltd.	WL S03L1-001	Latitude 65° 17' N., Longitude 126 0 51' W	August 29, 2004 to March 24, 2015
18	Oil and Gas	**Slater River Project:** Consolidation of various land use permits (LUPs) and water licenses (WLs) into this one which will act as an Operations Permit and Licence. Consolidated Permits and Licences are S11T-002, S11L3-002, S12F-007, S12L8-007. Husky Oil Operations Ltd. is permitted to increase camp capacity, increase fuel storage, extend the airstrip, convert a winter well pad to new helipad, convert a winter well pad into a new storage area, convert to an all-season barge landing, and allow additional water usage from the Mackenzie River (Deh Cho), hereafter referred to as Mackenzie River, and water use from groundwater well MW-09A and Vermillion Creek.	Husky Oil Operations Ltd.	WL S13L1-006 LUP S13X-003	Minimum Latitude: N 64°35' Maximum Latitude: N 65° 15' Minimum Longitude: W 125°40' Maximum Longitude: W 126°50'	October 24, 2013 to October 22, 2020

Activity ID[1]	Type of Activity	Project Name/Description	Proponent/ Owners	Regulatory Reference (if available)	Location	Timing and Duration
19	Oil and Gas	**Birch Island Barge Landing/Staging Site:** Staging construction and drilling equipment in support of winter drilling programs and equipment in support of summer heli-portable seismic operations	Husky Oil Operations Ltd.	LUP S07T-014	Staging area located at the confluence of Dahadinni and Mackenzie Rivers approximately 120 km SSW of Tulita	September 26, 2007 to September 25, 2012
20	Oil and Gas	**Little Bear River Staging Area:** Staging of equipment in an existing staging area	EnCana Corporation	LUP S03T-003	Confluence of the Little Bear River and Mackenzie River	October 12, 2003 to October 11, 2008
34	Municipal	**Hamlet of Tulita municipal water use, disposal of waste at the solid waste facility and disposal of wastewater at the sewage lagoon**	Hamlet of Tulita	WL S16L3-001, preceded by S15L3-003, S05L3-001	Hamlet of Tulita	Ongoing; current licence expires November 2, 2026
35	Municipal	**Town of Norman Wells municipal water use, disposal of solid waste and wastewater**	Town of Norman Wells	WL S18L3-003, preceded by S18L3-003, N3L3-0095	Town of Norman Wells	Ongoing; current licence expires November 18, 2028
23	Quarrying	**Little Bear River Quarry:** Winter quarrying and gravel haul to acquire granular material for the purpose of stockpiling for community-based infrastructure projects	Hamlet of Tulita	LUP S16Q-003	Approx. 3.0 km SW of Hamlet of Tulita, on Little Bear River (west side of Mackenzie River) Max Lat: 64.882844 Max Long: -125.914375	February 10, 2017 to February 9, 2022

Activity ID[1]	Type of Activity	Project Name/Description	Proponent/ Owners	Regulatory Reference (if available)	Location	Timing and Duration
24	Quarrying	**Sand Bar Quarrying:** To remove sand from the sandbars downstream of Islands 4, 5, and 6 near Norman Wells. The sand will be used for various existing projects.	Imperial Oil Resources Ltd.	S12L8-004, LUP S12Q-004	Islands 4, 5 and 6 in the Mackenzie River near Norman Wells. Within Crown Land which Imperial Leases, as well as	October 25, 2012 to October 24, 2017
25	Remediation	**Norman Wells Soil Treatment Facility:** To deposit waste associated with the construction and maintenance of a land treatment facility accepting and then remediating petroleum hydrocarbon-impacted soils	KBL Environmental Ltd., Mackenzie Valley Environmental Contractors Ltd.	WL S18L1-002, WL S13L8-003	Max Lat: 65.282303 Max Long: -126.746068	March 17, 2013 to October 21, 2023
30	Infrastructure	**Wrigley Water Treatment Plant and Reservoir**	Pehdzéh Kį First Nation Non-Profit Society	LUP MV2014X0014	Wrigley	June 19, 2014 to June 18, 2019

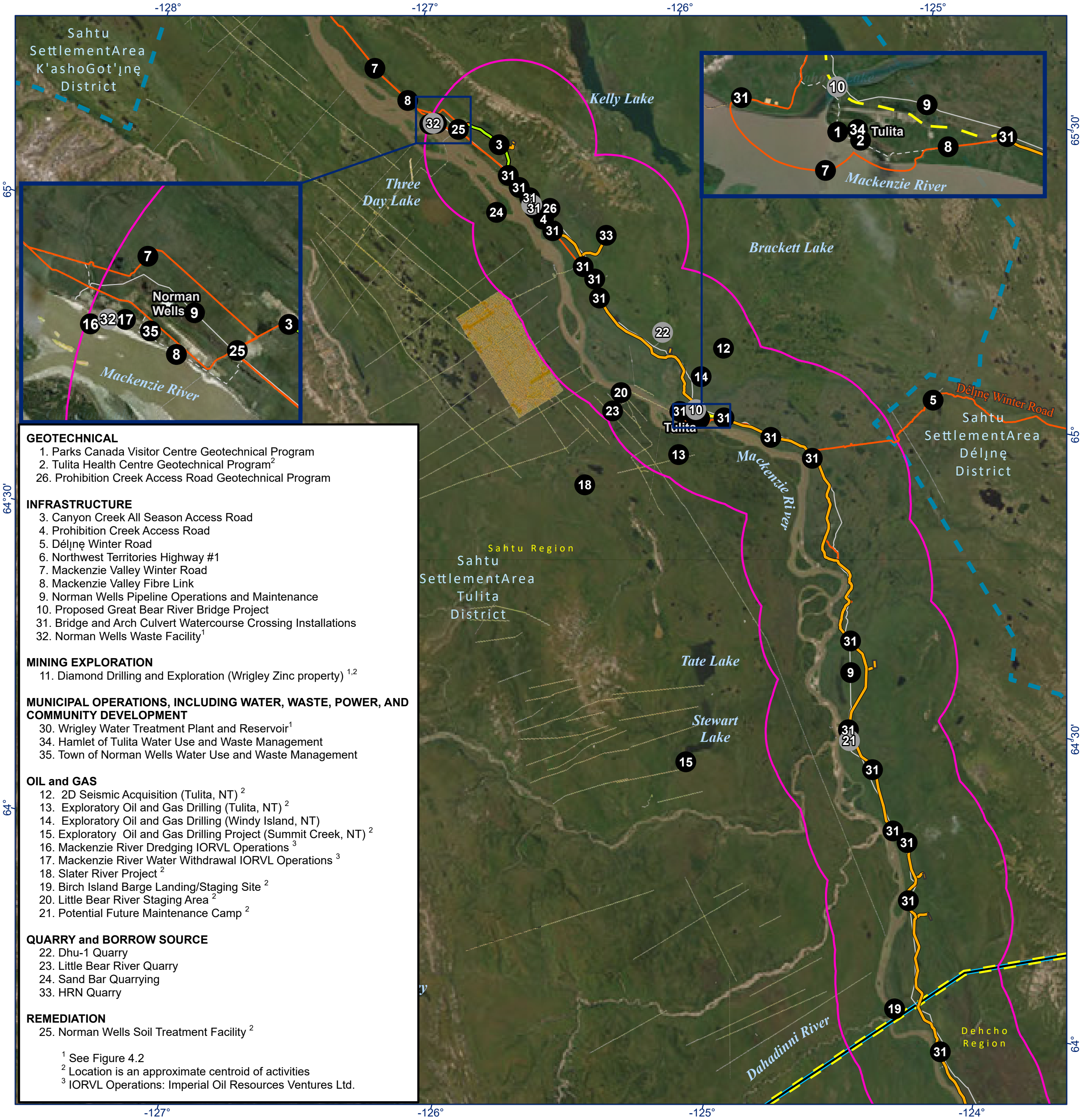
Activity ID[1]	Type of Activity	Project Name/Description	Proponent/ Owners	Regulatory Reference (if available)	Location	Timing and Duration
31	Infrastructure	**25 Bridge and Arch Culvert watercourse crossing installations along the Mackenzie Valley Winter Road**	GNWT - Department of Transportation	MV2010L8-0010, S00L8-004, S03L8-006, S03L8-014, S03L8-003, S03L8-018, S03L8-004, S03L8-019, MV2010X0003, MV2010L8-0002, MV2004L8-0004, MV2004X0047, MV2000E0050, MV2000E0048, S04E-014, S04L8-017, S12E-008, S12L8-008, S12E-009, S03L8-005	25 watercourse crossings along the MVWR between Wrigley and Norman Wells	2001 to 2016
33	Quarrying	**HRN Quarry:** Development and operation of quarry and 8 km winter road	HRN Contracting Ltd.	S13L8-008, S13Q-004	35 km southeast of Norman Wells, north of Vermillion Creek; same location as proposed quarry source 7.083 and access road	Winter 2013-2014

Activity ID[1]	Type of Activity	Project Name/Description	Proponent/ Owners	Regulatory Reference (if available)	Location	Timing and Duration
Reasonably Foreseeable Projects within 15 km of the PDA						
4	Infrastructure	**Prohibition Creek Access Road:** Construction of 13 km all-season access road from the southern end of the Canyon Creek All Season Access Road to the Prohibition Creek Bridge. This project includes the operation of a quarry (Edie Lake Quarry). No camp is required for the project.	GNWT-INF (Sahtu)	LUP S20S-001	Centroid 65° 13' 57" N, -126° 27' 3" W	November 19, 2020 to November 18, 2025
10	Infrastructure	**Proposed Great Bear River Bridge:** Construction of a permanent bridge spanning the Great Bear River and access roads (2 km north of Great Bear River and 4 km south of Great Bear River)	GNWT-INF (Sahtu)	WL S06L8-001 expired; applications for new authorizations not yet submitted	Great Bear River and Tulita, KM 932.0 to 951.5 of the Mackenzie Valley Winter Road (also KM 901.8 to 939.2 of the Project)	Winter 2024-Winter 2027
21	Oil and Gas	**Construction and operation Potential Future Maintenance Camp:** 80-person camp in support of Enbridge Line 21	MYB Construction Ltd.	LUP S20J-003	Adjacent to the current Enbridge project maintenance shop facility at KM 160 south side of Little Smith Creek; 65° 16' 55.23" N Longitude: 126° 45' 33.92" W	Reasonably Foreseeable project - timing unknown

Activity ID[1]	Type of Activity	Project Name/Description	Proponent/ Owners	Regulatory Reference (if available)	Location	Timing and Duration
22	Quarrying	**Dhu-1 Quarry:** Development of a new quarry Dhu-1 and winter access	GNWT-INF (Sahtu)	LUP S21Q-004	Dhu-1 Quarry Development and Operation Project, 16 km northwest of Tulita	November 22, 2021 to November 21, 2026
32	Remediation	**Norman Wells Waste Facility:** May be used for the long term and secure containment of non-treatable soils and wastes generated by closure and reclamation activities on the Norman Wells Operations	Imperial Oil Resources N.W.T. Ltd.	Applications withdrawn – not included in cumulative effects	Town of Norman Wells	Not considered a reasonably foreseeable project – timing unknown – scope unknown

Note:

[1] – Corresponds with numbered locations on Figure 26.1 and Figure 26.2



GEOTECHNICAL
1. Parks Canada Visitor Centre Geotechnical Program
2. Tulita Health Centre Geotechnical Program[2]
26. Prohibition Creek Access Road Geotechnical Program

INFRASTRUCTURE
3. Canyon Creek All Season Access Road
4. Prohibition Creek Access Road
5. Délı̨nę Winter Road
6. Northwest Territories Highway #1
7. Mackenzie Valley Winter Road
8. Mackenzie Valley Fibre Link
9. Norman Wells Pipeline Operations and Maintenance
10. Proposed Great Bear River Bridge Project
31. Bridge and Arch Culvert Watercourse Crossing Installations
32. Norman Wells Waste Facility[1]

MINING EXPLORATION
11. Diamond Drilling and Exploration (Wrigley Zinc property) [1,2]

MUNICIPAL OPERATIONS, INCLUDING WATER, WASTE, POWER, AND COMMUNITY DEVELOPMENT
30. Wrigley Water Treatment Plant and Reservoir[1]
34. Hamlet of Tulita Water Use and Waste Management
35. Town of Norman Wells Water Use and Waste Management

OIL and GAS
12. 2D Seismic Acquisition (Tulita, NT) [2]
13. Exploratory Oil and Gas Drilling (Tulita, NT) [2]
14. Exploratory Oil and Gas Drilling (Windy Island, NT)
15. Exploratory Oil and Gas Drilling Project (Summit Creek, NT) [2]
16. Mackenzie River Dredging IORVL Operations [3]
17. Mackenzie River Water Withdrawal IORVL Operations [3]
18. Slater River Project [2]
19. Birch Island Barge Landing/Staging Site [2]
20. Little Bear River Staging Area [2]
21. Potential Future Maintenance Camp [2]

QUARRY and BORROW SOURCE
22. Dhu-1 Quarry
23. Little Bear River Quarry
24. Sand Bar Quarrying
33. HRN Quarry

REMEDIATION
25. Norman Wells Soil Treatment Facility [2]

[1] See Figure 4.2
[2] Location is an approximate centroid of activities
[3] IORVL Operations: Imperial Oil Resources Ventures Ltd.

Past, Present and Reasonably Foreseeable Project
- Past / Present
- Reasonably Foreseeable
- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge

- Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- Existing Devlopment Footprint [3]
- Fibre Optic Line
- Pipeline
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres
(At original document size of 8.5x11)
1:1,100,000

N

Kalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

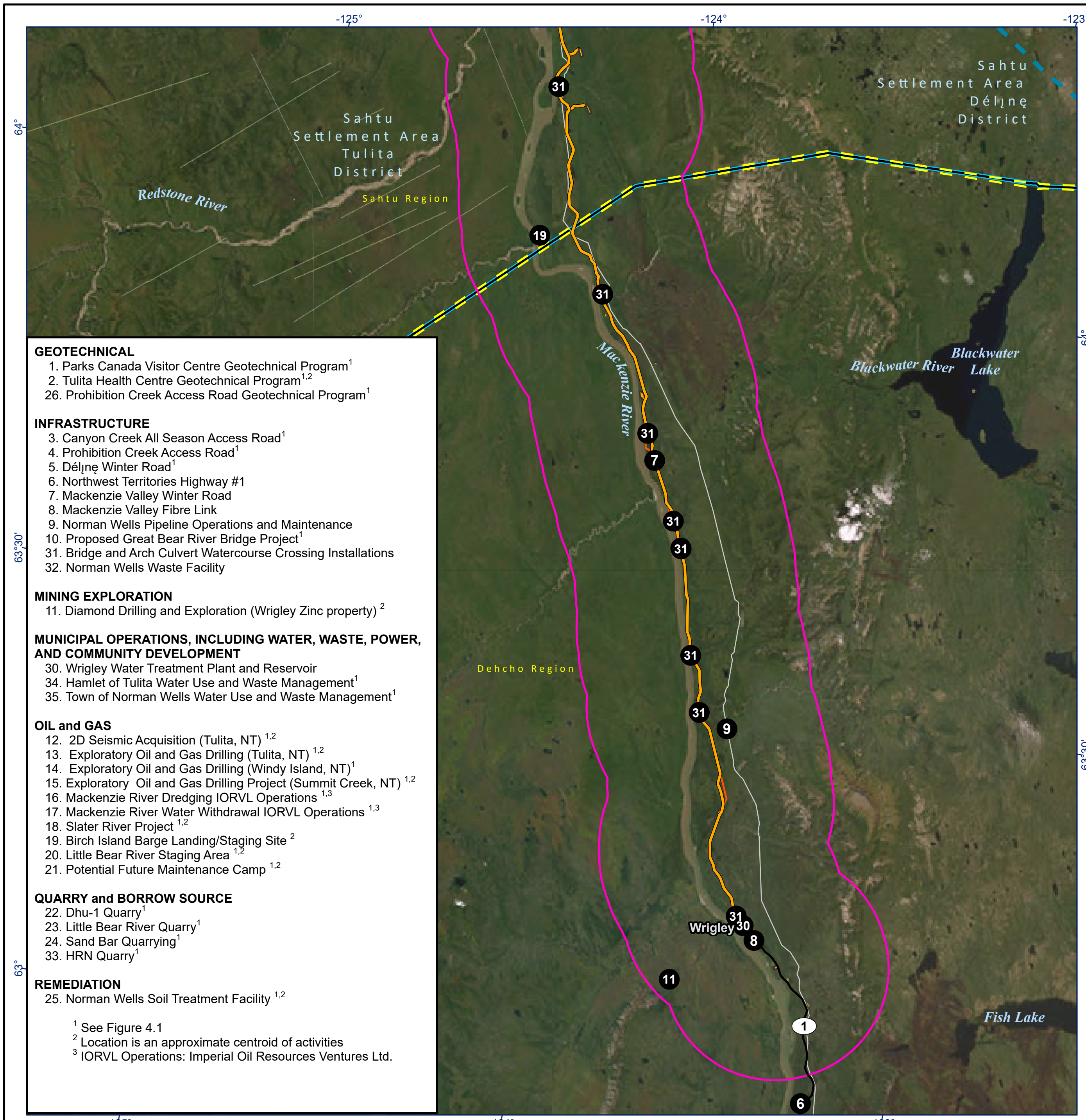
Prepared by CES on 8/4/2023
TR by CA on 8/4/2023

Client/Project
144903025-0107 REVA
Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
26.1

Title
Past, Present and Reasonably Foreseeable Projects - Sahtu Region

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Existing Development Footprint: Human Development Footprint (points, lines, areas) source - 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, and Caslys Consulting Ltd. 2015-2016
4. Background: Esri, FAO, NOAA, USGS, NRCan, Earthstar Geographics, Esri, USGS Imagery date: 2021



Past, Present and Reasonably Foreseeable Project

- Past / Present
- Reasonably Foreseeable
- Proposed Mackenzie Valley Highway Project
- Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- Existing Devlopment Footprint[3]
- Fibre Optic Line
- Pipeline
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 7.5 15 Kilometres
(At original document size of 8.5x11)
1:800,000

N

Kalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 8/4/2023
TR by CA on 8/4/2023

Client/Project
144903025-0135 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
26.2

Title
Past, Present and Reasonably Foreseeable Projects - 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. Existing Development Footprint: Human Development Footprint (points, lines, areas) source - 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, and Caslys Consulting Ltd. 2015-2016
4. Background: Esri, FAO, NOAA, USGS, NRCan, Earthstar Geographics, Esri, USGS Imagery date: 2021

Table 26.2 is a list of all potential projects to be considered in the cumulative effects assessment; however, each VC will use a unique subset of projects in the cumulative effects assessment, as they are unique to the VC effect being considered. The project inclusion list is considered in each VC assessment to identify, for each potential project cumulative effect, the interactions by which the cumulative effect may occur and the change in the state of the VC relative to existing conditions.

The cumulative effects assessment follows the same iterative process and format used for residual effects; namely, description and analysis of cumulative effects, mitigation of cumulative effects, and characterization of residual cumulative effects. A determination of the significance of residual cumulative effects is then made using the same standards or thresholds for significance developed for the VC. The Project's contribution to those cumulative effects is also analyzed and discussed. The results of the cumulative effects assessment are summarized in Sections 26.4.1 to 26.4.11.

26.2.3 Consideration of Climate Change

Consideration of climate change has been applied throughout the DAR. Where relevant, this is discussed within the assessment of each of the VCs in the context of changing conditions for the VC or identified as an uncertainty in the assessment.

26.3 Key Lines of Inquiry

26.3.1 Local Social and Economic Considerations

As per the ToR (MVEIRB, 2015 [PR#66]), local social and economic KLOI require describing and evaluating for the potential effects of the Project on socio-economic considerations. The Socio-economic Impact Assessment examined the following socio-economic VCs as well as the respective potential changes to each VC:

- Potential effects on human health and community wellness, including:
  - Change in population composition and migration
  - Change in population health
  - Change in community/family and social ties
  - Change in food security
  - Change in social pressures
  - Change in nuisance (air quality and noise)
  - Change in drinking and recreational water quality
  - Change in public safety
  - Change in social determinants of health

- Potential effects on education, training, and skills, including:
  - Change in level of education, certification/training, and skills development
  - Change in access to education, certification, and training programs
  - Change in capacity to meet demand for education, certification, and training programs
- Potential effects on employment and economy, including:
  - Change in employment and income
  - Change in Gross Domestic Product and government revenues
  - Change in economic opportunities and capacity of local businesses
  - Change in cost of living and consumer prices
  - Change in traditional economy
  - Change in the GNWT operations employment
- Potential effects on infrastructure, services, and institutional capacity, including:
  - Change in housing and accommodation
  - Change in social infrastructure and services
  - Change in public infrastructure and services
  - Change in institutional facilities and services
- Potential effects on non-traditional land and resource use, including:
  - Change in non-traditional land use
  - Change in access to non-traditional land use
  - Change in aesthetics
  - Change in non-traditional resource use

Generally, a significant adverse residual effect is one that, following the application of mitigation measures for adverse effects, is distinguishable from current conditions and trends and cannot be managed or mitigated through adjustments to programs, policies plans, or through other measures.

The significance determination for socio-economic VCs for residual effects considered:

- Measurable parameters
- Characterization of adverse residual effects
- Magnitude, duration, and reversibility of effects
- Input obtained from engagement with respect to limits of acceptable change and desired outcomes
- Specific descriptions of what is considered a significant adverse residual effect can vary among each of the socio-economic VCs

The assessment of cumulative effects on socio-economic VCs is described in Sections 26.3.1.1 through 26.3.1.5 in reference to the following assessment areas.

- **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, 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 LAA is established to assess the potential direct, indirect, and induced effects of the Project on the socio-economic environment for the communities to be directly connected by the Project. The LAA for socio-economic VCs consists of the communities of Wrigley, Tulita, and Norman Wells.
- **Regional Assessment Area (RAA):** The RAA is established to assess the potential direct, indirect, and induced effects of the Project on communities in the region that are not situated on the PDA. The RAA includes the communities of Fort Simpson, Fort Good Hope, Déline̜, and Colville Lake.

Determinations of significance for residual adverse effects are provided below for each socio-economic VC, as are the overall conclusions with respect to the assessment of potential cumulative effects. It is noted that for the effects that are anticipated to have both positive and adverse effects, only the adverse effects are included in the following sections on cumulative effects.

Mitigation measures described in Section 9.13 and the project-specific management plans will be implemented to reduce the contribution to cumulative effects of change on the socio-economic VCs. This includes adherence to the Safety and Security Plan for Vulnerable Community Members, Road Safety Plan, Contractor Training and Employment Plan, Social Monitoring Plan, Well-Being Adaptive Management Plan, and Wildlife Management and Monitoring Plan (WMMP).

26.3.1.1 Human Health and Community Wellness

For human health and community wellness, a significant adverse residual effect would result if the Project were to cause or further exacerbate adverse health and community wellness conditions that contribute to a decline in physical, mental and/or social health.

The Project will contribute low or moderate incremental increases in adverse effects on population health, community/family and social ties, food security, nuisance, and public safety. The adverse effects of the Project on change in social pressures will be significant. Most effects will be concentrated in the LAA with some lesser effects being experienced in the RAA communities.

During construction of the Project and considering past, present, and reasonably foreseeable projects, the Project may contribute to a small but incrementally adverse effect on population health in the LAA. This could be reflected in lower self-assessments of mental or physical health by residents as a result of ongoing effects related to the Project. Given that these may not be new effects on population health, it is anticipated that the Project’s contribution to the cumulative effect will be low. Cumulative effects extending into the RAA are not anticipated.

Considering past, present, and reasonably foreseeable projects along with the presence of the Project, it is not possible to completely remove the risk of non-residents or visitors acting unsafely or in a way that adversely affects community cohesion. Overall, it is anticipated that the contribution of the Project to the cumulative effect on the change in community/family and social ties will be adverse at a low level.

During construction and operation of the Project and considering past, present, and reasonably foreseeable projects, the LAA communities will see increased social pressures related to the presence of non-residents or visitors and the increased all-season road access to the communities. The RAA communities may see some increased social pressures, but to a lesser extent than the LAA communities. The Project's contribution to the cumulative effect will be adverse at a high degree of magnitude.

Following construction of the Project and considering past, present, and reasonably foreseeable projects, the LAA may continue to experience a relatively low level of air emissions or noise disturbances leading to a change in nuisance effects that may include interference with access to or enjoyment of recreational, traditional, or cultural activities on the land. It is not anticipated, however, that cumulative effects will extend to the RAA communities.

During construction and operation of the Project and considering past, present, and reasonably foreseeable projects, the LAA communities and the region may see incrementally more adverse effects on public safety (as measured by perceived safety of community and rate of accidents) as a result of the Project. The overall contribution of the Project to the cumulative effect will be moderate.

The Project will interact cumulatively with past, present, and reasonably foreseeable projects and activities, especially for projects that will increase or have increased access to the LAA communities, allowing for increased presence of non-residents or visitors, which may have several different effects. Overall, most effects that result from interactions between the project effects and those of past, present, and reasonably foreseeable projects will be low.

The construction and operation of the Project, combined with other past, present, and reasonably foreseeable project effects that increase access to and from communities and the presence of non-residents or visitors, is expected to exacerbate an already significant drug and alcohol problem that exists in LAA and RAA communities. The construction and operation of the Project, combined with other past, present, and reasonably foreseeable project activities that increase access to and from communities and provide for all-season access by road is anticipated to have an adverse cumulative effect on public safety levels, especially for vulnerable populations. It is not expected that mitigation measures will be able to eliminate the increasing adverse effects on social pressures and public safety, especially in the short-term and as a result the cumulative effects of the Project on social pressures and public safety will be significant.

Given that most effects are determined to be not significant and there is a commitment to develop and implement a monitoring and adaptive management plan, the cumulative effects on human health and community wellness overall are not significant.

26.3.1.2 Education, Training and Skills

A significant adverse residual effect for education, training and skills would result if the Project results in a lack of capacity or a decrease in the quality of education or training services provided.

The Project may result in a low magnitude increase in demand for training within the LAA. This increase in interest for training may strain the capacity on training institutions to meet demand for training.

During the construction phase of the Project, current and reasonably foreseeable projects may result in additional strain on training facilities to meet demand for training, over and above the capacity issues introduced by the Project alone. Cumulative effects extending into the RAA are not anticipated, nor are they expected during the operations and maintenance phase.

During the construction phase, training facilities in the LAA may have decreased capacity to meet demand for training because of higher levels of interest associated with the Project and other current and reasonably foreseeable activities. However, with a low magnitude, medium-term duration and irregular frequency, the residual cumulative effect on education, training and skills is considered not significant.

26.3.1.3 Employment and Economy

For employment and economy, a significant adverse residual effect would result if the Project were to cause or lead to conditions that contribute to an overall decline in employment levels or economic activity.

The Project will contribute a low magnitude, irregular decrease in access to country foods over the medium term due to the participation of community members in project employment and employment in other present and reasonably foreseeable projects and activities. The Project will draw upon local labour to undertake construction, which for some workers will require living in camps away from their home community during their 14-day shift and may affect the amount of traditional food available in the community. This effect does not extend into the operations and maintenance phase.

Following the application of mitigation measures, residual cumulative effects on traditional economy are not expected to threaten the ability of community members to participate in activities related to accessing or obtaining traditional foods.

In conclusion, the cumulative effects on employment and economy are not significant.

26.3.1.4 Infrastructure, Services and Institutional Capacity

A significant adverse residual effect for infrastructure, services and institutional capacity would result if the Project resulted in a lack of available capacity, or a substantial decrease in the quality of a service provided, on a persistent and ongoing basis.

The Project will contribute a low magnitude increase in demand for LAA community health services, infrastructure, and adult education/training during its construction phase; this will be in addition to any such demands placed by other projects in the area that may be under construction at the same time.

During the Project's operations and maintenance phase, the number of traffic accidents and their severity may increase in LAA communities, thereby increasing pressure on emergency services, protection services, and health services in these communities. In addition, the increase in LAA community access to alcohol and drugs will result in increased demand on protection services to deal with crimes and incidents associated with the consumption of drugs and alcohol and increased demand in health counselling and facility-based treatment services. In LAA communities that have three-officer RCMP detachments, capacity may on occasion be limited when two officers need to respond to an accident on Highway #1. Neither the past and present physical activities and resource uses, nor the reasonably foreseeable physical activities, are expected to interact with the Project's operations and maintenance phase and produce cumulative effects on social infrastructure and services.

Considering past, present, and reasonably foreseeable projects, and construction of the Project, LAA communities may experience increased demand for health services if the construction of one or more of these projects overlaps with the construction phase of the Project (due to the presence of construction workers who may get injured or ill). Cumulative effects extending into the RAA are not anticipated.

During the project construction phase, construction worker camps will make use of municipal infrastructure such as potable water, wastewater disposal, and solid waste disposal. Depending on the public infrastructure capacity of each LAA community, the Project may have an adverse effect on one or more of the utilities provided by one or more LAA community; Tulita (solid waste disposal) and Wrigley (potentially all utilities – to be determined) may be affected. Hence, cumulative effects on public infrastructure are possible during the Project's construction phase.

In the event that construction of one or more of the activities of the Great Bear River Bridge and/or Prohibition Creek Access Road (PCAR) coincide with the construction of the Project, and if either/both projects have construction worker camps that use the public infrastructure of Norman Wells and/or Tulita, the increased demand for public utilities can be expected to intensify due to the combined demands of multiple construction worker camps.

During construction of the Project and considering past, present, and reasonably foreseeable projects, one or more LAA communities may experience utility capacity challenges if two or more construction worker camps are within municipal boundaries, even with the implementation of mitigation measures. Cumulative effects are not expected to extend into the RAA.

During the project construction phase, some residents of the LAA and RAA communities who seek employment for project construction may either require or desire educational and training programs (e.g., adult literacy, trades training) prior to applying for employment. Such education and skills training will require training facilities (i.e., Community Learning Centres [CLCs]) in the communities to accommodate an increased number of community members. In the event that construction of one or more of the reasonably foreseeable physical activities of Great Bear River Bridge and/or PCAR coincide with the construction of the Project, the increased demand for the use of CLCs in LAA communities can be expected to intensify and therefore the capacity of the CLCs may be challenged by this cumulative demand.

During construction of the Project and considering past, present, and reasonably foreseeable projects, LAA communities may be challenged in providing sufficient training facilities (CLCs) to cater to community demand for educational and training programs if two or more projects have construction phases during the same time. Cumulative effects extending into the RAA are not anticipated.

In conclusion, cumulative effects on the infrastructure, services, and institutional capacity VC, including the Project, are not significant.

26.3.1.5 Non-Traditional Land and Resource Use

For non-traditional land and resource use, a significant adverse residual effect would result if:

- The Project does not comply with established land use plans, policies, or by-laws, or
- The Project will create a change or disruption that restricts or degrades present land use capability to a point where the non-traditional land use activities cannot continue at or near current levels and where compensation is not possible.

The Project will interact cumulatively with past, present, and reasonably foreseeable projects and activities in a way that will continue to increase the development of land in and around the LAA communities for infrastructure, industrial, and possibly commercial and residential land uses. However, being of low magnitude and irregular frequency, the residual cumulative effects on non-traditional land use will be not significant.

Despite the presence of various linear, mine, and oil and gas projects within the RAA (including the Project), the LAA will continue to be relatively undisturbed, as the opening up of new avenues of access to previously undisturbed areas for hunting, fishing, and recreational non-traditional land uses will likely be relatively limited. It is not anticipated that the small local non-Indigenous population will put much pressure on previously undisturbed areas and the driving distance between large centres of non-Indigenous populations and the LAA communities is a disincentive within the reasonably foreseeable future. Being of low magnitude and irregular frequency, the residual cumulative effects on access to non-traditional land use will be not significant.

Following construction of the Project and considering past, present, and reasonably foreseeable projects, the LAA will continue to experience a relatively low level of aesthetic disturbances due to noise and air pollution/dust. Being of low magnitude and irregular frequency, the residual cumulative effects on aesthetics will be not significant.

As no residual cumulative effects are anticipated for non-traditional resource use, a determination of significance is not warranted.

26.3.2 Caribou, Moose and Harvesting

As per the ToR (MVEIRB, 2015), the caribou, moose, and harvesting KLOI requires describing and evaluating for the potential effects of the Project on caribou and moose, and what this means to harvesting. The assessment examined the following potential changes to caribou and moose and cultural use, including harvesting:

- Change in caribou and moose habitat
- Change in caribou and moose movement
- Change in caribou and moose mortality risk
- Change in caribou and moose health
- Change in availability of traditional resources for cultural use
- Change in access to resources or areas for cultural use
- Change in sites or areas for cultural use

The assessment of cumulative effects on caribou and moose, and harvesting are described in Sections 26.3.2.1 through 26.3.2.2 in reference to the following assessment areas:

- **Project Development Area (PDA):** The area of direct project disturbance
- **Local Assessment Area (LAA):** For caribou and moose this is an area within approximately 15 km of the PDA where direct project effects and cumulative effects may occur (the Caribou and Moose LAA). For wildlife, vegetation, and culture and traditional land use, the LAA is the area within approximately 1 km of the PDA, extended to 2 km around borrow and quarry sources, where direct project effects may occur.
- **Regional Assessment Area (RAA):** For wildlife, vegetation, and culture and traditional land use, this is an area within approximately 15 km of the PDA, meant 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. For caribou and moose, there is no RAA.

26.3.2.1 Cumulative Effects on Caribou and Moose

A significant adverse residual effect on caribou and moose 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 caribou and moose populations in the Caribou and Moose LAA, whereby a viable population consists of the number of individuals required to persist over a given period of time (Middleton and Nisbet, 1997). A conservation-based undisturbed habitat threshold for boreal caribou is provided by ECCC in the federal recovery strategy (ECCC, 2020; and Section 10.1.6).

The assessment of residual effects and cumulative effects on caribou and moose is presented in Chapter 10. Below are key findings of the assessment.

26.3.2.1.1 Change in Habitat

The development of the Project is estimated to result in the direct loss of 2,315.2 ha of general habitat and, of that, 94.3 ha are considered selected boreal caribou habitat. This direct loss of habitat is expected to result in a 0.03% decrease of selected caribou habitat within the Caribou and Moose LAA compared to existing conditions. This change in habitat is expected to occur entirely in the Sahtu Region, as the PDA in the Dehcho Region does not include selected boreal caribou habitat (see Section 10.4.2.3.1.1).

Additionally, a 500 m buffer was applied to the Project's PDA as a measure of indirect habitat disturbance on caribou resulting from the combined effects of increased predation and avoidance. At the scale of the Caribou and Moose LAA, 1,466 ha of selected boreal caribou habitat is expected to be indirectly affected by the Project. The Project is predicted to result in the combined direct (94.3 ha) and indirect loss (1,466 ha) of caribou habitat in the Caribou and Moose LAA (0.15% of the Caribou and Moose LAA).

The Project's contribution to habitat loss is low; however, accounting for fires ≤40 years old (403,979 ha), and existing anthropogenic disturbances to which a 500 m buffer has also been applied (including those in Table 26.1), there is a combined existing disturbance of 527,867 ha (52.2%) in the Caribou and Moose LAA. The current level of cumulative habitat disturbance (not including the Project) in the Caribou and Moose LAA exceeds the 35% threshold identified by ECCC (2020).

Applied at different scales, there is 3,114,409 ha (20.9%) of disturbed habitat in the Sahtu Range Planning Region of the NT1 caribou range (below the conservation threshold), and 7,584,904 ha (46.7%) of disturbed habitat in the Southern NT1 Range Planning Region (above the threshold). The NT1 region as a whole has 13,730,535 ha (31.0%) of disturbed habitat (below the threshold).

Although additive, the reasonably foreseeable projects Great Bear River Bridge, Dhu-1 Quarry and Enbridge Maintenance Camp are comparatively small in terms of their contributions to habitat changes. The Project is expected to increase the existing total disturbance area by 0.003% (NT1 range), 0.004% (Sahtu Range Planning Region), 0.006% (Southern NWT Range Planning Region) and by 0.15% in the Caribou and Moose LAA. Regardless, there is a pre-existing high magnitude habitat effect in the Caribou and Moose LAA and the Southern NT1 Range Planning Region. The level of disturbance exceeds the ecological threshold (65% undisturbed habitat) that is required to maintain a self-sustaining population of boreal caribou (EC 2011, ECCC 2020). However, based on those disturbance metrics, the boreal caribou population is expected to persist in the broader NT1 range.

The Project will contribute to an existing cumulative effect and the exceedance of a conservation-based threshold. Therefore, the residual cumulative effect on change in habitat for boreal caribou is predicted to be significant.

It is estimated that 787.9 ha of suitable moose habitat will be lost with the construction of the Project. This direct loss is a 0.3% decrease in suitable moose habitat at the scale of the Caribou and Moose LAA compared to existing baseline conditions. Of this change, 75.5 ha (0.2%) of affected moose habitat is in the Sahtu Region and 712.4 ha (0.3%) of habitat loss is expected in the Dehcho Region. This estimate is conservative, because the existing MVWR and other past and current disturbances in the PDA have contributed to an existing anthropogenic disturbance of 47.8% of the PDA (i.e., 1,104.9 ha).

Mitigation measures described in Section 10.4.2.2 and the project-specific management plans will be implemented to reduce the contribution to cumulative effects of change in habitat on boreal caribou and moose.

This includes adherence to the project-specific WMMP, Spill Contingency Plan, Waste Management Plan (WMP), Erosion and Sedimentation Control Plan (ESCP), Permafrost Protection Plan (PPP) and Traffic Management Plan (TMP). Additional mitigation measures that may be required to reduce the cumulative effects of change in habitat on boreal caribou and moose will be determined as part of the ongoing development of the WMMP prior to construction.

26.3.2.1.2 Change in Movement

The pathway for the effect is mostly associated with creating physical and sensory barriers through development and reducing the likelihood of caribou or moose crossings and, with that, altering movement within and between parts of their range and suitable habitat types. The greatest potential for causing a change to boreal caribou movement patterns is the construction of infrastructure that could act as a barrier (e.g., roads) and the use of infrastructure that could reduce the likelihood of caribou moving across the feature (e.g., traffic). Past and present projects and physical developments that may have contributed to cumulative effects on boreal caribou and moose movement in the Caribou and Moose LAA (e.g., the creation of linear infrastructure acting as semi-permeable barriers) are oil and gas activities, mining and exploration activities, the Norman Wells Pipeline, the MVWR and other winter roads, Highway #1 and other all-season roads, and quarries and borrow sources. Reasonably foreseeable projects and developments with the potential to act cumulatively with the project effects are Dhu-1 Quarry, the Great Bear River Bridge, and the PCAR proposed within the boundaries of the Caribou and Moose LAA.

Mitigation measures described in Section 10.4.3.2 and the identified management and monitoring plans will be implemented to reduce the contribution to cumulative effects of change in movement on boreal caribou and moose.

This includes 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, including ongoing monitoring of caribou by the GNWT. No additional mitigation measures are required to reduce the contribution to cumulative effects of change in movement on boreal caribou and moose.

The Project is expected to result in an alteration of boreal caribou and moose movement patterns and potential movement corridors within the Caribou and Moose LAA, but it is unlikely that these changes will result in a measurable change in their distribution and/or abundance in the Caribou and Moose LAA (see Section 10.4.3.3). The project-related adverse effects may interact cumulatively with past, present, or reasonably foreseeable projects or physical activities. However, considering that past and present projects and developments are used in project construction to the extent possible, and given the small scale of the reasonably foreseeable projects and physical developments, the Project is not considered to add cumulatively to measurable changes in boreal caribou and moose distribution and/or abundance in the Caribou and Moose LAA following the implementation of project-specific mitigation measures.

26.3.2.1.3 Change in Mortality Risk

Project-related residual effects may contribute to cumulative changes in boreal caribou and moose mortality risk and the number of boreal caribou and moose fatalities through direct or indirect pathways. Direct mortality pathways include collisions with vehicles, and indirect mortality pathways include increased harvest pressure via improved hunter access and increased predation via facilitated predation or apparent competition (see Section 10.4.4.1).

Past and present projects and physical developments that have contributed to cumulative effects on boreal caribou, barren-ground caribou, and moose mortality risk in the Caribou and Moose LAA (e.g., through vehicle collisions, increased harvest pressure and predation) are oil and gas activities, mining and exploration activities, the Norman Wells Pipeline, the MVWR and other winter roads, Highway #1 and other all-season roads, and quarries and borrow sources. Reasonably foreseeable projects and developments with the potential to act cumulatively with the project effects are the Dhu-1 Quarry, the Great Bear River Bridge, and the PCAR proposed within the boundaries of the Caribou and Moose LAA.

Mitigation measures described in Section 10.4.4.2, and the identified management and monitoring plans will be implemented to reduce the contribution to cumulative effects of change in mortality risk on boreal caribou, barren-ground caribou, and moose.

This includes 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, including the TMP as well as monitoring of vehicle collisions resulting in wildlife fatalities (see Section 10.8) and continuation of the GNWT's harvest monitoring programs (see Section 10.8).

No additional mitigation measures are required to reduce the contribution to cumulative effects of change in mortality risk on boreal caribou and moose.

The Project is expected to result in changes in indirect and direct caribou and moose mortality within the Caribou and Moose LAAs. While annual traffic volumes will increase on the completed highway, it is anticipated that the change in mortality risk on boreal caribou and moose due to increased wildlife-vehicle collision risk will not alter the population viability or persistence of boreal caribou and moose within the Caribou and Moose LAAs. Similarly, access across the Caribou and Moose LAAs is expected to improve and may result in increased harvest pressure. Harvest will continue to be managed by the GNWT and the co-management boards, and, therefore, it is anticipated that any change in mortality risk will not alter the population viability or persistence of boreal caribou and moose within the Caribou and Moose LAAs.

The project-related adverse effects may interact cumulatively with past, present, or reasonably foreseeable projects or physical activities. However, considering that past and present projects and developments are contributing to current mortality risks, and given the small scale of the reasonably foreseeable projects and physical developments, the Project is not considered to add cumulatively to measurable changes in boreal caribou and moose mortality risk in the Caribou and Moose LAAs following the implementation of project-specific mitigation measures.

26.3.2.1.4 Change in Health

Project-related residual effects may contribute to cumulative changes in boreal caribou and moose health. The Project could expose boreal caribou and moose to potential contaminants or emissions that may affect their health, including changes in energetics and physical condition as a result of project-related sensory disturbance, increased predation, and increased hunting pressure. Changes in air and water quality can result in changes in the quality of vegetation consumed by boreal caribou and moose. However, the cumulative effects assessments for air quality (see Chapter 12) and water and sediment quality (see Chapter 16) concluded that there is no potential for cumulative effects on air or surface water and sediment quality; therefore, this exposure pathway is excluded from the cumulative effects assessment for change in health. The assessment is focused on sensory disturbance, increased predation, and increased hunting pressure that may result in changes in energetics and physical condition of boreal caribou and moose.

Disturbance to boreal caribou and moose through sensory stressors resulting from industrial development or infrastructure projects may reduce the effectiveness of adjacent habitats, affect movement patterns, and/or increase overall energy expenditures (through changes in the animals' activities) near the sources of sensory disturbance. Animals may be displaced by development of infrastructure projects, resulting in the temporary avoidance of areas near the source of disturbance. Changes in energy expenditure (e.g., through increased movements) may affect the physical condition of individual animals (including the presence of parasites and diseases), calf survival, and population viability (see Section 10.4.5.1). Effects from anthropogenic disturbance or displacement associated with development and infrastructure projects have the potential to add to effects from existing natural environmental variability, such as changes in climate and weather patterns, and influence the resilience of populations to cope with additional stress factors, such as predation and hunting pressure.

Past and present projects and physical developments that may have contributed to cumulative effects on boreal caribou and moose health in the Caribou and Moose LAA are oil and gas activities, mining and exploration activities, the Norman Wells Pipeline, the MVWR and other winter roads, Highway #1 and other all-season roads, and quarries and borrow sources. A reasonably foreseeable project with the potential to act cumulatively with the project effects is the PCAR proposed within the boundaries of the Caribou and Moose LAA.

Mitigation measures described in Section 10.4.5.2 and the identified management and monitoring plans will be implemented to reduce the contribution to cumulative effects of change in health on boreal caribou and moose.

This includes 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, including a SCP, WMP, ESCP and TMP. No additional mitigation measures are required to reduce the contribution to cumulative effects of change in health on boreal caribou and moose.

The Project is expected to result in changes in boreal caribou and moose health within the Caribou and Moose LAAs. While exposure to potential contaminants and sensory disturbance may occur within the Caribou and Moose LAAs as a result of the Project, it is anticipated that a change in boreal caribou and moose health will remain within the natural range of variability and the residual effect is not expected to alter the population viability or persistence of boreal caribou and moose within the Caribou and Moose LAAs.

The project-related adverse effects may interact cumulatively with past, present, or reasonably foreseeable projects or physical activities. However, considering that past and present projects and developments are contributing to current health conditions, and given the small scale of the reasonably foreseeable projects and physical developments, the Project is not considered to add cumulatively to measurable changes in boreal caribou and moose health in the Caribou and Moose LAAs following the implementation of project-specific mitigation measures.

26.3.2.1.5 Significance of Cumulative Effects on Caribou and Moose

Based on the habitat disturbance assessment completed for boreal caribou, (Section 10.5.2), the amount of existing disturbance (52.2%) in the Caribou and Moose LAA already exceeds the 35% disturbance threshold defined in the federal recovery strategy (ECCC 2020). The Project is predicted to result in the direct (94.3 ha) and indirect loss (1,466 ha) of caribou habitat in the Caribou and Moose LAA. Although this represents a relatively small percentage (0.15%) of the Caribou and Moose LAA, the Project will contribute to an existing cumulative effect and the exceedance of a conservation-based threshold. Therefore, residual cumulative effects on change in habitat for boreal caribou is predicted to be significant.

The relative contribution of the Project to existing cumulative effects varies with spatial scale, The Project would not result in a significant residual cumulative effect in the Sahtu Planning Region or the NT1 caribou range because the Project does not contribute to an exceedance of a conservation-based threshold or threaten the long-term persistence or viability of boreal caribou. However, similar to the Caribou and Moose LAA, the Southern NT1 range already exceeds the 35% disturbance threshold; and therefore, the Project's relatively small contribution (0.004 %) to an existing residual cumulative effect in the Southern NT1 range would further contribute to an exceedance of a conservation-based threshold; and therefore, residual cumulative effects on caribou is predicted to be significant but not expected to threaten the long-term persistence or viability of boreal caribou.

The Project is predicted to result in an alteration of movement patterns and movement corridors of boreal caribou and moose in the Caribou and Moose LAA, but is not expected to contribute to cumulative effects causing measurable changes in boreal caribou and moose movement in the Caribou and Moose LAA following the implementation of project-specific mitigation measures (see Section 10.5.3.3). Therefore, the Project is not expected to contribute cumulatively to effects from other past, present, and reasonably foreseeable projects and physical developments and threaten the long-term persistence or viability of boreal caribou and moose populations in the Caribou and Moose LAA. In conclusion, the cumulative effect of change in movement on boreal caribou and moose is assessed as not significant.

The Project is predicted to result in changes in direct and indirect mortality risk for boreal caribou and moose in the Caribou and Moose LAA, but is not expected to contribute to cumulative effects causing measurable changes in boreal caribou and moose mortality risk in the Caribou and Moose LAA following the implementation of project-specific mitigation measures (see Section 10.5.4.3). Therefore, the Project is not expected to contribute cumulatively to effects from other past, present, and reasonably foreseeable projects and physical developments and threaten the long-term persistence or viability of boreal caribou and moose populations in the Caribou and Moose LAA. In conclusion, the cumulative effect of change in mortality risk on boreal caribou and moose is assessed as not significant.

While the Project is predicted to result in changes in health of boreal caribou and moose habitat in the Caribou and Moose LAA, the Project is not expected to contribute to cumulative effects causing measurable changes in boreal caribou and moose health in the Caribou and Moose LAA following the implementation of project-specific mitigation measures (see Section 10.5.5.3). Therefore, the Project is not expected to contribute cumulatively to effects from other past, present, and reasonably foreseeable projects and physical developments and threaten the long-term persistence or viability of boreal caribou and moose populations in the Caribou and Moose LAA. In conclusion, the cumulative effect of change in health on boreal caribou and moose is assessed as not significant.

26.3.2.2 Cumulative Effects on Culture and Traditional Land Use

In the assessment, culture and traditional land use is referred to as 'cultural use' and is understood to encompasses various traditional activities, practices, sites, areas, and resources, including:

- Hunting
- Trapping
- Fishing
- Plant gathering
- Use of trails and travelways, including navigation
- Use of habitation areas (e.g., cabins, campsites, temporary shelters)
- Use of cultural and spiritual sites and areas

Cultural use also accounts for the conditions of use, seasonal cycles, inter-generational knowledge transmission, landforms and named places, and other factors that provide context, setting, or understanding for the practice of cultural use activities. The Project can affect cultural use through:

- Change in availability of resources for cultural use, affecting the ability to exercise cultural use activities (e.g., hunting, trapping, fishing, and plant gathering [harvested resources])
- Change in access to resources or areas for cultural use
- Change in sites or areas for cultural use through the disruption or alteration of a traditional use site or location (e.g., habitation areas, trails and travelways, and cultural or spiritual practices sites and areas)

The assessment of residual effects and cumulative effects on cultural use is presented in Chapter 11. Below are key findings of the assessment.

26.3.2.2.1 Change in Availability of Resources

Residual effects arising from past, present, and reasonably foreseeable activities have similar pathways as those arising from the Project (see Section 11.4.2.1) and have the potential to result in a cumulative effect on availability of resources for current use during the construction and operations and maintenance of the Project. These pathways include the direct loss of habitat through vegetation clearing, loss or alteration of fish habitat due to disturbance of watercourses, change in diversity and abundance of harvested species, and indirect effects through sensory disturbance, as well as effects on the experience of land users that adversely alter the perceived value of resources available for cultural use.

Past and present activities and projects that contribute to cumulative effects on availability of resources for cultural use in the 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 PCAR Project that occur within the LAA and RAA.

Chapter 11 identifies pathways effects related to change in availability of (harvested) resources through a review of publicly available literature and engagement with Indigenous Governments, Indigenous Organizations, and other affected parties, such as renewable resources councils. These relate to changes in habitat, movement, mortality risk, and health of wildlife and fish, and changes to plant species diversity and vegetation communities.

Implementation of the mitigation measures described in Section 11.4.2.2 are anticipated to reduce effects on availability of resources for cultural use. As well, mitigation designed to reduce effects on wildlife (see Section 19.4), vegetation (see Section 18.4), and fish (see Section 17.4) are anticipated to also mitigate effects on availability of resources for cultural use. These mitigation measures are also applicable to the effects of identified future physical activities.

After the application of mitigation measures, the Project will contribute a small, incremental increase in loss of habitat for plants, animals, and fish harvested by Indigenous Governments, Indigenous Organizations, and other affected parties and has potential to contribute to change in diversity and abundance of harvested plant species.

Cumulative effects on the availability of resources for cultural use due to sensory disturbance are not anticipated. The conclusions in the cumulative effects assessments for air quality (see Section 12.4.5) and water and sediment quality (see Section 16.5) indicate that there is no potential for cumulative effects on air quality or surface water quality. The cumulative effects assessment for noise (see Section 13.5.2) concludes that the Project will result in a negligible change in baseline that will be below Health Canada Noise Guidance thresholds and that the Project's contribution to cumulative effects on noise is not expected to be substantial.

The assessment of cumulative effects on wildlife and wildlife habitat (see Chapter 19) concluded that, following construction of the Project and considering past, present, and reasonably foreseeable projects, the RAA will continue to be relatively undisturbed and contain many large patches of undisturbed habitats for wildlife. The Project will increase the amount of linear disturbance; however, it is not anticipated to result in the alteration of large-scale wildlife movement patterns or movement corridors and is unlikely to interact cumulatively with any past, present, or reasonably foreseeable projects or activities.

The assessment of cumulative effects on vegetation and wetlands (see Section 18.5) concluded that fragmentation of the landscape will be reduced by aligning the Project with the MVWR along most of its length and patches of many sizes and shapes of all landcover types are expected to continue to be abundant in the RAA. Plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties are expected to persist in the LAA and RAA because all landcover types will remain common in the LAA and RAA.

The assessment of cumulative effects on fish and fish habitat (see Section 17.6) concluded that increased access to fishing due to the Project and its connection with other transportation corridors in the RAA can be expected to result in increased fishing pressure on some fish populations. The application of mitigation will reduce the cumulative effects, but not necessarily completely mitigate them. Fish species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties are expected to persist in the LAA ad RAA; however, fisheries management initiatives may need to be implemented to maintain current populations (see Section 17.6.4).

Plant, animal, and fish species harvested by Indigenous Governments, Indigenous Organizations and other affected parties are expected to continue to be available throughout the LAA and RAA and the Project is not expected to result in changes to the distribution, diversity, and abundance of traditionally harvested species.

26.3.2.2.2 Change in Access to Resources or Areas for Cultural and Traditional Land Use

Past, present, and reasonably foreseeable projects have the potential to result in a cumulative effect on access to resources or areas for cultural use through restriction or alteration of access (including trails and travelways) to traditional lands and resources. Indirect effects include the project-related increased access to harvesting areas as well as effects on the experience of Indigenous peoples that adversely alter the perceived value of access to areas for cultural use.

Notable past and present activities and projects that contribute to cumulative effects on access to resources or areas for cultural use in the 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 PCAR 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 on culturally used trails and travelways are anticipated to be minor following the application of project-specific mitigation measures. Cumulatively, the Project, the Great Bear River Bridge, and the PCAR contribute to permanent, all-season access for harvesters.

Chapter 11 identifies pathways effects related to change in access to resources or areas for cultural use through a review of publicly available literature and engagement with Indigenous Governments, Indigenous Organizations, and other affected parties, including renewable resources councils. These relate to changes in access created by linear infrastructure.

Implementation of mitigation measures described in Section 11.4.2.2 are predicted to avoid or reduce adverse effects on access to resources or areas for cultural use.

The Project will facilitate year-round access to harvesting areas not currently accessible with the presence of past and existing projects; however, additional access created by reasonably foreseeable projects could contribute additional access. As the identified reasonably foreseeable projects (Great Bear River Bridge and PCAR) will become part of the Mackenzie Valley Highway, the combined effects of these projects with the Project are inherently already assessed regarding these effects. Traditional land and resource use, along with recreational hunting, are activities that will continue to influence wildlife mortality risk in the RAA without the Project.

While the number of resource users or recreational hunters and fishers is not anticipated to change measurably in the foreseeable future, the locations in the RAA where resource use occurs may shift in response to changes in access (see Section 19.5.4). Following construction, the Project is not anticipated to impede the use of the Mackenzie River or other navigable waterways as travel routes.

The conclusions in the cumulative effects assessments for air quality (see Section 12.4.5) and water and sediment quality (see Section 16.5) indicate that there is no potential for cumulative effects on air quality or surface water quality. The cumulative effects assessment for noise (see Section 13.5.2) concludes that the Project will result in a negligible change in baseline that will be below Health Canada Noise Guidance thresholds and the Project's contribution to cumulative effects on noise is not expected to be substantial. Therefore, cumulative effects on the availability of resources for cultural use through sensory disturbances are not anticipated.

26.3.2.2.3 Change in Sites or Areas for Cultural and Traditional Land Use

Cumulative effects on sites or areas for cultural use are not anticipated. Direct residual effects from the Project to sites or areas for cultural use are expected to occur only within areas of direct physical disturbance; cultural use sites or areas outside the direct areas to be disturbed are expected to remain unchanged. Therefore, the localized residual effects of the Project on cultural use sites and areas are not anticipated to act cumulatively with residual effects of past, present, and reasonably foreseeable activities in the RAA.

With respect to indirect effects on sites or areas for cultural use, the conclusions in the cumulative effects assessments for air quality (see Section 12.4.5) and water and sediment quality (see Section 16.5) indicate that there is no potential for cumulative effects on air quality or surface water quality. The cumulative effects assessment for noise (see Section 13.5.2) concludes that the Project will result in a negligible change in baseline that will be below Health Canada Noise Guidance thresholds, and therefore the Project's contribution to cumulative effects on noise is not expected to be substantial. Therefore, effects from sensory disturbances on sites or areas for cultural use are not expected to act cumulatively with residual effects of past, present, and reasonably foreseeable activities.

26.3.2.2.4 Significance of Cumulative Effects on Cultural and Traditional Land Use

Although the Project will contribute a small, incremental increase in loss of habitat for plants, wildlife, and fish harvested by Indigenous peoples, plant, wildlife, and fish species harvested by Indigenous peoples are expected to continue to be available throughout the LAA and RAA. The Project will facilitate increased year-round access to harvesting areas to both local residents as well as non-residents and recreational hunters and fishers, but the number of resource users or recreational hunters and fishers is not anticipated to change measurably in the foreseeable future. Local harvesters also recognized that increased access may also result in positive effects (see Chapter 11). Cumulative effects on sites or areas for cultural use are not anticipated.

With mitigation and environmental protection measures, the residual cumulative effects on cultural and traditional land use are not significant as they will not result in the long-term loss of availability of cultural use resources or access to lands relied on for cultural use practices or sites and areas for cultural use such that these activities will be substantially diminished or lost from the RAA.

26.4 Subjects of Note

26.4.1 Air Quality

As described in Chapter 12, 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. 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.

The project highway will replace the MVWR during the operations and maintenance phase once all segments are completed, and thus the MVWR activities will interact cumulatively with the Project activities only during the construction phase. Cumulative criteria air contaminants (CAC) emissions from project mobilization and demobilization activities are expected to be less than their National Pollutant Release Inventory (NPRI) reporting thresholds except for particulate matter less than 10 microns (PM_{10}) and particulate matter less than 2.5 microns ($PM_{2.5}$). The dominant source of PM_{10} and $PM_{2.5}$ is the project mobilization of trucks and the light truck traffic on the MVWR (e.g., tailpipe emissions). The cumulative CAC emissions from project road construction activities are greater than their NPRI reporting thresholds except for sulphur dioxide (SO_2). The dominant source of carbon monoxide (CO) is the Project's blasting explosives. The dominant sources of nitrogen oxide (NO_x) are the rock trucks and haul trucks. The dominant source of PM_{10} is the Project's blasting activities. The dominant sources of $PM_{2.5}$ are the Project's rock trucks and haul trucks. 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 are not expected to be measurable during the winter when the ground is frozen and sometimes covered in snow. Ice fog is not expected to have a measurable effect on the public.

As greenhouse gas (GHG) emissions only have a global effect and not any effect localized to the RAA, there is no cumulative interaction between the project activities and the MVWR activity other than immeasurably within global climate change phenomena.

26.4.2 Noise

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

- If the effect is high magnitude, of moderate or high sensitivity timing, and is continuous, multiple irregular, or multiple regular in frequency
- If the duration is 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)

Noise effects from the Wrigley and Tulita Power Generation facilities occur from the continuous operation of the facility generators. The cumulative effects assessment on noise only considered long-term community annoyance during the Project's operations and maintenance phase. Residences in the community of Tulita are located farther away from the project activities so the Project's contribution to the cumulative effects is expected to be less impactful for Tulita residences; therefore, these residences were not assessed separately. Three receptors were identified as being most affected by the project activities associated with Wrigley Power Generation activity. The highest change in the percent highly annoyed (%HA), 0.0%, is below the threshold criteria of 6.5%. The cumulative interaction of Wrigley Power Generation activity with project operations and maintenance activities are not expected to cause long-term community annoyance.

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.

Under the assumption that the noise effects from the construction activities of the Great Bear River Bridge project are equivalent to the Project's 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.

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's 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's 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. As described in Section 13.5.2.3, the Project's contribution to cumulative noise effect is not significant.

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

26.4.3 Terrain, Soils, and Permafrost

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.

Cumulative effects on changes to terrain conditions, changes to soil conditions, and changes to permafrost conditions arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those from the Project. 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. The effect on soil conditions from all projects and physical activities in the RAA is considered low. Lessons learned from previous linear projects are well documented. Essentially, ground disturbance, which involved eliminating or greatly reducing plant growth or effecting 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 little or no adverse cumulative effects on terrain conditions, overall distribution of soil or the soil landscape, and on the abundance and distribution of permafrost in the RAA.

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.

26.4.4 Water Quantity

26.4.4.1 Groundwater

For groundwater quantity, the significance of potential project 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 significant or not significant evaluation highly relies on professional judgement.

Residual effects from the Project on 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. Residual effects from reasonably foreseeable projects and developments are not expected to act cumulatively with the Project. Therefore, 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. Timing, duration, frequency, and reversibility are expected to be high sensitivity, long-term, continuous, and irreversible, respectively.

Cumulative residual effects on groundwater quantity range from no measurable change to moderate effects geographically limited to the LAA. Timing, duration, frequency, and reversibility of cumulative residual effects on groundwater quantity are expected to be high sensitivity, long-term, continuous, and irreversible, respectively. Based on these characterizations, as well as the significance definition above, cumulative effects on groundwater quantity are not significant.

26.4.4.2 Surface Water

For surface water quantity, the significance of project 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 15.2. 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 significant or not significant evaluation highly relies on professional judgement.

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

The cumulative residual effects on streamflows and lake volumes 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 effects cannot be quantified because quantified magnitudes of change in streamflows and 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., if the Mackenzie Valley Land and Water Board [MVLWB] considers cumulative withdrawal of less than 10% when assessing the water licence applications).

The geographic extent of these cumulative effects on streamflows and lake volumes is limited to the LAA as the magnitude of change in discharge rates of the Mackenzie River downstream of the LAA is not predicted to be measurable (i.e., not > 5% of natural flow). Further, 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 effects on streamflows and lake volumes can be sensitive, particularly if water withdrawals occur during winter (i.e., under ice conditions); during the freeze-up or thaw seasons, which may have icing implications; or when lake volumes are reduced. The effects on streamflow and 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.

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 above, these cumulative residual effects on surface water quantity are not significant.

26.4.5 Water and Sediment Quality

26.4.5.1 Groundwater

A significant residual effect on groundwater is based on professional judgement, but is one that is of moderate magnitude and geographically extensive, or is high magnitude, combined with other considerations of geographic extent, duration, and reversibility. Residual effects from the Project on 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. The residual effects of other past or present projects on baseline groundwater quality conditions with the project LAA are difficult to determine. Existing groundwater quality data (groundwater chemistry) was lacking at a level of detail required to characterize baseline conditions beyond general statements on regional and local groundwater chemistry.

Reasonably foreseeable projects and developments are not expected to act cumulatively to affect groundwater quantity, which is the pathway through which these projects may cumulatively affect groundwater quality. 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. Timing, duration, frequency, and reversibility are expected to be high sensitivity, long-term, continuous, and irreversible, respectively. The cumulative residual effects on groundwater quality are not significant.

26.4.5.2 Surface Water

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.

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 for the Project. These effect pathways may interact cumulatively with project-related changes to surface water and sediment quality. Cumulative effects on surface water and sediment quality in the RAA are anticipated to be neutral. This is because cumulative effects are anticipated to result in no measurable long-term trend in surface water and sediment quality parameters 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, acid rock drainage and metal leaching (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). 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. 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). The cumulative residual effects on water and sediment quality are not significant.

26.4.6 Vegetation

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.

Cumulative effects on landscape diversity, community diversity (including merchantable timber), species diversity (including plant species of conservation concern [SOCC] and plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties), 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 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/hectare (ha) and 1,100 m/ha, for all natural landcover types, resulting in a moderate magnitude contribution to cumulative effects on landscape diversity at the RAA level. 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 40 m from the PDA) could affect an additional 2.0% of wetlands and 3.8% of forest in the LAA, resulting in a low magnitude contribution to cumulative effects on community diversity at the RAA level.

Although no plant SOCC occurrences have been documented in the PDA or LAA, 215 plant SOCC have 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. No plant species, including bryophytes, or lichen SOCC potentially occurring in the RAA are listed under *Species at Risk Act* (SARA) or Committee on the Status of Endangered Wildlife in Canada (COSEWIC). For these reasons, the Project could make a moderate magnitude contribution to cumulative effects on landscape diversity at the RAA level. The Project may result in a reduction of wetland function; however, drainage culverts will be installed to maintain water flow across the road 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.

The Project will make a low to moderate contribution to the effects on vegetation and wetlands. However, effects will be reduced by aligning the Project with the MVWR along most of its length and allowing the sections of the MVWR not incorporated into the Project and six quarry sites to naturally revegetate. Mitigation will also serve to reduce cumulative effects on vegetation and wetlands. Cumulative effects will extend from the PDA to the RAA. Effects for 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 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.

26.4.7 Fish and Fish Habitat

The potential effects of the Project are deemed significant if the productivity and sustainability of fish populations along the Mackenzie Valley Highway corridor 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).

The residual effects of change in fish habitat from both the loss and alteration of riparian areas and areas below the ordinary high-water mark (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 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), offsetting will be required to match or exceed lost or altered fish habitat. The type of effect is in an adverse direction within the RAA. The duration is long-term and continuous. Although the effect is irreversible the magnitude of the effect is low. The change in fish habitat due to the loss and alteration of riparian habitat and fish habitat below the OHWM is not significant.

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 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. 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.

26.4.8 Wildlife and Wildlife Habitat

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 species at risk (SAR)/SOCC, or species of cultural or traditional importance.

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 will result in the direct loss or alteration of 0.2% of wildlife habitat in the RAA compared to existing conditions. Similarly, direct loss or alteration of little brown myotis maternity roosting habitat and grizzly bear denning habitat is expected to be minor, with a change of 0.2% and 0.5% from existing conditions in the RAA, respectively. The Project is also 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. 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.

The Project will increase the amount of linear disturbance within the RAA and result in potential changes in wildlife movement due to physical and sensory barriers; however, effects on wildlife movement are expected to be minimal in the RAA. With mitigation, the contribution of the Project to residual cumulative effects on wildlife movement is expected to be low.

The Project will require clearing of 2,315.2 ha of wildlife habitat (including previously disturbed habitats) and result in an increase in traffic along the highway over the long-term that could increase wildlife mortality risk. With mitigation, the contribution from the Project to residual cumulative effects on wildlife mortality risk is expected to be low.

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. As such, the effects on wildlife and wildlife habitat are not significant.

26.4.9 Birds and Bird Habitat

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.

The Project is in a corridor within the Mackenzie Valley that is subject to disturbance from past and present activities and projects, including existing linear infrastructure. 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 minor, ranging from < 0.1 to 0.7% compared to existing conditions, depending on the species or species group. Since the Project proposes to use the existing MVWR alignment 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.

The Project will require clearing of 2,315.2 ha of bird habitat (including previously disturbed habitats) and result in an increase in traffic along the highway over the long-term that could increase bird mortality risk. 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.

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. As such, the cumulative effects on birds and bird habitat are not significant.

26.4.10 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).

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, a cumulative barrier to wildlife movement and gene flow, and edge effects during the construction and operations and maintenance of the Project.

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 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. As previously reported, (Section 26.3.2.2.1) existing combined disturbance of fire and anthropogenic disturbance exceeds the conservation threshold for boreal caribou in the assessment area. The Project's contribution is minimal but contributes to cumulative effects on caribou from habitat loss that are significant.

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. Overall, the RAA will remain connected and relatively undisturbed. 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. Cumulative effects on vegetation and wildlife (including SAR/SOCC) associated with habitat fragmentation and wildlife movement are predicted to be not significant.

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.

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. The Project is unlikely to cause a reduction in species richness and/or SAR diversity.

26.4.11 Heritage Resources

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).

If all requirements issued by the Territorial regulators and via the SLUP are fulfilled prior to Project construction, the territorial government would consider there to be no significant cumulative effects for Heritage Resources.

26.5 References

ECCC. 2020. Amended Recovery Strategy for the Woodland Caribou (Rangifer tarandus caribou), Boreal Population, in Canada. Species at Risk Act Recovery Strategy Series. Environment and Climate Change Canada, Ottawa. xiii + 143pp.

GNWT (The Government of the Northwest Territories). 2000. Investing in Roads for People and the Economy: A Highway Strategy for the Northwest Territories. Available at: https://www.inf.gov.nt.ca/sites/inf/files/resources/highway_strategy.pdf#:~:text=Investing%20in%20Roads%20for%20People%20and%20the%20Economy%3AA,access%20to%20commu%20-%20nities%20and%20economic%20developments. Accessed December 2022.

GNWT. 2002. Corridors for Canada. Final draft 3. May 2002. Available at: http://library.assembly.gov.nt.ca/2002/T/02-0020435.pdf#:~:text=The%20strategic%20investments%20proposed%20in%20Corridors%20for%20Canada,not%20just%20for%20northerners%2C%20but%20for%20all%20Canadians. Accessed December 2022.

GNWT. 2005. Corridors for Canada II: Building on Our Success. Draft 6 Part A. September 2005. Available at: http://library.assembly.gov.nt.ca/2005/T/a192561.pdf. Accessed December 2022.

GNWT. 2015a. Connecting Us – Northwest Territories Transportation Strategy. Tabled Document 267-17(5) Tabled on June 3, 2015. Available at: http://library.assembly.gov.nt.ca/2015/T/a344744.pdf. Accessed December 2022.

GNWT, 2015b. Mackenzie Valley Highway: Wrigley to Norman Wells – Business Case. Submitted to Infrastructure Canada. July 2015.

Government of Canada and Sahtu Secretariat Inc. 1993. Sahtu Dene and Métis Comprehensive Land Claim Agreement

MVEIRB (Mackenzie Valley Environmental Impact Review Board). 2015. Terms of Reference EA1213-02 Mackenzie Valley Highway Extension Project Wrigley to Norman Wells Government of Northwest Territories. February 13, 2015. PR#66.

SLUPB (Sahtú Land Use Planning Board). 2023. Sahtú Land Use Plan. Government of Northwest Territories. Fort Good Hope. Ratified but not available as of July 19, 2023; see https://sahtulanduseplan.org/plan.

27.0 DEVELOPER'S COMMITMENTS

27.1 Introduction

This section provides a summary of commitments made by the Government of the Northwest Territories (GNWT) in the Developer's Assessment Report (DAR) for the Mackenzie Valley Highway Project (the "Project"), including:

- Design commitments
- Mitigation measures to reduce adverse effects and cumulative effects on the environment
- Monitoring and management plans
- Engagement with Indigenous Governments, Indigenous Organizations and other affected parties (engagement)

Commitments may be based on:

- Regulatory requirements (i.e., legislation, regulations, permit conditions)
- Published guidance or management plans (i.e., guidelines, policies, manuals)
- Standard best practices for this area (i.e., accepted commercial or professional procedures)
- Traditional Knowledge or engagement input (i.e., engagement collaboration)
- Professional experience or precedent (i.e., learned through project experience)

The GNWT will establish a Mackenzie Valley Corridor Working Group (MVHCWG) as a forum for information exchange between the GNWT, Indigenous Governments, Indigenous Organizations, other affected parties, federal government departments, and the contractor. Through the MVHCWG, the GNWT will report on the Project and its commitments, and will receive input on management and monitoring of the Project as part of adaptive management.

The following tables summarize the commitments identified in various chapters of this DAR or through engagement. If an inconsistency is noted in the summary of commitments, the chapters or other source information (e.g., management plans) should be viewed as the authoritative resource for commitments. This may arise if the context of the commitment is relevant (for example it has been made in response to a comment received during engagement). Commitments may be applicable to more than one valued component (VC), however it is only presented once under the main category to avoid repetition.

27.2 Design Commitments

Design commitments reflect the standards, criteria, objectives and methods to be used to design the Project. Design commitments are used in part to define the scope of the Project to be assessed and to reduce potential adverse effects of the project on VCs. Table 27.1 lists design mitigation measures.

Table 27.1 Project Design Mitigation Measures

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Pl	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Opinion/ Experience/Precedent
01	The Project will meet the Rural Arterial Undivided (RAU)-90 design designation (Transportation Association of Canada [TAC], 2017).	x	x	x		
02	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.		x	x	x	
03	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.			x	x	x
04	The right-of-way (ROW) will be limited to 60 metres (m) width, except where large cut or fill sections are required.			x		
05	The highway alignment will optimize use of natural topography to reduce material requirements (such as avoiding the need for deep fills).			x		x
06	The highway alignment will reflect community engagement input to the extent practicable.		x	x	x	
07	Pullouts will not be located near watercourses with sport fish.				x	x
08	The Project will maintain cost-effectiveness in construction, operations, and maintenance.		x	x		x
09	Speed limits will be posted on the public highway.	x				

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Pl	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Opinion/ Experience/Precedent
10	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.		x	x		
11	Grading of stream banks at approaches shall be limited where possible.		x	x		
12	Borrow sources will not be located in areas where there is a high groundwater table.		x	x		x
13	Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns.		x	x	x	
14	Drainage culverts will be installed to accommodate storm events and maintain drainage patterns and in consideration of site-specific icing/glaciation effects.		x	x	x	x
15	Culverts will be designed and constructed to maintain water flow and fish passage.	x			x	
16	Modification to the location or number of drainage culverts will be determined in consultation with the Engineer as based on observed site conditions.			x		x
17	Only material with low acid rock drainage (ARD) and metal leaching (ML) potential will be used for the Project.		x			
18	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.		x			
19	Maintenance yards will have a liner or concrete installed under areas of vehicle storage and maintenance.		x			
20	A fill-only construction approach will be used, except at specific locations of road cuts.			x		x

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Opinion/ Experience/Precedent
21	Project design will avoid ice-rich areas where possible.		x	x	x	
22	Steep grades where subsidence may occur as a result of permafrost thaw will be avoided, where possible.		x	x		
23	To the extent possible, plan the Project highway alignment to avoid the base of Bear Rock.				x	x
24	Known areas of collection of plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties will be avoided where possible.			x	x	

27.3 Mitigation Commitments

Mitigation measures are specific actions that help to reduce, eliminate, or control adverse effects of the Project on VCs. The assessment of residual effects on VCs assessed in the DAR relies on implementing the mitigation measures identified for each potential effect. These mitigations are commitments that the GNWT as the proponent of the Project will uphold.

27.3.1 Biophysical and Cultural Environment Commitments

Biophysical and cultural environment commitments include mitigation measures found within the DAR related to biological, culture and traditional land use and heritage resources VCs. Table 27.2 includes mitigation commitments made by the GNWT applicable to the biophysical and cultural environment and have been grouped under the following categories:

- General – those that apply to multiple VCs and include commitments related to public safety
- Spill Prevention – those that apply to reducing the potential for, or consequence of, accidents or malfunctions
- Atmospheric Environment – those that apply to noise and air quality
- Aquatic Environment – those that apply to water and sediment quality, water quantity, and fish and fish habitat

- Wildlife and Terrestrial Environment – those that apply to soils, terrain and permafrost, vegetation and wetlands, caribou and moose, wildlife and wildlife habitat, birds and bird habitat
- Cultural and Heritage Resources Environment – those that apply to culture and traditional land and resource use and heritage resources

Table 27.2 Project Environmental Mitigation Measures

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
General						
25	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.		x			
26	Dust suppression will be conducted as necessary to reduce dust and sediment from entering watercourses or waterbodies.		x	x	x	
27	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.		x	x	x	
28	A minimum of 10 cm of packed snow or ice will be used on winter access roads.	x	x			
29	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.		x	x		
30	Best management practices for erosion control will be implemented according to the Erosion and Sedimentation Control Plan.	x	x			
31	Construction activities will be scheduled to reduce disruption to public and commercial vehicle access on the MVWR, where possible.			x		
32	Project vehicles will be regularly maintained.			x		

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
33	Project vehicles will travel on designated winter roads or constructed embankment only.		x	x		
34	Efficient project planning will be used to reduce haul distances and the number of trips required to move road construction materials.			x		
35	Equipment will be operated in a manner that minimizes disturbance to lake, river, or stream banks.		x	x		
36	Equipment will be operated on designated workspaces or existing roads only.		x	x		
37	Equipment, wastes and contaminated soils will be removed once construction is completed.	x			x	
38	If surface organic material must be removed for construction, it will be stockpiled and re-applied where possible.	x	x	x		
39	Off-road travel will be limited to frozen conditions (approximately December 15 to April 1), where possible		x	x		
40	Organic material and topsoil will be set aside for use during reclamation, where possible.	x	x	x		
41	Public access to active borrow sources and quarries and associated access roads will be restricted		x		x	
42	Sewage and greywater are to be stored in approved holding tanks for this purpose prior to removal from site or disposed of in accordance with the land use permit.	x	x	x		
43	The objective of site closure will be to approximate pre-development conditions to the extent possible.		x	x		
44	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.				x	x

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
45	Soil stripping operations in borrow areas will be conducted under the guidance of a qualified person.			x		
46	Temporary access roads, quarries and workspaces not needed after construction will be closed and reclaimed.	x	x			
47	The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical.		x	x		
48	Project vehicles will be confined to existing infrastructure roads and trails as much as possible to avoid disturbing vegetated areas.		x			
49	Vehicle and equipment speeds will be limited to 50 kilometres per hour (km/h) on unfinished project road surfaces.			x		x
50	A Project-specific Erosion and Sedimentation Control Plan (ESCP) will be developed and implemented.	x				
51	A Project-specific Permafrost Protection Plan (PPP) will be developed and implemented.			x		
52	A Quarry Development Plan (QDP) will be developed and implemented for each quarry and borrow source.	x				
53	A Traffic Management Plan will be developed and implemented.	x		x		
54	A Waste Management Plan (WMP) will be developed and implemented.	x				
55	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. Duration of the WMMP for the Project operations phase will be determined through further discussions during the EA	x				
56	An Emergency Response Plan for construction will be developed and implemented.	x				

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
57	An Explosives Management Plan will be developed and implemented.	x				
58	A Fish and Fish Habitat Protection Plan will be developed and implemented.			x		
59	A Heritage and Sites Protection Plan will be developed and implemented.		x	x		
60	A Spill Contingency Plan will be developed and implemented.	x				
Safety						
61	Access to construction areas will be limited to Project personnel only for safety reasons.		x			
62	All construction workers will have sufficient safety training to reduce potential for severe accidents.	x				
63	The GNWT will deliver public education around highway safety, provide proper highway signage and maintain the ROW to provide clear line of sight for drivers			x	x	
64	Quarry design, development and closure will take into account public safety.		x	x		
65	Signage and physical barriers will be used to identify areas of active construction and to provide separation between workspaces and the MVWR for public safety and security.	x	x			
66	The Traffic Management Plan will: a) identify the sections of the MVWR to be impacted by construction b) illustrates work zones and Project vehicle movements c) illustrates public vehicle detours d) specifies requirements for escorts, signage, lighting and speed reductions e) specifies work times and measures for public safety during non-work times f) specifies communication protocols between the Project construction team and MVWR operations team.	x				

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
67	To mitigate interaction with the Project and Mackenzie Valley Fibre Link (MVFL) the construction contractor will work with the owner (GNWT finance) and their partner (Northern Lights General Partnership, NLGP) to develop mitigation / construction measures to protect both assets.			x		
Spill Prevention						
68	Equipment laydown and staging areas will be located at least 100 m from the ordinary high water mark of any waterbody.	x	x			
69	Mobile equipment will be refueled more than 100 m away from the bank ordinary highwater mark of a watercourse or waterbody.	x				
70	Emergency spill response kits will be kept in vehicles and at fuel storage locations.	x	x			
71	Fuel handling and refueling will be in accordance with an Operating Procedure to be included in the Spill Contingency Plan.			x		
72	Fuel will be stored in containers with secondary containment capable of containing 110% of the largest container.	x				
73	Equipment such as vehicles, generators and pumps will have secondary containment installed capable of containing fuel drips or leaks during operations and refueling.	x	x			
74	Fuels and oils/lubricants must be stored more than 100 m from the ordinary highwater mark of a watercourse or waterbody.	x				
75	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.	x	x	x		
76	Material Safety Data Sheets for hazardous substances will be stored on site.	x				

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
77	Spill contingency measures will be implemented in accordance with the Spill Contingency Plan.	x	x			
78	The Spill Contingency Plan will include procedures to prevent and respond to spills.	x	x			
79	Vehicles parked for more than 2 hours will use drip trays.	x				
80	Construction activities will be scheduled to reduce disruption to public and commercial vehicle access on the MVWR, where possible.			x		
81	Prior to start of construction, the GNWT (or its contractor) will identify the location of the MVFL and will work with the operator of the MVFL to implement appropriate precautions to prevent damage.			x	x	
82	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.	x	x			
Atmospheric Environment						
83	Cold starts of equipment will be limited to the extent possible.			x		
84	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.	x	x			
85	Road surfaces will be repaired and maintained to reduce rolling resistance of vehicles.			x		x
86	The contractor will be encouraged to use modern Project vehicles that have lower GHG emissions.			x		
87	Equipment idling will be discouraged or limited.		x	x		
88	The contractor will be encouraged to use passenger vehicles (e.g., passenger van or bus) to move crews.			x		

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
89	Vehicles and equipment will be maintained regularly in good working order			x		
90	Blasting activities will be limited to daytime hours to the extent practical.	x				
91	Blast mats will be used when blasting near receptors sensitive to noise.		x			
92	Communities will be informed of time periods and characteristics of noise that may exceed the recommended noise threshold.			x		
93	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 noise when blasting in sensitive environments.			x		x
94	Project vehicles will avoid the use of residential roads, where possible.			x	x	
95	The use of modified blasting techniques will be considered to reduce noise, 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.					x
96	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).			x		
97	Use of residential roads by Project vehicles will be limited, where possible.			x	x	
98	Vehicles and equipment will be equipped with manufacturer recommended noise muffling equipment.			x		

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
Aquatic Environment						
99	No fording of watercourses will be permitted except to install a temporary work bridge.	x				
100	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 2022).	x	x			
101	Temporary bridges, if required, will not be placed below the ordinary high-water mark.	x	x			
102	Temporary crossings will be constructed perpendicular to the watercourse.		x			
103	Snow fill crossings will be v-notched prior to the spring melt/freshet before April 1 each year.	x				
104	Snow fill temporary crossings will be constructed of clean snow fill.	x				
105	Ice in culverts will be thawed by steaming, where needed to maintain flow.			x		

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
106	An Explosives Management Plan (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 ammonium nitrate/fuel oil (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.	x				
107	Blast holes will be kept free of water where possible to avoid the incomplete combustion of ANFO.			x		
108	Blast rock will not enter a waterbody or watercourse.	x				
109	Blasting will not occur within 100 m of fish-bearing waterbodies such that instantaneous pressure will be less than 50 kilopascals (kPa) where fish maybe present and particle velocity will be less than 13 mm/s (millimetres/second) near a spawning bed where eggs or larval fish may be present.	x				
110	Cleared snow will be directed away from watercourses and drainages.		x			
111	Explosives will be sealed and kept dry to prevent the incomplete combustion of ANFO.			x		

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
112	Instantaneous pressure change during blasting will be limited to no more than 50 kPa and particle velocity will be less than 13 mm/s within or near a spawning bed where eggs or larval fish may be present.		x			
113	In-water construction activities will be conducted during no or low flow periods where possible and with erosion control mitigation in place.		x			
114	Quarry operations will be located a minimum of 100 m from the ordinary high-water mark of any waterbody.	x				
115	Excavated spoil material will be placed at least 30 m from a watercourse.	x				
116	Ponded water will be directed away from watercourses.		x			
117	Rip rap repair and culvert construction will be timed to avoid restricted activity periods for fish as applicable to the watercourse.	x	x			
118	Rip rap will be free of silt and other debris.		x	x		
119	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.		x			
120	Temporary isolation will occur for the placement of rip rap and culverts and will follow the code of practice: temporary cofferdams and diversion channels (Interim) (DFO, 2020).		x			
121	To the extent possible, blasting activities will be completed during winter months to avoid freshet runoff.					
122	Water flow and fish passage will be maintained during construction.	x			x	
123	Instream work will be limited to the extent possible.		x			

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
124	Work within the active stream channel will be avoided where possible.		x			
125	Machinery will not be left in any waterbody.	x				
126	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.	x				
127	Banks will be restored to original condition or as design specifies.	x	x			
128	Water withdrawal will be in accordance with DFO measures to protect fish and fish habitat and the code of practice: end-of-pipe fish protection screens for small water intakes in freshwater (Interim) (DFO, 2020).	x	x			
129	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) and other applicable guidance.	x	x			
130	Winter water withdrawal will only occur at approved locations.	x				
131	Project-related all-terrain vehicles (ATVs) and mobile equipment will avoid steep banks at crossings.		x	x		
132	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.	x	x			
133	Erosion and sedimentation control measures and structures will be repaired if damage occurs.	x	x			

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
134	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.		x	x		
135	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.	x	x			
136	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).		x			
137	Non-biodegradable erosion and sediment control materials will be removed once the site is stabilized.	x	x			
138	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 to the extent possible.		x	x		
139	Sediment control measures will be in place prior to construction activities and before the spring melt/freshet.	x	x	x		
140	Sedimentation control measures will be used at all new watercourse crossings.	x	x			
141	Silt fencing will be used downgradient of the works where required.	x	x			
142	Quarry dewatering will be conducted in a manner that discharge will not directly enter wetlands, or lead to soil erosion.		x			
143	Riparian vegetation will be maintained whenever possible.		x	x		
144	Soils stripping will be postponed on borrow areas on coarse textured soil during windy conditions to reduce deterioration of soil conditions.			x		

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
145	The slope of the cut or fill will have a horizontal to vertical ratio accounting for the geotechnical properties of the materials.		x	x		x
146	To promote the stability of cuts and fills on slopes, fill material will be compacted and the tops of cut slopes will be rounded.		x	x		x
Wildlife and Terrestrial Environment						
147	An electric fence will be set up around temporary camps if deemed necessary to deter wildlife.			x		
148	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.	x				
149	Caribou and moose will have the right of way on all Project infrastructure during construction as detailed in the WMMP.		x			
150	Construction and quarry development activities will adhere to the applicable recommended setbacks and timing restrictions for wildlife outlined in the WMMP, where possible.	x	x			
151	Construction and quarry development activities will be limited during sensitive periods for wildlife in accordance with the WMMP.		x		x	
152	Construction and quarry development activities will be reduced, where possible and spatial overlap is expected, during sensitive periods for wildlife in accordance with the WMMP.		x		x	
153	Construction personnel will be prohibited from using recreational all-terrain vehicles and snowmachines while working on the Project.			x		
154	Equipment originating from outside of the Northwest Territories will be cleaned prior to mobilization to avoid introduction of invasive species.		x	x		

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
155	Food and other wildlife attractants will be stored in bear-proof containers.		x	x		
156	Food waste will be stored and disposed of in a manner to avoid attracting wildlife.	x				
157	GNWT will conduct a pre-construction rare plants survey in high potential areas of the project development area (PDA). This will include transplant or seed collection of observed rare or vulnerable plant species.	x				x
158	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.	x	x			
159	If an active bird nest is found, beneficial management practices (GNWT 2020d) will be followed, including applying an appropriate setback and timing restriction and GNWT-Environment and Climate Change (GNWT-ECC) and/or Environment and Climate Change Canada (ECCC) will be consulted, as appropriate.	x	x			
160	Machinery will arrive onsite and will be maintained in a clean condition and free of invasive species and noxious weeds.		x	x		
161	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.	x				
162	Non-merchantable trees will be limbed and stacked for community use, where possible.			x	x	
163	Personnel will not feed or harass wildlife while working on the Project.	x				
164	Pre-construction surveys will be completed to identify possible wildlife habitat features along the ROW (like mineral licks) and potential crossing locations.	x	x			

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
165	Project personnel will be prohibited from hunting and fishing while housed in work camps for the Project.			x		
166	Project staff will take the GNWT's Migratory Bird Awareness Training Webinar and obtain a certificate to demonstrate proof of training.		x	x		
167	Quarries will be maintained in accordance with beneficial management practices (GNWT 2020d) to reduce the potential for nesting by bank swallow.		x			
168	Removal of vegetation will be limited to the width of the ROW and workspaces.		x	x		
169	The height of snowbanks will be limited to the extent possible and to a height of less than 1 m.			x		x
170	The Project will follow setback distances specified in the WMMP.	x	x			
171	Breaks of approximately 10 m in width should be left in the windrow at approximately 300 m intervals to reduce blockage of wildlife movement.		x			
172	A bear deterrent procedure will be developed following consultation with ECC to determine appropriate bear deterrents (e.g., temporary fencing, bear bangers) and safety procedures.		x			
173	The application of unmanned aerial vehicles (UAV) (i.e., drones) will be considered to increase efficiency of observation during pre-blast surveys.					x
174	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).		x			
175	The Project will follow measures in the Quarry Operations Plan to reduce ponding, erosion and damage to permafrost during quarry operations and closure.		x			

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
176	Borrow source floors will be sloped to reduce ponding of water.		x			
177	Borrow source vegetated surface material where present will be replaced after development is completed.			x		
178	Cleared brush and unsalvageable trees will be windrowed, mulched and spread on the ROW where possible.			x		x
179	Clearing of new areas will be completed when the ground is frozen to limit disturbance to soils and permafrost.		x	x		
180	Where vegetation must be cut but is not removed, the cut will be made >10 centimetres (cm) above the ground to retain the root structure.		x			
181	Clearing will be completed by hand, where required to prevent damage to the ground such as rutting, compaction and erosion.		x			
182	Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the ROW and approved access roads).			x		
183	Clearing will be limited to areas required for construction and safe operations.			x		
184	Clearing will not be conducted during high rainfall or runoff events.		x	x		
185	Tree roots will be grubbed only in areas required for construction or stripping.			x		
186	Postpone soil salvage during wet weather or high winds to prevent erosion and/or damage to the soil structure.			x		
187	Trees will be felled toward the ROW and access roads wherever possible to reduce damage to vegetation outside of the ROW and access roads.			x		

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
188	Vegetation buffers will be used as visual barriers and to protect riparian vegetation, as appropriate.	x	x			
189	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.		x	x		
190	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.		x	x		
191	Vegetation control (brushing) will be implemented along ROW to decrease potential forage attraction and increase visibility for driver safety.			x		
192	Wildlife crossing locations will be identified and marked.			x		
193	The Project will follow setback distances for caribou as specified in the WMMP.		x			
194	Abandoned sections of MVWR ROW and access roads will be closed and reclaimed.			x		
195	A pre-construction beaver dam and lodge survey will be conducted, as per the WMMP, to identify those potentially to be impacted by construction.		x			
196	Construction on cleared ground will be conducted during dry or frozen conditions, or use rig matting to reduce soil compaction, rutting and erosion.		x	x		
197	Undisturbed areas will be avoided until they are scheduled for clearing/stripping to limit unnecessary soil degradation and compaction.			x		

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
198	Use of equipment on highly saturated soil will be avoided, where possible.		x	x		
199	Disturbance of the active layer during construction and maintenance activities will be avoided where possible.		x	x		
200	During spring, summer, and fall, suitable equipment will be used to prevent effects on sensitive terrain.		x	x		
201	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.		x			
202	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.		x	x		
203	Runoff control methods will be used to protect permafrost soils including but not limited to: the 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		x	x		
204	The Project will follow measures in Permafrost Protection Plan to reduce ponding, erosion and damage to permafrost.		x			
205	Where possible, cleared material will be mulched and spread over cleared areas within the Project footprint to protect the soil and permafrost.		x	x		x

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
206	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.			x		
207	Excavations will be contoured prior to closure to reduce steep slopes.		x			
208	Geotextile and embankment placement will be completed in the winter to limit disturbance to soils and permafrost.			x		
209	Ice-rich soils or materials that are susceptible to physical erosion encountered during excavation will be covered to reduce permafrost degradation.		x	x		
Cultural and Heritage Resources Environment						
210	A 30 m avoidance/setback from known archaeological resources will be implemented.	x	x			
211	Access to identified current use sites (located outside of the designated construction and project site limits) will be maintained during construction and operation.			x	x	x
212	An archaeological chance find protocol will be implemented.			x		x
213	Clearing schedules will be communicated in advance of clearing to provide an opportunity to collect plant material from the PDA.				x	x
214	Develop and maintain compliance with a chance find protocol (including worker education) for cultural materials and sites identified during construction.			x		x
215	Site-specific mitigations required by the Prince of Wales Northern Heritage Centre (PWNHC)as based on Archaeological Impact Assessments (AIAs) will be implemented.	x		x		

27.3.2 Socio-Economic Commitments

Socio-economic commitments include measures found within DAR related to social, cultural, human and economic VCs or topic discussion areas relevant to key lines of inquiry (KLOI). Additionally, the GNWT has made several commitments to create different working groups and management plans to address socio-economic considerations on the Project. Table 27.3 summarizes these commitments made by the GNWT that are intended to reduce or eliminate adverse effects to the human environment.

Table 27.3 Proposed Socio-Economic Commitments

Commitment Number	Commitments
216	The GNWT will establish a Mackenzie Valley Highway Corridor Working Group (MVHCWG) that supports the development and oversight of a Community Readiness Strategy that outlines the overarching approach to enhancing benefits and minimizing risk. The work of the MVHCWG and the Community Readiness Strategy will begin 1 year prior to the start of construction, be active during construction and will remain in effect for five years post-construction. The MVHCWG will meet face-to-face twice per year during the time that it is in place. The GNWT Role in and Commitments to MVHCWG: • Provide base annual funding to support the work of the MVHCWG • Provide one Department of Health and Social Services (HSS) position to focus on Socio-Economic Impact Assessment (SEIA) related monitoring associated with the Project • Provide one Department of Infrastructure (INF) position to focus on MVHCWG coordination and to chair meetings associated with the Project

Commitment Number	Commitments
217	The GNWT will develop and implement a Safety and Security Plan for Vulnerable Community Members. The plan, as it relates to the Project, will be developed in collaboration with the GNWT Interdepartmental Missing and Murdered Indigenous Women and Girls (MMIWG) Working Group and community-based organizations that are focused on protecting women, children, youth, and vulnerable populations (e.g., Two-Spirit, lesbian, gay, bisexual, transgender, queer, intersex and additional sexually and gender diverse people [2SLGBTQQIA+], homeless or underhoused) from gender-based violence, family abuse, and family neglect. The plan will: • Be based on a trauma-informed approach in order to be flexible enough to allow for the uniqueness of each community's and person's situation. • Align with the GNWT's response to MMIWG – Doing Our Part: Initial Response to 'Reclaiming Power And Place: The Final Report of the National Inquiry into Missing And Murdered Indigenous Women And Girls'. • Will consider findings from the social and well-being monitoring program for the Tłı̨chǫ Highway and the Social Monitoring and Adaptative Management Plan for the period of construction and a period of five years of operations after Project construction is completed. It will also consider findings and approaches from other jurisdictions (e.g., the 'Community Safety Toolkit' developed by the Carrier Sekani Family Services along the Highway of Tears). • Support the provision of safety education to women, youth and children to help them identify and assess risks of violence (physical, sexual, emotional) and reduce harms. • Support the provision of public safety information throughout the community to build a culture of safety. • Support the implementation and coordination of health and wellness promotional campaigns that target preparedness for change, addressing safety and security risks associated with the highway and health behaviour change as a result of the Project (e.g., sexually transmitted infections (STIs), family violence, mental health and addictions services) to women, children, and vulnerable populations. • Support increased access to: emergency shelters; safe and affordable transportation (along the highway); communication along the road; education and training opportunities; employment opportunities; and culturally-based (on the land) mental health and addictions programs.
218	To enhance positive effects from the Project the GNWT will establish a Training and Employment Sub-Working Group that informs and supports the development and implementation of a Contractor Training and Employment Plan and reports to the MVHCWG. The MVHCWG will collectively determine who should sit on the Working Group from the GNWT, education and industry partners, and community leadership and organizations. The GNWT will provide funding to coordinate and handle all logistics and expenses associated with the Training and Employment Sub-Working Group. The Sub-Working Group will meet face-to-face once per year and three times a year virtually for the time period it is in place.

Commitment Number	Commitments
219	The Contractor Training and Employment Plan will be developed in collaboration by the Training and Employment Sub-Working Group with communities and in partnership with Aurora College and other education partners. The plan will outline the overall approach to education, training, and employment readiness for LAA and RAA residents so they can enhance employment opportunities during construction and operations, will leverage existing programs and augment them through adaptative management and as identified through monitoring. The plan is project-specific and includes the following: • Identifies employment opportunities (types, numbers, timing/schedule and employment hiring requirements) during construction and operations, informed by information from the GNWT and contractors about the project schedule and well in advance of the beginning of construction. • Identifies availability of and gaps in skilled labour for construction employment opportunities in each of the communities including the creation of skill inventories, and seeks to address these to support optimizing training and employment opportunities. • Identifies barriers to increasing uptake in education and training courses (e.g., restricted licences in Tulita) and develops potential solutions to implement. • Identifies education, skills and training programs and courses required to address lack of available skilled labour for construction and operations in each of the communities, including sharing information about Labour Market Programs that can support communities, employers and organizations. • Identifies education and training programs and courses currently available (and where (local community learning centres (CLC) or campus)/how offered (in-person/remote/blended)) and new programs and courses required to meet local need (as well as whether or not additional staffing and space requirements are necessary). This could include the Virtual Learning Strategist and Build Your Skills services/programs currently offered by the Department of Education, Culture and Employment (ECE). • Identifies potential funding to support education and training prior to construction, during construction and operations. • Plans for employment and local opportunity catchment to reduce a surge in the required labour force during construction, reducing the potential for in-migration to the region. • Explores feasibility of building workshops in each community to support hands-on learning opportunities. • Identifies existing programs that support cultural awareness and anti-racism training to mitigate potential adverse effects associated with presence of non-resident workers. • Ensure all communities are supported to prepare the workforce for employment opportunities through coverage of existing ECE programs and positions (e.g., Career Development Officers). Communities will be encouraged to develop community labour market plans to evaluate their needs in relation to the Project.

Commitment Number	Commitments
220	The GNWT includes conditions in construction contracts that require the contractor to prepare a Contractor Training and Employment Plan that: • Outlines how they will increase on-the-job training for local assessment area (LAA) and regional assessment area (RAA) residents. • Demonstrates through reporting that LAA and RAA residents and Indigenous people are being trained. • Demonstrates how local and Indigenous labour and businesses will be sourced. • Commits to cultural awareness and anti-racism training to mitigate potential adverse effects associated with presence of non-NWT/non-LAA/RAA workers. Details how contractors will communicate and collaborate with LAA and RAA community governments and Indigenous organizations regarding their involvement in construction and operation.
221	ITI staff are available to discuss tourism readiness with communities and has funding available in various programs that can be used by communities to develop community led initiatives such as tourism plans as communities identify a need or desire to create a specific plan related to maximizing benefits and mitigating adverse effects associated with the operation of the Project, including: • Identifying barriers or gaps in the current state that need to be addressed to fully realize benefits from tourism; • Identifying future potential for tourism development and promotion; and Identifies additional needs and supports needed and available to mitigate adverse effects related to tourism as a result of the Project.
222	Establish a Road Safety and Security Sub-Working Group that is responsible for two plans: a Safety & Security Plan for Vulnerable Community Members and a Road Safety Plan. The Sub-Working Group will report to the MVHCWG.
223	Develop a Road Safety Plan (that aligns with the NWT Road Safety Plan, 2015) that supports safety along the Project by addressing the following needs: • Improving communication along the highway (e.g., signage, communications) • Raising public awareness about highway safety – Conducting highway safety information campaigns on topics such as: drinking/drugs and driving, hitchhiking risks, wildlife risks, winter driving risks, speed, seat belts • Exploring the use of restricted licences in Sahtu communities. • Identifying segments of the population that are most at risk on the road (e.g., youth, women, new drivers) to consider their unique circumstances and appropriately target education and awareness efforts and materials. Enforcing highway safety via implementation of standard practice patrols and check stops along the Project once operational.

Commitment Number	Commitments
224	• The GNWT will provide funding to coordinate and handle all logistics and expenses associated with the Road Safety and Security Sub-Working Group. • The GNWT will ensure that information about the Project is shared with the Road Safety and Security Sub-Working Group to inform decision-making and planning activities. • GNWT departments (Department of Justice [JUS], HSS, Department of Executive and Indigenous Affairs [EIA], Department of Municipal and Community Affairs [MACA) will provide expert knowledge and advice on components of the plans where applicable and when appropriate. • GNWT departments (JUS, HSS, EIA, MACA) will work with communities to identify existing programs and services that support LAA communities in achieving the objectives of the Road Safety Plan and Safety and Security Plans. • The GNWT will provide financial and in-kind support to the LAA communities to develop their own Safety and Security Plans. • The GNWT will provide financial support for 1 part-time community-based implementation coordinator per LAA community, specifically focused on the Road Safety Plan and the Safety and Security Plan for Community Members. The positions would be in place for the period of construction and five years of operations. The positions would be responsible to act as a liaison between communities and the Sub-Working Group on issues related to the work of the committee and keep community leadership and members informed about progress.
225	Establish a Social Monitoring and Adaptative Management Sub-Working Group that develops a Social Monitoring Plan and a Well-Being Adaptive Management Plan. The Sub-Working Group reports to the MVHCWG and will be active during construction and for a period of five years during operations. The Sub-Working Group is responsible for annually monitoring changes in community well-being indicators related to Project activities and/or effects and responding with appropriate adaptive management measures. The working group is to be comprised of representatives of the communities and community organizations, and from the GNWT Departments of INF, ECE, HSS, MACA, JUS, Housing NWT, as well as community governments, RCMP, and relevant social and health agencies or stakeholders. Given that Project-related social and health effects may be felt in both communities local to the Project (Norman Wells, Tulita, Wrigley) and also extend to regional communities (Fort Good Hope, Colville Lake, Délı̨nę, Fort Simpson), the Working Group will include representatives from both local and regional communities. The GNWT will provide funding to coordinate and handle all logistics and expenses associated with the Social Monitoring and Adaptive Management Sub-Working Group. The Sub-Working Group will meet face-to-face once per year and three times per year virtually for the time that it is in place.

Commitment Number	Commitments
226	The Well-Being Adaptive Management Plan will be collaboratively developed by subject matter experts and community members. It will identify actions to be implemented at the community level in the LAAs and/or the broader RAAs to mitigate negative effects. The developer will provide funding to support the implementation of these mitigations and additional work will be supported by the appropriate responsible program areas. Activities identified as part of the Well-Being Adaptive Management Plan will be informed by and build on existing GNWT policies and programs related to Project effects. Implementation of the Adaptive Management Plan is supported by the developer and will be focused in the following areas: • Community Safety • Community Wellness • Community Services • Substance Abuse and Bootlegging
227	• The Social Monitoring Plan provides the basis for the Social Monitoring and Adaptative Management Sub-Working Group and the MVHCWG to monitor socio-economic and well-being indicators. It will track the implementation of the activities identified in the Well-Being Adaptive Management Plan, the Contractor Training and Employment Plan, the Road Safety Plan and the Safety and Security Plan for Vulnerable Community Members. • This plan will include identifying appropriate well-being indicators, associated trends and thresholds for change, and measure the overall effects of the project on community well-being. • The Monitoring Plan will track the indicators that are identified in the Plan during the construction of the project and for the first five years of operations. The Social Monitoring and Adaptative Management Sub-Working Group Working Group will review and discuss the monitoring results on an annual basis and will provide annual reports to the communities, as well extend an invitation to meet and present directly to communities.
228	The GNWT will ensure that information about Project timing, progress and issues that arise are shared among all participants and with communities.
229	The GNWT will provide funding for expenses related to monitoring and public reporting and communications.
230	Once construction is complete, the GNWT will consider repurposing of construction camps for use as housing in LAA communities.

27.4 Compliance and Effects Monitoring Commitments

The DAR includes commitments to undertake compliance and effects monitoring, and to undertake a review of findings as part of an adaptive management framework. These commitments are summarized below. Management Plans have been proposed in the DAR. These include specific commitments for actions, monitoring and reporting relevant to the subject of each Management Plan. See Chapter 23 for details on how the GNWT will implement, manage, and report on environmental compliance and effects monitoring undertaken for the Project.

Commitments related to compliance and effects monitoring have been summarized in Table 27.4 the following categories:

- General – those that apply to multiple VCs and include commitments related to public safety
- Spill Prevention – those that apply to reducing the potential for, or consequence of, accidents or malfunctions
- Atmospheric Environment – those that apply to noise and air quality
- Aquatic Environment – those that apply to water and sediment quality, water quantity, and fish and fish habitat
- Wildlife and Terrestrial Environment – those that apply to soils, terrain and permafrost, vegetation and wetlands, caribou and moose, wildlife and wildlife habitat, birds and bird habitat
- Cultural and Heritage Resources Environment – those that apply to culture and traditional land and resource use and heritage resources

Table 27.4 Environmental Monitoring Commitments

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
General						
231	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.		x	x		
232	Several monitoring requirements have been identified that are designed to reduce the likelihood and severity of effects of environmental change on the Project. These are: • Periodic surrounding surface surveys using remote sensing techniques every 5 to 20 years to identify areas where surface features such as ground elevation, vegetation cover, surface water flow or areas of pond development have changed. • Engineer inspections after severe events to ensure the integrity of roadway and drainage systems. • Frequent inspections of the performance of the infrastructure (e.g., culverts are clear in the spring and the fall). • Regularly monitor road maintenance efforts and climate data to better correlate the change in road surface with climate-related parameters and their potential changes. • Develop an adaptative management approach to future maintenance and rehabilitation.					x
233	Contractor will obtain approval and agreement from the Town of Norman Wells, the Hamlet of Tulita, and Wrigley to use their community water supplies, their sewage lagoon and solid waste disposal facilities.	**x**				

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
234	The GNWT will develop a Project Complaints and Response Plan.			**x**		
235	The contractor will be required to provide an estimate of the amount of water required from the Town of Norman Wells, the Hamlet of Tulita, and Wrigley and the amount and type of domestic waste to be disposed into these communities prior to construction.	**x**				
236	Details of management and operation of incinerators will be included in the Waste Management Plan.		**x**			
237	The GNWT will conduct a review of all safety incidents and corrective actions.			**x**		
Spill Prevention						
238	All site personnel will receive spill contingency plan training and will have awareness of spill prevention.		x	x		
Atmospheric Environment						
239	GNWT will develop a system to track complaints and responses to manage and mitigate feedback from the public regarding noise concerns.					x
Aquatic Environment						
240	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 may be used to support future Project-specific monitoring programs.		x			x
241	Monitoring will be undertaken to confirm the project meets DFO criteria for under-ice withdrawals and other withdrawal related conditions as may be specified in water licences.	x	x			

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
242	Routine periodic inspection of culverts will be conducted 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.	x	x	x		
243	Surface water quality will be monitored during water course crossing construction and borrow and quarry operations.	x	x			
244	The Quarry Development Plan will include measures to assess and mitigate, if needed potential residual effects of excavation on groundwater quantity and quality for each borrow pit and quarry site. These plans will outline required actions should groundwater withdrawal and subsequent discharge begin to affect groundwater quantity or quality or other VCs.		x			
245	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.		x			
246	Erosion and drainage patterns will be observed and documented per the Erosion and Sedimentation Control Plan.		x	x		
247	Erosion and sedimentation control measures will be regularly inspected and maintained.	x	x			
248	Sediment and erosion control measures will be regularly inspected to confirm they are performing as intended.		x	x		

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
249	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 practical, monitoring of the thermal regimes to assess if the embankment performs as designed.			x		**x**
250	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.		x			
251	The stability of permafrost over time will be monitored.			x		x
252	Barren-ground caribou surveys, currently completed by GNWT-ECC and other organizations, will continue to monitor the distribution, abundance, and population trends of the Bluenose-East herd.	x			x	
253	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 operate as proposed.	x	x			

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
254	Survey programs, currently completed by ECC, will continue to collect ongoing information on distribution, abundance, and population trends of moose.			x	x	
255	Targeted vegetation and wetland surveys of species of conservation concern (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.	x			x	x
256	The boreal caribou collar program, currently completed by GNWT-ECC, will continue to collect ongoing information on distribution, movements, and mortality. Existing and newly collected data will be analyzed to obtain movement information to assist in determining adverse effects of the Project.	x			x	x
257	The database for wildlife-vehicle collisions, implemented and maintained by GNWT-ECC, will be extended to include the MVWR and segments of the highway during and after construction		x	x		
258	The GNWT-INF will install a combination of permanent traffic counting stations and temporary traffic counters along the highway.			x		
259	The ongoing collection of annual large game harvest success for all non-Indigenous hunters will be continued to determine if caribou and moose are harvested in proximity of the Project.			x	x	
260	The GNWT will undertake regular inspection for noxious/invasive weed occurrences during construction and apply weed management through mowing to reduce introduction and spread of weeds in the ROW and surrounding natural vegetation.			x	x	

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
261	Wildlife health will continue to be monitored through local initiatives and collection of specimens from hunters.			x	x	
262	Wildlife monitors will assess for the presence of wildlife in or near the PDA during project activities and mitigation will occur in accordance with the approved WMMP.	x	x			
263	Wildlife monitors will be in place during construction.		x			
264	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 community members on how best to incorporate their recommendations.		x	x		
265	The GNWT will work with Sahtú 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.					
266	The GNWT will continue its existing monitoring programs. No monitoring of invasive species is proposed.		x	x		

Commitment Number	Commitments	Regulatory Requirement	Published Guidance or Recent GNWT Management Plan	Best Practice for This Area	Traditional Knowledge or Engagement Input	Professional Experience/Opinion
267	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.		x			
Cultural and Heritage Resources Environment						
268	The GNWT is open to and interested in discussing with Indigenous Governments, Indigenous Organizations and other affected parties how best to integrate community-based monitoring into the Project.			x	x	
269	An AIA will be completed prior to construction in areas with known or suspected high archaeological potential.	x			x	
270	In areas designated in the Sahtu Land Use Plan or other areas by impacted Indigenous Governments and Organizations, 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.	x				
271	Requirements for protection of heritage resources such as additional AIA, avoidance of known sites through Project redesign or fencing during construction, mitigative archaeological excavation, surface collection of artifacts, historic structure recording, archival/documentary research, construction monitoring) will be implemented.	x				

27.5 Engagement and Enhancement Commitments

Commitments for the Project also include feedback gathered during engagement with Indigenous Governments, Indigenous Organizations, and other affected parties. These commitments may relate to all VCs or topic discussion areas relevant to the DAR. These commitments are not based on regulatory requirements, published guidance, best practice or professional experience. Primarily, these commitments relate to Traditional Knowledge and other input from the public or Indigenous perspective. Table 27.5 summarizes these commitments made by the GNWT that are intended to reduce or eliminate adverse effects related to the Project.

Table 27.5 Proposed Engagement and Enhancement Commitments

Commitment Number	Commitments
General	
272	The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties regarding perceived effects.
273	The GNWT will notify communities of project activities and schedules, including provision of Project maps and design components, and discuss key traditional harvesting periods.
274	The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning.
275	The GNWT will establish a Mackenzie Valley Highway Corridor Working Group (MVHCWG) one year prior to construction, which will provide a forum for information exchange. The MVHCWG will consist of representatives of GNWT departments, Indigenous Governments, Indigenous Organizations, other affected parties, federal government departments, and the contractor.
276	The GNWT will share the results of environmental and socio-economic studies completed to advance the Project with Indigenous Governments and Indigenous Organizations, and other affected parties.
277	The GNWT is open to further discussions with the Indigenous Guardians Program to explore how best implement it for the Project.
278	The WMMP will be designed to determine if the highway is resulting in a pattern or level of harvest mortality for moose and caribou that would suggest a conservation concern or need for additional harvest management actions.
Atmospheric Environment	
279	The GNWT will engage with communities to inform them of the activities and the noise sources that will occur prior to construction.
Cultural and Heritage Resources Environment	
280	The GNWT will investigate and/or mitigate 'known and suspected sites' as identified by community members during Consultation and engagement and/or through traditional land and resource use (TLRU) studies.

APPENDIX 24A

Climate Resilience Assessment

MACKENZIE VALLEY HIGHWAY PROJECT, WRIGLEY TO NORMAN WELLS – CLIMATE LENS PART 1: GREENHOUSE GAS MITIGATION ASSESSMENT

May 13, 2021

Prepared for:
Government of Northwest Territories
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Prepared by:
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File: 144903017

Attestation of Completeness

I/we the undersigned attest that this GHG Mitigation Assessment was undertaken using recognized assessment tools and approaches (i.e., *ISO 14064-2: Specification with guidance at the project level for quantification, monitoring, and reporting of greenhouse gas emissions reductions or removal enhancements, and the GHG Protocol for Project Accounting) and* complies with the General Guidance and any relevant sector-specific technical guidance issued by Infrastructure Canada for use under the Climate Lens. Stantec is an accredited ISO 14065 verification body.

Respectfully submitted,

Kãlo Stantec Limited

Digitally signed by Michael C. Murphy, PhD, P.Eng.
Date: 2021.05.13 16:13:15 -03'00'

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Date: 2021.05.14 07:59:56 -03'00'

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Executive Summary

The Mackenzie Valley Highway Project is a proposed 321 km stretch of all-season gravel roadway between the communities of Wrigley and Norman Wells. The project is located in the Mackenzie Valley of the Northwest Territories (NWT).

The Government of the Northwest Territories (GNWT) Department of Infrastructure (INF) is seeking federal funding under the Investing in Canada Infrastructure Program (ICIP). This Greenhouse Gas (GHG) Mitigation Assessment has been prepared in accordance with Infrastructure Canada requirements, specifically their Climate Lens General Guidance v.1.2 (the Guidance) (Infrastructure Canada 2019). The objective of the GHG Mitigation Assessment is to estimate the expected GHG emissions associated with the Project and to estimate the potential changes in GHGs associated with the Project compared to a functionally equivalent baseline scenario. In the case of this assessment, the baseline scenario is the annual construction and maintenance of a 321 km winter road to allow traffic to flow to and from local communities. The Project scenario involves the construction and annual maintenance of an all-season 321 km gravel road.

Construction of the Project is anticipated to occur over several years; the construction schedule has not yet been finalized. The construction period, if there is no non-construction wait time, could take up to 3 years. To align with the temporal boundaries applied in the Project's Climate Resilience Assessment, the estimate of service life for this GHG Mitigation Assessment is 20 years. Therefore, the total timeframe for this assignment is 23 years.

The baseline scenario GHG emissions are estimated to result in the release of 33,539 tonnes of carbon dioxide equivalent (t CO_2e). The Project-related GHG emissions from on- and off-road vehicles and equipment during the construction period are estimated to result in the release of 81,191 t CO_2e. Operation of the Project is expected to result in the release of approximately 3,443 t CO_2e per year. Additionally, 366 t CO_2e per year is expected from the loss of an available carbon sink (i.e., the boreal forest and supportive ecosystems) as a result of widening the existing right-of-way. The total net Project emissions are expected to result in the release of 3,809 t CO_2e per year, for a total of 157,370 t CO_2e over the lifetime of the Project. The Project is expected to result in a net cumulative increase of 123,830 t CO_2e over the baseline scenario. A summary of funding for the Project and a summary of the expected GHG emissions is provided in Table 1.

Table 1 Project Funding and GHG Emissions Summary

Aspect	Amount
Total Project Costs (Estimated and has not yet been Finalized)	\$700,000,000
Total Requested Funding Contribution (Estimated to be Approximately 75% of the Total Project Costs))	\$525,000,000
2030 GHG Results	
Baseline Scenario Emissions, in 2030 (1 year)	1,458 t CO_2e
Project Scenario Emissions, in 2030 (1 year)	3,809 t CO_2e
Net GHG Emissions, in 2030 (1 year)	2,351 t CO_2e
Federal Dollars/GHG Emissions in 2030 (Non-Cumulative)	\$233,336 per t CO_2e
2030 GHG Results – Cumulative to 2030	
Baseline Scenario Emissions, Cumulative to 2030	13,124 t CO_2e
Project Scenario Emissions, Cumulative to 2030	Construction Period: 81,191 t CO_2e Operation Period (2025 – 2030, inclusive): 22,854 t CO_2e Total Project Emissions: 104,044 t CO_2e
Net GHG Emissions, Cumulative to 2030	90,920 t CO_2e
Federal Dollars/GHG Emissions by 2030 (Cumulative)	\$5,774 per t CO_2e
Lifetime GHG Results	
Baseline Scenario Emissions, Lifetime (23 Years)	33,539 t CO_2e
Project Scenario Emissions, Lifetime (23 Years)	157,370 t CO_2e
Net GHG Emissions, Lifetime (23 Years)	123,830 t CO_2e
Total Project Cost (Construction Cost Over Lifetime/Cumulative GHG Emissions Over Lifespan)	\$5,653 per t CO_2e
Note: The Project is expected to result in a net cumulative increase of GHG emissions.	

Abbreviations

CH_4	methane
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CCASAR	Canyon Creek All-Season Access Road
GHG	greenhouse gas
GNWT	Government of the Northwest Territories
GWP	global warming potential
ECCC	Environment and Climate Change Canada
h	hour
HDV	heavy duty vehicle
HFC	hydrofluorocarbon
ha	hectares
ICIP	Investing in Canada Infrastructure Program
INF	Department of Infrastructure
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standards Organization
km	kilometre
kW	kilowatt
L	litre
LDV	light duty vehicle
m^3	cubic meters
N_2O	nitrous oxide
NF_3	nitrogen trifluoride
NIR	National Inventory Report
NWT	Northwest Territories
PFC	perfluorocarbon
SF_6	sulphur hexafluoride
t	metric tonne
WRI	World Resources Institute

1.0 INTRODUCTION

This report summarizes the Greenhouse Gas (GHG) Mitigation Assessment, performed as Part 1 of the Climate Lens Assessment, as required by the Investing in Canada Infrastructure Program (ICIP). The ICIP is a bilateral agreement between Infrastructure Canada and the provinces and territories.

The Government of the Northwest Territories (GNWT) Department of Infrastructure (INF) is seeking federal funding under the ICIP. This GHG Mitigation Assessment has been prepared in accordance with Infrastructure Canada requirements, specifically Climate Lens General Guidance v.1.2 (the Guidance) (Infrastructure Canada 2019). The objective of the GHG Mitigation Assessment is to estimate the expected GHG emissions associated with the Project and to estimate the potential changes in GHGs associated with the Project compared to a functionally equivalent baseline scenario.

1.1 PURPOSE

The objective of the GHG Mitigation Assessment is to assess whether the Project will result in a net increase or decrease in GHG emissions compared to a representative baseline scenario.

In the case of this assessment, the baseline scenario is the annual construction and maintenance of a 321 km winter road to allow traffic to flow to and from local communities. The Project scenario involves the construction and annual maintenance and operation of an all-season 321 km gravel road.

In accordance with the Guidance, the following components are included in this GHG Mitigation Assessment:

- Definition of the review area
- Characterization of the baseline scenario conditions within the review area, including
  - Baseline conditions for construction emissions
  - Baseline conditions for operation-related emissions.
- Characterization of the Project conditions within the review area, including
  - Project conditions for construction emissions
  - Project conditions for operation-related emissions.
- Mitigation measures to reduce/limit GHG emissions.

2.0 METHODOLOGY

The methods used to estimate GHG emissions in the baseline and Project scenarios are based on the accounting and reporting principles of the GHG protocol developed by the World Resource Institute (WRI) and the World Business Council for Sustainable Development (2013). This protocol is an internationally accepted accounting and reporting standard for quantifying and reporting GHG emissions.

The guiding principles of the protocol for compiling an inventory of GHG data are relevance, completeness, consistency, transparency, and accuracy. The principles described are also consistent with IS0-14064-2. In cases where uncertainty is high, conservative quantification parameters and assumptions were applied, resulting in a conservative (e.g., higher) estimate of GHG emissions reductions (WRI, 2004).

2.1 PROJECT BOUNDARY

2.1.1 Project Overview and Spatial Boundaries

The baseline scenario consists of the annual construction and maintenance of a 321 km winter road located between Wrigley and Norman Wells, NWT.

The Project scenario consists of the construction and operation of a 321 km all-season roadway, also located between Wrigley and Norman Wells, NWT.

In both the baseline and Project scenarios, the roadway is an extension to an existing segment of gravel road that extends in the northerly direction from the Town of Norman Wells to the Canyon Creek bridge, parallel to the Mackenzie River. Because GHG emissions disperse in the atmosphere and contribute cumulatively to global climate change, the boundaries of this assessment depict the limits of this assessment and are not necessarily or simply the physical boundaries of the Project.

A site location map for both the baseline and Project scenarios is provided in Figure 1. There are currently two sections of road that are currently being constructed and are therefore excluded from this assessment: 1) Canyon Creek to Prohibition Creek, and 2) Wrigley to Mount Gaudet. These sections of road are depicted in Figure 1.

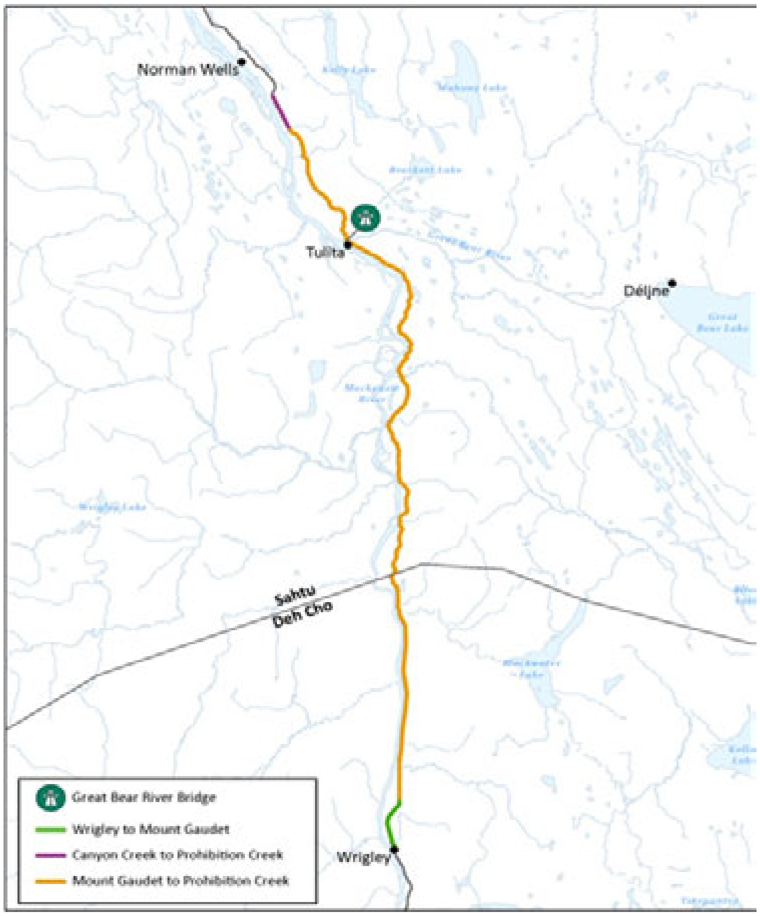

Figure 1 Site Location Map

2.1.2 Temporal Boundaries

The temporal boundaries used in this assessment include the Project construction and operation phases. Construction of the Project is anticipated to occur over several years; the construction schedule has not yet been finalized. The construction period, if there is no non-construction wait time, could take up to three years. Realistically, the construction timeframe could be much longer than three years as it is expected there will be periods of time when construction is not occurring due to wait times (e.g., for funding, materials, or equipment). Nevertheless, for this assessment, construction is assumed to take three consecutive years. To align with the temporal boundaries applied in the Project's Climate Resilience Assessment, the estimate of service life for this GHG Mitigation Assessment was 20 years. The total timeframe for this assessment is therefore 23 years for both the baseline and Project scenarios.

The assessment excludes anticipated major rehabilitative maintenance or decommissioning activities, supply chain, and embodied GHG emissions. See Section 2.4 and 2.5 for a comprehensive list of activities are included in the assessment. This approach is consistent with the Guidance.

2.2 GREENHOUSE GASES CONSIDERED

A GHG is any atmospheric gas that absorbs and re-emits infrared radiation, thereby acting as a thermal blanket for the planet and warming the lower levels of the atmosphere. Several natural and anthropogenic (human activity) sources release GHGs to the atmosphere (IPCC 2014).

Emissions of each of the specific GHGs are multiplied by their 100-year global warming potential (GWP) and are reported as carbon dioxide equivalent (CO_2e). As per the Guidance, the GWPs from the most up-to-date version of Canada's National Inventory Report (NIR) must be used. Therefore, GWPs have been obtained from the 2019 NIR – Part 1, Table 1-1 IPCC Global Warming Potentials (GWPs). The GWP of these GHGs are:

- Carbon dioxide (CO_2) = 1.0
- Methane (CH_4) = 25
- Nitrous oxide (N_2O) = 298
- Sulphur hexafluoride (SF_6) = 22,800
- Nitrogen trifluoride (NF_3) = 17,200
- Hydrofluorocarbon (HFC) gases range from 12 to 14,800
- Perfluorocarbon (PFC) gases range from 7,390 to 17,340

Not all GHGs listed above are applicable to this assessment. Those included in this assessment are CO_2, CH_4 and N_2O. Four GHGs and groups of GHGs have been excluded from the GHG assessment for reasons explained below:

- 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.
- 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. NF_3 is not expected to be used or released by the Project or the baseline.
- HFCs and PFCs – 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.

On this basis, carbon dioxide equivalents (CO_2e) for the Project are calculated as:

$$CO_2e = (\text{mass } CO_2 \times 1) + (\text{mass } CH_4 \times 25) + (\text{mass } N_2O \times 298)$$

2.3 GHG EMISSIONS SCOPES

This assessment considered the Project direct and indirect GHG emissions as well as any emission reductions linked to the Project as directed by the Guidance. Direct and indirect emissions are defined by Infrastructure Canada as follows:

- **Direct GHG Emissions**: Refers to GHG emissions or removals from sources or sinks that are owned or controlled by the proponent. At the GHG inventory level, direct emissions are also commonly referenced as Scope 1 emissions (Infrastructure Canada 2019).
- **Indirect GHG Emissions**: Refers to GHG emissions or removals that are a consequence of the Project, but which occur at GHG sources or sinks not owned or controlled by the applicant (Infrastructure Canada 2018). For example, reduced electricity consumption would be considered an indirect effect, as the GHG emissions generated from the production of electricity for this Project are outside of the Project's boundaries.

The following GHG emission sources have been included in this assessment (Table 2).

Table 2 Sources of GHG Emissions – Project and Baseline Scenarios

Phase	Item	Description	Source / Removal	Direct / Indirect	Scope
Baseline GHG Emissions Sources					
Construction	Mobile Equipment - Construction Equipment and Vehicles	GHG emissions are expected to result from the use of construction equipment, and on-road and off-road vehicles during construction of the winter road on an annual basis.	Source	Direct	Scope 1
Operation	Mobile Equipment – Construction Equipment and Vehicles	GHG emissions are expected from the use of on-road vehicles to maintain the winter road.	Source	Direct	Scope 1
Operation	Mobile Equipment - Vehicles	GHG emissions are expected to result from vehicle use in the winter months.	Source	Direct	Scope 1
Operation	Mobile Equipment – Vessels and Aircraft	GHG emissions are expected to result from the use of aircrafts, vessels, and trucks to transport goods to and from communities along the winter road	Source	Direct	Scope 1
Project GHG Emissions Sources					
Construction	Mobile Equipment	GHG emissions are expected to result from the use of construction equipment, and on-road and off-road vehicles to construct the all-season road.	Source	Direct	Scope 1
Construction	Worker Transport and Housing	GHG emissions are expected to result from the transportation of workers to the construction site, and from the operation of a construction camp to house construction workers.	Source	Direct	Scope 1

Table 2 Sources of GHG Emissions – Project and Baseline Scenarios

Phase	Item	Description	Source / Removal	Direct / Indirect	Scope
Construction	Blasting and Transportation of Materials	GHG emissions are expected to result from blasting rock from a quarry, and the transportation of the blasted rock to the construction site.	Source	Direct	Scope 1
Operation	Mobile Equipment	GHG emissions are expected to result from the use of on-road and off-road vehicles to maintain the all-season road.	Source	Direct	Scope 1
Operation	Mobile Equipment	GHG emissions are expected to result from vehicle use year-round.	Source	Direct	Scope 1
Operation	Mobile Equipment	GHG emissions are expected to result from the use of aircrafts, vessels, and trucks to transport goods to and from communities along the year-round road.	Source	Direct	Scope 1

Emissions are expected from the loss of an available carbon sink as a result of the widening of the existing right of way during construction of the Project. No indirect (Scope 2) GHG emissions are expected to occur as a result of the Project. No other indirect (Scope 3) GHG emissions, including upstream, downstream, or embodied GHG emissions, have been estimated, as these are not required by the Guidance.

2.4 DATA COLLECTION AND CALCULATION PROCEDURES

2.4.1 Baseline Scenario

The baseline scenario involves the annual construction and maintenance of a 321 km winter road. The purpose of winter road maintenance is to reduce the negative effects of snow and ice on traffic using the road (Hinkka, V. et al. 2016). For this assessment, the equipment that is expected to be used includes a grader, snowcat and a water truck.

Direct emissions resulting from the construction and maintenance of the winter road, related to on-road and off-road activities, are based on equipment inventories and project activity schedules that are expected to release GHG emissions (i.e., equipment with internal combustion engines).

Off-road sources of GHG emissions include equipment, engines or vehicles that are primarily used for construction activities (e.g., graders, excavators, and loaders). These emission sources are typically not approved to be driven on highways or public roads as they are designed for construction activities. On-road GHG sources include mobile equipment that are approved to travel on highways and public roads. All on-road and off-road equipment are assumed to be powered by diesel fuel. Estimations of GHG emissions for on-road and off-road construction equipment/vehicles are based on equipment inventories, hours operated, fuel consumption, in combination with GHG emission factors (i.e. CO_2, CH_4, and N_2O) from the 2019 NIR (ECCC 2019).

To estimate the emissions from annual construction and maintenance of the winter road, equipment inventories and data provided by GNWT staff were used. Specifically, a GHG emissions profile for the Canyon Creek All-Season Access Road (CCASAR) was used as the basis for generating an emissions profile for the baseline scenario. The CCASAR project involved the construction of a 14 km all-season gravel road and repairs to 4.75 km of existing road. The data was pro-rated per km to estimate construction and maintenance emissions in the baseline scenario.

For more information on emissions estimations related to the use of the winter road, as well as vessel and aircraft trips for the transportation of goods/cargo, see Section 2.5 and Appendix A.

No indirect (Scope 2) GHG emissions are expected to occur as a result of the baseline scenario. No other indirect (Scope 3) GHG emissions, including upstream, downstream, or embodied GHG emissions, have been estimated, as these are not applicable or required by the Guidance.

2.4.2 Project Scenario

The Project scenario involves the construction, and annual maintenance and operation, of a 321 km all-season gravel road. The emissions generated from this scenario are expected to be higher in comparison to the emissions generated from the construction and maintenance of the winter road (baseline scenario). More effort is required to clear snow and ice from an all-season road (which includes the use of a grader, plow truck, water trucks and a light duty truck) compared to maintaining a winter road (which includes the use of a grader, snowcat and a water truck).

Direct GHG emissions resulting from the construction and operation of the all-season road, related to on-road and off-road activities, are based on equipment inventories and project activity schedules that are expected to release GHG emissions (i.e., equipment with internal combustion engines).

The on-road and off-road equipment for the Project are assumed to be powered by diesel fuel. Estimations of GHG emission for on-road and off-road construction equipment/vehicles are based on equipment inventories, hours operated, fuel consumption, in combination with GHG emission factors (i.e., CO_2, CH_4, and N_2O) from the 2019 NIR (ECCC 2019).

To estimate the emissions from the construction and annual maintenance of the all-season road, equipment inventories and data provided by GNWT staff were used. Specifically, a GHG emissions profile for the Canyon Creek All-Season Access Road (CCASAR) was used as the basis for generating an emissions profile for the Project scenario. The data was pro-rated per km to estimate construction and maintenance emissions for the Project scenario. See Section 2.5 and Appendix A for more information.

For more information on emissions estimations related to annual use of the road, vessel and aircraft trips for the transportation of goods/cargo, worker transportation and housing, blasting/transportation of materials to the construction site, and emissions associated with a reduction in land carbon sequestration, see Section 2.5 and Appendix A.

No indirect (Scope 2) GHG emissions are expected to occur as a result of the Project activities. No other indirect (Scope 3) GHG emissions, including upstream, downstream, or embodied GHG emissions, have been estimated, as these are not required by the Guidance.

2.5 ASSUMPTIONS

The following assumptions have been made to estimate construction GHG emissions resulting from the baseline scenario:

- The GHG emissions calculations herein were completed prior to full Project design completion. As such, emission estimations are high-level; actual values depend on the actual equipment and fuels used over time and the use of the winter road.
- The winter road is 321 km long.
- The timeframe for the baseline scenario is the same as the Project scenario (23 years).
- The list of construction and maintenance equipment for the winter road and hours of operation data are from the CCASAR project (see Appendix A for details); the data were pro-rated per km for use in the baseline scenario calculations.
- Off-road and on-road equipment is assumed to be powered with diesel fuel.
- Fuel consumption rates (litres/hour) are based on Kãlo Stantec Limited’s (Stantec) experience with construction projects, and various information sources including NRCan (2019 and 2020) and Generator Source (2020).
- The winter road in the baseline scenario is expected to have relatively low traffic volumes (50 vehicles per day, with an estimated 15% of those as heavy truck traffic) due to the low overall population in the area; it is assumed the winter road is used between December 15 and April 5, based on data provided by GNWT.

- In the baseline scenario, aircrafts and vessels are used to transport goods and cargo to and from Norman Wells and Tulita, which then is transported to nearby communities in trucks. Stantec was provided with data from GNWT (Locke, pers.comm., 2020), who sourced data from various aircraft carriers and vessels.
  - The mass shipped by marine vessel is the average of 2018 and 2019 mass shipped, divided by the total trips per year. The total mass shipped for the year is included in these calculations.
  - CH_4 and N_2O emissions are not included in the calculation of GHG emissions from tugs/barges because emission factors are not readily available.
  - The aircraft GHG emissions estimation includes the transportation of cargo, but not people.
  - The distances travelled by the aircrafts are estimations.
  - It is assumed the cargo received via aircraft and vessel is transported no more than 100 km by a pick-up truck with a capacity of half a tonne.

The following assumptions have been made to estimate construction GHG emissions resulting from the Project:

- The GHG emissions calculations herein were completed prior to Project design completion. As such, the emission estimations are high-level; actual values depend on the actual equipment and fuels used over time and the use of the Project infrastructure.
- The all-season road will be 321 km long.
- The timeframe for the Project scenario is the same as the baseline scenario (23 years).
  - The construction period, if there is no non-construction wait time, could take up to three years. Realistically, the construction timeframe could be much longer than three years as it is expected there will be periods of time when construction is not occurring due to wait times (e.g., for funding, materials, or equipment). For this assignment, construction is assumed to take three consecutive years.
  - The Project's operational service life is 20 years.
- During the construction period, as the Project is built, the length of the winter road that is constructed annually will shorten, causing a reduction in GHG emissions. This reduction is not accounted for in the calculations due to insufficient information about the Project schedule.
- The list of construction equipment and hours of operation data are from the CCASAR project (see Appendix A for details). The construction equipment data was pro-rated per km for use in the calculations.
- Off-road and on-road equipment is assumed to be powered with diesel fuel.
- Fuel consumption rates (L/h) are based on Stantec's experience with construction projects, and various information sources including NRCan (2019 and 2020) and Generator Source (2020).
- For construction of the all-season road (the Project), it is assumed that 60 people (4 people per truck) travel half the length of the highway (to and from) for 3 years. An estimation of 5-60 people will be required per construction spread. For this assignment, it is assumed that two construction spreads are used, for a total of 120 people.
- A construction camp will be set up during the construction period, to house construction workers, and will use diesel for heat and electricity. The generators are assumed to run for 12 hours per day during the construction period (3 years).

- Approximately 50,000 m^3 of blasted rock will be required for every 13 km of the Project. The weight of the rock is assumed to be 2.3 tonnes/m^3, according to Stantec personnel working on projects along the Mackenzie Valley Highway (Pireaux, pers.comm., August 2020).
- It is assumed the blasted rock is transported 20 km by a typical large dump truck, capable of carrying 28,000 lbs, or 12.7 tonness per trip.
- It is assumed that the existing cleared right of way will increase from 10 to 30 m to 60 m wide, on average, which would eliminate 963 hectares (ha) of carbon-sequestering land.
- The road construction will involve the use of woven geotextile, placed on the existing ground, which would result in minimal ecological disturbance (i.e. no uproot and burn activities are expected).
- The all-season roadway is expected to have relatively low traffic volumes (50 vehicles per day, with an estimated 15% of those as heavy truck traffic) due to the low overall population in the area. The all-season road will be used 365 days per year.
- It is anticipated that there will be reduced aircraft and vessel trips, and an increase in transport truck activity in the summer months once the Project is complete. Insufficient data is available to understand how the completed all-season road would impact the transportation of goods/cargo. Therefore, Stantec assumed the same amount of cargo is going to be moved during the baseline scenario and the Project scenario by the same modes of transportation, and that the emissions from these activities will therefore be the same. These GHG emissions then effectively cancel each other out. Additional information can be provided when available.
- The installation and management of the road could result in permafrost melt resulting in the release of methane (CH_4). Due to limited data on the correlation between road construction and a measurable release of GHG emissions from permafrost decay in the Northwest, the release of CH_4 from permafrost decay was not factored into the analysis. See Appendix B for more information about permafrost melt.

3.0 GHG MITIGATION ASSESSMENT

The GHG emissions associated with the baseline and Project scenarios, and net GHG emissions, are presented in the following sections. A summary of GHG reductions and costs, and a list of GHG mitigation actions are also presented below.

3.1 BASELINE SCENARIO

The baseline scenario is estimated to result in the release of 33,539 t CO_2e over the full periods of construction and operation. Details are presented in the table below.

Table 3 Baseline GHG Emissions Estimates

Year	Baseline Emissions (A) (tCO_2e)	Baseline Removals (B) (tCO_2e)	Net Baseline Emissions & Removals (A-B) (tCO_2e)
Construction Period (2021-2024)	4,375	-	4,375
Operation Year 1 (2025)	1,458	-	1,458
Operation Year 2 (2026)	1,458	-	1,458
Operation Year 3 (2027)	1,458	-	1,458
Operation Year 4 (2028)	1,458	-	1,458
Operation Year 5 (2029)	1,458	-	1,458
Operation Year 6 (2030)	1,458	-	1,458
Operation Year 7 (2031)	1,458	-	1,458
Operation Year 8 (2032)	1,458	-	1,458
Operation Year 9 (2033)	1,458	-	1,458
Operation Year 10 (2034)	1,458	-	1,458
Operation Year 11 (2035)	1,458	-	1,458
Operation Year 12 (2036)	1,458	-	1,458
Operation Year 13 (2037)	1,458	-	1,458
Operation Year 14 (2038)	1,458	-	1,458
Operation Year 15 (2039)	1,458	-	1,458
Operation Year 16 (2040)	1,458	-	1,458
Operation Year 17 (2041)	1,458	-	1,458
Operation Year 18 (2042)	1,458	-	1,458
Operation Year 19 (2043)	1,458	-	1,458
Operation Year 20 (2044)	1,458	-	1,458
Total	**33,539**	**-**	**33,539**

3.2 PROJECT SCENARIO

The Project scenario is estimated to result in the release of 157,370 t CO_2e. Project emissions (3,809 t CO_2e per year) are expected to result from the operation of the Project (3,443 t CO_2e per year) and from the loss of an available carbon sink as a result of the widening of the existing right-of-way (366 t CO_2e per year). Details are presented in the Table 4 below.

Table 4 Project GHG Emissions

Year	Project Emissions (A) (tCO_2e)	Project Removals (B) (tCO_2e)	Net Project Emissions & Removals (A-B) (tCO_2e)
Construction Period (2021-2024)	81,191	-	81,191
Operation Year 1 (2025)	3,809	-	3,809
Operation Year 2 (2026)	3,809	-	3,809

Table 4 Project GHG Emissions

Year	Project Emissions (A) (tCO_2e)	Project Removals (B) (tCO_2e)	Net Project Emissions & Removals (A-B) (tCO_2e)
Operation Year 3 (2027)	3,809	-	3,809
Operation Year 4 (2028)	3,809	-	3,809
Operation Year 5 (2029)	3,809	-	3,809
Operation Year 6 (2030)	3,809	-	3,809
Operation Year 7 (2031)	3,809	-	3,809
Operation Year 8 (2032)	3,809	-	3,809
Operation Year 9 (2033)	3,809	-	3,809
Operation Year 10 (2034)	3,809	-	3,809
Operation Year 11 (2035)	3,809	-	3,809
Operation Year 12 (2036)	3,809	-	3,809
Operation Year 13 (2037)	3,809	-	3,809
Operation Year 14 (2038)	3,809	-	3,809
Operation Year 15 (2039)	3,809	-	3,809
Operation Year 16 (2040)	3,809	-	3,809
Operation Year 17 (2041)	3,809	-	3,809
Operation Year 18 (2042)	3,809	-	3,809
Operation Year 19 (2043)	3,809	-	3,809
Operation Year 20 (2044)	3,809	-	3,809
Lifespan Total	**157,370**	**-**	**157,370**

3.3 PROJECT NET GHG EMISSIONS

The annual GHG emissions for the Project are assessed against the baseline scenario and presented in the table below. Over the lifetime of the Project, it is estimated to result in a cumulative release of 123,830 t CO_2e over the baseline scenario.

Table 5 Net Change in GHG Emission

Year	Total Net Project Scenario Emissions & Removals (A) (tCO_2e)	Total Net Baseline Scenario Emissions & Removals (B) (tCO_2e)	Total Net Change In Emissions & Removals (A-B) (tCO_2e)
Construction Period (2021-2024)	81,191	4,375	76,816
Operation Year 1 (2025)	3,809	1,458	2,351
Operation Year 2 (2026)	3,809	1,458	2,351
Operation Year 3 (2027)	3,809	1,458	2,351

Table 5 Net Change in GHG Emission

Year	Total Net Project Scenario Emissions & Removals (A) (tCO_2e)	Total Net Baseline Scenario Emissions & Removals (B) (tCO_2e)	Total Net Change In Emissions & Removals (A-B) (tCO_2e)
Operation Year 4 (2028)	3,809	1,458	2,351
Operation Year 5 (2029)	3,809	1,458	2,351
Operation Year 6 (2030)	3,809	1,458	2,351
Operation Year 7 (2031)	3,809	1,458	2,351
Operation Year 8 (2032)	3,809	1,458	2,351
Operation Year 9 (2033)	3,809	1,458	2,351
Operation Year 10 (2034)	3,809	1,458	2,351
Operation Year 11 (2035)	3,809	1,458	2,351
Operation Year 12 (2036)	3,809	1,458	2,351
Operation Year 13 (2037)	3,809	1,458	2,351
Operation Year 14 (2038)	3,809	1,458	2,351
Operation Year 15 (2039)	3,809	1,458	2,351
Operation Year 16 (2040)	3,809	1,458	2,351
Operation Year 17 (2041)	3,809	1,458	2,351
Operation Year 18 (2042)	3,809	1,458	2,351
Operation Year 19 (2043)	3,809	1,458	2,351
Operation Year 20 (2044)	3,809	1,458	2,351
Lifespan Total	**157,370**	**33,539**	**123,830**

3.4 COST-PER-TONNE

During the 21st Conference of Parties (COP21) held in 2015 in Paris, Canada committed to a 30% reduction of national GHG emissions below the 2005 level by 2030 (ECCC 2019). Achieving this target would mean that the national GHG emissions total will be 511,000,000 t CO_2e in 2030 (down from 730,000,000 t CO_2e in 2005) (ECCC 2019). By 2030, the Project is estimated to increase baseline GHG emissions by 90,920 t CO_2e (cumulatively), which represents 0.02% of Canada's 2030 emissions target.

The construction costs are estimated to be $700,000,000 and requested federal funding contribution for this Project is estimated to be $525,000,000. Operational costs (e.g., maintenance activities) have not been estimated. Costs associated with maintenance would be negligible relative to overall Project construction costs.

Table 6 Project Cost-Per-Tonne

Aspect	Amount
Total Project Costs (Estimated and has not yet been Finalized)	\$700,000,000
Total Requested Funding Contribution (Estimated to be Approximately 75% of the Total Project Costs))	\$525,000,000
2030 GHG Results	
Baseline Scenario Emissions, in 2030	1,458 t CO_2e
Estimated Project Emissions, in 2030	3,809 t CO_2e
Net GHG Emissions, in 2030	2,351 t CO_2e
Federal Dollars/GHG Emissions in 2030 (Non-Cumulative)	\$233,336 per t CO_2e
2030 GHG Results – Cumulative	
Baseline Scenario Emissions, Cumulative to 2030	13,124 t CO_2e
Estimated Project Emissions, Cumulative to 2030	Construction Period: 81,191 t CO_2e Operation Period (2025 – 2030, inclusive): 22,854 t CO_2e Total Project Emissions: 104,044 t CO_2e
Net GHG Emissions, Cumulative to 2030	90,920 t CO_2e
Federal Dollars/GHG Emissions by 2030 (Cumulative)	\$5,774 per t CO_2e
Lifetime GHG Results	
Baseline Scenario Emissions, Lifetime (23 Years)	33,539 t CO_2e
Estimated Project Emissions, Lifetime (23 Years)	157,370 t CO_2e
Net GHG Emissions, Lifetime (23 Years)	123,830 t CO_2e
Total Project Cost (Construction Cost Over Lifetime/Cumulative GHG Emissions Over Lifespan)	\$5,653 per t CO_2e
Note: The Project is expected to result in a net cumulative increase of GHG emissions.	

3.5 GHG MITIGATION ACTIONS

Since a key objective of the Climate Lens is the facilitation of climate-focused change at the Project level, the following section presents GHG mitigation actions for the construction and operation/maintenance phases of the Project.

3.5.1 Construction

Mitigative management measures will be implemented during construction activities, where economically reasonable, to reduce the quantities of GHGs released to the atmosphere. The following are highlighted mitigative management measures proposed at this time:

- Procuring fuel-efficient equipment models, equipped with run-time indicators where possible, to assist in monitoring and lowering fuel consumption and cost.
- Assessing the capacity of the equipment being considered, and using only equipment that meets minimum size requirements, to reduce unnecessary fuel consumption.
- Regularly maintaining equipment to ensure efficient operation (e.g. regularly checking tire pressure, operational maintenance on the basis of engine hours. etc.).
- Where practical and applicable, multi-passenger vehicles will be used to transport crews to and from job sites.
- Installing energy efficient security and task lighting (e.g., LED lights)
- Minimizing area of disturbance by constructing the road in heavily disturbed areas, where possible.
- Arrange site toolbox talks to encourage compliance with the mitigation measures listed above, and to raise awareness of the benefits of the mitigation measures.

3.5.2 Operation and Maintenance

The following are highlighted operational and maintenance mitigation measures are proposed at this time:

- Monitoring energy use and GHG emissions and taking reasonable steps to minimize GHG emissions from Project-related sources.
- Completing preventative maintenance on vehicles and equipment according to them manufacturer's specifications for optimal performance.

4.0 CLOSURE

This report summarizes the GHG Mitigation Assessment performed as part of the Climate Lens Assessment as required by Infrastructure Canada's Disaster Mitigation and Adaptation Fund. The methods used to estimate GHG emissions for the baseline and Project scenarios are based on accounting and reporting principles of the GHG Protocol and aligned with ISO 14064-2. The report includes estimated depictions of the inputs and outputs of the scenarios based on a combination of data provided by the Government of the Northwest Territories Department of Infrastructure, third party studies, and available literature and documents. Stantec has completed this assessment using reasonably ascertainable information, obtained from a desktop review of documentation, informal data compilations, and telephone conversations. The assessment represents the information provided at the time of the assessment. Stantec did not conduct direct GHG emissions monitoring, site visits, or other environmental sampling and analysis in conjunction with this assessment. Readers of this report should ensure that they are aware of the assumptions made in the assessment and any limitations so created.

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APPENDIX A

Assessment of Construction and Operation GHG Emissions

Appendix A ASSESSMENT OF CONSTRUCTION AND OPERATION GHG EMISSIONS

This appendix describes the assessment of the construction, maintenance, and operation GHG emissions in the baseline and Project scenarios.

A.1 BASELINE SCENARIO

The baseline scenario is the annual construction and maintenance of a 321 km winter road. Construction GHG emissions are expected to originate from on-road and off-road construction equipment, on-road vehicles, and the transportation of goods/cargo. For more information, see Section 2.4.1 and Section 2.5.

A.1.1 On-Road and Off-Road Construction Equipment for Construction and Maintenance of the Winter Road

The table below provide inventories of potential construction equipment to be used during the baseline scenario. On-road and off-road GHG emission factors were obtained from the 2019 National Inventory Report (ECCC 2019).

Table 7 Construction Off-Road and On-Road Equipment – Operation of the Winter Road

Equipment	Quantity	Fuel Type	Classification	Hours Operated	Fuel Consumption (L/h/unit)	Fuel Consumed (L)
2012 Cat 14M Grader	1	Diesel	Off Road Diesel >= 19kW, Tier 4	60.00	17.00	1,020.00
2005 SnowCat	1	Diesel	Off Road Diesel < 19kW	60.00	19.00	1,140.00
2008 Water Trucks	1	Diesel	On Road Diesel, HDV	48.00	19.00	912.00

Sample calculations are provided in Section A.1.1.

A.1.2 On-Road Vehicles

During the baseline scenario, vehicles will be driven along the winter road between December 15 and April 5. Fuel consumption data was obtained from the Natural Resources Canada 2020 Fuel Consumption Guide. On-road GHG emission factors were obtained from the 2019 National Inventory Report (ECCC 2019).

Equipment	Quantity	Fuel Type	Classification	KM Travelled Per Day (km/day)	Fuel Consumption (L/100km/Unit)	Fuel Consumed (L)
Light Duty Trucks	4,675*	Diesel	On Road Diesel, LDT	321.00	10.00	150,068
Heavy Duty Trucks	825*	Diesel	On Road Diesel, HDV	321.00	39.50	104,606
*Traffic counts indicate approximately 50 vehicles are expected to travel per day. Stantec estimated approximately 15% of these vehicles are heavy duty trucks, and the remaining 85% are light duty trucks.						

Sample calculations are provided in Section A.1.2.

A.1.3 Transportation of Goods/Cargo

In the baseline scenario, aircrafts and vessels are used to transport goods and cargo to and from Norman Wells and Tulita, which then is transported to nearby communities in trucks. A summary of the activity data used in the calculations is provided below.

Table 8 Transportation of Goods/Cargo via Vessel, Air and Transport Truck – Baseline

	Destination	Distance Travelled (km)	Mass Shipped per year (on average) (tons)	tonne km
Equipment - Vessel				
Pusher - Towing Tug, Nunakput (789 gross tonnage)	Norman Wells (from Hay River)	901	189	154,484
Pusher - Towing Tug, Johnny Hope/Henry Christoffersen (783 gross tonnage)	Norman Wells (from Hay River)	901	189	154,484
Pusher - Towing Tug, Nunakput (789 gross tonnage)	Tulita (from Hay River)	816	57	42,195
Pusher - Towing Tug, Johnny Hope/Henry Christoffersen (783 gross tonnage)	Tulita (from Hay River)	816	57	42,195
Equipment - Aircraft				
North-Wright Airways (3,000 lbs of air cargo per month)	Tulita from Yellowknife)	614	16	10,026.20
Canadian North (airline) (1,500 lbs of air cargo every day)	Norman Wells (from Yellowknife)	682	248	169,368.98
Canadian North (airline) (3300 lbs of air cargo once a week)	Norman Wells (from Yellowknife)	682	78	53,084.42
Canadian North (airline) (2,600 lbs of air cargo once per week)	Tulita (from Norman Wells)	72	61	4,415.45
Buffalo (airline) (up to 520,000 lbs of air cargo per year)	Norman Wells (from Yellowknife)	682	236	160,861.87
Buffalo (airline) (approximately 318864 lbs of air cargo per year)	Tulita (from Yellowknife)	614	145	88,805.37

Equipment – Transport Truck	Quantity (Total Weight of Cargo / Truck Capacity)	Classification	KM Travelled (from airport/ port to destination)	Fuel Consumption (L/100 km)	Fuel Consumed (L)
Transportation of goods/cargo on land - Light Duty Trucks (F150 Pick Up Truck)	2,316	On Road Diesel, LDT	100	10.00	23,157

A sample of calculations are provided below.

Sample Calculation, Transportation of Goods/Cargo via Vessel and Air, Pusher - Towing Tug, Nunakput (789 gross tonnage)

tonne-km =	Distance travelled	km	x	Mass shipped	tons	x	0.907185	tonnes / ton
tonne-km =	901	km	x	189	tones	x	0.907185	tonnes / ton
tonne-km =	**154,484**							

The total may not sum due to rounding

Sample Calculation, Transportation of Goods/Cargo via Vessel and Air, Transportation of goods/cargo on land - Light Duty Trucks (F150 Pick Up Truck)

Fuel Consumed (L) =	weight of cargo (tons) / capacity of truck (tonnes)	x	0.91	tonnes (t) / ton	x	Distance per trip (km)	x	Fuel Consum -ption	L / 100 km			
Fuel Consumed (L) =	1,276 / 0.5	tons / t	x	0.91	t / ton	x	100	km	x	10	L / 100 km	
Fuel Consumed (L) =	**23,157**											

The total may not sum due to rounding

A.2 PROJECT SCENARIO

The Project scenario is the construction and annual maintenance of an all-season 321 km gravel road. Emissions are expected to originate from on-road and off-road construction equipment, on-road vehicles, stationary equipment, blasting of rock and transportation of the rock to the construction site, lost land carbon storage capability and the transportation of goods/cargo. For more information, see Section 2.4.2 and Section 2.5.

A.2.1 On-Road and Off-Road Equipment for Construction and Operation of the All-Season Gravel Road

The tables below provide inventories of potential construction equipment to be used during the Project scenario. On-road and off-road GHG emission factors were obtained from the 2019 National Inventory Report (ECCC 2019).

Table 9 Construction Off-Road and On-Road Equipment List – Construction

Equipment	Fuel Type	Classification	Hours Operated	Fuel Consumption (L/h/unit)	Fuel Consumed (L)
2006 Cat D8K Dozer	Diesel	Off Road Diesel >= 19kW, Tier 4	1,530	39.12	59,854
1987 Cat D7G Dozer	Diesel	Off Road Diesel >= 19kW, Tier 4	1,250	39.12	48,900
2005 Cat D6N Dozer	Diesel	Off Road Diesel >= 19kW, Tier 4	300	24.70	7,410
2004 Cat 330C Excavator	Diesel	Off Road Diesel >= 19kW, Tier 4	600	31.00	18,600
2011 Cat 345DL Excavator	Diesel	Off Road Diesel >= 19kW, Tier 4	700	31.00	21,700
2012 Cat 14M Grader	Diesel	Off Road Diesel >= 19kW, Tier 4	2,800	17.00	47,600
2007 Cat 980H Loader	Diesel	Off Road Diesel >= 19kW, Tier 4	1,530	21.75	33,278
2012 John Deere 644k Loader	Diesel	Off Road Diesel >= 19kW, Tier 4	1,200	21.75	26,100
1000lb Plate Tamper	Diesel	Off Road Diesel >= 19kW, Tier 4	620	2.27	1,409
Skidoo	Diesel	Off Road Diesel < 19kW	150	14.29	2,143
Walk Behind Packer	Diesel	Off Road Diesel >= 19kW, Tier 4	100	2.27	227
2004 Cat 262B Skid Steer	Diesel	Off Road Diesel >= 19kW, Tier 4	100	31.00	3,100
1998 Cat CS563 Packer Smooth Drum	Diesel	Off Road Diesel >= 19kW, Tier 4	2,000	31.00	62,000
2005 SnowCat	Diesel	Off Road Diesel < 19kW	110	19.00	2,090
Hydraulic 3500 Reed Drill	Diesel	Off Road Diesel >= 19kW, Tier 4	1,200	22.38	26,856
Hydraulic 345 Reed Drill	Diesel	Off Road Diesel >= 19kW, Tier 4	1,200	22.80	27,360
Rock Crusher	Diesel	Off Road Diesel >= 19kW, Tier 4	480	10.79	5,179
2002 Cat 730 articulating dump truck	Diesel	On Road Diesel, HDV	6,660	31.60	210,456
End dump truck	Diesel	On Road Diesel, HDV	6,000	31.60	189,600
4-F350 Pick Up Truck	Diesel	On Road Diesel, LDT	1,200	10.60	12,720
2-F450 Flat Deck Truck	Diesel	On Road Diesel, LDT	150	10.60	1,590
2007 Kenworth Winch Truck & Trailer	Diesel	On Road Diesel, HDV	100	31.60	3,160
2008 Water Trucks	Diesel	On Road Diesel, HDV	200	19.00	3,800
2008 Kenworth Fuel/Lube Service Truck	Diesel	On Road Diesel, HDV	200	19.00	3,800
2007 Ford Mechanic Welder Truck	Diesel	On Road Diesel, HDV	200	10.60	2,120

Table 10 Construction Off-Road and On-Road Equipment List – Operation

Equipment	Quantity	Fuel Type	Classification	Hours Operated	Fuel Consumption (L/h/unit)	Fuel Consumed (L)
2012 Cat 14M Grader	1	Diesel	Off Road Diesel >= 19kW, Tier 4	100.00	17.00	1,700.00
Plow truck	1	Diesel	On Road Diesel, HDV	100.00	31.60	3,160.00
2008 Water Trucks	1	Diesel	On Road Diesel, HDV	100.00	31.60	3,160.00
4-F150 Pick Up Truck	1	Diesel	On Road Diesel, LDT	100.00	10.00	1,000.00

The following is an example calculation for emissions from fuel combustion from on-road and off-road equipment:

Sample Calculation - Construction Equipment GHG Emissions, 2006 Cat D8K Dozer

Fuel Consumed (L) = $\text{hours} \times \frac{\text{L}}{\text{hour}}$

Fuel Consumed (L) = $1{,}530.00 \text{ hours} \times 39.12 \frac{\text{L}}{\text{hour}}$

Fuel Consumed (L) = **59,854**

Annual t CO_2e Emissions* = $\text{L} \times \frac{\text{t } CO_2e}{\text{L}}$

Annual t CO_2e Emissions* = $59{,}854 \text{ L} \times 0.0028 \frac{\text{t } CO_2e}{\text{L}}$

Annual t CO_2e Emissions* = **165**

This calculation is also used for other sources of GHG emissions and will not be repeated below

The total may not sum due to rounding

A.2.2 On-Road Vehicles During Construction and Operation

Construction workers will travel to and from the Project site during construction. During operation of the Project, vehicles will be driven along the year-round road. Fuel consumption data was obtained from the Natural Resources Canada 2020 Fuel Consumption Guide. On-road GHG emission factors were obtained from the 2019 National Inventory Report (ECCC 2019).

Table 11 Equipment List for On-Road Vehicle Use of the Road during Construction and Operation (Non-Construction Vehicles)

Equipment	Quantity	Fuel Type	Classification	KM Travelled Per Day (km/day)	Fuel Consumption (L/100km/Unit)	Fuel Consumed (L)
Worker Transportation to and from the Construction Site (Construction)						
F150 Pick Up Trucks	30*	Diesel	On Road Diesel, LDT	321.00	10.60	1,117,754
On-Road Vehicles (Annual Road Use – Operation)						
Light Duty Trucks (F150 Pick Up Truck)	15,513**	Diesel	On Road Diesel, LDT	321.00	10.00	497,968
Heavy Duty Trucks	2,738**	Diesel	On Road Diesel, HDV	321.00	39.50	347,165

* Assuming 60 workers (4 per truck) travel half the length of the highway (to and from) for 3 years. Assumed there will be 2 construction spreads with 60 workers each.

**Traffic counts indicate approximately 50 vehicles are expected to travel per day. Stantec estimated approximately 15% of these vehicles are heavy duty trucks, and the remaining 85% are light duty trucks.

The following is a sample calculation for on-road worker transport (fuel consumed):

$$\text{Fuel Consumed (L)} = \frac{\text{km}}{\text{day}} \times \frac{\text{L}}{\text{km}} \times \frac{\text{Quantity per day}}{\text{(60 people, 4 per vehicle)}} \times \text{days}$$

$$\text{Fuel Consumed (L)} = \frac{321\ \text{km}}{\text{day}} \times \frac{0.11\ \text{L}}{\text{km}} \times 30 \times 1095\ \text{days}$$

Fuel Consumed (L) = **1,117,754**

The total may not sum due to rounding

A.2.3 Camp Operation

A construction camp will be required during to house workers. Fuel consumption data was obtained from Generator Source (2020). Emission factors were obtained from the 2019 National Inventory Report (ECCC 2019). An equipment list and fuel estimation are provided below.

Table 12 Construction Camp Equipment List

Equipment	Fuel Type	Hours Operated	Fuel Consumption (L/h/unit)	Fuel Consumed (L)
60 kW Diesel Generator	Diesel	13,140.00	18.17	238,753

The following is a sample calculation for the construction camp (fuel consumed):

Sample Calculation Camp Operation GHG Emissions, 60 kW Diesel Generator

$$\text{Fuel Consumed (L)} = \text{hours} \times \frac{\text{L}}{\text{hour}}$$

$$\text{Fuel Consumed (L)} = 13{,}140 \text{ hours} \times 18.17 \frac{\text{L}}{\text{hour}}$$

Fuel Consumed (L) = **238,753**

The total may not sum due to rounding

A.2.4 Blasting and Materials Transport

Rock will be blasted at a nearby quarry and transported to the Project site for use in the construction of the road. The emission factors used in calculating blasting emissions are from Dyno Mobel (2010) and Rescan Environmental Services (2013). Details on activity data used in the calculations are provided in the following tables.

Table 13 Blasting and Material Transport to Site for Construction – Equipment List

Aspect	Quantity of Rock (m^3)	Typical Weight of Blast Rock (tonnes / m^3)	Total Weight (tonnes)	Powder Factor (tonne explosive / m^3 rock)*	Total Explosive Required (Tonnes)
Blasting GHG Emissions	12,346,154	2.30	28,396,154	0.00035	4,321

Table 14 Material Transport to Site for Construction – Fuel Consumed

Aspect	Quantity (Total Weight of Blasted Rock / Truck Capacity)	Fuel Type	Classification	KM Travelled (from Quarry to the Project Site)	Fuel Consumption (L/100km/ Unit)	Fuel Consumed (L)
Transportation of Blasted Rock to Project Site - Dump Truck	2,235,918	Diesel	On Road Diesel, HDV	20.00	31.60	14,130,999

Sample calculations are provided below in relation to blasting and material transport to site.

Sample Calculation Blasting GHG Emissions

$$\text{Required Explosive (tonnes)} = \text{m3 (rock)} \times \text{Powder factor} \frac{\text{tonnes explosive}}{m^3 \text{ (rock)}}$$

$$\text{Required Explosive (tonnes)} = 12{,}346{,}154 \ m^3 \times 0.00035 \frac{\text{tonnes explosive}}{m^3 \text{ (rock)}}$$

Required Explosive (tonnes) = **4,321**

The total may not sum due to rounding

Sample Calculation	Blasting GHG Emissions		
t CO_2e =	tonnes explosive required	x	tonnes CO_2e / tonnes explosive required
t CO_2e =	**817**		
The total may not sum due to rounding			

Sample Calculation Materials Transport GHG Emissions

Fuel Consumed (L) =	tonnes of blasted rock / Truck Capacity (tonnes)	x	Distance (km)	x	Fuel Consum-ption	L / 100 km		
Fuel Consumed (L) =	28,396,154 / 12.7	tonnes / tonnes	x	20	km	x	31.60	L / 100 km
Fuel Consumed (L) =	2,235,918		x	20	km	x	0.32	L / km
Fuel Consumed (L) =	**14,130,999**							

The total may not sum due to rounding

A.2.5 Lost Land Carbon Storage Capability

It is assumed that the existing cleared right of way will increase from 10 to 30 m to 60 m wide during construction of the road, on average, which would eliminate 963 ha of carbon-sequestering land. The emission factor used for the calculations was obtained from a paper published by Kurz, W.A. et al. (2013).

A.2.6 Transportation of Goods/Cargo

It is anticipated that there will be reduced aircraft and vessel trips, and an increase in transport truck activity in the summer months once the Project is complete. Insufficient data is available to estimate these emissions. Therefore, Stantec assumed the same amount of cargo is going to be moved with the same modes of transportation during the Project scenario as the baseline scenario, and that the emissions from these activities will be the same.

APPENDIX B

Permafrost Melt

Appendix B PERMAFROST MELT

In reviewing the GHG emissions inventory for the MacKenzie Valley Highway Extension Project between Wrigley and Norman Wells, Stantec raised a question on whether GHGs during the construction phase of the Project might arise from the thawing of permafrost in the right of way, and whether this should be accounted for in this assessment. The figure below depicts the layers of permafrost (thermal profile). The active layer at the top of the figure is the section of ground that thaws in the summer.

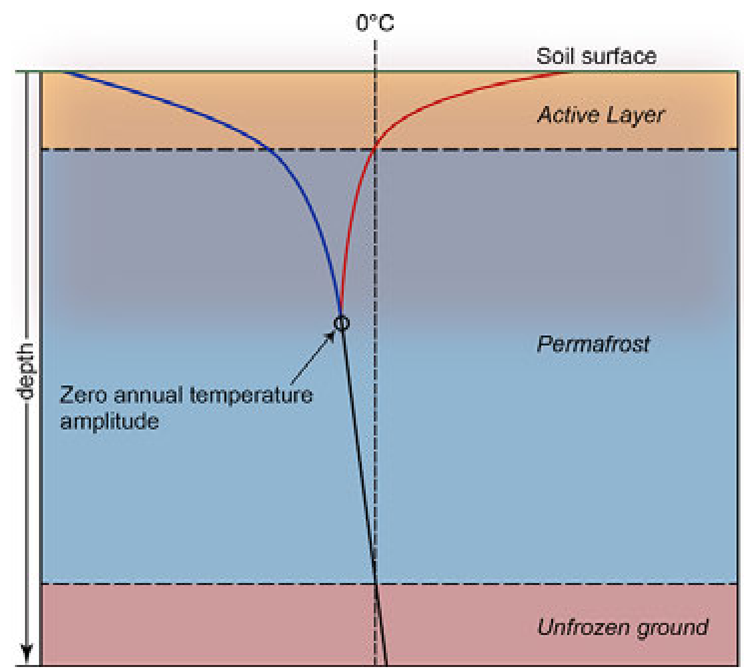

Figure 2 Trumpet Curve of Permafrost Thermal Profile (ADAPT 2020)

A brief literature search was conducted and while there are several sources available on various aspects of methane emissions in the Arctic, no simple emission factors for Arctic tundra were found. Sources of uncertainty related to the permafrost carbon feedstock in the Arctic region, described by Ciais et al. 2013, include:

i) Physical thawing rates
ii) Fraction of carbon released (CO_2 and CH_4) after thawing
iii) The timescales for the releases
iv) Spatially variability in the permafrost degradation
v) The quantity of thawed carbon that will decompose to CO_2 CH_4

Global climate models usually do not account for the soil carbon decomposition to CO_2, CH_4 and N_2O. Although the total quantity of newly thawed soil could be significant by 2100, not all carbon would be immediately transferred to the atmosphere (Ciais et al. 2013). Any significant loss of permafrost soil carbon will likely occur over long periods of time (100s to 1,000s of years). Wetlands and anthropogenic activities are much larger sources of CH_4 than terrestrial permafrost. There is low confidence in the magnitudes of CO_2 and CH_4 losses to the atmosphere from permafrost (Ciais et al. 2013).

Recent research papers describe some ambient monitoring for methane in the Arctic (Thonat et al. 2017, Struzik 2020). Another study presented results from modeling permafrost at the Iqaliut Airport in Nunavut; however, no information related to GHG emissions was included (Ghias et al, 2017).

In 2018, Ellen Gray of NASA reported on the expected gradual thawing of permafrost, and the associated release of GHGs to the atmosphere by abrupt thawing. Abrupt thawing occurs under a certain type of lake in the Arctic, known as a thermokarst lake, that forms when permafrost thaws. This type of permafrost melt could result in an influx of methane into the atmosphere by the mid-21st century. Because thermokarst lakes are small and scattered throughout the Arctic, computer models of their behavior are currently not incorporated into global climate prediction models (Ellen Gray 2018).

On the basis of this review, in the sense that not enough is known just yet, Stantec will assume that the quantities of GHGs that might be released during the construction of the Project are small and negligible, compared to the emissions from burning petroleum fuels during the baseline and Project scenarios.

APPENDIX C

References

ADAPT (Arctic Development and Adaptation to Permafrost Transition). 2020. Communications / Permafrost 101. Available at: http://www.cen.ulaval.ca/adapt/communications/permafrost101.php. Last accessed: September 28, 2020.

Ciais, P., C. Sabine, G. Bala, L. Bopp, V. Brovkin, J. Canadell, A. Chhabra, R. DeFries, J. Galloway, M. Heimann, C. Jones, C. Le Quéré, R.B. Myneni, S. Piao and P. Thornton, 2013: Carbon and Other Biogeochemical Cycles. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Dyno Nobel. 2010. Blasting and Explosives Quick Reference Guide. Available at: https://www.leg.mn.gov/docs/2015/other/150681/PFEISref_1/Dyno%20Nobel%202010.pdf. Last accessed September 22, 2020.

Environment and Climate Change Canada (ECCC). 2019. National Inventory Report. 1990-2017: Greenhouse gas sources and sinks in Canada. Parts 1, 2, and 3. Available at: https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019. Last accessed September 22, 2020.

Generator Source. 2020. Approximate Diesel Fuel Consumption Chart. Available at: https://www.generatorsource.com/Diesel_Fuel_Consumption.aspx. Last accessed September 22, 2020.

Ghias, M.S., Therrien, R., Molson, J. and J.M. Lemieux. 2017. Controls on permafrost in a coupled groundwater flow and heart-transport system: Iqaliuit Airport, Nunavut, Canada. Hydrogeol J., 25:657-673. Available at: https://link.springer.com/article/10.1007/s10040-016-1515-7. Last accessed: September 28, 2020.

Gray, Ellen. 2018. Unexpected future boost of methane possible from Arctic permafrost. NASA Global Climate Change – Vital Signs of the Planet. Available at: https://climate.nasa.gov/news/2785/unexpected-future-boost-of-methane-possible-from-arctic-permafrost. Last accessed: September 28, 2020.

Hinkka, V., Pilli-Sihvola, E., Mantsinen, H., Leviäkangas, P., Aapaoja, A. and Hautala, R. Integrated Winter Road Maintenance Management – New Directions for Cold Research Regions. 2016. Cold Regions Science and Technology. 121: 108-117. Available at: https://www.sciencedirect.com/science/article/pii/S0165232X15002542. Last accessed: September 30, 2020.

Infrastructure Canada. Climate Lens. General Guidance. Version 1.2. September 2019. Available at: https://www.infrastructure.gc.ca/pub/other-autre/cl-occ-eng.html. Last accessed August 5, 2020.

Intergovernmental Panel on Climate Change (IPCC). 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. Available at: https://www.ipcc.ch/report/ar5/syr/. Last accessed September 22, 2020.

Kurtz, W.A., C.H. Shaw, C. Boisvenue, G. Stinson, J. Metsaranta, D. Leckie, A. Dyk, C. Smyth, and E.T. Neilson. 2013. Carbon in Canada's Boreal Forest – A Synthesis. Environ. Rev. 21: 260-292. Available at: https://cfs.nrcan.gc.ca/pubwarehouse/pdfs/35301.pdf Last accessed: September 28,2020.

NRCan (Natural Resources Canada). 2019. Fuel Efficiency Benchmarking in Canada's Trucking Industry. https://www.nrcan.gc.ca/energy/efficiency/transportation/commercial-vehicles/reports/7607. Last accessed: October 1,2020.

NRCan (Natural Resources Canada). 2020 Fuel Consumption Guide. Available at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/oee/pdf/transportation/tools/fuelratings/2020%20Fuel%20Consumption%20Guide.pdf. Last accessed: September 28,2020.

Rescan Environmental Services. 2013. Application for an Environmental Assessment Certificate / Environmental Impact Statement. Seabridge Gold Inc. Available at: https://www.ceaa-acee.gc.ca/050/documents_staticpost/49262/89281/13_Chapter_6_Greenhouse_Gas_Emissions_Climate_Change_.pdf. Last accessed September 22, 2020.

Struzik, J. 2020. How thawing permafrost is beginning to transform the Arctic. Yale Environment 360. Available at: https://e360.yale.edu/features/how-melting-permafrost-is-beginning-to-transform-the-arctic. Last accessed: September 28, 2020.

Thonat, T., Saunois, M., Bousquet, P., Pison, I., Tan, Z., Zhuang, Q., Crill, P.M., Thornton, B.F., Bastviken, D., Dlugokencky, E.J., Zimov, N., Laurila, T., Hatakka, J., Hermansen, O. and D.E.J. Worthy. 2017. Detectability of Arctic methane at six sites performing continuous atmospheric measurements. Atmos. Chem. Phys., 17, 8371–8394, 2017. Available at: https://acp.copernicus.org/articles/17/8371/2017/. Last accessed: September 28, 2020.

WRI and WBCSD (World Resources Institute and World Business Council for Sustainable Development). 2013. The GHG Protocol for Project Accounting. Available at: http://www.ghgprotocol.org/sites/default/files/ghgp/standards/ghg_project_accounting.pdf. Last accessed September 22, 2020.

PERSONAL COMMUNICATION

Locke, Darren. Government of Northwest Territories. August, 2020 (several emails).

Pireaus, Olivier. Stantec. August, 2020 (email).

Mackenzie Valley Highway Project

Climate Lens Part II: Climate Change Resilience Assessment

April 26, 2021

Prepared for:

Government of the Northwest Territories
Infrastructure Department

Prepared by:

K'alo-Stantec Ltd.
Yellowknife, NWT

Project Number: 144903017

Attestation of Completeness

I/we, the undersigned attest that this Resilience Assessment was undertaken using recognized assessment tools and approaches (i.e., ISO 31000:2009 Risk Management—Principles and Guidelines) and complies with the General Guidance and any relevant sector-specific technical guidance issued by Infrastructure Canada for use under the Climate Lens.

Prepared by: ______________________________

Shane O'Hanlon, B.Eng., M.Sc.

Prepared by: ______________________________

Bernadette Middleton, M.Sci,, ENV SP

Prepared by: ______________________________

Riley Morris M.Sc., P.Eng

Validated by* ______________________________

Wayne Penno, P.Eng., MBA

*Resilience Assessments must be prepared, or at a minimum validated by, a licensed professional engineer, certified planner, or appropriately specialized biologist or hydrologist.

Respectfully Submitted,

K'ALO-STANTEC LTD.

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Warren McLeod, P.Eng., Principal

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Executive Summary

The Mackenzie Valley Highway Project is a proposed 321 km stretch of all-season gravel roadway between the communities of Wrigley and Norman Wells. The project is located in the Mackenzie Valley of the Northwest Territories (NWT).

As the Project proponent is seeking federal funding under the Investing in Canada Infrastructure Program (ICIP), a Climate Resilience Assessment (CRA) has been prepared in accordance with Infrastructure Canada requirements and in accordance with Infrastructure Canada's Climate Lens General Guidance V.1.2 (Infrastructure Canada 2019). This CRA covers the infrastructure and systems of the Project. This assessment applies approaches consistent with ISO 31000:2018 standard Risk Management—Principles and Guidelines, which are appropriate for Climate Resilience assessments for new assets under the Climate Lens.

The typical design life of a gravel roadway in the north is expected to be between 20 and 25 years, after which time it is expected that the proponent will rehabilitate the roadway. The timescale selected for assessment of future climate change impacts on the Project will therefore follow two iterations of this design life and consider climate projections to the 2080s, i.e. the climate period from 2071-2100. A longer time horizon will allow for more forward planning related to longer-term impacts, such as permafrost degradation. The assessment summarizes projected climate data for the greenhouse gas emissions scenario, Representative Concentration Pathways (RCP) 8.5, as defined by the Intergovernmental Panel on Climate Change (IPCC).

This assessment has identified the following climate parameters that may pose hazards to The Project:

- Mean Seasonal Temperatures
- High Temperature Extremes
- Low Temperature Extremes
- Precipitation Extremes
- Sustained Rainfall
- Dry Spells
- Daily Frost
- Freeze-Thaw Days

Infrastructure interactions to each climate parameter were examined and an associated risk rating was assigned to each. The climate parameters that presented the greatest number of risks to the Project are mean seasonal temperatures, extreme high and low temperatures, and extreme precipitation.

Based on professional judgement, the following recommendations have been made regarding climate risk management measures that seek to address the highest-rated risks:

- Consider incorporating the following mitigative measures into road design parameters:
    - where applicable, apply active and passive heat mitigation techniques such as thermosyphons, air convection embankments (ACE), air ducts and heat drains (HD), reflective surfaces, insulation and embankment thickening to reduce permafrost degradation.
    - using a fill only, embankment concept rather than a cut and fill approach to reduce permafrost degradation.
    - use woven geotextile to reinforce embankments and reduce differential settlement due to permafrost degradation.
    - incorporate approaches to lowering the water table in the immediate vicinity of the roadbed by using ditches or similar components to reduce permafrost degradation.
    - use geofabrics, geosynthetic materials, wattles or other erosion control products in ditches covered by organics to minimize erosion of the existing fine-grained soils.
    - take advantage of the natural topography and grades along the alignment that are gentle so sidehill cuts are eliminated to reduce permafrost degradation.
    - stage the construction such that the placement of granular surfacing is delayed until any significant differential settlement has occurred.
    - confine the project footprint to the extent possible, to existing cut lines and areas that have already been disturbed to reduce permafrost degradation.
- Plan for more frequent inspections and monitoring of the performance of the infrastructure (e.g., culverts are clear in the spring and the fall) and ensure that there are sufficient additional resources for maintenance and rehabilitation for repairs when settlement occurs. Regularly monitor road maintenance efforts and climate data to better correlate the change in road surface with climate related parameters and their potential changes. Use this information as part of an adaptative management approach to future maintenance and rehabilitation efforts.
- Focus on collecting baseline information for the components that are thought to be most vulnerable to climate change. Avoid constructing in these areas if possible, and where not, deploy methods to minimize thermal disturbance (e.g., incorporating approaches to lowering the water table in the immediate vicinity of the roadbed by using ditches or similar components).
- Review and refresh operator training program on best practices as it relates to the management of gravel roads (e.g. straight salt and liquids should not be used).
- Rapid pothole repair/regrading may be needed to reduce potential infiltration of water into the sub-base with more frequent rain events. Develop a policy to complete road inspections after extreme weather events.
- Maintain natural drainage patterns by using adequately sized and positioned culverts. Consider additional snow clearing in the ditches during winter to allow for a controlled spring runoff.

- Where possible, snow should be bladed down the side slopes, away from the shoulders. Late-winter maintenance should blade snow and hard pack down to the embankment's side slope area prior to spring melt. Ensure that late winter maintenance clears ice pack and snow from the road surface to prevent damming of melt water. Frequent snow removal can minimize the insulating effect of the snow.
- Where possible, implement a more aggressive road monitoring and maintenance program. Conduct periodic surrounding surface surveys. Remote sensing techniques such as LiDAR, SAR, or Optical methods, can be repeated every 5 to 20 years to identify those areas where surface features such as topography, vegetation, surface water flow, pond developments, or thermograms activities have changed. Conduct inspections after severe events to ensure the integrity of roadway and drainage systems.

The analysis and recommendations in this assessment are based on information available within the timeline and scope of this project, and on the authors' experience with climate risks assessments. As the Project is still in the design phase, a full application of the Engineers Canada's Public Infrastructure Engineering Vulnerability Committee's vulnerability assessment protocol (PIEVC Protocol) process was not possible. Rather, a methodology consistent with the PIEVC Protocol and that conforms to the ISO 31000:2018 standard Risk Management—Principles and Guidelines has been used. This approach is aligned and compatible with PIEVC Protocol methodology and conforms with the requirements of ISO 31000:2018.

Abbreviations

CCHIP	Climate Change Hazards Information Portal
CRA	Climate Risk Assessment
HVAC	Heating, Ventilation and Air Conditioning
GHG	Greenhouse gas
GCM	Global Climate Models
ICIP	Investing in Canada Infrastructure Program
IDF	Intensity, Duration, Frequency
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standards Organization
O&M	Operations and Maintenance
NRCAN	Natural Resources Canada
PIEVC	Public Infrastructure Engineering Vulnerability Committee (Engineers Canada Vulnerability Assessment Protocol)
Project	Mackenzie Valley Highway Project
RCP	Representative Concentration Pathways
RSI	Risk Sciences International
UNEP	United Nations Environment Programme
WMO	World Meteorological Organization

1.0 INTRODUCTION

This report summarizes the Climate Resilience Assessment performed as part of the Climate Lens Analysis as required by the Investing in Canada Infrastructure Program (ICIP). The ICIP is a bilateral agreement between Infrastructure Canada and the provinces and territories. As the Project proponent is seeking federal funding under the Community, Culture and Recreation Fund, a Climate Resilience Assessment has been prepared in accordance with Infrastructure Canada requirements (Infrastructure Canada 2018). This report has been prepared in accordance with Infrastructure Canada's Climate Lens General Guidance V.1.2 (Infrastructure Canada 2019).

1.1 PURPOSE

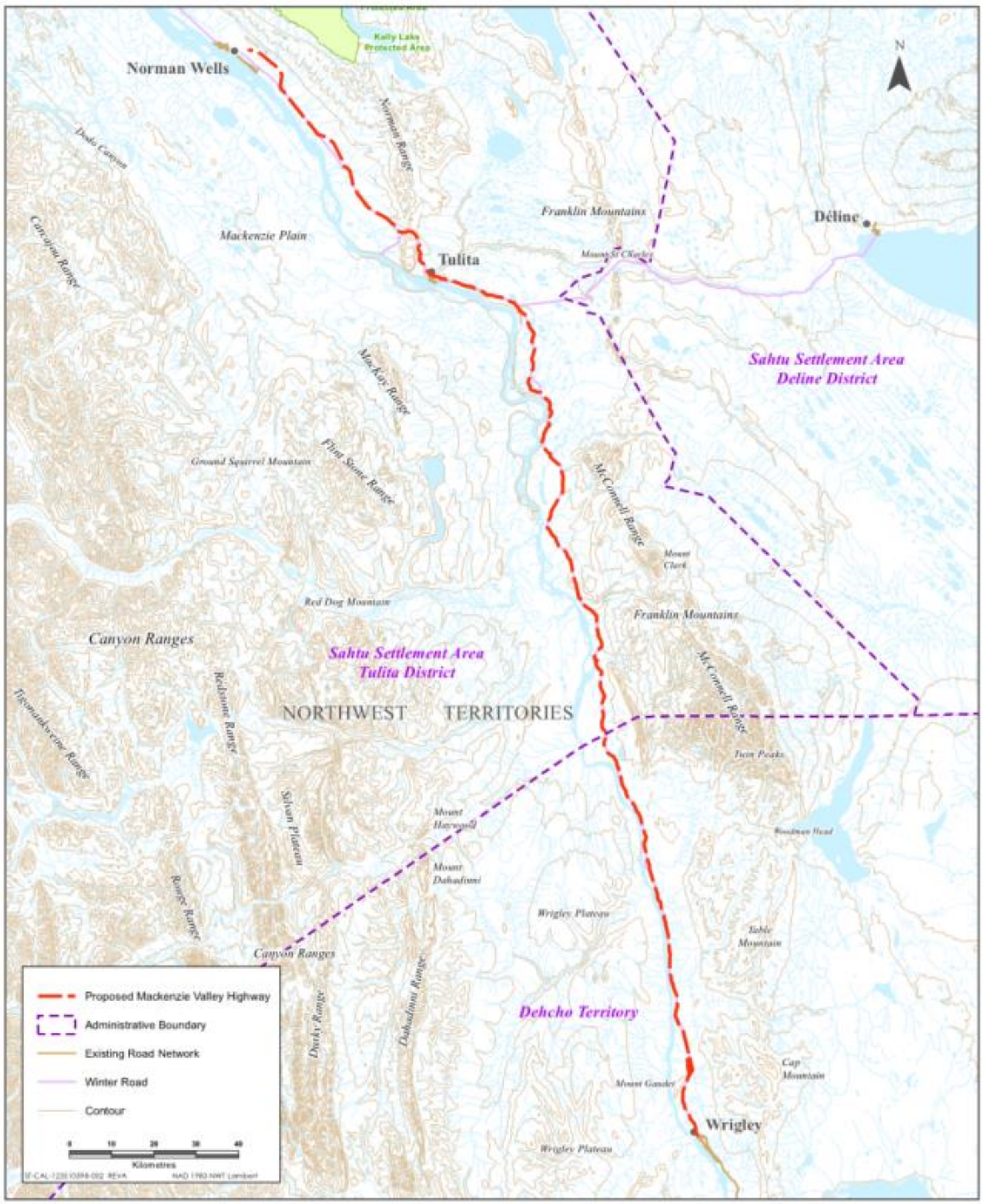
The intent of Infrastructure Canada's Climate Lens is to "incent behavioral change and consideration of climate impacts into the planning of infrastructure projects with a view to implementing Canada's mid-century goals of a clean growth low-carbon economy" (Infrastructure Canada, 2018). This assessment 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. This assessment is intended to inform the design team of projected changes in climate and associated risks to consider at the project's detailed design stage.

1.2 PROJECT OVERVIEW

The Mackenzie Valley Highway Project is a proposed 321 km stretch of all-season gravel roadway between the communities of Wrigley and Norman Wells. The development includes the following components:

- Construction of a 321 km all-season gravel highway from Wrigley to Norman Wells;
- Construction of select watercourse crossing structures;
- Construction and operation of temporary and permanent borrow sources;
- Construction and operation of temporary support infrastructure and workspaces including camps, laydowns and staging areas;
- Ongoing highway operations and maintenance; and
- Reclamation of areas not required for ongoing operations.

Figure 1. Site Location Map



The focus of this assessment is on the physical assets proposed for the Project and does not consider other elements (such as third-party goods or services suppliers and administration, etc.) that are usually included in a PIEVC Protocol climate risk assessment. A review of this assessment, possibly leading to a more in-depth analysis, is recommended during future design stages of the Project, specifically design development.

1.3 GENERAL CLIMATE PROFILE

Climate data and trends—current and future projections—used in this assessment were obtained from published literature, the Risk Sciences International (RSI) Climate Data Portal (CCHIP) and the Norman Wells A (ID: 2202800) weather monitoring station. The scope of the assessment did not include additional, site specific future climate modelling. Future climate projections were based on downscaled, climate data published Intergovernmental Panel on Climate Change (IPCC).

Cross-verification for the gathered climate data was completed to identify possible discrepancies between the data sources used. The typical design life of a gravel roadway in the north is expected to be between 20 - 25 years, after which time it is expected the Proponent will rehabilitate the roadway. The timescale selected for assessment of future climate change impacts on the Project will therefore follow two iterations of this design life and consider climate projections to the 2080s (i.e. the climate period from 2071-2100). A longer time horizon will allow for more forward planning related to longer-term impacts, such as permafrost degradation. The assessment summarizes projected climate data for GHG emissions scenario, representative concentration pathways (RCP) 8.5, as defined by the IPCC. Additional details on the climate profile used in this assessment are presented in Appendix A.

The general topography of the region is represented by a rolling surface with a variable topography including ridges reaching 1040m above sea level. Permafrost conditions are highly variable, with continuous to extensive and discontinuous conditions with low to medium ice content.

Stantec's additional research into the climate trends and projections confirmed the following findings:

- The area has experienced (and is projected to continue experiencing) increases for annual mean daily temperature, average maximum daily temperature and average minimum daily temperature. This trend applies to all seasons. By the 2080s, the annual mean daily temperature is projected to increase by 5.5 degrees under RCP 8.5 for Norman Wells and 6.2 degrees for Fort Simpson. This represents an increase in the risk of permafrost thaw.
- The number of extreme heat temperature events—i.e., days with temperatures greater than 30°C—has averaged around 2.1 days/year from 1981 to 2010 at Norman Wells - Tulita and 4.2 days/year from 1981 to 2010 at Wrigley-Fort Simpson. By the 2080's, the number of days over 30°C is projected to increase to 14.4 days/year (under RCP 8.5), at Norman Wells - Tulita and 24.8 days/year, at Wrigley-Fort Simpson.
- The number of extreme cold temperature days—i.e., days below minus 30°C—is expected to decline from 51 days per year (1981-2010) to 10.7 days/year by 2080 under RCP 8.5 for Norman Wells – Tulita and from 37.5 days per year (1981-2010) to 6.5 days/year at Wrigley – Fort Simpson.

- Total annual precipitation in the area has increased between 1981 - 2010. Future climate projections indicate continued increases in precipitation both annually and seasonally (more so during the summer) in the coming decades. By the 2080s, under RCP 8.5 total annual precipitation is projected to increase 21.3% for Norman Wells and 25.2% for Fort Simpson.
- Projections for snowfall in the area are less confident than for other precipitation and temperature-based climate variables and are not included in this Climate Lens assessment.
- Precipitation events are projected to become 17.0% to 56.2% more intense for Norman Wells, and 14.4% to 49.4% more intense for Fort Simpson under RCP 8.5, for all design storms ranging from 5 minute to 24-hour duration, and 2 to 100-year return frequency, based on historic and projected Intensity Duration Frequency (IDF) curves. This translates to increased over-land flooding due to the overwhelming of storm and drainage systems. Flooding is also likely to occur due to more rapid snow melt periods, and an increase in the number and intensity of rainfall events.
- The length of dry spells in the area are expected to remain relatively consistent in the future.
- The number of days without frost is expected to increase by approximately 30% for both Norman Wells and Fort Simpson under the 2080’s RCP 8.5. With warmer temperatures projected for the coming decades, the number of freeze-thaw events for the area is projected to have a slight decrease under future climate. The decrease is only slight because most freeze-thaw events typically happen in months with temperatures fluctuating around 0°C. The number of freeze-thaw events in May, August, September, October and November are projected to decrease significantly, while there is a slight increase projected in November, December, January, February and March. By the 2080’s, fluctuations around 0°C are projected to be more common all through the winter months.

2.0 METHODOLOGY

The Climate Lens General Guidance V1.2 recognizes Engineers Canada's PIEVC Protocol as a methodology for climate change resilience. As the Project is still in the design phase, a full application of the PIEVC process was not possible. Rather, a methodology consistent with the PIEVC Protocol and that conforms to the ISO 31000:2009 standard Risk Management—Principles and Guidelines has been used. It is recommended the proponent complete a more detailed climate resilience analysis once the funding is in place.

2.1 RISK ASSESSMENT PROCESS

This climate resilience assessment evaluates the future climate impacts on the Project's proposed components and associated infrastructure and identifies the potential risks associated with future changes in climate and extreme weather events. It is a high-level assessment of risks to the infrastructure, buildings or facilities due to extreme weather and climate uncertainty based on current climate and future climate projections in the area. Extreme weather events may include, but are not limited to, extreme heat, high intensity / short duration precipitation, and high wind.

The resilience assessment team solicited input on the climate risks to the Project through interviews with the design consultants, potential operators, and Government of Northern Territories (the client, see professionals listed in Table 10). Data gaps were filled through desktop analysis of relevant Project documents or related publicly available data. The climate resilience assessment (based on the requirements of the Guidance) uses similar principles as those of the PIEVC Protocol and other risk assessment methodologies that conform to ISO 31000:2009 to identify relevant climate parameters and relevant infrastructure responses, establishing a risk evaluation matrix, and assigning risk ratings to each infrastructure response to climate considerations. This assessment will inform design teams of potential risks that should be considered during the design stage of Project implementation. Figure 2 below shows the general risk assessment process.

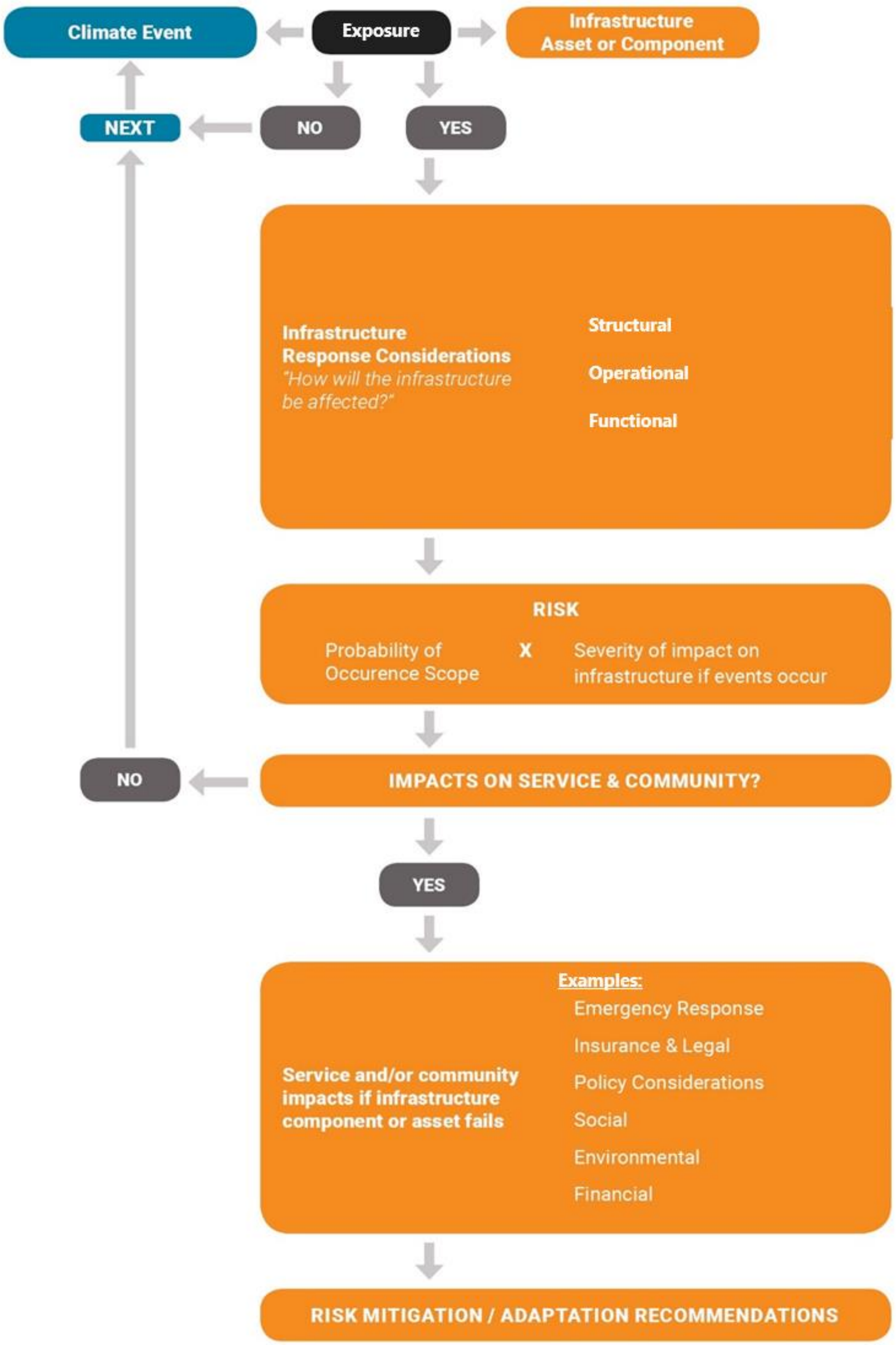


Figure 2. Illustration of the Risk Assessment Process

2.2 TIMESCALE OF ASSESSMENT

The typical design life of a gravel roadway in the north is expected to be between 20 - 25 years, after which time it is expected the proponent will rehabilitate the roadway. The timescale selected for assessment of future climate change impacts on the Project will therefore follow two iterations of this design life and consider climate projections to the 2080s (i.e. the climate period from 2071-2100). A longer time horizon will allow for more forward planning related to longer-term impacts, such as permafrost degradation. Short-term (up to 2020s) and mid-term (up to 2050s) climate change implications trend in the same direction for the climate parameters identified for this assessment and thus have not been separately discussed.

2.3 PLAUSIBLE CLIMATE SCENARIOS

Climate modeling uses various GHG emissions scenarios, known as Representative Concentration Pathways (RCPs), to project future climate variables under different concentrations and rates of release of GHGs to the atmosphere, as well as different global energy balances.

Various future trajectories of GHG emissions are possible depending on the global mitigation efforts in the coming years. RCPs are established by the IPCC, the international body for assessing the science related to climate change. The IPCC was set up in 1988 by the World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) to provide policymakers with regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation (IPCC, 2014).

The IPCC has set four GHG emissions scenarios through RCPs. RCP 8.5 is the internationally recognized most pessimistic - “business as usual” GHG emissions scenario. Other GHG emissions scenarios represent more substantial and sustained reductions in GHG emissions: RCP 6, 4.5 and 2.6 (Figure 3). For example, the RCP 2.6 emissions scenario may be achievable with extensive adoption of biofuels/renewable energy and large-scale changes in global consumption habits, along with carbon capture and storage. RCP2.6 is representative of a scenario that aims to keep global warming likely below 2°C above pre-industrial temperatures. RCP 4.5 is considered the ‘medium stabilization’ scenario where global mitigation efforts result in intermediate levels of GHG emissions (IPCC, 2014).

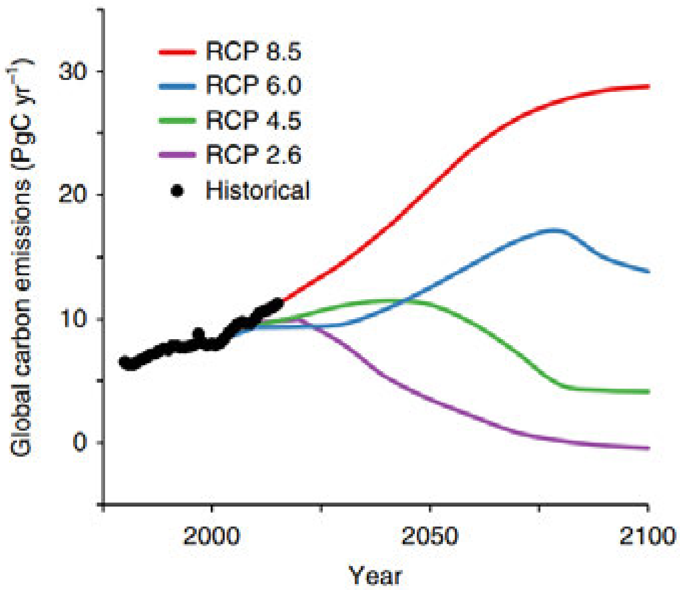


Figure 3. Historical CO_2 emissions for 1980-2017 and projected emissions trajectories to 2100 for the four Representative Concentration Pathway (RCP) scenarios. Figure from Smith and Myers, 2018.

Although some progress has been made, current estimates of GHG emissions are still close to following the RCP 8.5 path and thus this assessment is based on climate parameters estimated under the RCP 8.5 scenario. The recent IPCC Special Report on Global Warming of 1.5ºC (Allen et al., 2018) supports the selection of the RCP 8.5 for this assessment.

2.4 IDENTIFICATION AND ASSESSMENT OF CLIMATE HAZARDS

For this assessment, a rating system compatible with the PIEVC Protocol was adopted for the likelihood (probability) of a climate event occurring and for the consequence (severity of the impact) on the components of the infrastructure system, should the climate event occur.

Based on the information and documents reviewed for this assessment, the climate events presented in Table 1 were identified as having potential impacts on Project components. These climate events were evaluated for their projected change in probability of occurrence (likelihood) at the selected assessment time-horizon. The table also presents the confidence level associated with the projections for each climate parameter. For example, projections based on Global Climate Models (GCMs) and downscaling of such models are considered:

- Adequate (higher confidence) for general temperature and precipitation projections
- Less adequate (lower confidence) for extreme parameters
- Inadequate for combined events (low confidence) such as hail, freezing rain, etc.

Combined events are inferred based on other parameters, resulting in lower confidence for projections of combined event parameters. For example, freshet events are a complex process and the study area experiences freshet snow-melt events. These events are difficult to project and are dependent on various other climate variables. Flooding projections studies have suggested that, under future climate, snowmelt-driven floods will increase and occur earlier in the season due to the projected increases in winter and spring temperatures (Poitras et al., 2011; Gaur et al., 2018; Bonsal et al., 2019; Gaur et al., 2019). With increasing winter temperatures, an increase in winter streamflow and an earlier peak in snowpack melt is projected (Poitras et al., 2011; Gaur et al., 2018). Earlier snowmelt has already been observed within Canada (Zhang et al., 2001; Burn et al., 2016). Results from Gaur et al. (2018) suggest spring snowmelt-driven floods will occur up to two months earlier by the end of the century. Confidence may also refer to whether other studies have been done for the climate events projections in the geographical area.

Table 1. Climate Parameters Selected for Resilience Assessment (2080s-Time Horizon)

Climate Parameter	Trend	Confidence Level	Parameter Remark
Temperature			
Mean Seasonal Temperatures	Increase	High	**Norman Wells -** Average temperature is expected to increase by 5.5°C with winter increasing the most (7.7°C), spring and autumn temperatures following average (5.5°C), and summer to increase on average by about 3.2°C by the 2080s. **Fort Simpson -** Average temperature is expected to increase on average by 6.2°C with winter increasing the most (8.6°C), spring and autumn temperatures following the average (5.9°C), and summer to increase on average by about 4.4°C by the 2080s.
High Temperature Extremes	Increase	High	**Norman Wells -** There is a significant increase in number of days with temperature >= 30°C with the number of maximum temperature events increasing from 2 days to 14 days by the 2080s. **Fort Simpson -** There is a significant increase in number of days with temperature >= 30°C with the number of maximum temperature events increasing from 4 days to 25 days by the 2080s. This is likely to result in an increased risk of wildfires and the warming of permafrost layers.
Low Temperature Extremes	Decrease	High	**Norman Wells -** There is a significant decline in number of days with temperatures <= -30°C with the number of maximum temperature events declining from 51 days to 11 days by the 2080s. This is likely to result in more rain events occurring in the shoulder seasons (Autumn and Spring) and may be in the form of rain on snow events. **Fort Simpson -** There is a significant decline in number of days with temperatures <= -30°C with the number of maximum temperature events declining from 38 days to 7 days by the 2080s. This is likely to result in more rain events occurring in the shoulder seasons (Autumn and Spring) and may be in the form of rain on snow events. This could affect the performance of the gravel road since, on a frozen base, the wet surface would degrade and cause problems.
Precipitation			
Precipitation Extremes	Increase	Medium-High	Projected IDF information suggests increased storm intensity for all short duration rainfalls (5 min events to 24-hour events). The projected percentage increase from the historical data to the period of 2039- 2100 for precipitation event intensities range from 17% – 56.2 % for Norman Wells and 14.4% - 49.4% for Fort Simpson.

Climate Parameter	Trend	Confidence Level	Parameter Remark
Sustained Rainfall	No Change	Medium-Low	Similar to short duration events, 3, 5, and 7-day rainfall accumulations are expected to remain relatively stable.
Dry Spells	No Change	Medium-Low	**Norman Wells -** The number of dry days appear to be slightly increasing. **Fort Simpson -** The number of dry days appear to be slightly decreasing. The maximum dry spell length between the two areas are generally stable over the previous 35-year span. The difference between the two sites could be largely driven by four specific years where Norman Wells' dry periods were much longer than those in Fort Simpson.
Daily Frost	Decrease	Medium-High	**Norman Wells -** Average frost-free days are expected to increase by approximately 30% and both Norman Wells and Fort Simpson by the 2080s. This will have an impact on the warming of permafrost layers and lead to an increased risk of ground shifting.
Freeze-Thaw Days	Decrease	Medium-High	**Norman Wells -** The number of freeze-thaw events is projected to decrease from 44 to 30 per year by the mid-2080s. **Fort Simpson -** The number of freeze-thaw events is projected to decrease from 58 to 39 per year by the mid-2080s. Most freeze-thaw events typically happen in months with temperatures fluctuating around 0°C.

2.5 ASSETS UNDER ASSESSMENT

The Project assets and systems were grouped into the categories as presented in Table 2.

Table 2. List of Project Components Being Assessed

Project Infrastructure Component	Project Infrastructure Sub-Components
Structural Elements / Physical Infrastructure	• Road Base and Subgrade • Road Embankments / Cuts • Surface Drainage • Culverts & Ditches
Miscellaneous	• Maintenance • Emergency Response • Administration / Personnel & Engineering

This climate resilience assessment does not include the deconstruction or rehabilitation of the gravel road and associated structures at the end of their useful life. In addition, this assessment has been limited to the roadway structure and does not include associated infrastructure (e.g., bridges, camps, laydowns, pits). Any subsequent climate assessments completed at a later stage of the project could include ancillary infrastructure.

2.5.1 Consequence of Impact

Table 3 shows the three consequence of impacts that were considered as part of this assessment. The list of consequence of impacts provides a framework for considering the potential impacts of climate on the Project's components.

Table 3. Consequence of Impact

Consequence of Impact
Structural Integrity *For example, climate change may lead to premature failure of structural elements due to external stresses.*
• Component Failure • Component Deterioration • Increased Loading / Stress • Change in Materials Performance
Operations & Maintenance (O&M) *For example, climate change may increase the need for maintenance to the roadway and drainage systems.*
• Occupational Safety, Health & Safety • Reduced Serviceability • Increased Maintenance / Rehabilitation Cycles and Frequencies • Increased Public Vehicle Maintenance Requirements • Change in Operational Performance
Functionality *For example, climate change may impact the ability of the infrastructure system to deliver at normal levels of service (i.e. lane or roadway closures, reduced surface quality).*
• Violation of Policies and Procedures • Public/Occupant Health and Safety Hazard • Loss of Service (Temporary) • Loss of Service (Permanent)

The consequence of community and environmental impacts were not assessed in detail as part of this assessment.

2.5.2 Impact on Project Assets

The potential impacts from both extreme events and incremental or slow onset climate parameters on Project assets are presented in Table 4.

Table 4. Potential Climate Impact on the Project Assets

Climate Parameter	Infrastructure Component Impacted	Description of Interaction
Temperature		
Mean Seasonal Temperatures	Structural Elements / Physical Infrastructure: Road Base and Subgrade	Ground temperatures are highly influenced by air temperatures. Increasing air and ground temperatures will initiate thawing and will result in changes to the permafrost active layer. These changes to the active layer can result in settlement and damage to the road surface resulting in structural failure and potential safety issues. This could result in higher maintenance requirements to ensure the road surface and user safety.
Mean Seasonal Temperatures	Structural Elements / Physical Infrastructure: Road Embankments / Cuts	Long-term warming has the potential to melt or weaken the permafrost. The melting of the permafrost has the potential to affect surface and groundwater flows and the groundwater table. Changes to the groundwater regime could result in differential settlement, erosion, cracking and flooding of the road surface. These all present a safety issue to road users and increased maintenance requirements for the O&M team.
Mean Seasonal Temperatures	Structural Elements / Physical Infrastructure: Surface Drainage	Significant thawing of the permafrost could result in ponding on road surface and impacts to roadside drainage (culvert erosion, culvert blockage) and roadside erosion. Where the road is constructed on-ice rich permafrost, settlement could be extreme resulting in significant surface water ponding and pothole formation.
Mean Seasonal Temperatures	Miscellaneous: Maintenance	In the permafrost zone, accelerated melting and differential settlement would result in damage to the road surface which would require increased maintenance needs to ensure user safety.
High Temperature Extremes	Miscellaneous: Emergency Response	Increasing air and ground temperatures could result in increases in the occurrence of forest fires resulting in localised road closures to minimise hazardous driving conditions and site safety risks.
High Temperature Extremes	Miscellaneous: Administration / Personnel & Engineering	Heat waves could result in worker heat stroke, fatigue, and exhaustion.
Low Temperature Extremes	Miscellaneous: Maintenance	Freezing rain and snow may cause unsafe driving conditions and resultant road closures. These weather conditions would increase the level of roadside maintenance and the volume of salt and sand needed on the road surface.
Precipitation		
Precipitation Extremes	Structural Elements / Physical Infrastructure: Road Base and Subgrade	Saturated roads may reduce the structural integrity of the road, resulting in potholes and increased erosion of the road surface.
Precipitation Extremes	Structural Elements / Physical Infrastructure: Road Embankments / Cuts	Heavy periods of rainfall could result in both internal and surface saturation of roadside embankments. This saturation could result in reduced structural integrity and increased levels of erosion, washout, and loss of sediment. These could impact wildlife in local watercourses.

Climate Parameter	Infrastructure Component Impacted	Description of Interaction
Precipitation Extremes	Miscellaneous: Maintenance	Increased frequency of rainfall will mainly affect road surface maintenance work. More frequent flooding events may require increased maintenance of the ditches, culverts and road surface.
Sustained Rainfall	Structural Elements / Physical Infrastructure: Culverts & Ditches	Heavy rainfall events could result in exceeding the design flow capacities of the roads proximal culverts and bridges. These events could result in water overtopping, ponding, fast flowing water and erosion.
Sustained Rainfall	Miscellaneous: Administration / Personnel & Engineering	Extreme storms may hinder maintenance activities. In addition, it affects road safety and the ability of personnel to get to their workplace.
Daily Frost	Structural Elements / Physical Infrastructure: Culverts & Ditches	Low temperatures combined with periods of precipitation and snow can result in blockages of roadside culverts from ice and snow. These blockages prevent roadside water drainage and can result in localised flooding.

2.6 RISK ANALYSIS AND EVALUATION

In this assessment, the risk rating is defined as follows.

Risk Rating = Probability Rating x Consequence of Impact Rating

- Likelihood Rating: a rating that represents the probability or likelihood of occurrence of a climate event above a selected threshold, ranging from 1 (highly unlikely) to 5 (frequent)
- Consequence of Impacts Rating: a rating of the impacts on the infrastructure asset or component should the climate event occur, ranging from 1 (insignificant) to 5 (catastrophic)

Risks are evaluated under current climate conditions to establish a baseline. Future risks are assessed considering future (projected) climate changes. The condition of the infrastructure in the future climate is assumed to be well maintained and thus will maintain a similar level of resilience to climate events. Deterioration of the Project components is not considered in the selected lifespan of this assessment.

The trends indicated for each climate parameter are based on the change in probability from the current climate to the future climate. For this assessment, a rating scale of 1 to 5 for the probability (likelihood) of a climate event occurring was adopted (Table 5). The probability score is assigned based on the evaluation of historical occurrences and future climate projections for each climate variable.

Table 5. Probability Rating Based on Climate Event Occurrence

Occurrence	Qualitative Descriptor	Descriptor	Rating
>1:50 year	Highly Unlikely	Not likely to occur in assessment period; or not likely to increase in intensity and/or duration during the assessment period	1
1:10-50 year	Remotely Possible	Likely to occur once between 10-50 years; or likely to increase in intensity and/or duration over a 10 to 50-year period	2
1:1-10 year	Occasional	Likely to occur at least once a decade; or likely to increase in intensity and/or duration over a decade	3

Occurrence	Qualitative Descriptor	Descriptor	Rating
10/year to 1:1	Normal	Likely to occur between once-ten times annually; or likely to increase in intensity and/or duration on an annual basis	4
>10/year	Frequent	Likely to occur more than ten times annually	5

Using Table 5, the following future likelihood ratings for the climate parameters selected were assessed and are presented in Table 6. For the risk assessment, the climate parameters and probability ratings used are based on the period 2071 to 2100. The events considered are those at an intensity that causes disruptions in service (functionality), damages (structural integrity) or O&M disruptions.

Table 6. Future Probability Rating for Selected Climate Parameters (2080s)

Climate Parameter	Probability Rating
Mean Seasonal Temperatures	5
High Temperature Extremes	5
Low Temperature Extremes	4
Frost Days	3
Freeze-Thaw Days	3
Precipitation Extremes	2
Sustained Rainfall	5
Dry Spells	4

With the selected climate event probabilities determined for future climate conditions, a “severity of impact” rating must also be determined. This constitutes the “Infrastructure Response Considerations” step of the Assessment Process presented in Figure 2. The specific severity of impact rating criteria is presented in Table 7. These ratings are partially based on the degree to which a climate event causes a loss of service. For example, taking a component such as the road base and subgrade - a minor rating would mean that a grader or other maintenance equipment may need to be sent out, outside of the regular maintenance cycle, to maintain the roadway surface, but would not result in a closure of the roadway. A severe rating may require the closure of the building for a period of time. Service in the context of the Project is defined as the roadway’s ability to provide reliable and safe passage, free of disruption. It is assumed the Project design will be appropriately suited to the current climate.

Table 7. Severity of Impact Rating

Severity		
1	**Insignificant** - No serious impact from a weather event	• Can be corrected through routine maintenance with no impact to O&M budgets • No structure damage to the road
2	**Minor** - Some extra costs for repairs and maintenance.	• No loss of service. • Infrastructure is still operable and accessible • Some extra costs associated with O&M budgets but no requirement for regional response funds

3	**Moderate** - Some damage to infrastructure	• Extra costs and labour required to complete repairs. • Some specialized labour or equipment required to complete repairs • Some loss of service.
4	**Major** - Significant damage to infrastructure.	• Significant extra costs and labour required to complete repairs • Specialized labour or equipment required to complete repairs • Replacement of component required • Significant loss of service – closure of one lane.
5	**Catastrophic** - Complete loss of the asset after a weather event.	• Repair not possible • Extended period of loss of service – road closure.

Using the equation “Risk Rating = Probability Rating x Consequence Rating” provides numerical risk ratings from 0-25 as shown in Figure 4.

Severity Rating (S) (Consequence)							
	Catastrophic (Very High)	**5**	**5**	**10**	**15**	**20**	**25**
	Major (High)	**4**	**4**	**8**	**12**	**16**	**20**
	Moderate	**3**	**3**	**6**	**9**	**12**	**15**
	Minor (Low)	**2**	**2**	**4**	**6**	**8**	**10**
	Insignificant (Very Low)	**1**	**1**	**2**	**3**	**4**	**5**
			1	**2**	**3**	**4**	**5**
			Highly unlikely (Very Low)	Remotely possible (Low)	Occasional (Moderate)	Normal (High)	Frequent (Very High)
			Probability Rating (P) (Likelihood)				

Figure 4. Risk Ratings - Evaluation Matrix. Adapted from Climate Lens General Guidance

In Table 8, risk ratings are explained with suggested risk treatments as per the Climate Lens General Guidance.

Table 8. Risk Classification. Adapted from Climate Lens General Guidance

Risk Classification	Risk Rating	Description of Risk	Risk Treatment
Negligible	1	No permanent damage. No service disruption occurs.	Risks do not require further consideration
Low	2-3	Minor asset/equipment damage. Minor service disruption may be possible. No permanent damage. Minor repairs or restoration expected.	Controls likely, but not required.
Moderate	4-6	Expected limited damage to asset or to equipment components. Minor repairs and some equipment replacement may be required.	Some controls required to reduce risks to lower levels. Risk to be monitored

Risk Classification	Risk Rating	Description of Risk	Risk Treatment
		Brief service disruption may be possible.	for changes over time.
High	8-12	May result in significant permanent damage; or loss of asset or component that may require complete replacement. More lengthy service disruption may be possible.	High priority control measures required.
Extreme	>15	May result in significant permanent damage; or loss of asset or component that may require complete replacement. Significant service disruptions may be possible.	Immediate controls required.

3.1 RISK PROFILE

The purpose of this assessment is to identify the climate risks to the Project at a broad systems-level for a future climate scenario. As such, a risk profile for project assets and components under future climate conditions was prepared (Table 9). The confidence in future climate projections was considered in assessing the risks shown in the risk profile.

It is important to note the climate change impacts risk profile is a prioritization of impacts relative to each other, not against an external benchmark. Designations of ‘moderate’ or high’ risk items should be considered in the context that many risks can be mitigated or monitored through future operations and maintenance policies and procedures.

In general, many climate risks can be mitigated through O&M policies and procedures. It is outside the scope of this assessment to complete a detailed review of O&M policies for their effectiveness in reducing climate risks. However, this assessment may motivate an internal review of O&M policies with a focus on adapting to climate risks.

The most significant risk to the project is related to the potential degradation of permafrost soils. Permafrost conditions in the project area are highly variable, where some locations present more stable soil, while more ice-rich, thaw-sensitive permafrost are very unstable and sensitive to change (conversation with senior, northern civil engineer 2019, Couture 2003). Construction over these highly sensitive soils (which are suspected to exist within the project site area) can lead to significant settlement and increased maintenance or regular rehabilitation (conversation with senior, northern civil engineer 2019). It is recommended that a geotechnical assessment be completed prior to roadway construction.

Table 9. Project Risk Profile Under Projected Future Climate

Climate Parameter	Infrastructure Component Impacted	Description of Climate Interaction	Probability	Severity	Risk Rating	Adaptation Considerations
Temperature						
Mean Seasonal Temperatures	Structural Elements / Physical Infrastructure: Road Base and Subgrade	Ground temperatures are highly influenced by air temperatures. Increasing air and ground temperatures will initiate frost thawing and will result in changes to the depth of the active layer of the permafrost. These changes to the active layer of permafrost can result in settlement and damage to the road surface resulting in potholes and potential safety issues. This could result in higher maintenance requirements to ensure the road surface and user safety.	5	3	15	Consider incorporating the following mitigative measures into road design parameters: - where applicable, apply active and passive heat mitigation techniques such as thermosyphons, air convection embankments (ACE), air ducts and heat drains (HD), reflective surfaces, insulation and embankment thickening. - using a fill only, embankment concept rather than a cut and fill approach. - use woven geotextile to reinforce embankments and reduce differential settlement. - incorporate approaches to lowering the water table in the immediate vicinity of the roadbed by using ditches or similar components. - use geofabrics, geosynthetic materials, wattles or other erosion control products in ditches covered by organics to minimize erosion of the existing fine grained soils. - take advantage of the natural topography and grades along the alignment that are gentle so sidehill cuts are eliminated. - stage the construction such that the placement of granular surfacing is delayed until any significant differential settlement has occurred. - confine the project footprint to the extent where possible, to cut lines and other areas that have already been disturbed.
Mean Seasonal Temperatures	Structural Elements / Physical Infrastructure: Road Embankments / Cuts	This warning can result in permafrost soils melting or weaken and unfrozen soils heaving. This can reduce the service life of the road embankment. Subgrade temperatures may also be affected by changes in ground and surface water flows. Where the subgrade is unfrozen, changes in the ground water table can result in settlement and shifting of the road / embankments (sloughing) and the sinking and cracking of road shoulders resulting in road instability, and structural failure that presents safety issues.	5	4	20	Plan for more frequent inspections, and monitoring, of the performance of the infrastructure (e.g., culverts are clear in the spring and the fall) and that there are sufficient additional resources for maintenance and rehabilitation when settlement occurs. Regularly monitor road maintenance efforts and climate data to better correlate the change in road surface with climate related parameters and their potential changes. Use this information as part of an adaptative management approach to future maintenance and rehabilitation efforts.

Climate Parameter	Infrastructure Component Impacted	Description of Climate Interaction	Probability	Severity	Risk Rating	Adaptation Considerations
Mean Seasonal Temperatures	Structural Elements / Physical Infrastructure: Surface Drainage	Thawing of permafrost also results in ponding of surface water and potential erosion and drainage issues. Abrupt differential thaw settlements on road surfaces are commonly observed where the road is constructed over a foundation that transitions between bedrock and ice-rich permafrost soils. Where massive ice has been initially present in the soil, these settlements can become extreme. With ground temperatures being strongly influenced by air temperatures, this interaction could become more prevalent.	5	3	15	Focus on collecting baseline information for the components that are thought to be most vulnerable to climate change, including the identification and documentation of locations of ice-rich permafrost. Avoid constructing in these areas if possible, and where not, deploy methods to minimize thermal disturbance (e.g., incorporating approaches to lowering the water table in the immediate vicinity of the roadbed by using ditches or similar components). Review seasonal load limits to be enforced during spring thaw periods. Also consider posting reduced speed signs in problematic areas when road conditions seasonally deteriorate.
Mean Seasonal Temperatures	Structural Elements / Physical Infrastructure: Culverts & Ditches	Increasing temperature would initiate snowmelt through either freshet or precipitation events. These events create fast flowing surface water and increase the potential erosion of ditches and culverts through the generation of fast flowing surface water.	5	4	20	No recommendation.
Mean Seasonal Temperatures	Miscellaneous: Maintenance	In the continuous permafrost zone, occurrence of icings on road surfaces may increase with climate warming, as active permafrost layers become thicker and subsurface water flows increase.	5	4	20	Complete road inspection activities during spring thaw to evaluate drainage and thaw-related problems. Address problems like rutting, etc. in a timely manner.
Mean Seasonal Temperatures	Structural Elements / Physical Infrastructure: Road Base and Subgrade	Extreme temperatures and dry periods can result in cracking of the edges of the road. Cracking of the edges of the road can present safety issues for road users and would result in increased maintenance.	5	2	10	No recommendation.
High Temperature Extremes (>30degC)	Structural Elements / Physical Infrastructure: Road Base and Subgrade	Wildfires destroy insulating ground cover (grasses / vegetation) and can increase ground temperatures. This may impact permafrost resulting in accelerated thawing and structural problems.	5	3	15	No recommendation.

Climate Parameter	Infrastructure Component Impacted	Description of Climate Interaction	Probability	Severity	Risk Rating	Adaptation Considerations
High Temperature Extremes (>30degC)	Miscellaneous: Emergency Response	Wildfires are also a public and maintenance staff safety risk and can result in road closures.	5	3	15	No recommendation.
High Temperature Extremes (>30degC)	Miscellaneous: Administration / Personnel & Engineering	Heat waves can result in worker fatigue and exhaustion.	5	2	10	No recommendations, as a public notification system is already in place to help mitigate bottlenecks and other effects of closure as a result of fire.
Low Temperature Extremes (<-30degC)	Structural Elements / Physical Infrastructure: Culverts & Ditches	During low temperature events water flowing through non-heated roadside culverts can become frozen blocking the culvert. This blockage will prevent surface water flow and can result in localized and roadside flooding.	4	4	16	Plan for more frequent inspections, and monitoring, of the performance of the infrastructure (e.g., culverts are clear in the spring and the fall) and that there are sufficient additional resources for maintenance and rehabilitation when settlement occurs. Summer maintenance activities include grading, blading, replacement of surface gravel, dust control, and clearing of culverts. Winter maintenance activities will include snow removal and ice control as part of the road maintenance.
Low Temperature Extremes (<-30degC)	Miscellaneous: Maintenance	Freezing rain is a significant traffic hazard. Untrained operators may over-sand which can physically change the road's crown, shoulders and compromise the load bearing capacity, or over-salt the road which can turn the road into mud.	4	3	12	Implement an operator training program on best practices as it relates to the management of gravel roads (e.g., straight salt and liquids should not be used).
Precipitation						
Precipitation Extremes	Structural Elements / Physical Infrastructure: Road Base and Subgrade	Intense rain events may exceed the design flow capacities for culverts, resulting in water ponding against, overtopping, or flowing uncontrollably through the road embankment. Saturated road embankments may lose structural strength, causing potholes when heavily loaded.	2	3	6	Fast pothole repair may be needed to reduce potential infiltration of water into the subbase with more frequent rain events. Develop a policy to complete road inspections after extreme weather events.
Precipitation Extremes	Structural Elements / Physical Infrastructure: Road Embankments / Cuts	Embankments can be susceptible to changes in spring melt, rainfall frequency, intensity and duration, as well as groundwater levels resulting in internal erosion. Internal and external erosion can impact the structural integrity, raising the possibility of washouts, more repair work and loss of sediment to watercourses, affecting the	2	4	8	Maintain natural drainage patterns by using adequately sized and positioned culverts. Consider additional snow clearing in the ditches during winter to allow for a controlled spring runoff.

Climate Parameter	Infrastructure Component Impacted	Description of Climate Interaction	Probability	Severity	Risk Rating	Adaptation Considerations
		surrounding environment (e.g. sensitive or fish-bearing watercourses).				
Precipitation Extremes	Structural Elements / Physical Infrastructure: Culverts & Ditches	More snow accumulation requires increased effort in snow clearing, which is likely to result in additional load to the road surface. Insufficient late winter snowpack removal can result in soft areas. High-volume snowmelt may also result in flooding and increase pore water pressure and erosion, damaging permafrost.	2	4	8	Late-winter maintenance should blade snow and hard pack down the embankment's side slope area prior to spring melt. Ensure that late winter maintenance clears ice pack and snow from road surfaces to prevent damming of melt water. Frequent snow removal can minimize the insulating effect of the snow.
Precipitation Extremes	Miscellaneous: Maintenance	Increased amounts and frequency of rainfall will mainly affect road surface maintenance work. More frequent flooding events may require increased maintenance of the ditches and culverts.	2	4	8	Where possible, conduct inspections after severe events to ensure integrity of systems. Implement a more aggressive road monitoring and maintenance program. Conduct periodic surrounding surface surveys. Remote sensing techniques such as LiDAR, SAR, or Optical methods, can be repeated every 5 to 20 years to identify those areas where surface features such as topography, vegetation, surface water flow, pond developments, or thermograms activities have changed.
Sustained Rainfall	Structural Elements / Physical Infrastructure: Culverts & Ditches	Extreme weather events may overwhelm the capacity of some existing drainage-structures which can result in localized flooding and washouts, and negative effects to the surrounding environment. Drainage structures that cross the embankment, such as culverts and rock drains, are considered at higher risk to climate change than diversion structures that do not (e.g., flow channels and ditches) because of the potential severity.	5	2	10	Develop emergency planning procedures for flooding and erosion control at susceptible locations. Additional studies may be required to identify critical locations susceptible to flooding and to better understand flooding hazards / potential water volumes.
Sustained Rainfall	Miscellaneous: Administration / Personnel & Engineering	Extreme storms may hinder maintenance activities. In addition, it affects road safety and the ability of personnel to get to their workplace	5	2	10	Consider preparing O&M, construction policies, and worker safety policies on working and traveling in extreme weather events.
Dry Spells	Miscellaneous: Maintenance	Dust may form after long droughts and limit visibility on the road. Dust particles that settle directly onto plants can smother leaf surfaces and increase leaf surface temperature, all of which can reduce the overall photosynthetic efficiency in the plant	4	2	8	Consider employing water-based dust control methods during construction and restrict construction traffic to the planned footprint. In terms of maintenance, it is recommended that: - road inspections occur more frequently that the current norm. - there are sufficient resources for the maintenance and rehabilitation of the road, particularly during summer months when traffic is likely to generate more dust from the road surface.

Climate Parameter	Infrastructure Component Impacted	Description of Climate Interaction	Probability	Severity	Risk Rating	Adaptation Considerations
						- lower speed limits are posted as slower travel will generate less dust in summer, dryer months.
Frost Days	Structural Elements / Physical Infrastructure: Culverts & Ditches	Road surface or culverts can be structurally affected by changing numbers of frost cycles due to deformations associated with the volumetric changes when water freezes to ice and vice-versa. The increase in the number of frost-free days is likely to reduce this impact.	3	3	9	No recommendation.
Freeze-Thaw Days	Structural Elements / Physical Infrastructure: Road Base and Subgrade	Snowmelt-driven flooding creates fast flowing surface water and increases groundwater which can result in roadside flooding. Flooding on the road can cause potholes and damage to the road surface. Freezing of floodwater on the road can cause safety implications to road users.	3	3	9	Regular maintenance and clearing of culverts will reduce the potential for blockages and any associated roadside flooding.
Freeze-Thaw Days	Structural Elements / Physical Infrastructure: Road Embankments / Cuts	Snowmelt-driven flooding create fast flowing surface water and groundwater and surface water flow which can lead to erosion and material movement down from steep embankments	3	3	9	No recommendation.
Freeze-Thaw Days	Structural Elements / Physical Infrastructure: Culverts & Ditches	Snowmelt-driven flooding creates fast flowing surface water and increases the potential of erosion of ditches and culverts.	3	4	12	To avoid the premature erosion at the base of roadside culverts could be layered with a geotextile membrane with overlying rocks and gravel. Steam heaters will reduce the amount of freeze related blockages at culverts.

3.0 ANALYSIS OF RESILIENCE OPTIONS

3.1 IDENTIFICATION OF RESILIENCE MEASURES

As shown in Table 9, there are many risks to infrastructure that can be efficiently and effectively addressed through operations and maintenance procedures. It is recommended O&M policies and procedures be reviewed and revised as necessary to ensure they have an emphasis on improving system resilience, and health and safety requirements of users and Project staff, under a changing climate.

3.2 COST/BENEFIT ANALYSIS

Cost/benefit analysis of resilience design options are not available as final design details were not available at the time of the assessment. It is outside the scope of this assessment to complete a cost/benefit analysis of resilience design options. Furthermore, many resilience measures can be addressed through operations and maintenance procedures, and as such have no costs associated with design measures.

3.3 CONSIDERATION OF RESILIENCE PRINCIPLES

As recommended by the Climate Lens—General Guidance V1.2, the following is a discussion of how the climate change resilience principles have been incorporated into this assessment.

3.3.1 Proportionate Assessment

The Mackenzie Valley Highway Project is a proposed 321 km stretch of all-season gravel roadway between the communities of Wrigley and Norman Wells.

The analysis and recommendations in this Resilience Assessment are based on information available within the timeline and scope of this project, and on the authors' experience with climate risks assessments, for example, the application of Engineers Canada's Public Infrastructure Engineering Vulnerability Committee (PIEVC) vulnerability and risk assessment tool - the PIEVC Protocol. This assessment represents a level of effort and detail consistent with the criticality of the Project's service and the level of detail of information available.

The Project will be a critical asset to the Government of the Northwest Territories and as such, an extensive climate risk assessment, using, for example, the PIEVC Protocol vulnerability assessment in the Project's detailed design stage to ensure that owners, designers, construction team and operators of the Project understand the full range of climate risks to the Project over its operational life. A full PIEVC Protocol assessment can take 3-6 months and involve numerous multiday and multiple stakeholder workshops but would result in higher capacity for the Project team to understand the broad spectrum of climate risks to the Project.

3.3.2 Systemic Analysis of Risk

By using an approach which aligns with Engineers Canada's PIEVC Protocol and conforms to ISO 31000 Risk Management framework, this high-level risk identification and assessment was carried out with the intention to meet the requirements set by Infrastructure Canada's Climate Lens—General Guidance V1.2.

3.3.3 Pursuit of Multiple Benefits

This assessment has identified that many climate risks to the Project can be addressed through O&M policies and procedures. As the Project is an extension to an existing gravel roadway, existing O&M policies and procedures will be adopted based on the recommendations in this report. It is outside the scope of this climate resilience assessment to complete detailed review of existing O&M policies for effectiveness in reducing climate risks. However, this climate assessment may motivate internal reviews of O&M policies with a focus to adapting to climate risks for the Project as these have been identified in this assessment.

3.3.4 Avoidance of Unintended Consequences

At the current stage of the Project, it is too early to fully consider the unintended consequences of risk transference or mitigation strategies. Stantec recommends this principle to be considered in detail during the design-build of the Project. For example, regular maintenance including grading must be completed to avoid excessive corrugation, pitting, uneven settlement, etc. Due to the projected increase in severe weather events and permafrost degradation, maintenance needs may increase. Maintenance activities such as these will help to maintain the asset to its intended level of service, however, may lead to increased GHG emissions as an unintended consequence. In general, O&M measures for climate adaptation are not GHG intensive. For potentially energy and GHG-intensive risk mitigation strategies, Stantec recommends incorporating design targets for the reduction of operational GHGs to avoid long-term unintended environmental consequences.

3.4 RESILIENCE MEASURES SELECTION

As the Project is in the preliminary design stage, resilience measures for individual system components have not been designed in detail.

Stantec recommends that resilience measures be further developed and evaluated as the Project progress into procurement, detailed design, construction and operation. This may be done through referencing the climate vulnerabilities identified through this assessment as a starting point, and by conducting a full PIEVC Protocol climate vulnerability assessment involving multiple internal and external stakeholders to develop a comprehensive profile of climate risks throughout the Project's lifecycle.

4.0 DESCRIPTION OF EVIDENCE BASE

To anticipate the climate vulnerabilities for the Project infrastructure, Stantec relied on the review of documents from other projects completed by other agencies with similar infrastructure or with similar climate hazards, and discussions with expert staff advisors. The infrastructure responses and comments regarding the impact to each selected climate parameter are evaluated based on the professional judgement of the assessors and a review of the following documents.

- Canada's Climate Change Report - Environment and Climate Change Canada, 2019;
- Other published literature

A series of interviews were carried out with members of the Owner's Design Team to discuss climate risks that can be addressed through design or may impact the construction.

Table 10 Interview Participants

Name	Role, Organization
Dustin Dewer	Norther Territories GOVT
Michael Hempler	Northern Territories GOVT
Todd McCauley	GNWT – Regional superintendent Sahtu Region
Rob Thom	GNWT – Transportation Planner

4.1 CLIMATE DATA

Stantec evaluated climate data from nearby weather stations, which was obtained through the CCHIP created by RSI. For this assessment, climate data from the Norman Wells A weather monitoring station (ID: 2202800) was used to represent the climate at the project site location.

Future climate projections are based on downscaled, published Intergovernmental Panel on IPCC data; the scope of this assessment did not include additional, site-specific future climate modelling. Cross-verification between climate information sources was conducted to identify possible discrepancies between the data sources used and are described in the detailed climate analysis report (Appendix A).

4.2 INDIGENOUS HISTORICAL KNOWLEDGE OF CLIMATE

Indigenous historical knowledge of climate for the Project area was not referenced for this assessment. This type of climate knowledge is typically relied upon in project locations where relevant climate data from weather stations is unreliable, unusable, or otherwise unavailable. For the Project, historical climate data from nearby Environment Canada weather stations was readily available and reliable and thus have been used.

4.3 PROJECT TEAM

This resilience assessment was prepared by K'alo-Stantec Ltd. Table 11 identifies Stantec team members that were involved with the assessment.

Table 11. Resilience Assessment Team

Name	Qualifications	Project Role
Bernadette Middleton	M.Sci, ENV SP	Resilience Assessor
Riley Morris	M.Sc., P.Eng.	Climate Advisor
Shane O'Hanlon	M.Sc., B.Eng.	Reviewer - Resilience Assessor
Wayne Penno	P.Eng., MBA	Qualified Validator – Resilience
Warren McLeod	P.Eng.	Independent Peer Reviewer

5.0 CONCLUSION

This climate resilience assessment conducted for the Project was generally based on the principles of Engineers Canada's PIEVC Protocol assessment and is consistent with ISO 31000 Risk Management Framework. This assessment serves to inform the proponent on the future climate related risks that should be considered at the design and construction stages of the Project.

This assessment has identified eight climate parameters that can pose hazards to Project infrastructure. Infrastructure interactions to each climate parameter were examined and an associated risk rating was assigned to each. The climate parameters that presented the greatest number of risks to the Project are mean seasonal temperatures, extreme high and low temperatures, and extreme precipitation.

Table 9 lists all the estimated risks to the Project. It is important to note that the climate change impacts are a prioritization of impacts relative to each other, not against an external benchmark. Designations of 'moderate' or high' risk items should be considered in the context that many risks can be mitigated or monitored through O&M policies and procedures. This assessment does not include an evaluation of the effectiveness of O&M policies to reduce or mitigate climate risks, as these have not been confirmed. Some of the risks may be addressed at the detailed design stage of Project.

Although moderate and high risks have been identified at this stage of the project, many risks can be monitored or mitigated as part of O&M policies and procedures during the lifecycle of the assets. Furthermore, since the design life of the roadway is less than the time horizon for this assessment, some mitigation measures can be applied or managed sequentially with regular roadway rehabilitation cycles.

Recommended climate risk management measures for the highest rated risks ('Extreme') include:

- Consider incorporating the following mitigative measures into road design parameters:
  - where applicable apply active and passive heat mitigation techniques such as thermosyphons, ACE, air ducts and HD, reflective surfaces, insulation and embankment thickening to reduce permafrost degradation.
  - using a fill only, embankment concept rather than a cut and fill approach.
  - use woven geotextile to reinforce embankments and reduce differential settlement.
  - incorporate approaches to lowering the water table in the immediate vicinity of the roadbed by using ditches or similar components.
  - use geofabrics, geosynthetic materials, wattles or other erosion control products in ditches covered by organics to minimize erosion of the existing fine-grained soils.
  - take advantage of the natural topography and grades along the alignment that are gentle so sidehill cuts are eliminated.
  - stage the construction such that the placement of granular surfacing is delayed until any significant differential settlement has occurred.

   - confine the project footprint to the extent where possible, to cut lines and other areas that have already been disturbed.

- Plan for more frequent inspections, and monitoring, of the performance of the infrastructure (e.g., culverts are clear in the spring and the fall) and that there are sufficient additional resources for maintenance and rehabilitation when settlement occurs. Regularly monitor road maintenance efforts and climate data to better correlate the change in road surface with climate related parameters and their potential changes. Use this information as part of an adaptative management approach to future maintenance and rehabilitation efforts.
- Focus on collecting baseline information for the components that are thought to be most vulnerable to climate change, including the identification and documentation of locations of ice-rich permafrost. Avoid constructing in these areas if possible, and where not, deploy methods to minimize thermal disturbance (e.g., incorporating approaches to lowering the water table in the immediate vicinity of the roadbed by using ditches or similar components).
- Review and refresh the operator training program on best practices as it relates to the management of gravel roads (e.g. straight salt and liquids should not be used).
- Rapid pothole repair may be needed to reduce potential infiltration of water into the subbase with more frequent rain events. Develop a policy to complete road inspections after extreme weather events.
- Maintain natural drainage patterns by using adequately sized and positioned culverts. Consider additional snow clearing in the ditches during winter to allow for a controlled spring runoff.
- Where possible, snow should be bladed down the side slopes, away from the shoulders. Late-winter maintenance should blade snow and hard pack down to the embankment’s side slope area prior to spring melt. Ensure that late winter maintenance clears ice pack and snow from road surfaces to prevent damming of melt water. Frequent snow removal can minimize the insulating effect of the snow.
- Where possible, implement a more aggressive road monitoring and maintenance program. Conduct periodic surrounding surface surveys. Remote sensing techniques such as LiDAR, SAR, or Optical methods can be repeated every 5 to 20 years to identify those areas where surface features such as topography, vegetation, surface water flow, pond developments, or thermograms activities have changed. Conduct inspections after severe events to ensure the integrity of roadway and drainage systems.

6.0 REFERENCES

Allen, M.R., O.P. Dube, W. Solecki, F. Aragón-Durand, W. Cramer, S. Humphreys, M. Kainuma, J. Kala, N. Mahowald, Y. Mulugetta, R. Perez, M.Wairiu, and K. Zickfeld, 2018: Framing and Context. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

Bonsal, B.R., D.L. Peters, F. Seglenieks, A. Rivera, and A. Berg. 2019. Changes in freshwater availability across Canada; Chapter 6 in Bush, E. and D.S. Lemmen (Eds.) Canada's Changing Climate Report. Government of Canada, Ottawa, Ontario, pp. 261-342

Burn, D.H., P.H. Whitfield, and M. Sharif. 2016. Identification of changes in floods and flood regimes in Canada using a peaks over threshold approach. Hydrological Processes, 30: 3303-3314. doi:10.1002/hyp.10861

Couture, R., S. Smith, S.D. Robinson, M.M. Burgess, and S. Solomon. 2003. On the Hazards to Infrastructure in the Canadian North Associated with Thawing of Permafrost. Geological Survey of Canada, Edmonton, Alberta.

Ecological Stratification Working Group. 1995. A National Ecological Framework for Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch, Ottawa/Hull. Report and national map at 1:7500 000 scale.

Engineers Canada. 2012. PIEVC Engineering Protocol for Infrastructure Vulnerability Assessment and Adaptation to a Changing Climate Principles & Guidelines, Revision PG-10, May 2012

Gaur, A., A. Gaur, and S.P. Simonovic. 2018. Future Changes in Flood Hazards across Canada under a Changing Climate. Water, 10: 1441. doi:10.3390/w10101441

Gaur, A., A. Gaur, D. Yamazaki, and S.P. Simonovic. 2019. Flooding Related Consequences of Climate Change on Canadian ities and Flow Regulation Infrastructure. Water, 11: 63. doi:10.3390/w11010063

Infrastructure Canada. 2019. Climate Lens General Guidance V1.2 , 2019. Retrieved online from https://www.infrastructure.gc.ca/pub/other-autre/cl-occ-eng.html

IPCC 2014 Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. Retrieved online from https://ar5-syr.ipcc.ch/ipcc/ipcc/resources/pdf/IPCC_SynthesisReport.pdf

McHattie, R.L. 2015. Low Volume Gravel Roads in Alaska: A Practical Guide for Owners and Others.

NRCAN. 2008. From Impacts to Adaptation: Canada in a Changing Climate. Retrieved online from https://www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/reports/assessments/2008/10253

Poitras, V., L. Sushama, F. Seglenieks, M.N. Khaliq, and E. Soulis. 2011. Projected Changes to Streamflow Characteristics over Western Canada as Simulated by the Canadian RCM. Journal of Hydrometeorology, 12: 1395-1413. doi:10.1175/JHM-D-10-5002.1

Smith, M.R. and S.S. Myers. 2018. Impact of anthropogenic CO_2 emissions on global human nutrition. *Nature Climate Change*, 8: 834-839.

APPENDICES

Appendix A CLIMATE PROFILE

1.0 INTRODUCTION

1.1 DESCRIPTION OF CLIMATE PROFILES

Climate is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of meteorological variables such as temperature, precipitation and wind over a period of time. Climate profiles are important tools that describe what climate trends have been occurring in recent history (i.e., over the last 30 years or longer), and also describe future climate conditions to help inform design and/or adaptation actions. Climate profiles rely on the historical climate record (usually in the form of meteorological data measured at weather stations) to describe climate from recent history, and on climate projections (developed by global climate models or GCMs). The historical climate profile puts future climate projections into context: e.g. design performance from the past can be compared to both historical and future climate to better understand what (if any) design changes should be implemented to ensure better performance in the future.

When developing a profile of the historic climate of an area, the most valuable data is typically temperature, precipitation, and wind. Meteorological data from the last 30 years is preferred to help give a representative estimate of the climate of recent history at a given location – though longer periods are of even greater benefit in that they add even more to the story of an area's historical climate. Environment and Climate Change Canada (ECCC) provides the largest database of observational historical climate data in Canada.

Climate projections are descriptions of the future climate and are most often collected from Global Climate Models (GCMs) developed by many organizations across the world. It is not recommended to rely only on one or two of these GCMs to estimate future climate. Instead, an average of several GCMs tends to give a more reliable estimate of future climate. There are nearly 40 GCMs that have contributed to the Fifth Coupled Model Intercomparison Project (CMIP5; Taylor et al., 2012), which forms the basis of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC, 2013). The Pacific Climate Impacts Consortium (PCIC) has taken a subset of 24 of these models to produce reliable, high-resolution downscaled climate projections localized to specific areas of interest in Canada (Cannon, 2015; Cannon et al., 2015).

In addition to the physics of the GCMs, global progress towards meeting GHG emissions targets is also a large source of uncertainty in future climate projections. There are four Representative Concentration Pathways (RCP)[1] scenarios adopted by the IPCC that are based on various future greenhouse gas concentration scenarios. This climate profile will focus on the "business as usual" greenhouse gas concentrations scenario, RCP 8.5. Current global GHG concentrations are closer to following the RCP 8.5 pathway, despite global agreements/targets for GHG emissions reductions (Smith and Myers, 2018).

> The IPCC is the international body for assessing the science related to climate change. The IPCC was set up in 1988 by the World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) to provide policymakers with regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation.
>
> IPCC assessments provide a scientific basis for governments at all levels to develop climate related policies, and they underlie negotiations at the UN Climate Conference – the United Nations Framework Convention on Climate Change (UNFCCC). The assessments are policy-relevant but not policy-prescriptive: they may present projections of future climate change based on different scenarios and the risks that climate change poses and discuss the implications of response options, but they do not tell policymakers what actions to take.

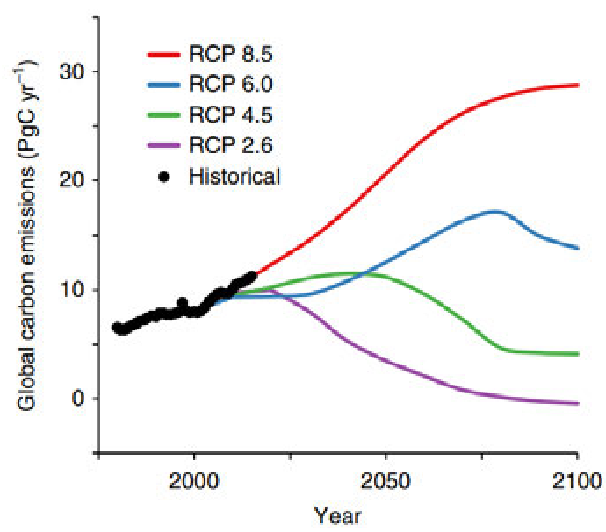


Figure 5 Historical CO_2 emissions for 1980-2017 and projected emissions trajectories until 2100 for the four RCP scenarios. Figure from Smith and Myers, 2018

[1] RCP: Representative Concentration Pathways – a greenhouse gas concentration (not emissions) trajectories adopted by the Intergovernmental Panel on Climate Change (IPCC) for its Fifth Assessment Report (AR5) in 2013.

1.2 CLIMATE PROFILES FOR THE MACKENZIE VALLEY HIGHWAY PROJECT

Two climate zones were defined, corresponding with ecological regions in the area, which generally align with differentiation in climate and weather patterns of the breadth of the Mackenzie Valley Highway. Regardless, comparison of the datasets between available data in the area suggests that Fort Simpson A is adequately representative of the climate in the region.

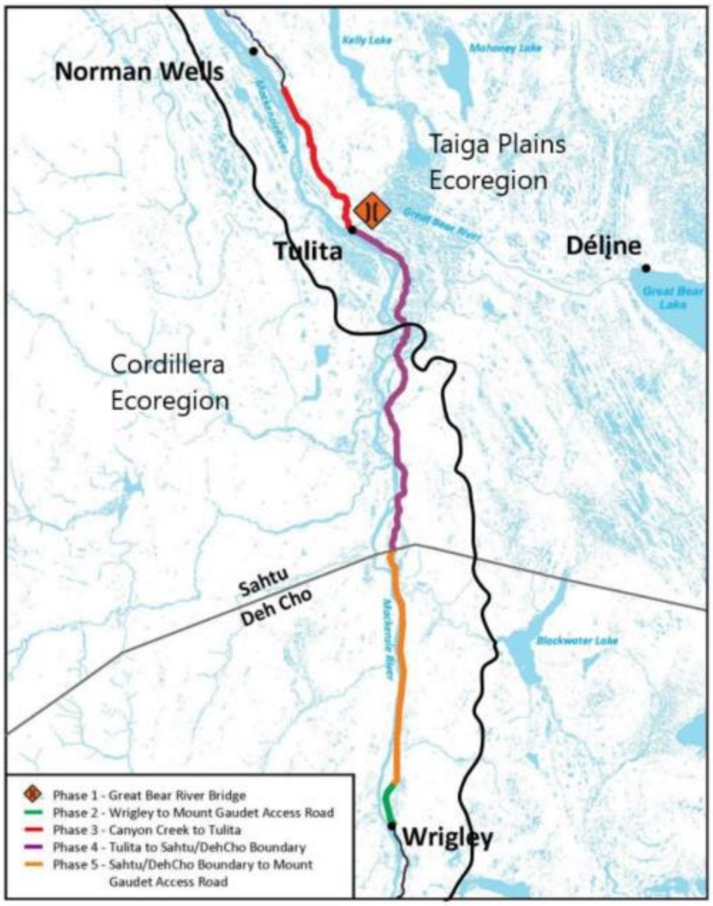


Figure 6 Map of Proposed Highway Construction Plan, Overlain by Climate Zones Selected for this Assessment: Cordillera and Taiga Plains Eco Regions.

A review of available historical observation data identified various weather stations throughout the region with data archived by ECCC. Many of these stations, however, either are no longer in operation or have short records and do not provide sufficient data for climate analysis (including the calculation of 1981-2010 Climate Normals values). Of the stations with sufficiently long records covering the recent decades, an individual station was selected to represent each climate zone and used for detailed analysis (Table 12); selected stations shaded in grey). Station proximity to the proposed highway was also considered when selecting the representative stations. A summary of the coordinates of the ECCC weather stations used for each climate zone is shown in Table 11. In this case, the Norman Wells A station was selected because of its long record, the completeness of the dataset, and its location with respect to the proposed highway. The Fort Simpson A station was chosen for similar reasons; however, it is located at a distance (~180km SE) from the proposed terminus of the highway. This distance in location was prioritised in this case over the poor dataset at the Wrigley A weather station, which has a significant number of missing days of data. Regardless, comparison of the datasets between available data in the area suggests that Fort Simpson A is adequately representative of the climate in the region. In order to characterize the general differences between the two climate zones, general comparisons of 1981-2010 Climate Normals values between weather stations is presented in Table 12.

Table 12 Location of Observation Stations used for Historical Climate Profile

Climate Zone	Observation Station Name (Station ID)	Latitude	Longitude	Record Range (Length in yrs)
Norman Wells – Tulita	Norman Wells A (ID: 2202800)	65.2813 N	-126.7986 W	1943-2020 (78)
	Tulita A (ID: 2201700)	64.9097 N	-125.5694 W	1903-2020 (118)
Wrigley – Fort Simpson	Wrigley A (ID: 2204000)	63.2094 N	-123.4366 W	1943-2020 (78)
	Fort Simpson A (ID: 2202104)	61.7602 N	-121.2366 W	1895-2020 (126)

Table 13 Climate Normals Differences between the Two Climate Zones

Climate Parameter	Norman Wells A (ID: 2202800/1) 1981-2010	Fort Simpson A (ID: 2202104) 1981-2010
Annual Mean Temperature (°C)	-5.1	-2.9
Annual Maximum Temperature (°C)	-0.4	2.7
Annual Minimum Temperature (°C)	-9.9	-8.2
Annual Total Precipitation (mm)	294.4	387.6
# of Days/Year with Tmax > 30°C	2.1	4.2
# of Days/Year with Tmin < -30°C	51.0	37.5

The time horizons for the study were selected as current conditions (based on 1981-2010 Climate Normals) establishing the baseline. This climate profile presents projected climate information for three time horizons: the 2020s (2010 to 2039), the 2050s (2040 to 2069), and the 2080s (2070 to 2099). Typically, the 2020s are used to evaluate how recent trends correlate with projections in the near future. The 2050s and 2080s climate time horizons are presented as longer-term climate projections to help inform infrastructure design and adaptation planning.

2.0 TEMPERATURE

2.1 MEAN TEMPERATURE

Table 14 Change in Annual Mean Temperature from the 1981-2010 Baseline under RCP 8.5

Time Period	Climate Zone (Station Name; ID)	1981-2010 Baseline (°C)	Projected Change in Annual Mean Temperature from 1981-2010 Baseline (°C)		
			2020s	2050s	2080s
Annual	Norman Wells A (ID: 2202800)	-5.1	1.0	3.1	5.5
	Fort Simpson A (ID: 2202104)	-2.8	1.7	3.7	6.2
Winter	Norman Wells A (ID: 2202800)	-24.5	1.5	4.3	7.7
	Fort Simpson A (ID: 2202104)	-22.2	2.4	5.2	8.6
Spring	Norman Wells A (ID: 2202800)	-5.7	0.8	2.7	5.1
	Fort Simpson A (ID: 2202104)	-1.6	1.5	3.4	5.9
Summer	Norman Wells A (ID: 2202800)	15.3	-0.2	1.3	3.2
	Fort Simpson A (ID: 2202104)	15.8	1.0	2.5	4.4
Fall	Norman Wells A (ID: 2202800)	-5.6	1.7	3.8	5.9
	Fort Simpson A (ID: 2202104)	-3.1	1.7	3.8	5.9

2.2 MAXIMUM TEMPERATURE

2.2.1 Annual and Seasonal Average

Table 15 Change in Annual Maximum Temperature from the 1981-2010 Baseline under RCP 8.5

Time Period	Climate Zone (Station Name; ID)	1981-2010 Baseline (°C)	Projected Change in Annual Maximum Temperature from 1981-2010 Baseline (°C)		
			2020s	2050s	2080s
Annual	Norman Wells A (ID: 2202800)	-0.4	0.8	2.7	5.0
	Fort Simpson A (ID: 2202104)	2.7	1.6	3.5	5.8
Winter	Norman Wells A (ID: 2202800)	-20.4	1.1	3.7	6.8
	Fort Simpson A (ID: 2202104)	-17.5	2.2	4.8	7.9
Spring	Norman Wells A (ID: 2202800)	0.2	0.3	2.0	4.3
	Fort Simpson A (ID: 2202104)	4.8	1.4	3.1	5.4
Summer	Norman Wells A (ID: 2202800)	20.7	-0.2	1.2	3.1
	Fort Simpson A (ID: 2202104)	22.1	1.0	2.4	4.3
Fall	Norman Wells A (ID: 2202800)	-1.9	1.3	3.3	5.3
	Fort Simpson A (ID: 2202104)	1.3	1.5	3.5	5.5

2.2.2 Extreme Maximum Temperature Frequency

It is useful to view projected increases in temperatures as the change in the occurrence of days with a temperature higher than a certain extreme heat threshold. The climate projections for the occurrence of days with temperatures greater than 30°C are presented below.

Table 16 Occurrence of Maximum Daily Temperatures > 30°C: Historic (1981-2010) and Projected under RCP 8.5

Climate Zone (Station Name)	Annual Occurrence of Days with Max. Temp > 30°C (days/year)			
	1981-2010	2020s	2050s	2080s
Norman Wells-Tulita (Norman Wells A)	2.1	2.6	7.0	14.4
Wrigley-Fort Simpson (Fort Simpson A)	4.2	5.8	12.9	24.8

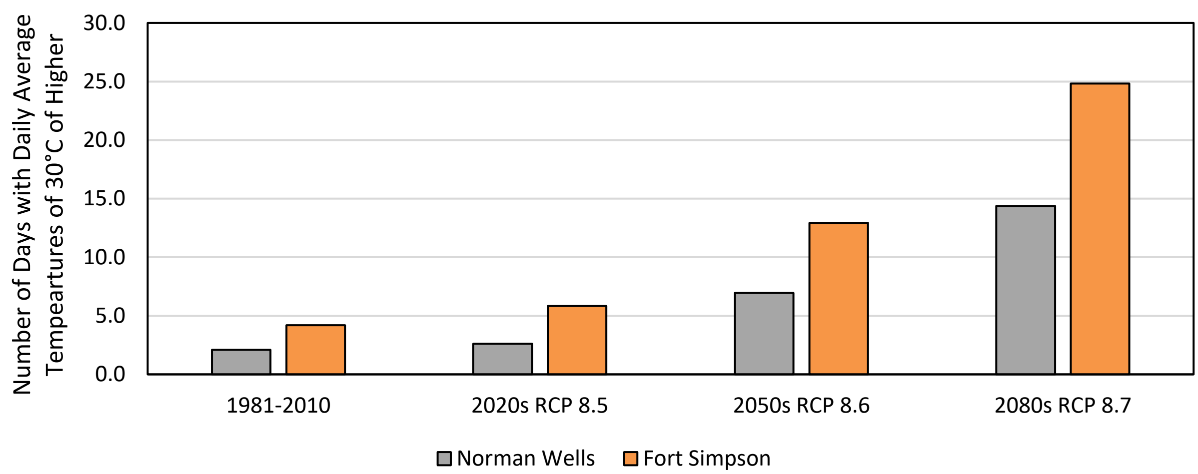


Figure 7 Occurrence of Maximum Daily Temperature > 30°C by Time Period and Location

2.3 MINIMUM TEMPERATURE

2.3.1 Annual and Seasonal Average

Table 17 Change in Annual Minimum Temperature from the 1981-2010 Baseline under RCP 8.5

Time Period	Climate Zone (Station Name; ID)	1981-2010 Baseline (°C)	Projected Change in Annual Minimum Temperature from 1981-2010 Baseline (°C)		
			2020s	2050s	2080s
Annual	Norman Wells A (ID: 2202800)	-9.9	1.3	3.5	6.1
	Fort Simpson A (ID: 2202104)	-8.2	1.7	3.9	6.5
Winter	Norman Wells A (ID: 2202800)	-28.5	1.7	4.7	8.5
	Fort Simpson A (ID: 2202104)	-26.8	2.5	5.5	9.3
Spring	Norman Wells A (ID: 2202800)	-11.6	1.2	3.3	5.9
	Fort Simpson A (ID: 2202104)	-8.1	1.6	3.7	6.3
Summer	Norman Wells A (ID: 2202800)	9.7	0.0	1.6	3.5
	Fort Simpson A (ID: 2202104)	9.5	1.0	2.6	4.5
Fall	Norman Wells A (ID: 2202800)	-9.3	2.0	4.3	6.5
	Fort Simpson A (ID: 2202104)	-7.6	1.8	4.1	6.3

1. Extreme Minimum Temperature Frequency

It is useful to view projected increases in temperatures as the change in the occurrence of days with a temperature lower than a certain extreme cold threshold. The climate projections for the occurrence of days with temperatures less than -30°C are presented below.

Table 18 Occurrence of Minimum Daily Temperatures < -30°C: Historic (1981-2010) and Projected under RCP 8.5

Climate Zone (Station Name)	Annual Occurrence of Days with Min. Temp < -30°C (days/year)			
	1981-2010	2020s	2050s	2080s
Norman Wells-Tulita (Norman Wells A)	51.0	40.8	24.0	10.7
Wrigley-Fort Simpson (Fort Simpson A)	37.5	29.4	16.7	6.5

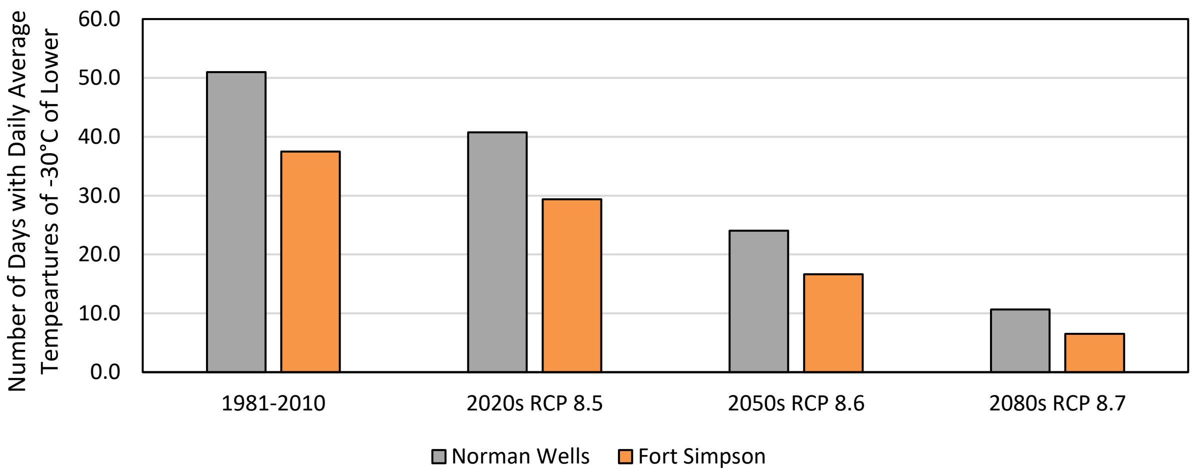


Figure 8 Occurrence of Minimum Daily Temperature < -30°C by Time Period and Location

3.0 PRECIPITATION

3.1 TOTAL ANNUAL & SEASONAL ACCUMULATION

Table 19 Projected Percent Change in Average Total Annual Precipitation from the 1981-2010 Baseline under RCP 8.5

Time Period	Climate Zone (Station Name; ID)	1981-2010 Baseline (°C)	Projected Change in Total Annual Precipitation from 1981-2010 Baseline (%)		
			2020s	2050s	2080s
Annual	Norman Wells A (ID: 2202800)	294.4	1.10	1.00	0.92
	Fort Simpson A (ID: 2202104)	387.6	0.92	1.00	1.10
Winter	Norman Wells A (ID: 2202800)	48.7	0.83	0.73	0.67
	Fort Simpson A (ID: 2202104)	55.6	0.67	0.73	0.83
Spring	Norman Wells A (ID: 2202800)	40.8	0.54	0.60	0.68
	Fort Simpson A (ID: 2202104)	61.8	0.54	0.60	0.68
Summer	Norman Wells A (ID: 2202800)	126.3	1.45	1.56	1.65
	Fort Simpson A (ID: 2202104)	173.8	1.45	1.56	1.65
Fall	Norman Wells A (ID: 2202800)	78.5	1.02	1.11	1.25
	Fort Simpson A (ID: 2202104)	96.4	1.02	1.11	1.25

Precipitation

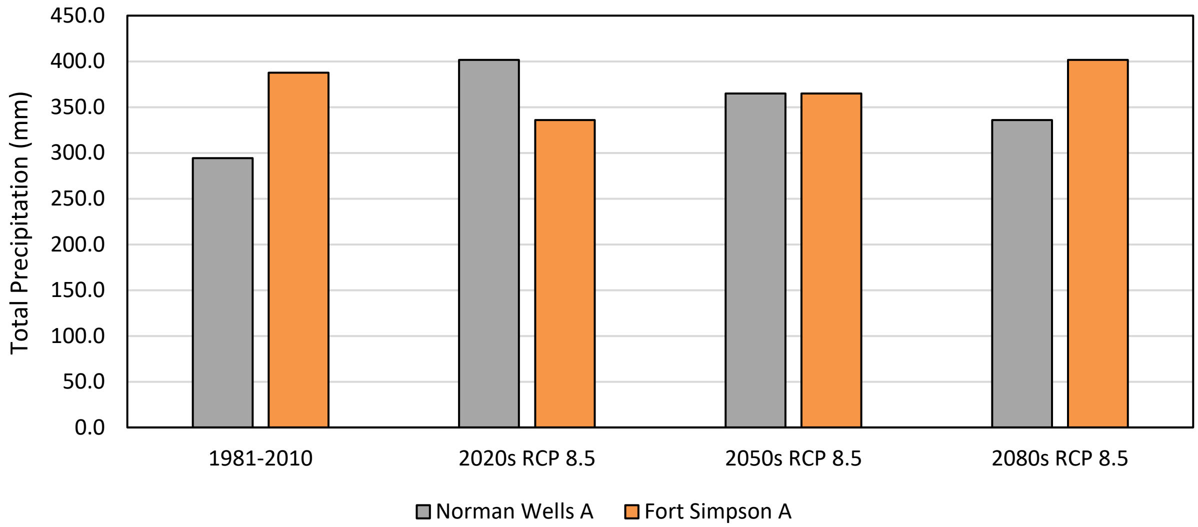


Figure 9 Average Annual Total Precipitation by Time Period and Location

3.2 INTENSITY-DURATION-FREQUENCY (IDF)

In the following subsections, total precipitation amount (mm) for specific time intervals (5 minutes to 24 hours) for various return periods (2 years to 100 years) are provided. These precipitation amounts are part of IDF data, which relates short-duration, high rainfall intensity with its frequency of occurrence. Evaluating historic and projected IDF data provides insight into how the short-duration, high intensity rainfall events will change under future climate conditions. Ideally, IDF data generated by Environment and Climate Change Canada from a weather station within the climate zones would be used. Both the Norman Wells A and Fort Simpson A weather stations present IDF projection data, which were used in this climate profile, as described under sections 3.2.1 and 3.2.2, respectively. Projections for future climate IDF data are available based on results from 24 Global Circulation Models that simulate future climate conditions. The projected IDF data presented here is based on bias-corrected results from 9 downscaled climate models under the RCP 8.5 emission scenario from the Pacific Climate Impacts Consortium. The "ungauged" interpolations and projections are published by the Institute for Catastrophic Loss Reduction (ICLR) at Western University, London, Ontario.

3.2.1 Norman Wells – Tulita Climate Zone

For the Norman Wells-Tulita climate zone, a gauged station at the Norman Wells A weather monitoring station (latitude, longitude: 65.28, -126.80) with data spanning from 1974 to 2016 used. Historical and projected total precipitation amount (mm) in specific time intervals (5 minutes to 24 hours) for various return periods (2 years to 100 years) are provided below.

Table 20 Historical Precipitation Event Accumulation IDF data (mm) – Norman Wells A

T (years)	2	5	10	25	50	100
5 min	2.92	4.62	5.74	7.17	8.22	9.27
10 min	4.25	6.7	8.32	10.37	11.89	13.4
15 min	5.06	7.81	9.63	11.93	13.63	15.32
30 min	6.58	10.32	12.8	15.93	18.25	20.56
1 h	8.82	13.58	16.74	20.72	23.68	26.61
2 h	11.17	15.97	19.15	23.16	26.14	29.1
6 h	16.37	22.01	25.74	30.45	33.95	37.42
12 h	39.43	54.38	66.74	86.01	101.83	113.15
24 h	48.51	65.25	76.43	90.82	101.83	113.15

Table 21 Projected Precipitation Event Accumulation IDF data (mm) and Percent Change from Historical (%), Norman Wells A, RCP 8.5, 2020s (2010-2039)

T (years)	2		5		10		25		50		100	
	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change
5 min	3.12	6.8%	4.85	5.0%	6.36	10.8%	8.25	15.1%	9.69	17.9%	11.19	20.7%
10 min	4.6	8.2%	7.21	7.6%	9.43	13.3%	12.03	16.0%	13.88	16.7%	16	19.4%
15 min	5.48	8.3%	8.46	8.3%	10.96	13.8%	13.92	16.7%	16	17.4%	18.37	19.9%
30 min	7.15	8.7%	10.94	6.0%	14.16	10.6%	18.04	13.2%	20.82	14.1%	23.86	16.1%
1 h	9.45	7.1%	14.27	5.1%	18.38	9.8%	23.86	15.2%	28.02	18.3%	32.14	20.8%
2 h	12.37	10.7%	17.63	10.4%	21.87	14.2%	26.64	15.0%	29.6	13.2%	33.07	13.6%
6 h	18.82	15.0%	25.39	15.4%	30.02	16.6%	33.62	10.4%	35.38	4.2%	37.18	-0.6%
12 h	22.43	12.9%	30.5	13.1%	36.69	15.9%	42.62	13.3%	45.63	8.6%	50.07	7.9%
24 h	25.86	7.2%	37.16	5.2%	46.43	8.7%	60.34	15.9%	70.66	19.7%	80.32	21.9%

Table 22 Projected Precipitation Event Accumulation IDF data (mm) and Percent Change from Historical (%), Norman Wells, RCP 8.5, 2050s (2040-2069)

T (years)	2		5		10		25		50		100	
	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change
5 min	3.19	9.2%	5	8.2%	6.32	10.1%	8.27	15.3%	9.91	20.6%	12.18	31.4%
10 min	4.71	10.8%	7.41	10.6%	9.35	12.4%	12.16	17.3%	14.37	20.9%	17.34	29.4%
15 min	5.61	10.9%	8.68	11.1%	10.89	13.1%	14.05	17.8%	16.57	21.6%	20.06	30.9%
30 min	7.32	11.2%	11.26	9.1%	14.1	10.2%	18.18	14.1%	21.48	17.7%	26.16	27.2%
1 h	9.66	9.5%	14.67	8.0%	18.39	9.9%	23.8	14.9%	28.53	20.5%	35.1	31.9%
2 h	12.69	13.6%	18.14	13.6%	21.92	14.5%	27.06	16.8%	31.35	19.9%	37.11	27.5%
6 h	19.49	19.1%	26.07	18.4%	30.03	16.7%	34.99	14.9%	38.97	14.8%	42.11	12.5%
12 h	23.12	16.4%	31.42	16.5%	36.83	16.3%	43.86	16.6%	49.79	18.5%	56.62	22.0%
24 h	26.44	9.6%	38.14	8.0%	47	10.0%	60.11	15.4%	71.33	20.9%	88.27	33.9%

Table 23 Projected Precipitation Event Accumulation IDF data (mm) and Percent Change from Historical (%), Norman Wells A, RCP 8.5, 2080s (2070-2099)

T (years)	2		5		10		25		50		100	
	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change
5 min	3.45	18.2%	5.4	16.9%	7.02	22.3%	9.17	27.9%	11.39	38.6%	13.95	50.5%
10 min	5.09	19.8%	8.02	19.7%	10.4	25.0%	13.32	28.4%	16.35	37.5%	19.32	44.2%
15 min	6.07	20.0%	9.4	20.4%	12.08	25.4%	15.39	29.0%	18.86	38.4%	22.15	44.6%
30 min	7.92	20.4%	12.17	17.9%	15.62	22.0%	19.96	25.3%	24.52	34.4%	29	41.1%
1 h	10.44	18.4%	15.75	16.0%	20.3	21.3%	26.48	27.8%	32.9	38.9%	38.75	45.6%
2 h	13.75	23.1%	19.47	21.9%	24.07	25.7%	29.18	26.0%	34.92	33.6%	38.76	33.2%
6 h	21.12	29.0%	28.18	28.0%	32.82	27.5%	36.27	19.1%	40.38	18.9%	42.01	12.3%
12 h	25.06	26.1%	33.72	25.0%	40.26	27.1%	46.3	23.1%	53.04	26.2%	56.88	22.6%
24 h	28.53	18.2%	41.07	16.3%	51.37	20.2%	66.7	28.1%	82.87	40.4%	102.95	56.2%

The above results indicate an increase in precipitation accumulation can be expected for all rainfall events at Norman Wells, identified as being representative of the Norman Wells-Tulita climate zone. Under RCP 8.5, the projected percentage increase from the interpolated historical data for precipitation events range from -0.6% to 21.9% for the 2020s (2010-2039), 8.0% to 33.9% for the 2050s (2040-2069), and 12.3% to 56.2% for the 2080s (2070-2099).

Historical and projected intensity rates (mm/hr) in specific time intervals (5 minutes to 24 hours) for various return periods (2 years to 100 years) are provided below.

Table 24 Historical Precipitation Event Intensity IDF data (mm/hr) – Norman Wells A

T (years)	2	5	10	25	50	100
5 min	35.02	55.42	68.93	86	98.66	111.22
10 min	25.52	40.21	49.93	62.21	71.33	80.37
15 min	20.24	31.23	38.51	47.7	54.53	61.3
30 min	13.16	20.65	25.6	31.86	36.5	41.11
1 h	8.82	13.58	16.74	20.72	23.68	26.61
2 h	5.59	7.99	9.57	11.58	13.07	14.55
6 h	2.73	3.67	4.29	5.08	5.66	6.24
12 h	1.66	2.25	2.64	3.13	3.5	3.87
24 h	1.01	1.47	1.78	2.17	2.46	2.75

Table 25 Projected Precipitation Event Intensity IDF data (mm/hr) and Percent Change from Historical (%), Norman Wells A, RCP 8.5, 2020s (2010-2039)

T (years)	2		5		10		25		50		100	
	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change
5 min	37.49	7.1%	58.24	5.1%	76.28	10.7%	99.01	15.1%	116.3	17.9%	134.29	20.7%
10 min	27.58	8.1%	43.28	7.6%	56.58	13.3%	72.18	16.0%	83.29	16.8%	96.02	19.5%
15 min	21.9	8.2%	33.82	8.3%	43.82	13.8%	55.67	16.7%	64.02	17.4%	73.47	19.9%
30 min	14.3	8.7%	21.88	6.0%	28.32	10.6%	36.09	13.3%	41.64	14.1%	47.73	16.1%
1 h	9.45	7.1%	14.27	5.1%	18.38	9.8%	23.86	15.2%	28.02	18.3%	32.14	20.8%
2 h	6.18	10.6%	8.81	10.3%	10.94	14.3%	13.32	15.0%	14.8	13.2%	16.53	13.6%
6 h	3.14	15.0%	4.23	15.3%	5.00	16.6%	5.6	10.2%	5.9	4.2%	6.2	-0.6%
12 h	1.87	12.7%	2.54	12.9%	3.06	15.9%	3.55	13.4%	3.8	8.6%	4.17	7.8%
24 h	1.08	6.9%	1.55	5.4%	1.93	8.4%	2.51	15.7%	2.94	19.5%	3.35	21.8%

Table 26 Projected Precipitation Event Intensity IDF data (mm/hr) and Percent Change from Historical (%), Norman Wells, RCP 8.5, 2050s (2040-2069)

T (years)	2		5		10		25		50		100	
	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change
5 min	38.33	9.5%	59.98	8.2%	75.87	10.1%	99.28	15.4%	118.89	20.5%	146.15	31.4%
10 min	28.24	10.7%	44.45	10.5%	56.10	12.4%	72.98	17.3%	86.19	20.8%	104.05	29.5%
15 min	22.43	10.8%	34.73	11.2%	43.55	13.1%	56.22	17.9%	66.30	21.6%	80.24	30.9%
30 min	14.64	11.2%	22.51	9.0%	28.19	10.1%	36.35	14.1%	42.96	17.7%	52.32	27.3%
1 h	9.66	9.5%	14.67	8.0%	18.39	9.9%	23.80	14.9%	28.53	20.5%	35.10	31.9%
2 h	6.35	13.6%	9.07	13.5%	10.96	14.5%	13.53	16.8%	15.67	19.9%	18.56	27.6%
6 h	3.25	19.0%	4.35	18.5%	5.01	16.8%	5.83	14.8%	6.49	14.7%	7.02	12.5%
12 h	1.93	16.3%	2.62	16.4%	3.07	16.3%	3.66	16.9%	4.15	18.6%	4.72	22.0%
24 h	1.10	8.9%	1.59	8.2%	1.96	10.1%	2.50	15.2%	2.97	20.7%	3.68	33.8%

Table 27 Projected Precipitation Event Intensity IDF data (mm/hr) and Percent Change from Historical (%), Norman Wells A, RCP 8.5, 2080s (2070-2099)

T (years)	2		5		10		25		50		100	
	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change
5 min	41.42	18.3%	64.8	16.9%	84.24	22.2%	110.06	28.0%	136.66	38.5%	167.43	50.5%
10 min	30.56	19.7%	48.15	19.7%	62.42	25.0%	79.91	28.5%	98.1	37.5%	115.9	44.2%
15 min	24.27	19.9%	37.58	20.3%	48.33	25.5%	61.56	29.1%	75.43	38.3%	88.59	44.5%
30 min	15.83	20.3%	24.33	17.8%	31.24	22.0%	39.93	25.3%	49.04	34.4%	58.01	41.1%
1 h	10.44	18.4%	15.75	16.0%	20.3	21.3%	26.48	27.8%	32.9	38.9%	38.75	45.6%
2 h	6.88	23.1%	9.74	21.9%	12.04	25.8%	14.59	26.0%	17.46	33.6%	19.38	33.2%
6 h	3.52	28.9%	4.7	28.1%	5.47	27.5%	6.05	19.1%	6.73	18.9%	7	12.2%
12 h	2.09	25.9%	2.81	24.9%	3.35	26.9%	3.86	23.3%	4.42	26.3%	4.74	22.5%
24 h	1.19	17.8%	1.71	16.3%	2.14	20.2%	2.78	28.1%	3.45	40.2%	4.29	56.0%

3.2.2 Wrigley – Fort Simpson Climate Zone

For the Wrigley-Fort Simpson climate zone, a gauged station at the Fort Simpson A weather monitoring station (latitude, longitude: 61.76, -121.24) with data spanning from 1969 to 2017 is used. Historical and projected total precipitation amount (mm) in specific time intervals (5 minutes to 24 hours) for various return periods (2 years to 100 years) are provided below.

Table 28 Historical Precipitation Event Accumulation IDF data (mm) – Fort Simpson A

T (years)	2	5	10	25	50	100
5 min	4.23	6.46	7.94	9.81	11.2	12.58
10 min	6.22	9.8	12.17	15.16	17.39	19.59
15 min	7.62	12.14	15.13	18.9	21.71	24.49
30 min	9.61	14.98	18.54	23.03	26.37	29.68
1 h	11.51	17.29	21.12	25.96	29.55	33.12
2 h	14.37	20.34	24.29	29.29	33	36.68
6 h	21.22	28.34	33.05	39.01	43.43	47.82
12 h	26.89	35.71	41.55	48.92	54.4	59.83
24 h	34.09	47.09	55.7	66.58	74.65	82.66

Table 29 Projected Precipitation Event Accumulation IDF data (mm) and Percent Change from Historical (%), Fort Simpson A, RCP 8.5, 2020s (2010-2039)

T (years)	2		5		10		25		50		100	
	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change
5 min	4.37	3.3%	6.63	2.6%	8.13	2.4%	10.34	5.4%	12.70	13.4%	15.09	20.0%
10 min	6.38	2.6%	10.08	2.9%	12.52	2.9%	16.14	6.5%	19.95	14.7%	23.72	21.1%
15 min	7.92	3.9%	12.76	5.1%	15.79	4.4%	20.36	7.7%	24.88	14.6%	29.01	18.5%
30 min	10.24	6.6%	16.14	7.7%	19.58	5.6%	24.95	8.3%	29.56	12.1%	34.25	15.4%
1 h	12.55	9.0%	19.03	10.1%	22.46	6.3%	28.10	8.2%	32.18	8.9%	36.95	11.6%
2 h	16.09	12.0%	22.83	12.2%	25.91	6.7%	31.47	7.4%	34.33	4.0%	38.63	5.3%
6 h	24.44	15.2%	32.33	14.1%	35.48	7.4%	41.05	5.2%	43.59	0.4%	46.53	-2.7%
12 h	31.19	16.0%	40.90	14.5%	44.70	7.6%	51.27	4.8%	54.17	-0.4%	57.36	-4.1%
24 h	38.78	13.8%	53.12	12.8%	59.27	6.4%	70.31	5.6%	75.50	1.1%	83.11	0.5%

Table 30 Projected Precipitation Event Accumulation IDF data (mm) and Percent Change from Historical (%), Fort Simpson A, RCP 8.5, 2050s (2040-2069)

T (years)	2		5		10		25		50		100	
	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change
5 min	4.62	9.2%	6.87	6.3%	8.85	11.5%	11.53	17.5%	13.80	23.2%	16.01	27.3%
10 min	6.73	8.2%	10.42	6.3%	13.67	12.3%	18.00	18.7%	21.68	24.7%	25.31	29.2%
15 min	8.33	9.3%	13.18	8.6%	17.32	14.5%	22.67	19.9%	27.08	24.7%	31.71	29.5%
30 min	10.71	11.4%	16.67	11.3%	21.59	16.5%	27.67	20.1%	32.50	23.2%	37.73	27.1%
1 h	13.08	13.6%	19.65	13.6%	24.89	17.9%	31.04	19.6%	35.72	20.9%	40.49	22.3%
2 h	16.73	16.4%	23.58	15.9%	28.87	18.9%	34.51	17.8%	38.53	16.8%	42.41	15.6%
6 h	25.32	19.3%	33.58	18.5%	39.53	19.6%	45.01	15.4%	48.42	11.5%	51.23	7.1%
12 h	32.30	20.1%	42.58	19.2%	49.80	19.9%	56.22	14.9%	59.98	10.3%	63.07	5.4%
24 h	40.21	18.0%	54.99	16.8%	66.05	18.6%	77.08	15.8%	84.62	13.4%	91.38	10.5%

Table 31 Projected Precipitation Event Accumulation IDF data (mm) and Percent Change from Historical (%), Fort Simpson A, RCP 8.5, 2080s (2070-2099)

T (years)	2		5		10		25		50		100	
	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change
5 min	4.87	15.1%	7.39	14.4%	9.4	18.4%	12.37	26.1%	15.31	36.7%	18.60	47.9%
10 min	7.12	14.5%	11.19	14.2%	14.5	19.1%	19.35	27.6%	24.03	38.2%	29.27	49.4%
15 min	8.81	15.6%	14.15	16.6%	18.39	21.5%	24.46	29.4%	29.80	37.3%	35.90	46.6%
30 min	11.31	17.7%	17.91	19.6%	22.94	23.7%	29.91	29.9%	35.95	36.3%	42.70	43.9%
1 h	13.81	20.0%	21.15	22.3%	26.45	25.2%	33.59	29.4%	39.05	32.1%	44.51	34.4%
2 h	17.65	22.8%	25.51	25.4%	30.69	26.3%	37.37	27.6%	42.09	27.5%	46.51	26.8%
6 h	26.75	26.1%	36.46	28.7%	42.03	27.2%	48.75	25.0%	52.88	21.8%	56.44	18.0%
12 h	34.12	26.9%	46.22	29.4%	52.92	27.4%	60.88	24.4%	65.60	20.6%	69.57	16.3%
24 h	42.48	24.6%	59.58	26.5%	70.23	26.1%	83.49	25.4%	92.32	23.7%	100.29	21.3%

The above results indicate an increase in precipitation accumulation that can be expected for all rainfall events at the Fort Simpson A weather station, determined to be representative of the Wrigley-Fort Simpson climate zone. Under RCP 8.5, the projected percentage increase from the interpolated historical data for precipitation events range from -4.1% to 21.1% for the 2020s (2010-2039), 5.4% to 29.5% for the 2050s (2040-2069), and 14.2% to 49.4% for the 2080s (2070-2099).

Historical and projected intensity rates (mm/hr) in specific time intervals (5 minutes to 24 hours) for various return periods (2 years to 100 years) are provided below.

Table 32 Historical Precipitation Event Intensity IDF data (mm/hr) – Fort Simpson A

T (years)	2	5	10	25	50	100
5 min	50.76	77.57	95.33	117.76	134.4	150.92
10 min	37.29	58.78	73	90.98	104.31	117.55
15 min	30.48	48.54	60.5	75.62	86.83	97.95
30 min	19.23	29.97	37.08	46.07	52.74	59.35
1 h	11.51	17.29	21.12	25.96	29.55	33.12
2 h	7.18	10.17	12.15	14.65	16.5	18.34
6 h	3.54	4.72	5.51	6.5	7.24	7.97
12 h	2.24	2.98	3.46	4.08	4.53	4.99
24 h	1.42	1.96	2.32	2.77	3.11	3.44

Table 33 Projected Precipitation Event Intensity IDF data (mm/hr) and Percent Change from Historical (%), Fort Simpson A, RCP 8.5, 2020s (2010-2039)

T (years)	2		5		10		25		50		100	
	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change
5 min	52.41	3.3%	79.53	2.5%	97.54	2.3%	124.02	5.3%	152.35	13.4%	181.13	20.0%
10 min	38.26	2.6%	60.46	2.9%	75.11	2.9%	96.83	6.4%	119.70	14.8%	142.29	21.0%
15 min	31.70	4.0%	51.02	5.1%	63.15	4.4%	81.42	7.7%	99.51	14.6%	116.05	18.5%
30 min	20.47	6.4%	32.28	7.7%	39.16	5.6%	49.89	8.3%	59.11	12.1%	68.50	15.4%
1 h	12.55	9.0%	19.03	10.1%	22.46	6.3%	28.10	8.2%	32.18	8.9%	36.95	11.6%
2 h	8.05	12.1%	11.42	12.3%	12.95	6.6%	15.74	7.4%	17.16	4.0%	19.31	5.3%
6 h	4.07	15.0%	5.39	14.2%	5.91	7.3%	6.84	5.2%	7.26	0.3%	7.75	-2.8%
12 h	2.60	16.1%	3.41	14.4%	3.72	7.5%	4.27	4.7%	4.51	-0.4%	4.78	-4.2%
24 h	1.62	14.1%	2.21	12.8%	2.47	6.5%	2.93	5.8%	3.15	1.3%	3.46	0.6%

Table 34 Projected Precipitation Event Intensity IDF data (mm/hr) and Percent Change from Historical (%), Fort Simpson A, RCP 8.5, 2050s (2040-2069)

T (years)	2		5		10		25		50		100	
	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change
5 min	55.38	9.1%	82.39	6.2%	106.24	11.4%	138.38	17.5%	165.59	23.2%	192.15	27.3%
10 min	40.40	8.3%	62.52	6.4%	82.02	12.4%	108.01	18.7%	130.06	24.7%	151.85	29.2%
15 min	33.31	9.3%	52.71	8.6%	69.28	14.5%	90.69	19.9%	108.33	24.8%	126.83	29.5%
30 min	21.42	11.4%	33.34	11.2%	43.18	16.5%	55.35	20.1%	65.01	23.3%	75.45	27.1%
1 h	13.08	13.6%	19.65	13.6%	24.89	17.9%	31.04	19.6%	35.72	20.9%	40.49	22.3%
2 h	8.36	16.4%	11.79	15.9%	14.44	18.8%	17.25	17.7%	19.27	16.8%	21.20	15.6%
6 h	4.22	19.2%	5.60	18.6%	6.59	19.6%	7.50	15.4%	8.07	11.5%	8.54	7.2%
12 h	2.69	20.1%	3.55	19.1%	4.15	19.9%	4.69	15.0%	5.00	10.4%	5.26	5.4%
24 h	1.68	18.3%	2.29	16.8%	2.75	18.5%	3.21	15.9%	3.53	13.5%	3.81	10.8%

Table 35 Projected Precipitation Event Intensity IDF data (mm/hr) and Percent Change from Historical (%), Fort Simpson A, RCP 8.5, 2080s (2070-2099)

T (years)	2		5		10		25		50		100	
	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change	Total (mm)	% Change
5 min	58.50	15.2%	88.71	14.4%	112.74	18.3%	148.45	26.1%	183.74	36.7%	223.23	47.9%
10 min	42.70	14.5%	67.16	14.3%	86.98	19.2%	116.13	27.6%	144.20	38.2%	175.63	49.4%
15 min	35.22	15.6%	56.59	16.6%	73.55	21.6%	97.83	29.4%	119.21	37.3%	143.60	46.6%
30 min	22.63	17.7%	35.82	19.5%	45.88	23.7%	59.83	29.9%	71.90	36.3%	85.40	43.9%
1 h	13.81	20.0%	21.15	22.3%	26.45	25.2%	33.59	29.4%	39.05	32.1%	44.51	34.4%
2 h	8.83	23.0%	12.75	25.4%	15.35	26.3%	18.68	27.5%	21.04	27.5%	23.25	26.8%
6 h	4.46	26.0%	6.08	28.8%	7.00	27.0%	8.12	24.9%	8.81	21.7%	9.41	18.1%
12 h	2.84	26.8%	3.85	29.2%	4.41	27.5%	5.07	24.3%	5.47	20.8%	5.80	16.2%
24 h	1.77	24.6%	2.48	26.5%	2.93	26.3%	3.48	25.6%	3.85	23.8%	4.18	21.5%

3.3 1,3,5 DAY ACCUMULATION

Table 36: Record Maximum 1/3/5 Day Precipitation Accumulation

Climate Zone (Station Name)	Duration	Precipitation Accumulation (mm)	Event End Date
Norman Wells-Tulita (Norman Wells A)	1-day	50.8	September 6, 1988
	3-day	77.8	June 24, 1981
	5-day	82.0	June 27, 1981
Wrigley-Fort Simpson (Fort Simpson A)	1-day	86.4	July 24, 1935
	3-day	127.9	July 2, 1988
	5-day	132.4	July 2, 1988

1-day (24 hour) accumulation projections are provided in the IDF section above. While projections for multi-day (3 and 5 day) accumulations are available, these projections do not necessarily capture extremes and have higher uncertainty and, therefore, are not provided in this climate profile. Nevertheless, based on the projected increases in precipitation accumulations for shorter duration events (i.e. up to 24-hour duration events), it is highly probable this increasing trend would also extend to longer duration accumulations as well.

3.4 SNOW FALL

Total annual snowfall is presented in Figure 10 for historical periods at Norman Wells A from 1943 to 2019 and at Fort Simpson A from 1895 to 2019. Projections for snowfall are less confident than for other precipitation and temperature-based climate variables and are thus not presented in the climate risk assessment. Historical trends in precipitation falling as snow are generally observed to increase in this area. Significant departures from the mean are intermittently observed. These inconsistencies may be due to sporadic short periods of extreme precipitation resulting from subtropical air currents that flow northeastwards from the Hawaiian Islands towards the Mackenzie Basin (termed the "Pineapple Express") (Woo et al 2007), resulting in a high level of variability in precipitation records for the area.

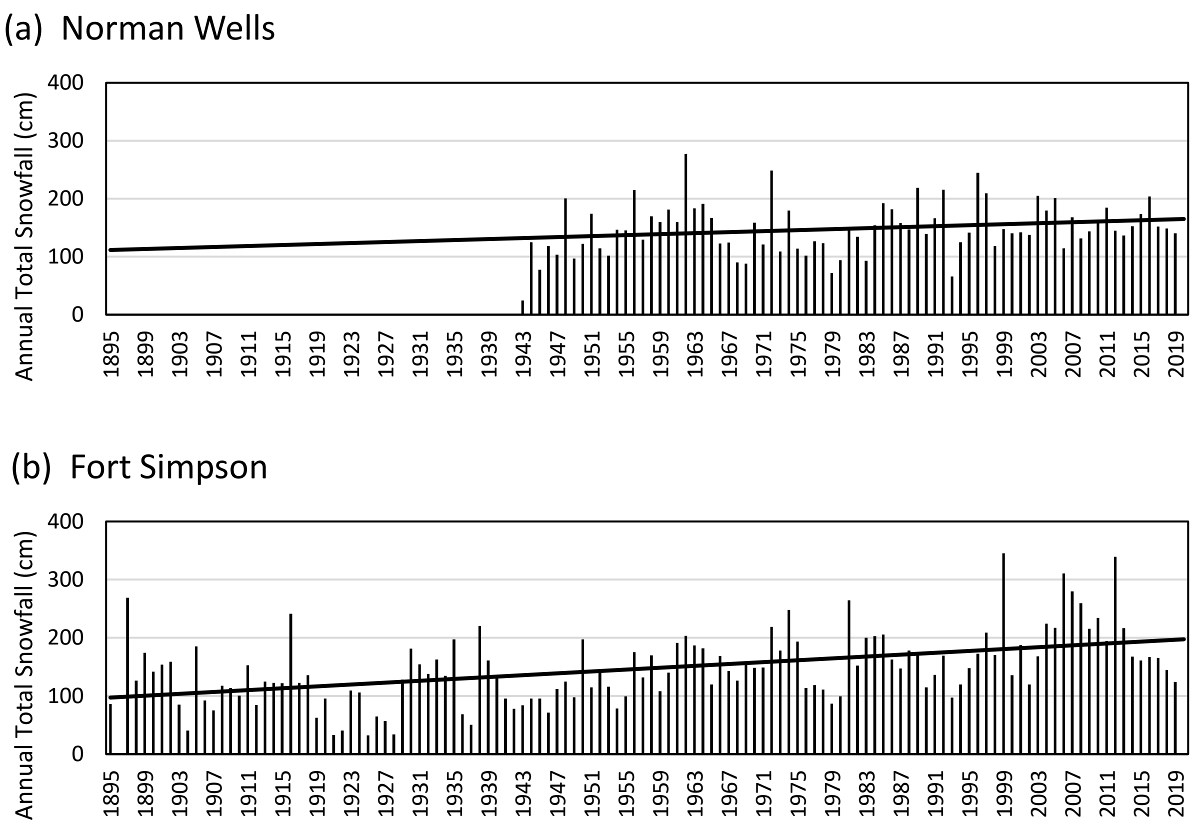


Figure 10: Annual Total Snowfall for (a) Norman Wells A and (b) Fort Simpson A for available data between 1943 and 2019 and 1895 and 2019 respectively.

3.5 DRY SPELLS

Dry spells are a measure of the number of consecutive days where daily precipitation is less than 1 mm. The historic data for longest annual dry spell duration for Norman Wells and Fort Simpson is summarized in Figure 11. It should be noted there may be more than one dry spell of significant length in a given year but Figure 11 only shows the longest dry spell.

The figure shows that between the two locations, slightly diverging trends appear in the maximum annual dry spell length between 1984 to 2019. Norman Wells' dry days appear to be slightly increasing while Fort Simpson is slightly decreasing. This difference could be largely driven by four specific years where Norman Wells' dry periods were much longer than those in Fort Simpson – for the highest of which, there was no available data for Fort Simpson. Nonetheless, maximum dry spell length between the two areas are generally stable over the 35-year span presented below. Projected dry spell durations under the future effects of climate change were unavailable for this assessment, however the trend shown in Figure 11 could be extrapolated to the future to suggest the length of dry spells may continue to present a generally stable trend, possibly increasing very slightly. The projections for dry spell duration are not made with the same level of confidence as other climate variables in this report.

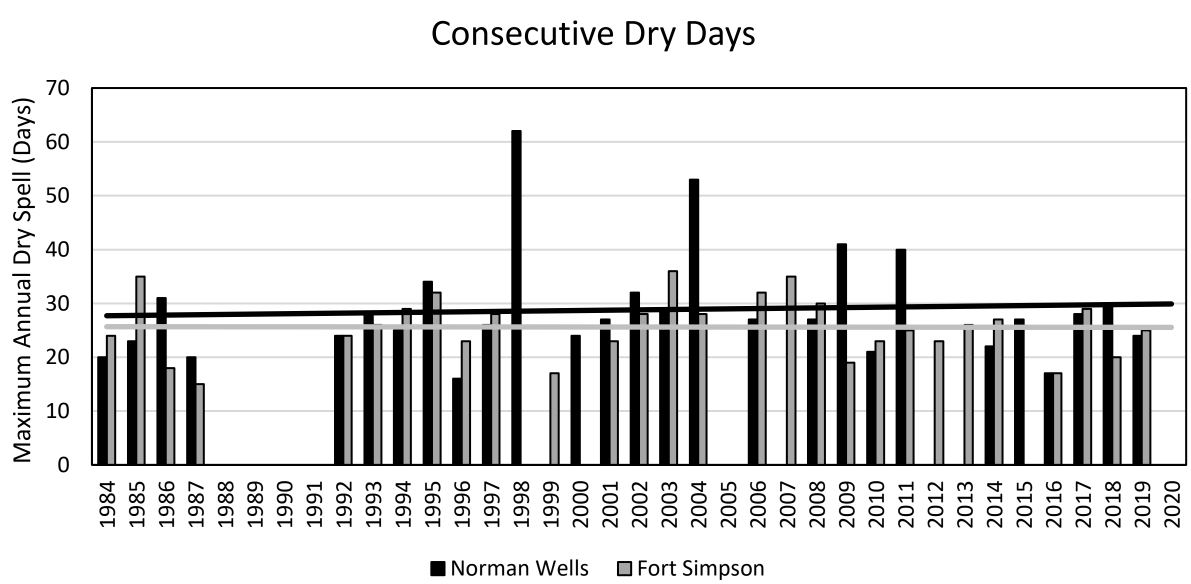


Figure 11: Maximum Annual Dry Spells, Norman Wells A and Form Simpson A, 1984-2019

4.0 FROST DAYS

The number of frost days per year for the historical baseline period as well as future projections periods is summarized in the table below for Norman Wells and Fort Simpson. Frost days are defined as the number of days per year where the minimum daily temperature is less than 0°C. The data presented here demonstrates a projected decreasing trend in the number of frost days per year, which aligns with temperature trends identified in Section 2.

Table 37: Average Frost Days, Norman Wells

Frost Days		
Period	**Norman Wells-Tulita (Norman Wells)**	**Wrigley-Fort Simpson (Fort Simpson)**
Baseline (Historical 1981-2010)	240.0	224.7
2020s (2011-2040)	228.4	212.5
2050s (2041-2070)	214.5	197.2
2080s (2071-2100)	201.1	182.8

5.0 FREEZE-THAWS

Freeze-thaw cycles are days (24-hr periods) when the air temperature fluctuates between freezing and non-freezing temperatures. A freeze-thaw cycles is therefore a day with the maximum temperature greater than 0°C and the minimum temperature equal to or less than -1°C. A minimum temperature threshold of -1°C (instead of 0°C) is used to increase the likelihood that water present at the surface actually freezes. The historic and projected annual number of freeze-thaw cycles for each climate zone is presented below.

Table 38 Annual Freeze-Thaw Cycles (Day with Maximum Temperature > 0°C & Minimum Temperature ≤ -1°C): Historical (1981-2010) and Projected under RCP 8.5

Climate Zone (Station Name)	Average Annual Freeze-Thaw Cycles			
	1981-2010	2020s	2050s	2080s
Norman Wells-Tulita (Norman Wells A)	43.8	36.4	32.3	30.3
Wrigley-Fort Simpson (Fort Simpson A)	57.1	49.7	44.0	39.1

For both climate zones, the annual number of freeze-thaw cycles is projected to decrease under future climate conditions. The number of freeze-thaw cycles per month will likely continue to be greatest during the fall and spring “transition” or “shoulder” seasons (e.g., November and March) through mid-century before notably declining by the end of the century. Despite the projected overall decrease in the annual number of freeze-thaw cycles, the number of freeze-thaw cycles during the winter months is projected to increase slightly. With warmer winter conditions projected under climate change, a shift is projected in the typical times of year that have temperatures fluctuating around the freezing mark – i.e., temperature fluctuations around 0°C are projected to become more common during the winter months. Freeze-thaw cycles during winter months, such as January and February, have the potential to be particularly damaging to infrastructure.

6.0 WIND

Wind data is available at the Norman Wells A and Fort Simpson A weather stations sporadically from 1960 through to 2020, with increasing data frequency in recent years. Climate Normal data from 1981-2010 and daily maximum gust data are available at both stations. Climate Normals data is presented in Table 39 and Table 40 below and windroses based on daily maximum and hourly mean gust data are provided in Figures 12 through 15.

Table 39 1981 to 2010 Canadian Climate Normals, Wind, Norman Wells A Station (source: Environment and Climate Change Canada, Climate Normals)

Month	Speed (km/h)	Most Frequent Direction	Maximum Hourly Speed (km/h)	Date (yyyy/dd)	Direction of Maximum Hourly Speed	Maximum Gust Speed (km/h)	Date (yyyy/dd)	Direction of Maximum Gust	Days with Winds >= 52 km/h	Days with Winds >= 63 km/h
Jan	8.3	SE	80	1962/22	W	113	1962/22	W	0.6	0.1
Feb	8.9	SE	74	1986/19	NW	106	1986/19	NW	0.5	0.2
Mar	10.3	W	66	1971/07	SE	114	1965/10	NW	0.3	0.1
Apr	11	SE	68	1965/12	W	97	1965/12	W	0.2	0.1
May	11.9	SE	59	1980/03	NW	85	1979/02	SE	0.1	0
Jun	11.7	SE	65	1979/11	NW	83	1979/11	NW	0.2	0
Jul	11	SE	61	1959/25	NW	100	1967/24	W	0.2	0
Aug	10.5	SE	80	1962/31	W	117	1962/31	W	0.2	0.1
Sep	10.7	SE	70	1988/06	NW	94	1988/07	NW	0.1	0.1
Oct	10.4	NW	63	1978/31	NW	93	1990/27	E	0.2	0
Nov	8.4	NW	67	1977/21	NW	101	1962/03	E	0.3	0.1
Dec	8.3	SE	72	1963/12	E	105	1963/12	E	0.5	0.1
Year	10.1	SE	80	1962/22	W	117	1962/31	W	3.3	0.9

Table 40 1981 to 2010 Canadian Climate Normals, Wind, Fort Simpson A Station (source: Environment and Climate Change Canada, Climate Normals)

Month	Speed (km/h)	Most Frequent Direction	Maximum Hourly Speed (km/h)	Date (yyyy/dd)	Direction of Maximum Hourly Speed	Maximum Gust Speed (km/h)	Date (yyyy/dd)	Direction of Maximum Gust	Days with Winds >= 52 km/h	Days with Winds >= 63 km/h
Jan	7.2	NW	46	2003/07	NW	80	1985/03	SW	0	0
Feb	8.4	NW	59	1988/21	NW	89	1988/21	NW	0.1	0
Mar	9.8	NW	50	1995/22	N	79	1967/13	N	0	0
Apr	10.1	SE	56	1986/20	SW	83	1984/16	SW	0.2	0
May	10.1	SE	59	1983/21	N	91	1983/21	N	0.2	0.1
Jun	9.1	SE	46	2002/22	NW	72	1964/26	N	0.2	0
Jul	8.2	NW	48	1964/10	S	89	1970/19	S	0.1	0
Aug	8.5	NW	66	1974/04	SW	146	2004/17	N	0.1	0
Sep	8.5	SE	65	1985/12	NW	87	1964/04	N	0.1	0
Oct	8.7	NW	50	1971/25	N	77	1971/25	N	0	0
Nov	7.9	NW	46	1985/20	N	78	1985/20	N	0	0
Dec	6.8	NW	48	1999/24	NW	80	1999/23	SW	0	0
Year	8.6	SE	66	1974/04	SW	146	2004/17	N	1.2	0.2

Wind

Wind data from the three Norman Wells Airport stations were merged to generate windroses[2] for this climate profile. In addition, the Fort Simpson Airport station was used to produce daily and hourly windroses. Figure 12 displays hourly mean wind speed and direction observed from 1953-2019 at the Norman Wells Airport while Figure 13 displays the speed and direction of the maximum hourly wind observed each day from 1958 to 2019. The following windroses contain some missing information as direction information was not recorded when wind gusts were less than 31 km/h. These points were excluded from the plots.

[2] Windroses show the distribution of wind direction (direction from which the wind is blowing) observed at a particular location over a time period. The length of each line represents the frequency of the wind from that direction and, therefore, windroses provide information on the prevailing wind direction(s) at a given location. Windroses also provide information on the wind speeds observed from each direction.

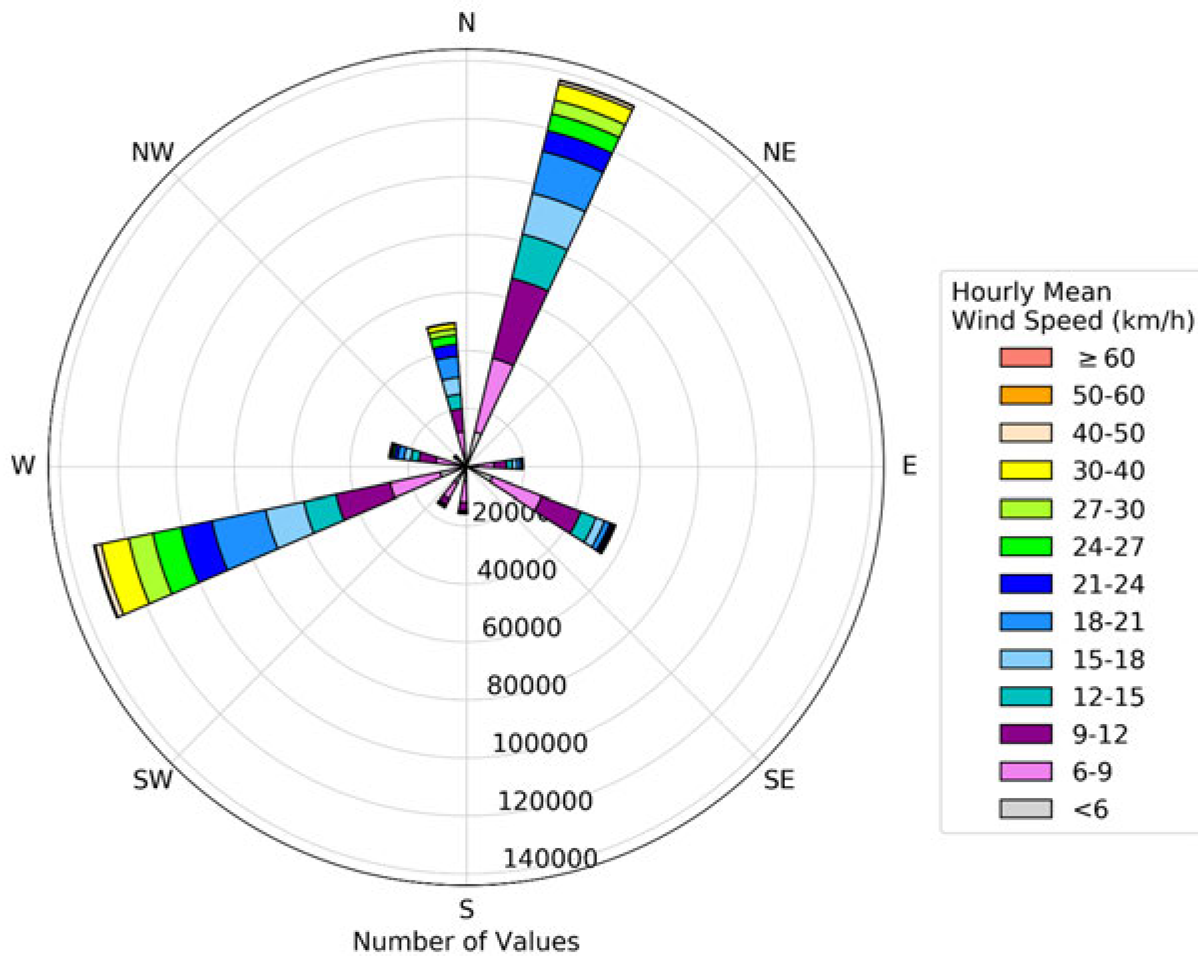


Figure 12 Hourly mean wind speed and direction from 1953-2019 observed at the Norman Wells A.

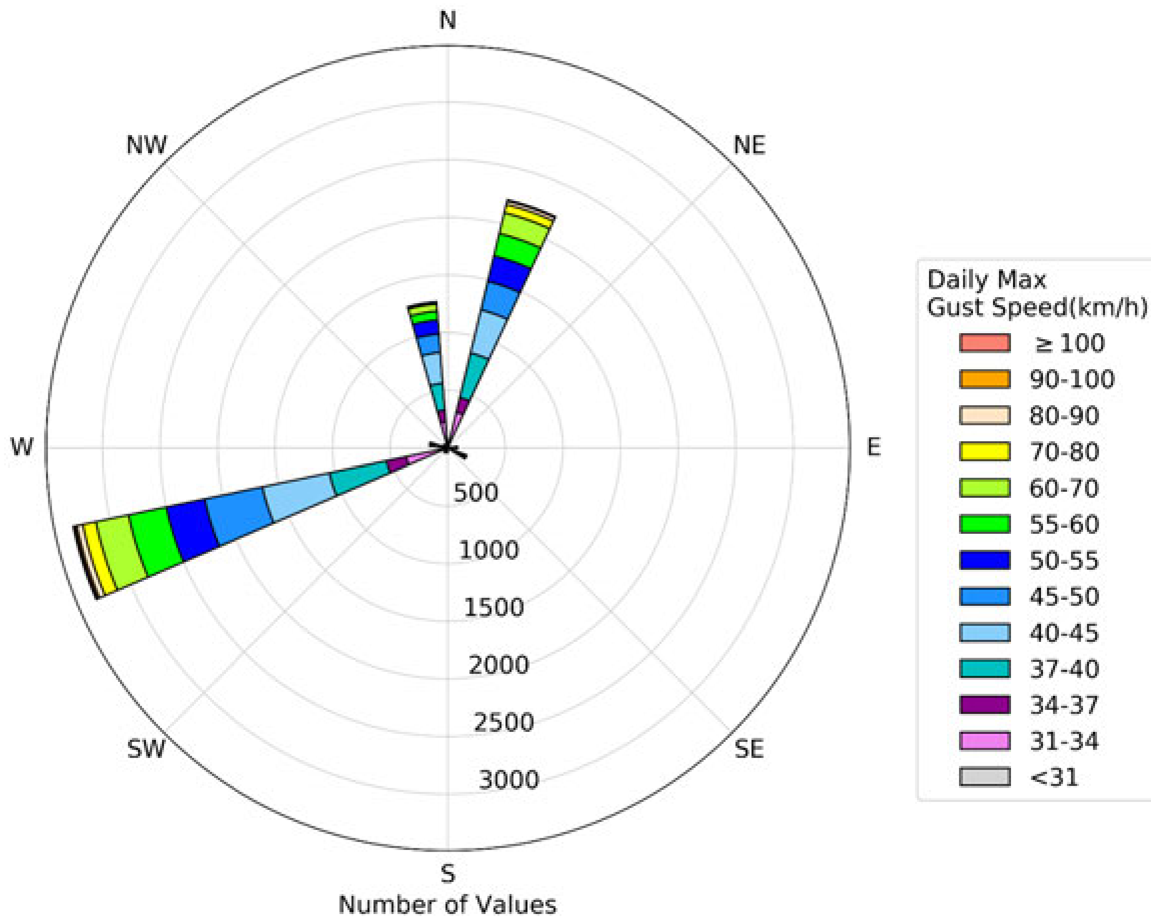


Figure 13 **Daily maximum wind gust speed and direction from 1958-2019 observed at the Norman Wells A.**

Figure 14 displays hourly mean wind speed and direction observed from 1953-2019 at the Fort Simpson A station while Figure 15 displays daily maximum wind gust speed and direction observed from 1960-2019.

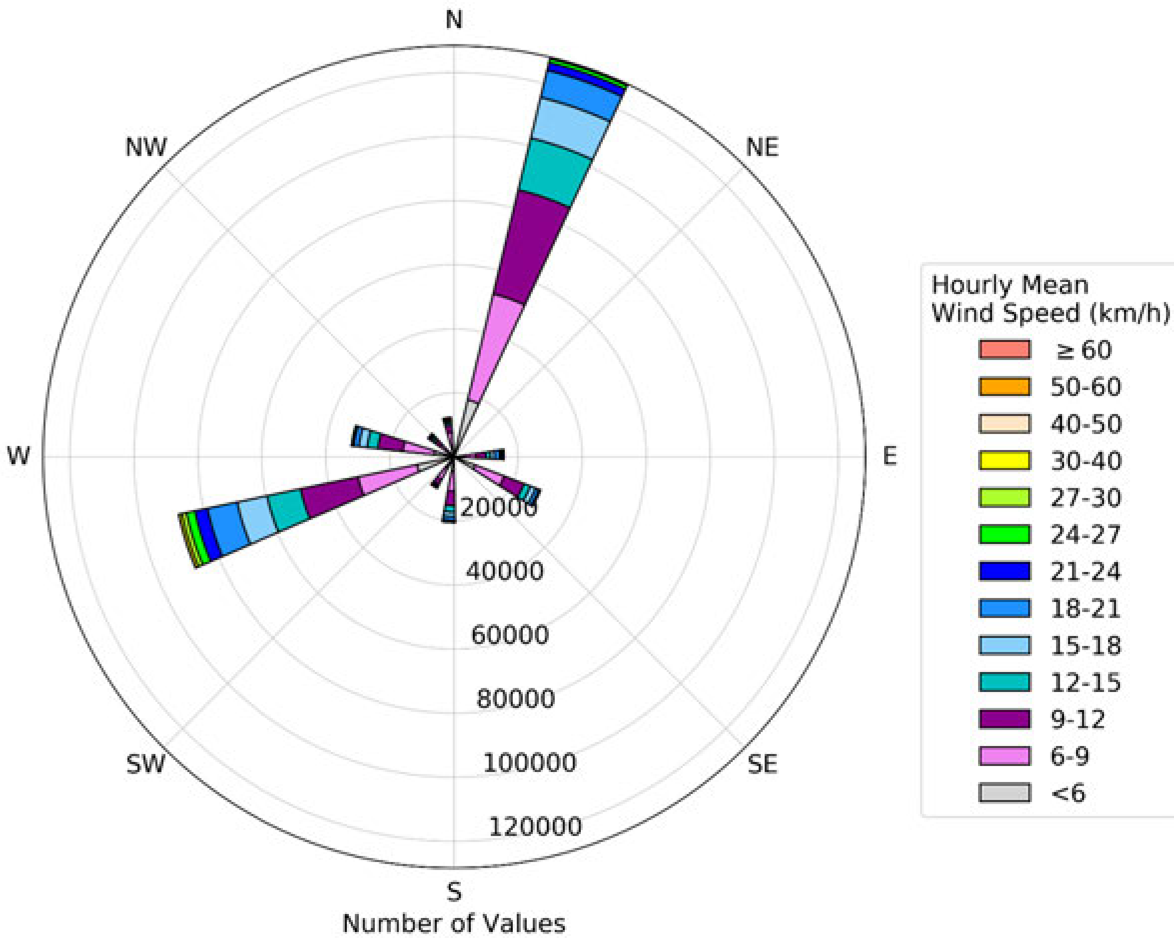


Figure 14 **Hourly mean wind speed and direction from 1953-2019 observed at the Fort Simpson A.**

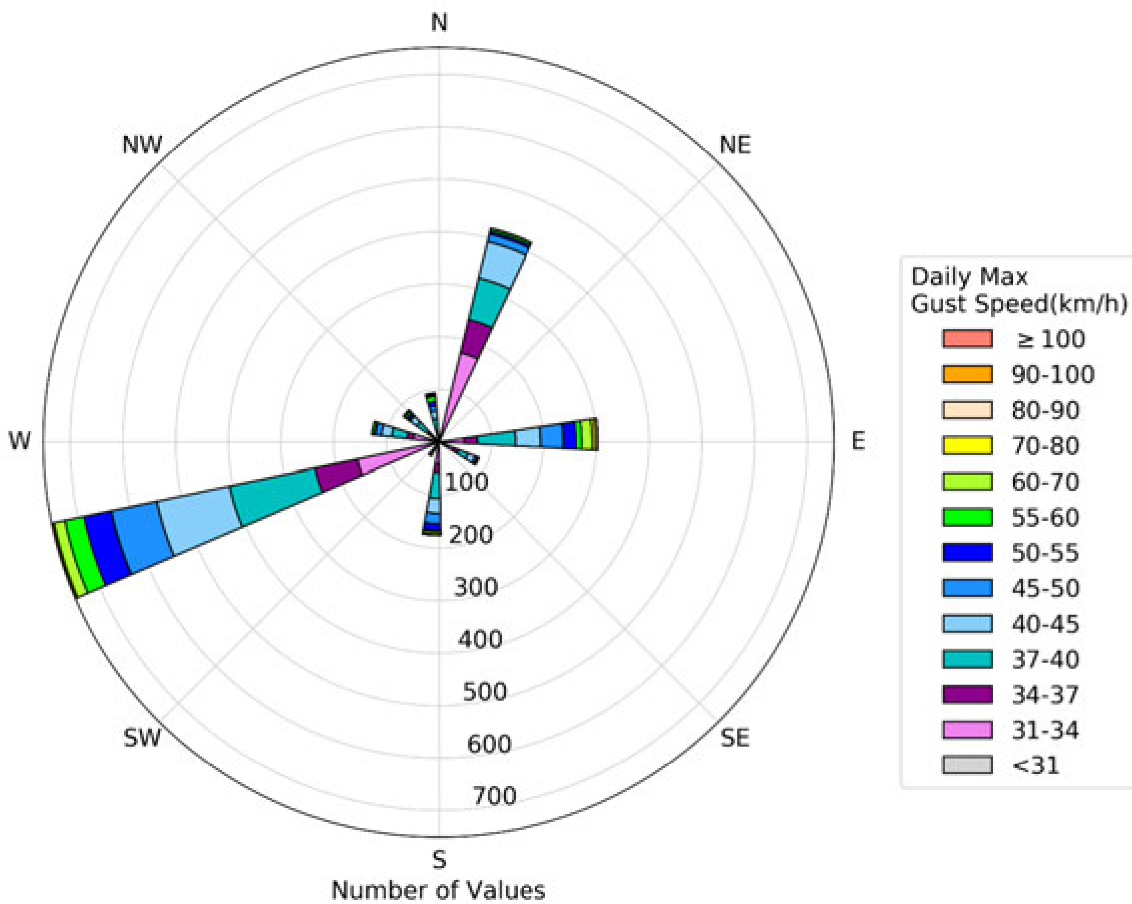


Figure 15 **Daily maximum wind gust speed and direction from 1960-2019 observed at the Fort Simpson A.**

7.0 REFERENCES

Cannon, A. J. 2015. Selecting GCM Scenarios that Span the Range of Changes in a Multimodel Ensemble: Application to CMIP5 Climate Extreme Indices. *Journal of Climate*, 28: 1260-1267. doi:10.1175/JCLI-D-14-00636.1

Cannon, A.J., S.R. Sobie, and T.Q. Murdock. 2015. Bias Correction of GCM Precipitation by Quantile Mapping: How Well Do Methods Preserve Changes in Quantiles and Extremes? *Journal of Climate*, 28: 6938-6959. https://doi.org/10.1175/JCLI-D-14-00754.1

Donat, M.G., L.V. Alexander, H. Yang, I. Durre, R. Vose, J. Caesar. 2013b. Global Land-Based Datasets for Monitoring Climatic Extremes, Bull. Amer. Meteor. Soc., 94, 997–1006. https://doi.org/10.1175/BAMS-D-12-00109.1. Download: Donat, et al. (2013b) GHCNDEX (PDF).

IPCC. 2013. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

Schardong, A., A. Gaur, S.P. Simonovic, and D. Sandink. 2018. *Computerized Tool for the Development of Intensity-Duration-Frequency Curves under a Changing Climate: Technical Manual v.3*; Water Resources Research Report No. 103. Facility for Intelligent Decision Support, Department of Civil and Environmental Engineering: London, Ontario, Canada; p, 67. ISBN 978-0-7714-3107-4.

Smith, M.R. and S.S. Myers. 2018. Impact of anthropogenic CO_2 emissions on global human nutrition. *Natural Climate Change*, 8: 834-839. https://doi.org/10.1038/s41558-018-0253-3

Taylor, K.E., R.J. Stouffer, and G.A. Meehl. 2012. An Overview of CMIP5 and the Experiment Design. *Bulletin of the American Meteorological Society*, 93: 485-498. https://doi.org/10.1175/BAMS-D-11-00094.1

Woo, M-K, P. Modeste, L. Martz, J. Blondin, B. Kochtubajda, D. Tutcho, J. Gyakum, A. Takazo, C. Spence, J. Tutcho, M. Modeste, B. Kenny, and W. Modeste. 2007, Science Meets Traditional Knowledge: Water and Climate in the Sahtu (Great Bear Lake) Region, Northwest Territories, Canada. Arctic 60(1): 37-46.