Government of Northwest Territories
Gouvernement des Territoires du Nord-Ouest

Topic: MVEIRB-1 Construction Schedule

Preamble from the Mackenzie Valley Environmental Impact Review Board (Review Board): The GNWT has proposed a construction timeline that extends unusually far into the future (up to 20 years). This extended timeline introduces additional uncertainty into construction impact predictions by requiring the Review Board and parties to assess impacts based on conditions that may well change over the lengthy construction period.

In a 2013 letter (attached) to the developer (PR#39), the Review Board previously raised this specific concern about the challenges of confidently predicting impacts given the unusual length of the proposed construction period. The Review Board expressed concern about the accuracy of impact predictions on wildlife, water resources, climate and permafrost, and socio-economics. Aspects of the environment, such as fire regime, certainly appear to have changed even since the Review Board raised the concern.

The Board has read GNWT's statement, in section 5.4.1 of the Developer's Assessment Report, that adaptive management and ongoing engagement are sufficient to predict and mitigate impacts and uncertainties in the future. This approach relies on adaptive management to quickly detect important impacts and for those impacts to be mitigated before they become significant. The Review Board is not convinced that the assurance of adaptive management is a sufficient substitute for credible impact prediction.

Request from the Review Board:

A. How likely is the predicted or alternative construction timeline presented in the Developer's Assessment Report?

B. Please justify and provide further details on the statement in DAR section 5.4.1 that adaptive management and ongoing engagement are sufficient to predict and mitigate impacts and uncertainties on the environment and people once construction is complete (a minimum of 20 years from now into the mid-2040s) and the road is entirely open to the public.

C. Please describe the GNWTs optimal construction schedule (that is, if financial resources are available to build the highway upon receipt of permitting approval), including:

  - How long would it take to build the road from Wrigley to Norman Wells on this basis?
  - Would the GNWT consider building from multiple headings at the same time (for example, from Normal Wells, Tulita, and Wrigley simultaneously)? What would this construction schedule look like?

Attachments:

1. MVEIRB letter to GNWT October 29, 2013
2. GNWT Response to MVEIRB November 13, 2013

Response from the Government of the Northwest Territories:

A. The GNWT has combined its responses to A and C in this section.

In its information requests, the Review Board is inquiring with respect to the GNWT's optimal construction schedule, as well as the predicted and alternative construction schedules as currently presented in the DAR.

i) Optimal schedule:

The GNWT's optimal schedule, subject to available financing and receipt of project authorizations, would be to construct the project from multiple headings at the same time, in as little as three to four years.

Given recent logistical challenges associated with forest fires, low water conditions on the Mackenzie River and the subsequent disruption of critical community resupply operations over the past two years, there is an urgent need for all-season access to the Sahtú Region. Unprecedented challenges this year associated with historic low water conditions along the Mackenzie River have resulted in the recent decision to cancel barging services to the communities of Norman Wells and Tulita, further amplifying the need for all season access to these communities.

Based on these factors, the GNWT's optimal construction approach and schedule for the Mackenzie Valley Highway Project would be to advance construction of the entire alignment concurrently and from multiple headings (e.g. construction advancing concurrently from Norman Wells to Tulita as well as from Tulita to Norman Wells; Wrigley to Tulita as well as Tulita to Wrigley). Section 7.3.2.2.1 of the DAR suggests that project construction can be completed in as few as three to four years, but this timeframe could extend outwards depending on the factors listed below.

Several significant assumptions are necessary to facilitate such an expedited schedule, including:

a. Design for construction, for the entire alignment, would need to be completed concurrent to the environmental assessment;

b. Land tenure, for the entire alignment, would need to be secured prior to the start of construction;

c. Funding to complete regulatory authorizations and advance construction, for the entire alignment, would need to be secured;

d. Regulatory authorizations and associated permitting, for the entire alignment, must be completed prior to construction; and

e. Procurement for construction, for the entire alignment, would need to be successful (i.e. successful bid from a contractor with the capacity to undertake the work in the period requested at an acceptable cost).

As demonstrated by the assumptions described above, executing an optimized project delivery schedule will require continued commitment from the GNWT, Government of Canada, Indigenous Governments, and other parties to plan, fund, and execute the project. It is clear that a more expedited construction schedule is strongly desired by Indigenous Governments and community residents who are experiencing recurring extreme weather events that both interrupt supply chains and impede community egress routes. The GNWT has clearly heard this feedback, and in response, work is underway to define an optimized schedule and potential implications for environmental and socio-economic impacts.

ii) Predicted and Alternate Construction Schedules

The conceptual schedule used as the basis for the environmental assessment is presented in Section 5.4.1 of the Developers Assessment Report (DAR) and illustrated in Figure 5.3. This conceptual schedule assumes the project will be delivered in three consecutive phases:

- Segment 1: Wrigley 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)

Construction of each phase is contingent upon the completion of final design, acquisition of construction funding and appropriate land tenure, regulatory approvals, and procurement, prior to construction.

The conceptual schedule presented in Section 5.4.1 of the DAR was informed by lessons learned on the Tłı̨chǫ Highway and Inuvik to Tuktoyaktuk Highway projects and was developed to achieve the goal of maximizing business, employment, and training opportunities for local workers, contractors and businesses.

The goal of maximizing employment opportunities by extending the construction period, was a strong theme discussed during early engagement (see Section 2.1.6.3, Table 2.3 Summary of Project Updates and Engagement Feedback; and Section 2.1.6.5, Table 2.5 Summary of Assessment Findings and Project Effects Engagement Feedback) but predates the unprecedented environmental conditions in recent years which have significantly impacted community re-supply. As mentioned above, it is clear that a more expedited construction schedule is strongly desired by many Indigenous Governments and community residents.

Consideration of schedules associated with alternate construction approaches is presented in

Section 7.3.1 of the DAR, and evaluation of construction approaches is presented in Section 7.3.2. The alternative construction schedule includes short highway segments (20 km or less) constructed under separate contracts over a timeframe that would likely exceed 20 years.

As stated in Section 7.3.2.3 of the DAR, both construction options are feasible. The likelihood of either approach being advanced depends on various factors including funding availability, strategic priorities, feedback from Indigenous Governments and community organizations, and the findings from the environmental assessment.

B. The GNWT has indicated in Section 5.4.1, that should the *construction* schedule [emphasis added] extend beyond 20 years, there may be a need for additional studies and mitigation measures to address uncertainty in predicting effects of construction activities specifically (which are generally of greater intensity than those of the operations and maintenance phase) on the environment so far into the future.

The statement was not made in the context of highway *operations*, which are inherently expected to extend well beyond 20 years into the future, and whose effects are already assessed in the DAR. The GNWT has discussed uncertainties and prediction confidence in each assessment section, applied a precautionary approach where needed, and has also committed to monitoring and adaptive management.

The GNWT's approach to adaptive management is described in Section 23.2. It is consistent with the adaptive management approach applied during the construction (complete) and operations (ongoing) of the Tłı̨chǫ Highway, and approaches in other jurisdictions (e.g., BCMECCS, 2022; Government of Yukon, 2021).

Adaptive management is not proposed to reduce prediction uncertainty. Adaptive management is proposed as a process to monitor, evaluate, and if necessary, respond, if specific conditions are observed that may indicate mitigation measures are not working as intended. Adaptive management can also identify when additional management actions are required to address any unanticipated effects.

The GNWT will engage with Indigenous Governments, Indigenous organizations, other land and resource managers, and co-management organizations on adaptive management actions.

C. See combined response above.

References:

British Columbia Ministry of Environment ad Climate Change Strategy (BCMECCS). 2022. Development and Use of Adaptive Management Plans v.3.0. Technical Guidance MIN-20. Available at: tg20_guide_to_preparing_adaptive_management_plans.pdf (gov.bc.ca)

Government of Yukon. 2021. Guidelines for developing adaptive management plans in Yukon. Water-related components of quartz mining projects. Available at: env-amp-guidelines.pdf (yukon.ca)

Topic: Mackenzie Valley Environmental Impact Review Board (Review Board) Information Request -2 Future Environmental Conditions

Preamble from the Review Board: The Review Board's 2013 letter (as described in the preamble of IR#1 above) described concerns about the long construction schedule and the uncertainties and challenges this creates for impact prediction. The GNWT responded, on Nov. 13, 2013, that "… the assessment will also include a review of best available data relating to predicted future potential changes to baseline conditions. For example, the potential effects of climate change (sic). This data will be used in the assessment to discuss how baseline conditions may change and how that could affect the conclusions of the assessment" (PR#40).

Section 24 and Appendix 24A provide clear evidence that climate conditions will be very different in the future than compared to historical conditions, for example in relation to permafrost. However, the Review Board sees little evidence of the GNWT considering this for most of its impact predictions in the DAR, and is not satisfied with the GNWT's efforts to do so for the majority of valued components. In the absence of predicted future conditions as resulting from climate change, the Review Board and parties cannot adequately evaluate the likely impacts on the highway, and stemming from the highway, nor adequately evaluate the effectiveness of proposed mitigations measures.

The Review Board understands the difficulties inherent in predicting future habitat and wildlife conditions. However, the evidence that past conditions are not likely to represent future conditions is clear (for example, looking at changes in fire regimes). A reasonable assessment approach to dealing with the range of potential future conditions is to project scenarios of environmental conditions, and assess what these mean for different valued components. These scenarios should be at a scale appropriate to evaluate project specific and cumulative effects to Key Lines of Inquiry and Subjects of Note.

Request from the Review Board:

A. Please apply the climate projections from the Climate Lens Part II: Climate Change Resilience Assessment (Appendix 24A) and assess what this would mean for future environment conditions, including for habitat and wildlife.
    i. Please provide projections of future environmental and habitat conditions for areas that include project local and regional assessment areas, as well as areas in relevant Boreal Caribou Range plans over the time periods used in Appendix 24A:
        - 2020s (2010 to 2039)
        - 2050s (2040 – 2069)
        - 2080s (2070 to 2099)
    ii. As part of these projections of future environmental conditions, the developer should:
        - consider changes to forest fire intensity and magnitudes
        - consider environmental extremes such as heat, wind, precipitation, icing events
        - base projections on best available science and Indigenous Traditional Knowledge
        - provide a detailed description of assumptions and limitations

Response from the Government of the Northwest Territories:

Introduction

The GNWT's response to Parts i. and ii. have been combined. To inform the response to the request for projections of future environmental and wildlife habitat conditions over the requested timeframes, the GNWT has provided an updated climate profile for the Project, based on more recent climate modeling information. The attached Climate Change Resilience Assessment (CCRA) Addendum (K'alo-Stantec, 2024) is an update to the CCRA previously included in the DAR as Appendix 24A. The CCRA Addendum includes an updated climate profile in Appendix A. To address the request to consider how forest fires and environmental extremes contribute to future environmental and wildlife habitat conditions, the GNWT has reviewed and summarized relevant scientific literature and available Traditional Knowledge[1] for each of the environmental valued components (VCs) including key lines of inquiry (caribou and moose), and subjects of note (vegetation, wildlife and wildlife habitat, birds, and bird habitat), and additionally, species at risk. Each VC section discusses uncertainties and limitations of the predictions presented in the published literature. After review of the scientific literature and Traditional Knowledge, conclusions of the assessment remain unchanged.

Overall, the updated climate profile projections for the Project (in K'alo-Stantec 2024), in combination with a literature review of potential climate-related changes to vegetation and wildlife habitat, suggest there could be both positive and adverse changes in the local and regional assessment areas (LAA and RAA) for valued components (VCs). These predictions are made with considerable uncertainty. Therefore, project design and adaptive management are appropriate to manage the considerable uncertainties associated with predicting environmental and habitat conditions into the far future.

The GNWT has taken into account that over the indeterminate, long life of the Project, there will be changes in future environmental and habitat conditions in the NWT and within the LAA and RAA. Measurable parameters of climate change (e.g., air temperature, active layer depth, precipitation, permafrost extent) are some of the variables that may contribute to changes in VCs over the long-term operation of the Project. Potential yet uncertain changes to baseline environmental and habitat conditions have been acknowledged in the DAR (Sections 15.7.2 [water quantity], 17.8.2 [fish and fish habitat], 18.7.2 [vegetation and wetlands], 19.7.2 [wildlife and wildlife habitat], birds and bird habitat [20.7.2]). It is the GNWT's view that, for the purposes of environmental assessment, current conditions are adequate to predict project effects, proposed management plans are likely to be effective, and conclusions can be relied upon.

In acknowledgement of uncertainty associated with predicting effects over a long timeframe, the GNWT has proposed various programs of additional monitoring, evaluation, and response as part of an adaptive management process to manage the effects of the Project on the environment over the long

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[1] The GNWT-INF provided capacity funding for Pehdzéh Kį First Nation and Łíídlı̨ı̨ Kų́ę́ First Nation to complete project-specific traditional land and resource use (TLRU) studies for the Project. No TLRU reports have been received from Pehdzéh Kį First Nation as of June 19 2024. Łíídlı̨ı̨ Kų́ę́ First Nation's TLRU study report is anticipated in summer 2024.

term of operations. Adaptive management steps are included in the draft Wildlife Management and Monitoring Plan, draft Erosion and Sedimentation Control Plan, draft Fish and Fish Habitat Protection Plan, and draft Permafrost Protection Plan (DAR Volume 5).

The Importance of Considering Climate Change

The Review Board's request highlights the importance of considering climate change in project decisions. The GNWT's principal purpose for conducting a Climate Change Resilience Assessment (Appendix 24A, as updated in K'alo-Stantec [2024]) and assessing effects of the environment on the Project (Section 24), was to understand how climate change could impact the Project. This is especially important given that the Project will be piece of strategic infrastructure in the NWT. A key purpose of the Mackenzie Valley Highway is to provide resilient infrastructure to address the ongoing effects of climate change on the reliability of current transportation systems that connect communities in the Mackenzie Valley (winter road, barges). The design and ongoing management of the Project will reflect the GNWT's understanding of future impacts and risks associated with climate change. To this end, the CCRA's identification of risks to the infrastructure considered how changes to climate parameters can lead to impacts to the highway infrastructure and highway users through pathways such as loss of permafrost, changes in hydrology, increase in wildfires, wind events and icings. The GNWT's view is that adaptation to climate risks to infrastructure is the most important focus of consideration of climate change for a project of this size and importance.

In response to the Review Board's Information Request, additional information related to climate change projections of future environmental and wildlife habitat conditions is presented below. However, in addition to impacts to biophysical aspects of the Project, it is also important to consider how climate change will affect people and communities. In 2021, the GNWT contracted Intrinsik Corp, SLR Consulting (Canada) Ltd, and Sijja Consulting to prepare a Climate Change and Health Vulnerability Assessment for the Northwest Territories. While this report is not specific to the Mackenzie Valley Highway project itself, the report describes the impact of Climate Change on individuals and communities across the NWT (Intrinsik Corp et al. 2021). The report outlined that individuals who are already vulnerable, through existing long-term illness or disability, low income, or another social disadvantage, are likely to be disproportionately affected by climate change. Climate change and related events have been linked to increased mental health impacts, including rates of depression, anxiety, and pre- and post- traumatic stress; increased drug and alcohol usage; and increased suicidal ideation, suicide attempts, and death by suicide. In the NWT, Indigenous populations, on average, face poorer health outcomes primarily due to longstanding socioeconomic inequities, which are a result of the ongoing legacy of colonialism, the inter-generational trauma of residential schools, and inequalities in access to health services. Climate change impacts are likely to exacerbate these inequities. Increase in, and unpredictability of, extreme weather events can also have adverse impacts on traditional hunting and trapping grounds, including impacts to accessing them, impacts to the safety of those accessing them, and impacts to the animals that are hunted and trapped. This may eventually lead to a greater difficulty in Traditional Knowledge sharing between generations. Please note, the Climate Change and Health Vulnerability Assessment will be submitted to the Review Board's Public Registry as a separate document and will be available for the public to review.

Vegetation

The average annual mean temperatures in Norman Wells and Fort Simpson was predicted to increase 3.9 to 4.1 degrees by the 2050s and 6.5 to 6.9 degrees by the 2080s (K'alo-Stantec, 2024). With increasing temperature, there is a predicted reduction in area of permafrost and increase in fire frequency, intensity, and the length of the fire season (Canadian Forest Service 2024; K'alo-Stantec 2024). These factors were predicted to potentially change the composition and distribution of vegetation within the Taiga Plains ecozone in the NWT, which includes the RAA (Stewart et al. 2023). Regardless of the distribution of future landcover types in the LAA and RAA, with the mitigation for Project effects on vegetation presented in the DAR, there are no anticipated changes to the conclusions in the DAR, Section 18.

Predictions of the nature, extent, and distribution of the vegetation changes due to climate change varies by climate prediction model. Some models predicted a change from conifer dominated forest (either black spruce, white spruce, or both) to deciduous dominated forest (aspen) (Stewart et al. 2023). Specifically, Stewart et al. (2023) predicted that there will be a general shift from conifer to deciduous or mixedwood forest in the NWT (including the RAA) except in the Dehcho South region which is located south of the RAA. In this region, an increase in coniferous forest with a reduction in deciduous forest was predicted. In addition, they projected an average net increase in forest biomass in the NWT of 76 tons per hectare during the 21st century (Stewart et al. 2023).

Stewart et al. (2023) also predicted that the spread of invasive plant species into natural ecosystems and the spread of forest pests in the NWT including the RAA will accelerate with climate change. The spread was predicted to move from south to north along roads and other disturbances.

Although not specific to the RAA, Reid et al. (2022) identified widespread expansion of shrub communities and reduced tree growth in the Arctic including in the NWT as being directly attributable to warming temperatures, drought, and increased fire intensity associated with climate change. They further asserted there will be a shift from coniferous to deciduous dominance throughout the western boreal forest including in the NWT in general (Reid et al. 2022). In their estimation vegetation communities in some areas of the NWT and Yukon, generally, may begin to resemble existing vegetation communities in Alberta and British Columbia (Reid et al. 2022).

Associated with predictions of increased drought, Reid et al. (2022) predicted a potential increase in the extent of grasslands and a decrease in the extent of forest in the Yukon. They also predicted that drier conditions and associated increase in fire frequency and intensity will cause conversion of some coniferous forest to deciduous forest in the Yukon (Reid et al. 2022).

Blyth et al. (2016), citing Hogg and Bernier (2005), indicated that some models predicted that precipitation will be reduced due to climate change resulting in drying lakes and resulting in bogs being replaced by parkland and grassland ecosystems in the southern NWT including southern portions of the RAA. In addition, they also predicted a reduction in extent of conifer forest due to reduced precipitation resulting in lower rates of conifer regeneration. They estimated that conifer forest would be replaced by deciduous (aspen) forest in the southern NWT including southern portions of the RAA (Blyth et al. 2016).

Huberman et al. (2022) indicated that thawing permafrost across southern and central portions of the NWT including portions of the RAA has been linked to localized flooding and would result in replacement of coniferous forests with shrub- and moss-dominated plant communities. Specifically, they indicated that thawing permafrost would cause spruce-lichen vegetation communities to be replaced with non-forested shrub and moss communities associated with permafrost collapse scars. Conversely, Huberman et al. (2022) estimated that permafrost thaw may lead to the development of forest in previously non-forested land and greater rates of tree growth in wetlands in the NWT; however, they indicated that this has not yet been observed in the NWT and they did not indicate what tree species would be favoured by this mechanism.

Huberman et al. (2022) further predicted that climate change would increase wildfire frequency and intensity, which would alter forest species composition by decreasing peat accumulation and increasing forest cover in the NWT generally, although not specifically in the RAA (Huberman et al 2022). They also did not specify which tree species have increase under this scenario.

Using ecosystem climate envelope (cliome) modelling, the University of Alaska Fairbanks (2012) predicted that under a whole world high emissions scenario landcover in southern portions of the NWT could become grasslands and that no areas of the NWT would retain their current landcover by the end of the 2090s. Using the Climate Moisture Index (CMI), Lemprière et al. (2008) and Wang et al. (2014) suggested significant change in NWT vegetation that it could become too dry for closed canopy forests in currently forested portions of the NWT, particularly in the southern NWT, by 2100 under a high emissions scenario.

As presented in the DAR, Section 18, coniferous forest is the most common landcover type in the RAA followed by wetlands and less commonly by shrublands. Deciduous (broadleaf) forest and mixedwood forest as well as herbaceous and unvegetated areas are the least abundant landcover types in the RAA.

Based on potential effects on landcover type distribution due to climate change (discussed in the preceding paragraphs), including potential changes in fire regime and permafrost distribution, it is possible that some of the current coniferous forest landcover in the LAA and RAA could change to deciduous or mixedwood forest by 2050 and an additional portion by 2080. Likewise, shrublands in the LAA and RAA could increase by 2050 and additionally by 2080. The percentage of wetland area may decrease with a warming and drying climate. The amount of deciduous and mixedwood forest could increase or decrease depending upon how much lost area of these landcover types is offset by gained area elsewhere in the LAA and RAA.

The literature and models discussed above do not provide enough certainty or precision to further quantitatively characterize changes to vegetation at the scale of the RAA. However, climate change is not expected to completely remove any of the existing landcover types from the LAA or RAA by 2050. Effects on vegetation cover over a longer period of time are more uncertain, but may include the removal of one or more landcover types.

Caribou

Based on results published in literature relevant to the boreal caribou (*Rangifer tarandus caribou*) NT1 range and Caribou and Moose local assessment area (LAA), climate change may both positively and negatively affect boreal caribou habitat and habitat selection. All studies emphasized that there is considerable uncertainty in these types of predictions due to the high variability in climate models, and the dynamic and complex nature of ecosystems, making it especially difficult to predict the effects of fire, particularly, on boreal caribou habitat.

Traditional Knowledge-related concerns regarding climate change and risks to boreal caribou are summarized in the updated CCRA for the Project (K'alo-Stantec, 2024; Addendum to Appendix 24A) and include observations of changing shifts in the timing of caribou calving; ice-crusting events making foraging and escape from predators difficult; changing weather patterns affecting lichen availability; and higher water levels in smaller waterbodies facilitating increased hunter access into caribou habitat. Other than those observations, no Traditional Knowledge was provided that specifically provides an answer to this Information Request.

The updated CCRA, and published reports of studies are relevant to describing potential climate-related changes to boreal caribou habitat. Studies that are pertinent to the Caribou and Moose LAA and NT1 range are discussed below.

One report and one published paper considered climate change and potential effects on caribou habitat in the NT1 range/Taiga Plans ecozone. 'Blyth et al. (2016) modelled combined forest fire and timber harvesting with different climate change scenarios to predict boreal caribou habitat disturbance levels up to 2090. Stewart et al. (2023) simulated forest growth and wildfire including changes to a caribou resource selection function (RSF) habitat model (also used in this assessment, DeMars et al. 2020) as well as caribou population growth from 2011 through 2100 in southern and northern monitoring areas within the NT1 population unit. Although the projections are not specific to the multi-decadal units requested, the information helps to consider caribou habitat possibilities to 2100.

Blyth et al. (2016) conducted 120 scenarios incorporating climate change in future fire regimes, forest succession and harvest, linear and areal disturbance, and disturbance recovery to 2090. The northern extent of the study includes the Dehcho portion of the Caribou and Moose LAA within the NT1 range. Based on some forecasting uncertainty that included mean annual burn rates, variability in climate models, forest fuel recovery, and no additional anthropogenic disturbance over time, boreal caribou habitat (based on a measure of disturbance) in the southern part of NT1 may change ±15% through to 2090, depending on the climate model used. There was no attempt to link habitat results to caribou population growth parameters.

Stewart et al. (2023) simulated forest growth and wildfire, changes to the caribou RSF habitat model and predicted caribou population growth from 2011 through 2100 in southern and northern monitoring areas within the NT1 population unit. The results suggest that habitat suitability might increase in the central and southwest regions of the NT1 range/Taiga Plains ecozone but decrease in the southern and northwestern portions of the area, suggesting a potential shift in the boreal caribou range. Regardless of the expected changes in habitat conditions, population growth rates were predicted to remain stable until 2100, with no notable changes in the decadal periods requested by the Review Board. That study listed several assumptions and limitations associated with their forecasting approach, including uncertainty in local demographic rates, unknown changes to anthropogenic disturbance, and the assumption that caribou behaviour will remain unchanged through the modelling period.

The above studies have attempted to forecast habitat conditions with climate change considerations and anthropogenic disturbances to the end of the century, though not specific to the decadal periods requested. They clearly showed that climate change may positively and negatively affect boreal caribou habitat selection in the Caribou and Moose LAA. These specific studies also emphasized the considerable uncertainty in the model predictions.

Moose

Several publications have suggested changes in moose (*Alces alces*) distribution associated with climate-induced changes to habitat. Based on the climate-related habitat change predictions noted in the literature and the summary of likely changes in vegetation noted previously, moose abundance and distribution will likely change in the RAA over the next century. No information was specific to the decadal periods requested by the Review Board, and no Traditional Knowledge information specific to moose and climate change was made available for this assessment.

Moose habitat conditions in northern Canada might increase with climate change. Across the North American continent, the moose range might increase by 34–40% by 2070, depending on the climate scenario considered (regions where climate conditions will be similar to that in the range already occupied) (Deb et al. 2020). This range expansion, mostly northward, might continue and has already been observed in Arctic North America, with moose abundance increasing above the tree line and climate-related increasing shrub habitat (Tape et al. 2016a, b).

A changing fire regime associated with climate change is noted in the updated CCRA for the Project (K'alo-Stantec, 2024; Addendum to Appendix 24A). Based on a study in northwestern Alaska, an expected increase in the average annual number of areas burned will bring habitat change that might benefit moose (Joly et al. 2012). While core caribou winter habitat is negatively affected, moose habitat might increase with increased fire regularity up to 2054 and be substantially greater by 2099 (Joly et al. 2012). If the RAA experiences a similar change in fire ecology (as predicted in the updated CCRA), proportional changes could be observed in the RAA over the next century.

As noted in other sections, numerous assumptions and limitations are associated with predicting climate change effects on moose and moose habitats. None of the papers explicitly stated the limitations of their models, but there were many implied limitations. Projections were limited by the ability of the forecasting models to account for the interaction of variables (e.g., changing temperature, moisture regimes, fire ecology) and effects on vegetation succession patterns. Deb et al. (2020) noted that detailed knowledge about dispersal and colonization capabilities limits their predictions on moose range expansion. Joly et al. (2012) acknowledged the challenges of unpredictable wildfire behaviour (e.g., extent and variability) and predicting vegetation successional pathways associated with climate change. They also noted the lack of inland climate monitoring stations as a data gap.

Wildlife and Wildlife Habitat

Based on the climate profile in the updated CCRA for the Project (K'alo-Stantec, 2024; Addendum to Appendix 24C), and projected changes in vegetation communities described earlier, future habitat conditions will likely change habitat suitability for wildlife species of conservation concern (SOCC), including species at risk and those considered to be important to Indigenous governments, Indigenous organizations, or other affected parties. The projected changes to fire regimes and possible shifts from coniferous to deciduous forest in parts of the NWT (Stewart et al. 2023) could potentially reduce habitat abundance or connectivity for marten (*Martes americana*) (Wasserman et al. 2012), lynx (*Lynx canadensis*), black bear (*Ursus americanus*), and grizzly bear (*Ursus arctos*) (Friggens et al. 2018) in the RAA, with potential increases in habitat for moose (see above) and little brown myotis (*Myotis lucifugus*). An increase in early successional habitats (due to wildfire) and shrub-dominated habitats might benefit moose (i.e., browse) or bears (i.e., berry-producing shrubs) depending on shrub species composition. The potential effects of climate change on wildlife species associated with wetlands will likely vary depending on projected changes to various wetland types (e.g., bog, fen, open water) and species-specific habitat requirements (e.g., muskrat [*Ondatra zibethicus*], beaver [*Castor canadensis*]). Although climate change projections indicate there will likely be changes to landcover and habitat suitability for various wildlife species, there is uncertainty associated with the spatial location and extent of landcover change (e.g., wildfire) in the RAA, which will vary over the short (2020s), medium (2050s) and long term (2080s). Prediction uncertainty is as noted previously for boreal caribou and moose.

Species at Risk

Singer and Lee (2021) provided a broad overview of the vulnerability of NWT species at risk to climate change. A summary of the vulnerability risk assessment for species at risk with potential to occur in the RAA is provided below.

Overall, forest fire frequency and intensity may increase in the future, which could result in heat stress as well as potential phenological mismatches between timing of forage availability and peak forage requirements for many mammal species. Climate change effects are expected to affect species range and distributions, food availability/accessibility, migration, health and survivability, with both positive and adverse changes possible.

Specifically, climate change may result in grizzly bear range expansion in the NWT due to changes in multiple climate variables (e.g., warmer summer temperatures) while other changes to vegetation communities due to fires, flooding, or drought, may affect grizzly bear food availability. In addition, climate change may result in shifts in the timing of seasons, and mismatches between spring den emergence and food availability (Singer and Lee 2021).

Wolverines (*Gulo gulo*) require spring snow cover for denning and reduced spring snow cover associated with climatic warming is expected to reduce the extent of wolverine habitat, with an associated loss of connectivity (Copeland et al. 2010). The climate profile in K'alo-Stantec (2024) indicated snow accumulation may not substantially change over the short (2020s) or medium term (2050s); but there could be a 10-20% reduction by 2100. In addition, the duration of snow cover was expected to decline, which could affect spring snow cover and reduce denning habitat suitability. In the NWT, a projected increase in snowfall may be offset by a shorter snow season. In addition, earlier springs may improve primary productivity in wolverine habitat, resulting in a possible benefit to wolverines in the northern parts of their range (Singer and Lee 2021) including the RAA.

A warming climate may result in both positive and negative effects on hibernating bats in the RAA. Although an increase in mean annual and seasonal temperatures may increase the foraging season and decrease the duration of hibernation, changes to temperature and humidity conditions in hibernacula could result in a reduction in hibernation habitat suitability and survival. Warmer temperatures could also result in a northward range expansion for little brown myotis, but this will depend on roost availability. How climate change will affect the spread and virulence of white-nose syndrome is uncertain (Singer and Lee 2021).

Singer and Lee (2021) also assessed vulnerability of insect species at risk including gypsy cuckoo bumble bee (*Bombus bohemicus*), yellow-banded bumble bee (*Bombus terricola*), western bumble bee (*Bombus occidentalis*) and transverse lady beetle (*Coccinella transversoguttata*). The potential for mismatches to develop between bee emergence and flowering times/host emergence as a result of climate change could affect all three bumble bee species potentially present in the RAA and could result in severe population declines. The transverse lady beetle was expected to be less sensitive to climate change because they feed on a variety of prey items (i.e., not limited by a potential decline in one prey item) and are also threatened by competition from non-native beetles.

Although climate change has potential to change wildlife and wildlife habitat over the long term, it is important to recognize there is considerable uncertainty associated with predictions of ecological response to future climate changes, and each species adaptive capacity to respond to a changing climate will vary. In addition, there are non-climate stressors (e.g., anthropogenic disturbance, harvesting) (Singer and Lee 2021) that can also affect wildlife abundance and distribution in the RAA.

Birds and Bird Habitat

Based on the results of the climate profile included in the updated CCRA for the Project (K'alo-Stantec, 2024; Addendum to Appendix 24C), and projected changes in vegetation communities described above, future habitat conditions will likely result in changes to habitat suitability for bird species of conservation concern (SOCC) in the RAA, including species at risk, as well as those considered to be important to Indigenous governments, Indigenous organizations, or other affected parties.

Changes or shifts from coniferous to deciduous forest, where and if they occur in the RAA, will potentially reduce habitat abundance for spruce grouse (*Falcipennis canadensis*); however, changes in bird habitats are also influenced by fire severity (Knaggs et al. 2020). For example, an increase in fire frequency and severity may result in an increase in habitat for birds that utilize burns such as olive-sided flycatcher *(Contopus cooperi*) or black-backed woodpecker (*Picoides arcticus*), however, other species may respond negatively to fire (e.g., ruby-crowned kinglet [*Regulus calendula*]) (Knaggs et al. 2020). A potential increase in shrub-dominated habitats might benefit upland game birds. Overall, it is difficult to predict potential effects of climate change on bird species that utilize a variety of landcover types. For example, Swainson's thrush (*Catharus ustulatus*) was detected in coniferous, broadleaf as well as mixedwood and shrubland habitats during the breeding bird surveys completed for the Project (Section 20.0, Appendix 20A, Birds and Bird Habitat Technical Data Report). As such, a projected decrease in coniferous forest over time may be partly offset by a potential increase in other suitable habitat types (e.g., deciduous, shrublands) for generalist species. The potential effects on bird species associated with wetlands will likely vary depending on projected changes to various wetland types (e.g., bog, fen, open water) and species-specific habitat requirements (e.g., rusty blackbird [*Euphagus carolinus*], yellow rail [*Coturnicops noveboracensis*], lesser yellow legs [*Tringa flavipes*], waterfowl).

The potential effects of climate change on specific bird species and/or groups have been addressed for specific regions in the NWT. For example, Micheletti et al. (2021) developed statistical and simulation models to integrate boreal landbird density, wildfire, and forest growth using the Spatial Discrete Event Simulation (SpaDES) modeling framework. The SpaDES models were developed and applied to the Taiga Plains ecozone in the NWT, which overlaps the RAA.

Projected changes in climate and habitat resulted in an increase in species distributions for 47 of 64 (73%) bird species studied, and a decrease in distributions for 16 of 64 (25%) bird species within the Taiga Plains ecozone by 2100 (Micheletti et al. 2021). Overall, the results of the SpaDES indicated that climate change would result in "winners" and "losers" depending on individual species habitat associations. Specifically, species that utilize a diverse range of habitat types and species associated with deciduous forest (e.g., yellow warbler [*Setophaga petechia*], ruffed grouse) were predicted to increase whereas species dependent on conifer forests (e.g., boreal chickadee [*Poecile hudsonicus*]), non-forested habitats (Lincoln's sparrow [*Melospiza lincolnii*]) and treeline-tundra (horned lark [*Eremophila alpestris*]) were expected to have less habitat available by 2100. Projected net decreases in bird species richness (i.e., number of bird species) were more pronounced in the northeast and south-central regions of the NWT outside of the RAA. Although there are areas between Tulita and Norman Wells that were projected to result in a reduction in bird species richness, other areas along the Mackenzie River were projected to show a potential increase in bird species richness (Micheletti et al. 2021).

Overall, Micheletti et al. (2021) reported that the abundance and distribution of landbirds were affected by climate change through the indirect effects of climate on their habitat (vegetation) as well as through direct climate effects (e.g., physiological responses to temperature and precipitation) (Riddell et al. 2021). However, direct climate effects were two orders of magnitude more important in explaining predicted changes in landbird occupancy than climate-induced changes in vegetation or wildfire (i.e. indirect effects). Micheletti et al. (2021) suggested that the marginal response of indirect effects on the distribution of boreal landbirds in the NWT may be due to time lags in vegetation response to changes in climate. They also acknowledged that the SpaDES did not include all ecological processes (e.g., wetland dynamics, permafrost, extreme weather events).

Gahbauer et al. (2022) used bird species distribution models to predict changes in environmental suitability during summer and winter for 434 bird species under a 2˚C warming scenario in Canada's national park system including parks representative of the Taiga region in the NWT. These authors acknowledged that there is considerable variability in the distributional shift of individual species, and in the resulting changes in community composition at individual parks. The parks assessed in the NWT (e.g., Nahanni National Park Reserve, outside of the RAA) indicated potential increases in bird species richness during both summer and winter. Although 70% of projections of suitability were predicted to change over time, those changes included both potential increases and decreases in suitability depending on individual bird species. In addition, parks were projected to experience either species colonization or extirpation.

The vulnerability risk assessment completed by Singer and Lee (2021) also addressed bird species at risk. The authors reported that changes to the forest fire frequency and intensity as well as changing moisture conditions are likely to result in changes to the abundance and distribution of suitable habitat for individual bird species. Specifically, forest fire frequency and severity are expected to increase with climate change, which may reduce the amount of breeding habitat available. Depending on the intensity, location and time since burn, insect availability (i.e., food source) may increase or decrease (Singer and Lee 2021).

Declines in insect prey availability and the potential for phenological mismatch between timing of insect emergence and bird breeding seasons are likely to affect aerial insectivores such as bank swallow, common nighthawk, and olive-sided flycatcher. In addition, extreme weather events, particularly rainfall, river flooding, and bank collapse can also cause mortality of adults and nestlings, which affects bird survival. The potential effects of climate change on birds may result in some bird species distributions shifting northwards (Singer and Lee 2021).

Overall, how animals respond to climate change (e.g., adapt, decline, move or shift) remains uncertain (Singer and Lee 2021) and the complexity of ecological interactions poses limitations to predicting how climate change will affect species-specific interactions such as predator-prey relationships (Laws 2017, Gahbauer et al. 2022).

Conclusion

The results of the climate profile projections for the Project (in K'alo-Stantec 2024), in combination with a literature review of potential climate change-related changes to vegetation and wildlife habitat, suggested there could be both positive and adverse changes in the RAA through the 2020s, 2050s and 2080s, depending on species-specific habitat associations. These predictions were made with considerable uncertainty.

The GNWT accepts that over the indeterminate, long life of the Project there will be changes in future environmental and habitat conditions in the NWT and within the RAA used to assess potential effects on environmental VCs. Measurable parameters of climate change (e.g., temperature, precipitation) will likely represent some of the many variables contributing to potential changes in environmental VCs over the long-term operation of the Project. The inherent complexity of ecosystem response is reflected in the uncertainty of conclusions emphasized in the referenced literature. Potential, yet uncertain changes to baseline environmental and habitat conditions have been acknowledged in the DAR (Section 15.7.2 [water quantity], 17.8.2 [fish and fish habitat], 18.7.2 [vegetation and wetlands], 19.7.2 [wildlife and wildlife habitat], birds and bird habitat [20.7.2].

Notwithstanding the uncertainties, it is GNWT's view that, for the purposes of providing information in support of an environmental assessment, current conditions are adequate to predict effects, proposed effects management plans are likely to be effective, and conclusions can be relied upon. Climate change predictions do not necessarily improve the certainty of conclusions in the assessment. Uncertainty is acceptable in environmental assessment if actions are implemented to address uncertainty, through adaptive management. Adaptive management is not proposed to reduce prediction uncertainty – rather it is proposed to monitor specific predicted effects, so that changes (to management actions) are made if needed to manage the effects of the Project on the environment and the environment on the Project over the long term of operations.

The GNWT's approach to adaptive management is described in Section 23.2 of the DAR. It is consistent with purpose and approaches used in other jurisdictions (e.g., BCMECCS, 2022; Government of Yukon, 2021).

Throughout the DAR, and specifically in draft Management Plans of Volume 5 (for example the draft Wildlife Management and Monitoring Plan), adaptive management, or inspection and response, is described as a process to monitor, evaluate, and if necessary respond if specific conditions are observed that may indicate mitigation measures are not working as intended. Some management actions require collaboration with Indigenous governments, Indigenous organizations, other land and resource managers, and co-management organizations.

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Mackenzie Valley Highway Project – Climate Change Resilience Assessment Addendum (2024)

Prepared for:

Government of the Northwest Territories

Prepared by:

K’alo-Stantec Limited

June 19, 2024

Project No.: 123514886

K'alo-Stantec

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Executive Summary

K'alo-Stantec Ltd. (Stantec) completed an update to the 2021 Mackenzie Valley Highway Project – Climate Lens Part II: Climate Change Resilience Assessment (CCRA). The main objectives of this update were to utilize new climate change projection data and subsequently update the CCRA, add new climate parameters to the assessment, and incorporate Traditional Knowledge gathered for the Mackenzie Valley Highway Project. For consistency, the same CCRA methods used in the 2021 CCRA were also used in this update.

The 2021 CCRA climate assessment was completed using Coupled Model Intercomparison Project Phase 5 (CMIP5) climate projections. CMIP5 climate projections formed the basis of the IPCC's *Fifth Assessment Report* (IPCC, 2013). Since the completion of the CCRA, the IPCC *Sixth Assessment Report* (IPCC, 2021) has been released with the latest global and regional assessments of climate change and its impacts using a set of five new illustrative emissions scenarios, referred to as Share Socioeconomic Pathways (SSP). The SSP-driven climate projections were completed for the Coupled Model Intercomparison Project Phase 6 (CMIP6) and downscaled for Canada by the Pacific Climate Impacts Consortium (PCIC). For climate hazards with limited or no CMIP6 SSP-derived climate projections available, CMIP5 RCP8.5-driven projections and/or specialized studies/scientific literature were utilized.

The updated CCRA resulted in an increase in risk ratings for precipitation extremes (short duration, high intensity precipitation) and freeze-thaw days. For most precipitation extremes and freeze-thaw days risks the risk classification remained consistent. For the three additional climate parameters added to the CCRA – wildfire, wind, and icing – high risks were identified associated with maintenance of the roadway and the health & safety of maintenance staff, road users, and other personnel. Adaptation recommendations developed in the 2021 CCRA remain relevant, and recommendations were developed for the new climate parameters. Adaptation recommendations for the three additional climate parameters include the following:

- Routine inspection of roadway for erosion and undertake maintenance actions as necessary
- Design and install permanent erosion control measures in areas anticipated to be suspectable to erosion
- Work with communities in the region to establish evacuation plans which take into consideration the possibility of road closure due to climate and weather-related events
- Establish Operations and Maintenance (O&M) policies for working in adverse conditions and include contingency plans in the event of wildfire and/or road closure
- Continue to use the established public notification system to communicate with road users and report on maintenance activities, road conditions, and weather conditions

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1 Introduction

K'alo-Stantec Ltd. (Stantec) completed a Climate Change Resilience Assessment (CCRA) in 2021 as part of the Climate Lens Analysis as required by the Investing in Canada Infrastructure Program (ICIP) for the Mackenzie Valley Highway (the Project). The ICIP is a bilateral agreement between Infrastructure Canada and the provinces and territories. As the Project proponent is seeking federal funding under the ICIP Community, Culture and Recreation Fund, the CCRA was prepared in accordance with Infrastructure Canada requirements and Infrastructure Canada's Climate Lens General Guidance Version 1.2[1]. The assessment applied 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.

Since the completion of the 2021 CCRA, the Intergovernmental Panel on Climate Change (IPCC) *Sixth Assessment Report* (IPCC, 2021) has been released with the latest global and regional assessments of climate change and its impacts using a set of five new illustrative emissions scenarios, referred to as Share Socioeconomic Pathways (SSP). This addendum report provides an updated climate assessment and related updates to the risk assessment and resilience measures reported in the 2021 CCRA. Additionally, Traditional Knowledge was not incorporated into the 2021 CCRA, therefore, this update will highlight Traditional Knowledge gathered through engagement and studies completed for the Project. This addendum report should be read in conjunction with the original report: *Mackenzie Valley Highway Project – Climate Lens Part II: Climate Change Resilience Assessment* (Stantec, 2021).

1.1 Background

The 2021 CCRA identified climate risks to the Project at a broad systems-level, providing an understanding of the potential climate impacts on the Project over its construction and operational life. The assessment was intended to inform the design team of projected changes in climate and associated risks to consider at the Project's detailed design stage. The Project assets and systems assessed in the CCRA are presented in Table 1-1. The assessment was limited to the roadway structure and did not include associated infrastructure (e.g., bridges, maintenance yards, camps, laydowns, pits). Additionally, the CCRA did not include the deconstruction or rehabilitation of the gravel road and associated structures at the end of their useful life.

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[1] https://www.infrastructure.gc.ca/pub/other-autre/cl-occ-eng.html

Table 1-1 Project Components Assessed

Project Infrastructure Component	Project Infrastructure Sub-Components
Structural Elements / Physical Infrastructure	• Road Base and Subgrade • Road Embankments • Surface Drainage • Culverts
Miscellaneous	• Maintenance • Emergency Response • Administration / Personnel & Engineering

Climate parameters selected for assessment in the CCRA are as follows:

- Mean seasonal temperatures
- High temperature extremes
- Low temperature extremes
- Precipitation extremes
- Sustained rainfall
- Dry spells
- Frost days
- Freeze-thaw days

Permafrost thaw is strongly related to increases in air temperature and, therefore, changes in the temperature parameters were used as proxies for changes in permafrost in the 2021 CCRA. Potential impacts of permafrost thaw on the Project and possible resilience measures were developed during the 2021 CCRA. While permafrost thaw was considered in the original CCRA, a section on permafrost was added to the updated Climate Profile (Appendix A) to provide additional insight into the climate parameter. Similarly, temperature parameters were used as proxies for wildfire impacts.

1.2 Objective

The main objectives of this update to the Project CCRA were as follows:

- Utilize the new SSP-driven climate projection data and subsequently update the risk assessment
- Add new climate parameters to the CCRA that were noted by the Mackenzie Valley Environmental Impact Review Board in Information Request 2
- Incorporate Traditional Knowledge gathered through engagement with affected parties and Traditional Land and Resource Use studies

1.3 Scope

The following tasks have been completed as part of the CCRA update:

- The Climate Profile of the CCRA was updated using the SSP-driven climate projections and specialized studies. This task also included adding three new climate parameters (forest fires, wind, and icing), which were noted in the Mackenzie Valley Environmental Impact Review Board Information Request 2.
- The climate parameter probability scores used in the risk assessment were updated.
- Traditional Knowledge gathered for the Project was summarized and incorporated into the CCRA where appropriate.
- A Stantec Subject Matter Expert (SME)[2] was consulted to identify possible impacts on the Project associated with the new climate parameters added to the CCRA as well as assign consequence scores for use in the risk assessment.
- The risk assessment was updated to reflect changes in the probability scores and the addition of the new climate parameters.
- Adaptation considerations previously developed for high and extreme risks were reviewed and updated as necessary. Adaptation considerations were also developed for the high and extreme risks associated with the new climate parameters.

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[2] Walter Orr, B.Sc., P.Eng., Principal Civil Engineer

2 Climate Assessment Update

This section presents the climate projections used to update the CCRA, a summary of the updated climate parameter data (including the new climate parameters added to the CCRA), and the updated climate parameter probabilities. The climate parameters assessed, and methods used to estimate probabilities align with the 2021 CCRA, except where otherwise noted.

The supplementary Climate Profile (Appendix A) provides further information on the climate data sources and the historical and projected climate conditions for the climate parameters considered in the CCRA.

2.1 Climate Projections

The climate assessment completed for the 2021 CCRA was based on Coupled Model Intercomparison Project Phase 5 (CMIP5; Taylor et al., 2012) Global Climate Models (GCMs) climate projections. CMIP5 climate projections formed the basis of the IPCC's *Fifth Assessment Report* (IPCC, 2013). Probability scores for the 2080s (2071-2100) time horizon were assessed based on the multi-model ensemble projections under the RCP8.5 scenario.

Since the completion of the 2021 CCRA, the IPCC's *Sixth Assessment Report* (IPCC, 2021) has been released with the latest global and regional assessments of climate change and its impacts using a set of five new illustrative emissions scenarios, referred to as Share Socioeconomic Pathways (SSP; Riahi et al., 2016). There are five SSP scenarios which were adopted by the IPCC for its Sixth Assessment Report, ranging from very low emissions (SSP1-1.9) to low emissions (SSP1-2.6) to intermediate emission (SSP2-4.5) to high emissions (SSP3-7.0) to very high emissions (SSP5-8.5). The SSP5-8.5 trajectory more closely aligns with historical and current emissions and represents a plausible emissions track into the future (Smith and Myers, 2018; Pedersen et al., 2020; Schwalm et al., 2020). While recent studies (Hausfather and Peters, 2020) suggest that the higher emissions scenarios (e.g., SSP5-8.5) may have become less likely due to technological developments and emerging climate policies, the higher emissions scenarios remain plausible trajectories and provide insight into "high-end" risks of climate change (IPCC, 2022). The SSP5-8.5 very high emissions scenario was therefore used in the CCRA update to present a conservatively high estimate of projected climate change and its associated impacts in the climate assessment. The SSP5-8.5 and RCP8.5 emissions scenarios generally correspond (Riahi et al., 2016).

The SSP-driven climate projections were completed for the Coupled Model Intercomparison Project Phase 6 (CMIP6; Eyring et al., 2016) GCMs. Downscaling methods are often used to produce finer spatial resolution projections from GCMs. Approximately 35 GCMs have contributed to CMIP6. The Pacific Climate Impacts Consortium (PCIC)[3] uses a subset of 26 of these models to produce reliable, high-resolution (~10 km) downscaled climate projections localized to specific areas of interest in Canada, referred to as the Canadian Downscaled Climate Scenarios – Univariate (CMIP6) (CanDCS-U6) (Cannon, 2015; Cannon et al., 2015). Where possible, probability scores for the 2080s time horizon were assessed

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[3] https://www.pacificclimate.org/

based on the CanDCS-U6 multi-model ensemble projections under the SSP5-8.5 emissions scenario. For climate hazards with limited or no CMIP6 SSP-derived climate projections available, CMIP5 RCP8.5-driven projections and/or specialized studies/scientific literature were utilized.

2.2 Climate Parameters Update

Three additional climate parameters were noted by the Mackenzie Valley Environmental Impact Review Board in Information Request 2: forest fires (referred to as wildfires in the Climate Profile and henceforth in this report), wind, and icing. Information on the climate data sources and the historical and projected climate conditions for these additional climate parameters are presented in the supplementary Climate Profile (Appendix A). Table 2-1 presents an updated summary of the climate parameters assessed in the CCRA, reflecting the new SSP5-8.5 climate projections.

Table 2-1 Updated Climate Parameters Summary

Climate Parameter	Trend	Confidence Level in Projections	Parameter Remark*
Temperature			
Mean Seasonal Temperatures	Increase	High	**Norman Wells –** Average annual temperature is projected to increase by 6.9°C by the 2080s, with the largest seasonal increase (9.1°C) in winter and smallest seasonal increase (5.5°C) in the summer. **Fort Simpson -** Average annual temperature is projected to increase by 6.5°C by the 2080s, with the largest seasonal increase (8.4°C) in the winter and the smaller seasonal increase (5.7°C) in the summer.
High Temperature Extremes	Increase	High	There is a projected increase in the average annual number of days with a maximum temperature ≥ 30°C. **Norman Wells –** A projected increase from ~2 days/year in the baseline to ~24 days/year in the 2080s. **Fort Simpson –** A projected increase from ~4 days/year in the baseline to ~35 days/year in the 2080s.
Low Temperature Extremes	Decrease	High	There is a projected decline in the average annual number of days with a minimum temperature ≤ -30°C. **Norman Wells –** A projected decline from ~51 days/year in the baseline to ~7 days/year in the 2080s. **Fort Simpson –** A projected decline from ~38 days/year to ~3 days/year by the 2080s.
Frost Days	Decrease	Medium-High	A decrease in the average annual number of frost days (days with a minimum temperature < 0°C) is projected, resulting in a longer, extended frost-free season. **Norman Wells –** A projected decrease from ~240 frost days/year in the baseline to ~203 frost days/year in the 2080s. **Fort Simpson –** A projected decrease from ~225 frost days/year in the baseline to ~185 frost days/year in the 2080s.

Climate Parameter	Trend	Confidence Level in Projections	Parameter Remark*
Freeze-Thaw Days	Decrease	Medium-High	The average annual number of days with a freeze-thaw cycle is projected to decrease. **Norman Wells –** A projected decrease from ~44 freeze-thaw days/year in the baseline to ~37 freeze-thaw days/years in the 2080s. **Fort Simpson –** A projected decrease from ~57 freeze-thaw days/year in the baseline to ~45 freeze-thaw days/years in the 2080s.
Precipitation			
Precipitation Extremes	Increase	Medium-High	IDF data[4] projections indicate an increase in storm intensity for short duration rainfall events (5 min events to 24-hour events) under a warming climate. **Norman Wells –** Short duration rainfall event intensity is projected to increase by ~60% in the 2080s, relative to the 1974-2021 period. **Fort Simpson –** Short duration rainfall event intensity is projected to increase by ~55% in the 2080s, relative to the 1969-2021 period.
Sustained Rainfall	Increase	Medium-Low	Similar to short duration events, sustained rainfall events (e.g., 3- and 5-day rainfall accumulations) are likely to increase in intensity under a warming climate.
Dry Spells	Slight Decrease	Medium-Low	Historically, the trend in average maximum dry spell length for the region has been generally stable. In the future, the average annual longest dry spell duration (i.e., maximum number of consecutive dry days [days with < 1 mm of precipitation]) is projected to slightly decrease. **Norman Wells –** A projected decrease from a maximum of ~29 consecutive days/dry spell in the baseline to a maximum of ~25 consecutive days/dry spell in the 2080s. **Fort Simpson –** A projected decrease from a maximum of ~29 consecutive days/dry spell in the baseline to a maximum of ~27 consecutive days/dry spell in the 2080s.

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[4] IDF (intensity-duration-frequency) data relates short-duration, high intensity rainfall with its frequency of occurrence. IDF data provides total precipitation amounts in specific time intervals (5 minutes to 24 hours) for various return periods (2 years to 100 years).

Climate Parameter	Trend	Confidence Level in Projections	Parameter Remark*
Additional Parameters			
Wildfires[5]	Increase	Low	The average annual number of large (> 200 ha) fires was 5 to 10 fires annually per 100,000 km^2 in the Great Bear Lake homogeneous fire regime (i.e., the Mackenzie Valley Highway region) during the 1961-1990 period. The average annual number of large fires is projected to increase by 2 to 3 times – up to 30 fires/year – in the 2080s. The average annual area burned and fire size are also projected to increase. Additionally, the fire season is projected to increase under a warming climate.
Wind[6]	Slight Increase	Low	The average annual number of days with high wind gusts (≥80 km/hr) is projected to increase slightly under a warming climate. **Norman Wells –** An increase from ~1.9 days/year in the baseline to ~2.3 days/year in the 2080s. During the 1981-2010 period, the maximum wind gust recorded at the Norman Wells airport was 106 km/hr. **Fort Simpson –** An increase from ~0.3 days/year in the baseline to ~0.4 days/year in the 2080s. During the 1981-2010 period, the maximum wind gust recorded at the Fort Simpson airport was 91 km/hr.
Icing[7]	Increase	Low	In the Mackenzie Valley Highway region, freezing rain events are historically short-duration events, with an average of up to ~3 to 4 hours annually of freezing rain, occurring typically in the fall, winter, or spring. Under a warming climate, the average annual number of hours of freezing rain are projected to increase by approximately 5 to 10 hours by the end of the century. Additionally, the 1-in-20-year ice accretion load is projected to increase by 60-100% by the end of the century.

Note:

* Projected changes are relative to the 1981-2010 period, unless otherwise noted.

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[5] Wildfire specialized studies utilized include Boulanger et al., 2014, Huberman et al., 2022, Wang et al., 2022, and Jones et al., 2022.

[6] Wind specialized study utilized is Cheng et al., 2014.

[7] Icing specialized studies utilized are Kochtubajda et al., 2017, Cannon et al., 2020, Mekis et al., 2020, and McCray et al., 2022.

2.3 Climate Parameter Probabilities

Climate parameter probabilities were assigned using a rating scale of 1 to 5 (Table 2-2).

Table 2-2 Probability Rating

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
10/year to 1:1	Normal	Likely to occur between one to 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

Table 2-3 presents a comparison of the 2080s (2071-2100) probability ratings from the 2021 CCRA based on RCP8.5 climate projections and the updated probability ratings based on SSP5-8.5 climate projections. Table 2-3 also presents the probability ratings for the additional climate parameters (wildfires, wind, and icing). For climate parameters projected to undergo gradual changes under climate change (e.g., mean seasonal temperature), the probability rating reflected the likely rate of change (e.g., notable change on an annual, decadal, or multi-decadal scale).

Table 2-3 2080s Probability Ratings: 2021 CCRA vs. 2024 Update

Climate Parameter	2080s Probability Rating	
	2021 CCRA	2024 Update
Temperature		
Mean Seasonal Temperatures	5	5
High Temperature Extremes	5	5
Low Temperature Extremes	4	4
Frost Days	3	3
Freeze-Thaw Days	3	4
Precipitation		
Precipitation Extremes	2	3
Sustained Rainfall	5	5
Dry Spells	4	4
Additional Parameters		
Wildfires	N/A	5
Wind	N/A	4
Icing	N/A	4

3 Traditional Knowledge

Weather stations, such as those located at the Norman Wells and Fort Simpson airports used in the CCRA, provide detailed records of location-specific meteorological and climatic conditions. Traditional Knowledge provides holistic regional descriptions of observed changes including descriptions of changes in the meteorology, climatology, hydrology, geology, vegetation, and wildlife of a region. Weather stations and Traditional Knowledge both complement and supplement each other in developing an understanding of historic conditions and observed changes of a region. Traditional Knowledge typically provides qualitative descriptions of observed conditions and changes and can provide guidance into climate parameter selection for a CCRA. Traditional Knowledge, however, may not provide information on all climate parameters of interest for a CCRA and/or the quantitative details necessary to complete the assessment. As such, weather station records provide a main resource for CCRAs. Nevertheless, Traditional Knowledge is invaluable documentation of long-term environmental changes and is provided, as appropriate, as part of this CCRA to further highlight and reflect its importance.

The GNWT engaged with Indigenous Governments, Indigenous Organizations, and other affected parties such as renewable resource councils (including Tulita Renewable Resources Council [TRRC] and Norman Wells Renewable Resources Council [NWRRC]), which included project-specific community engagement activities and development of Traditional Land and Resource Use (TLRU) studies (between 2010-2012 and 2021-2023). Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided Project-specific information related to culture and traditional land use, including harvesting, hunting, and trapping. The information provided included observations and concerns about climate change, and the effects of a warming climate observed in the Study Area.

The Project occurs within the Dehcho Region and the Sahtu Region. Reported climate change concerns and observations relevant to the Project are organized by the Dehcho and Sahtu regions below.

3.1 Dehcho Region

Pehdzéh Kį First Nation reported the importance of water resources in the Dehcho Region, and identified watercourses and riverbanks that are important traditional land use areas, and rivers (e.g., Ochre River, Mackenzie River, Blackwater River) which are considered important habitat for waterfowl (Dessau, 2012 [PR#13]). Dehcho First Nations indicated many factors influence the water quantity in the Dehcho Region and noted that the region is getting warmer and wetter overall with more rainfall in August and September and even into October, which is resulting in higher water levels on smaller rivers and streams (Dehcho First Nations, 2011). Dehcho First Nations explained that increased wetness and rainfall has led to increased ice crusting along the ground, subsequently resulting in foraging difficulty for boreal caribou, and increased difficulty for caribou to escape predators at the end of summer. In addition, Dehcho First Nations reported that warmer temperatures, thawing permafrost, and other environmental changes, as a result of climate change, create overall environmental concerns in region, including thawing of frost, which harbours and protects lichens and will reduce the availability of lichen-rich habitats important for caribou in the region (Dehcho First Nations, 2011). Dehcho First Nations further report, warmer wetter summers and falls increase water levels on smaller rivers and streams, allowing more boat access into boreal caribou habitat areas, potentially increasing hunting pressure on caribou (5658 NWT Ltd. and GNWT, 2011 [PR#16]; Dehcho First Nations, 2011; McDonald, 2010). Pehdzéh Kį First Nation and Dehcho First Nations identified concerns about potential effects on lands and forests, in particular changes in vegetation and wetlands and changes resulting from removal of permafrost resulting in decreased plants and plant harvesting locations available to Indigenous harvesters (Dessau, 2012 [PR#13]; Dehcho First Nations, 2011).

3.2 Sahtu Region

Participants of the NWRRC project-specific TLRU study reported observed changes to the land that they attribute to changes in the climate. They identified concerns about changing temperatures and effects of climate change on vegetation (NWRRC, 2023). NWRCC study participants explained that Elders of Norman Wells used to be able to predict weather patterns, but the recent fluctuations in weather have made predictions much more difficult (NWRRC, 2023). Study participants observed that weather in the Study Area has changed over the last few years, which affects the land and the permafrost and can influence the flow of creeks (NWRRC, 2023). NWRRC study participants observed that changing weather patterns can influence the accessibility and availability of lichen for caribou (NWRRC, 2023). A previous report stated that weather plays a significant role in the health and well-being of boreal caribou, noting that increasing extremes in temperatures and flooding negatively affect herds (McDonald, 2010). Other documented information relevant to the Project includes concerns that climate change, including change in ambient temperatures, are shifting the timing of caribou calving and reducing the availability of lichen-rich habitats, which is a primary source of caribou subsistence (SRRB, 2016). SRRB has reported concern that change in ambient temperature will cause early green-ups, and off-set the timing in relation to caribou calving (SRRB, 2016).

NWRRC TLRU study participants reported that the water in the lakes and rivers are taking longer to freeze because the temperatures are warmer and changing every year (NWRRC.4; NWRRC, 2023). It was also reported that large chunks of ice are no longer carried down the rivers because the water has been too low to move it. NWRRC TLRU study participants communicated that in general, snow dries up faster, and there is less rain and less snow, which has caused surface water to dry up (NWRRC, 2023). They raised concerns and provided examples of creeks and lakes drying up in the NWRRC TLRU Study Area (NWRRC, 2023).

NWRRC TLRU study participants identified concerns about warming temperatures affecting permafrost, especially around the Norman Wells Pipeline right-of-way (ROW), observing that thawing permafrost has contributed to land sinking around the pipeline (NWRRC, 2023). Through Project-specific TLRU studies, TRRC and NWRRC participants also discussed concerns about thawing permafrost and existing issues along the current winter road. Generally, in the Sahtu Region, the effects of climate change, in combination with wildfire, thawing permafrost, ground slumping, and shoreline erosion pose additional safety risks to infrastructure, including roads and buildings, as well as risks to traditional economies and TLRU (SLUPB, 2022). Erosion due to climate change can lead to sedimentation entering important waterbodies and can negatively affect water quality and important fish habitat.

Through Project-specific TLRU studies, NWRRC and TRRC study participants stated that the Study Area is important for harvesting [berries] in the summer months (NWRRC, 2023). NWRRC (2023) reported that there are not as many berries available for harvesting in the Study Area now as in the past, which participants attribute to the land drying up, potentially related to effects of climate change.

The SRRB has reported that fish habitat, populations, and abundances have decreased over the last 50 years as a result of past industrial disturbance and habitat disturbance as well as indirect effects associated with climate change (SRRB, 2021b). Elders and land users in the Sahtu Region have also expressed concern about potential effects in the Sahtu area, which may affect the health of the region's fish, specifically fish habitat, spawning, and fish abundance due to direct effects from development and industry, as well as indirect effects from climate change (SRRB, 2021b; Golder, 2015). In addition, through the Project-specific engagement program, NWRRC TLRU study participants reported that climate change affects food security, and explained that more people will fish if wildlife moves away, which may potentially affect fish and fish habitat (NWRRC, 2023).

4 Risk Assessment Update

4.1 Methods

In the CCRA, the risk rating is defined as follows:

Risk Rating = Probability Rating x Consequence of Impact Rating

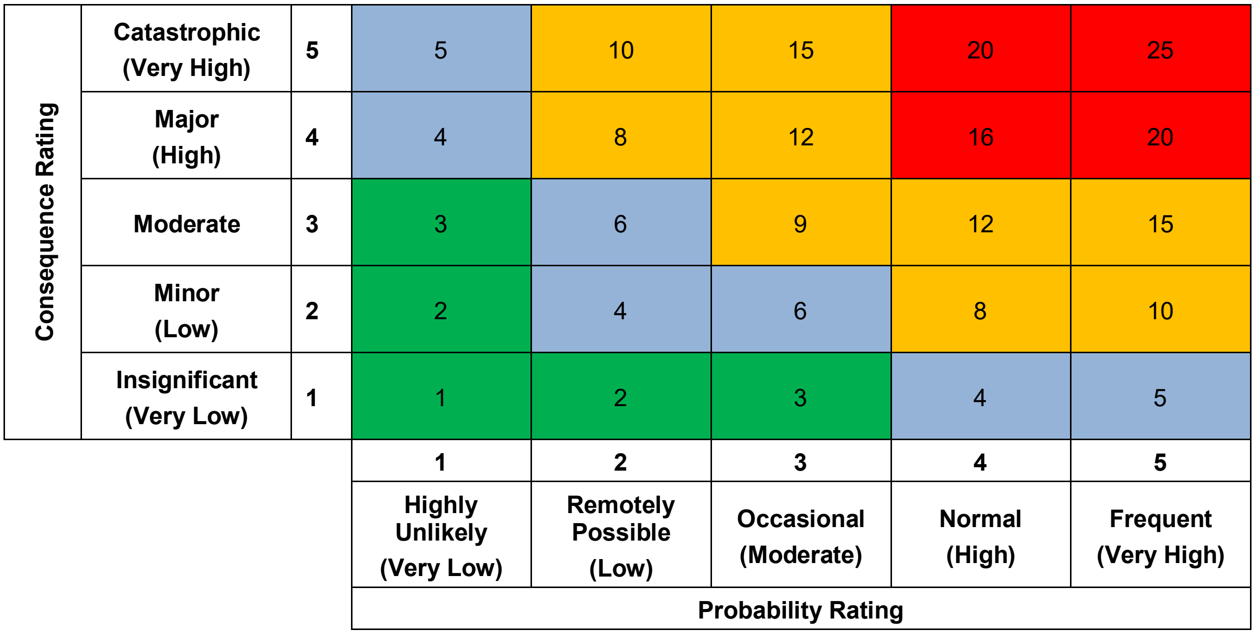
- Probability Rating: a rating that represents the probability or likelihood of occurrence of a climate event above a selected threshold, ranging from 1(highly unlikely) to 5 (frequent)
- Consequence of Impact Rating: a rating of the impacts on the infrastructure asset or component should the climate event occur, ranging from 1 (insignificant) to 5 (catastrophic)

In the CCRA, 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 CCRA.

The risk rating calculation provides numerical risk ratings of 1 to 25 as shown in Figure 4-1. In Table 4-1, risk ratings are described along with suggested risk treatments as per the Climate Lens General Guidance. It should be noted that, since the completion of the 2021 CCRA, the Climate Lens General Guidance has been updated (Version 2.1; https://publications.gc.ca/collections/collection_2024/infc/T94-51-2023-eng.pdf). To remain consistent with the methods used in the 2021 CCRA, however, the previous version of the Guidance (Version 1.2) is used in this update.

Figure 4-1 Risk Ratings Calculation Matrix

Risk Rating = Probability Rating x Consequence of Impact Rating



Consequence Rating	**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				

Table 4-1 Risk Classification and Treatment

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, 5, 6	• Expected limited damage to asset or to equipment components. • Minor repairs and some equipment replacement may be required. • Brief service disruption may be possible.	• Some controls required to reduce risks to lower levels. Risk to be monitored for changes over time.
High	8, 9, 10, 12, 15	• 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	16, 20, 25	• 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.

Risk ratings calculation matrix presented in Figure 4-1

4.2 Consequence Ratings for Additional Climate Parameters

Potential interactions with the Project infrastructure were assessed for the three climate parameters added to the CCRA update – wildfire, wind, and icing. Consequence (severity of impact) ratings were assigned using a rating scale of 1 to 5 (Table 4-2) and considered impacts to the structural integrity, operations and maintenance (O&M), and functionality of the infrastructure (additional details on the consequence categories are provided in Table 3 of the 2021 CCRA [Stantec, 2021]).

Table 4-2 Consequence (Severity of Impact) Rating

Consequence Rating	Qualitative Descriptor	Descriptor
1	**Insignficant** – 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.

Potential interactions and consequence ratings for the additional climate parameters are presented in Table 4-3. Consequence ratings assigned in the 2021 CCRA were not reassessed for this update. It should be noted that, while permafrost thaw is strongly related to increases in air temperature, permafrost is also vulnerable to other climate and weather events, such as wildfires, and can thaw rapidly once it is disturbed. Potential impacts of permafrost thaw on the Project and possible resilience measures were developed during the 2021 CCRA using changes in the temperature parameters as proxies for changes in permafrost. The occurrence of wildfire impacting sections of the roadway with permafrost may quicken and/or exacerbate the impacts of permafrost thaw.

Table 4-3 Potential Climate Parameter Impacts and Consequence Ratings for Additional Climate Parameters

Climate Parameter	Infrastructure Impacted		Description of Impact	Consequence Rating
	Component	**Sub-Component**		
Wildfire	Structural Elements / Physical Infrastructure*	Surface Drainage	A loss of vegetation from wildfire could result in increased runoff and impacts on roadside drainage (e.g., increased volume exceeding design flow capacity of culverts) and roadside erosion. Wildfire occurrence may quicken and/or exacerbate permafrost thaw and its impacts on the roadway drainage system.	2
		Culverts		
	Miscellaneous	Emergency Response	Wildfires could result in road closures, adding to the wildfire related health & safety risks to road users and maintenance staff.	3
		Administration / Personnel & Engineering	Wildfires and related poor air quality could result in a health & safety risk to road users, maintenance staff, and other personnel.	2
Wind	Miscellaneous	Maintenance	High winds could result in branches and windblown debris on the roadway, requiring increased maintenance to clear the road of potential obstacles. High winds may result in snow drifts which could results in additional maintenance and temporary road closure.	3

Climate Parameter	Infrastructure Impacted		Description of Impact	Consequence Rating
	Component	Sub-Component		
		Administration / Personnel & Engineering	High winds could result in reduced air quality due to dust, creating a health & safety risk to road users, maintenance staff, and other personnel. High winds also present an operational hazard to large vehicles (e.g., reduced visibility due to dust or blowing snow, potential for tipping over of tractor trailers).	2
Icing (including icing due to freezing rain and/or aufeis [overflow])	Structural Elements / Physical Infrastructure	Culverts	Icing could result in ice buildup in culverts, requiring thawing by maintenance staff to restore full functionality.	3
	Miscellaneous	Maintenance	Icing of the road surface could result in increased maintenance (distribution of gravel and/or grading) to maintain road access.	3
		Administration / Personnel & Engineering	Icing of the road surface and roadsides could result in a health & safety risk to road users, maintenance staff, and other personnel (e.g., increase potential for road accidents, slip-and-fall risk)	2

* While outside the scope of the CCRA, it should be noted that wildfire could damage or destroy maintenance yard infrastructure and, subsequently, result in impacts to the roadway (e.g., reduced ability to maintain the roadway and possible loss of service).

4.3 Risk Rating Updates

Table 4-4 presents a comparison of the 2080s (2071-2100) risk ratings from the 2021 CCRA and the updated risk ratings for the climate parameter-infrastructure component interactions with a change in probability rating (as previously presented in Table 2-3). Table 4-4 also presents the risk ratings for the identified climate parameter-infrastructure component interactions for the additional climate parameters (wildfires, wind, and icing).

Table 4-4 2080s Risk Ratings: 2021 CCRA vs. 2024 Update

Climate Parameter	Infrastructure Impacted		2080s Risk Rating	
	Component	**Sub-Component**	**2021 CCRA**	**2024 Update**
Precipitation Extremes	Structural Elements / Physical Infrastructure	Road Base and Subgrade	6	9
		Road Embankments	8	12
		Culverts	8	12
	Miscellaneous	Maintenance	8	12
Freeze-thaw Days	Structural Elements / Physical Infrastructure	Road Base and Subgrade	9	12
		Road Embankments	9	12
		Culverts	12	16
Wildfire	Structural Elements / Physical Infrastructure	Surface Drainage	N/A	10
		Culverts	N/A	10
	Miscellaneous	Emergency Response	N/A	15
		Administration / Personnel & Engineering	N/A	10
Wind	Miscellaneous	Maintenance	N/A	12
		Administration / Personnel & Engineering	N/A	8
Icing	Structural Elements / Physical Infrastructure	Culverts	N/A	12
	Miscellaneous	Maintenance	N/A	12
		Administration / Personnel & Engineering	N/A	8

Risk Classification	**Negligible/Low**	**Moderate**	**High**	**Extreme**

5 Adaptations Update

Adaptation considerations were developed for high and extreme risks identified in the CCRA. While many climate risks can be mitigated through Operations and Maintenance (O&M) policies and procedures, it is outside the scope of the CCRA to complete a detailed review of O&M policies for their effectiveness in reducing climate risks. Table 5-1 presents a 2080s Project risk profile with adaptation considerations for the additional climate parameters (wildfires, wind, and icing).

Adaptation considerations developed in the 2021 CCRA remain applicable and valid. Nevertheless, additional adaptation considerations were developed during the update and are presented in Table 5-2. Adaptation considerations presented in Table 5-2 are in addition to the considerations developed in the 2021 CCRA and should, therefore, be assessed together.

Table 5-1 2080s Project Risk Profile – Wildfire, Wind, and Icing Climate Parameters

Climate Parameter	Infrastructure Component Impacted	Description of Climate Interaction	2080s Probability Rating	Consequence Rating	2080s Risk Rating	Adaptation Considerations
Wildfire	Structural Elements / Physical Infrastructure: Surface Drainage	A loss of vegetation from wildfire could result in increased runoff and impacts on roadside drainage (e.g., increased volume exceeding design flow capacity of culverts) and roadside erosion. Wildfire occurrence may quicken and/or exacerbate permafrost thaw and its impacts on the roadway drainage system.	5	2	10	Routine inspection of roadway sections impacted by wildfire for erosion and undertake maintenance actions as necessary. Design and install permanent erosion control measures in areas anticipated to be suspectable to erosion.
	Structural Elements / Physical Infrastructure: Culverts		5	2	10	Consider runoff volumes with no vegetation present in design criteria decisions. Establish an O&M policy for regular inspection to confirm culverts are working effectively and maintaining drainage patterns.
	Miscellaneous: Emergency Response	Wildfires could result in road closures, adding to the wildfire related health & safety risks to road users and maintenance staff.	5	3	15	Work with communities in the region to establish evacuation plans which take into consideration the possibility of road closure. Establish O&M policies that include contingency plans for maintenance staff in the event of wildfire and road closure.
	Miscellaneous: Administration / Personnel & Engineering	Wildfires and related poor air quality could result in a health & safety risk to road users, maintenance staff, and other personnel.	5	2	10	Establish O&M policies for working in adverse conditions, including poor air quality and heat, and regular monitoring of wildfire activity in the region.

Climate Parameter	Infrastructure Component Impacted	Description of Climate Interaction	2080s Probability Rating	Consequence Rating	2080s Risk Rating	Adaptation Considerations
Wind	Miscellaneous: Maintenance	High winds could result in branches and windblown debris on the roadway, requiring increased maintenance to clear the road of potential obstacles. High winds may result in snow drifts which could results in additional maintenance and temporary road closure.	4	3	12	Complete a roadway patrol for and removal of branches and windblown debris following high wind events. Use the established public notification system to communicate with road users and report on maintenance activities. Establish snow clearing practices as part of O&M that provide adequate capacity for clearing snow drifts from the most impacted areas of the roadway.
	Miscellaneous: Administration / Personnel & Engineering	High winds could result in reduced air quality due to dust, creating a health & safety risk to road users, maintenance staff, and other personnel. High winds also present an operational hazard to large vehicles (e.g., potential for tipping over of tractor trailers).	4	2	8	Establish O&M policies for working in adverse conditions, including poor air quality. Monitor weather forecasts and apply dust control measures prior to high wind events to reduce airborne dust. Use the established public notification system to communicate with road users and report on weather conditions.
Icing (including icing due to freezing rain and/or aufeis [overflow])	Structural Elements / Physical Infrastructure: Culverts	Icing could result in ice buildup in culverts, requiring thawing by maintenance staff to restore full functionality.	4	3	12	Establish an O&M policy to inspect culverts and complete necessary thawing prior to spring thaw or cold season rainfall events.
	Miscellaneous: Maintenance	Icing of the road surface could result in increased maintenance (distribution of gravel and/or salt) to maintain road access.	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).

Climate Parameter	Infrastructure Component Impacted	Description of Climate Interaction	2080s Probability Rating	Consequence Rating	2080s Risk Rating	Adaptation Considerations
	Miscellaneous: Administration / Personnel & Engineering	Icing of the road surface and roadsides could result in a health & safety risk to road users, maintenance staff, and other personnel (e.g., increase potential for road accidents, slip-and-fall risk)	4	2	8	Use the established public notification system to communicate with road users and report on road conditions.

Risk Classification	Negligible/Low	Moderate	High	Extreme

Table 5-2 2080s Project Risk Profile – Additional Adaptation Considerations

Climate Parameter	Infrastructure Component Impacted	Description of Climate Interaction	2080s Probability Rating	Consequence Rating	2080s Risk Rating	Additional Adaptation Considerations
Mean Seasonal Temperatures	Structural Elements / Physical Infrastructure: Culverts	Increasing temperature would initiate snowmelt through either freshet or precipitation events. These events create fast flowing surface water and increase the potential erosion around culverts through the generation of fast flowing surface water.	5	4	20	Routine inspections for erosion and undertake maintenance actions as necessary. Design and install permanent erosion control measures in areas anticipated to be suspectable to erosion.
	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	Routine inspections for roadway damage and undertake maintenance actions as necessary
High Temperature Extremes (>30°C)	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	Where permafrost is present, 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.
	Miscellaneous: Emergency Response	Wildfires are also a public and maintenance staff safety risk and can result in road closures.	5	3	15	Work with communities in the region to establish evacuation plans which take into consideration the possibility of road closure. Establish O&M policies that include contingency plans for maintenance staff in the event of wildfire and road closure.

Climate Parameter	Infrastructure Component Impacted	Description of Climate Interaction	2080s Probability Rating	Consequence Rating	2080s Risk Rating	Additional Adaptation Considerations
Precipitation Extremes	Structural Elements / Physical Infrastructure: Road Embankments	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	Routine inspections for erosion and undertake maintenance actions as necessary. Design and install permanent erosion control measures in areas anticipated to be suspectable to erosion. Consider projected changes in precipitation (including short duration, high intensity rainfall events) in the sizing of culverts.
Freeze-Thaw Days	Structural Elements / Physical Infrastructure: Road Embankments	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	Routine inspections for erosion and undertake maintenance actions as necessary. Design and install permanent erosion control measures in areas anticipated to be suspectable to erosion.

Risk Classification	Negligible/Low	Moderate	High	Extreme

6 Limitations

This update to the Mackenzie Valley Highway Climate Change Resilience Assessment (CCRA) was conducted using the best information available to the assessment team at the time of the study. The climate data and trends (current and future projections) used in this study were obtained through various sources. Cross-verification between climate information sources was conducted where possible to identify potential discrepancies between the data sources used. Climate data is inherently uncertain. The climate parameter probabilities provided should be considered as high-level estimates of future conditions. The primary source of uncertainty in climate projections is the estimate of greenhouse gas emissions that will be observed over the current century. Additional sources of uncertainty include (but are not limited to) climate model parameterization, bias, and resolution.

The CCRA provides a broad system-level assessment of the Project assets. The risk assessment for future time horizons is based on the assumption that the vulnerability of infrastructure components is the same as in today's climate, i.e., the infrastructure is maintained in the same physical condition as at the time of the study, and that maintenance and operation policies and processes will not change in the future.

Climate hazards can cause situational/locational impacts outside the CCRA Project boundary and result in cascading impacts to the Project. Climate related event impacts to other regions outside the Mackenzie Valley Highway region could result in cascading impacts, including services provided by third parties (e.g., supply chain issues), and have significant impacts to the Project. The boundary limits for this CCRA focus on the FBC service area, assets, and services and has not assessed the risks associated with cascading climate events occurring outside of the immediate Project boundary.

7 Conclusion

This update to the 2021 Mackenzie Valley Highway Climate Change Resilience Assessment was completed by K'alo-Stantec to provide updated climate projections under the SSP5-8.5 emissions scenario, climate parameter probability ratings and associated risk ratings, and adaptation recommendations. This update also considered three additional climate parameters noted by the Mackenzie Valley Environmental Impact Review Board in Information Request 2. Additionally, Traditional Knowledge gathered through engagement with affected parties and Traditional Land and Resource Use studies was incorporated into the CCRA update.

The updated climate assessment resulted in a 2080s (1971-2100) probability rating increase for the precipitation extremes (short duration, high intensity precipitation) and freeze-thaw days climate parameters. While risk ratings subsequently increased, the majority of the 2021 CCRA and 2024 update risk ratings are classified as high risk. The 2080s risk to culverts associated with freeze-thaw days, however, did change from high risk to extreme risk with the updated climate assessment. Adaptation recommendations developed in the 2021 CCRA remain relevant for the risks associated with precipitation extremes and freeze-thaw days.

For the three additional climate parameters – wildfire, wind, and icing – high risks were identified associated with maintenance of the roadway (e.g., increased maintenance necessary) and health & safety hazards to maintenance staff, road users, and other personnel (e.g., poor air quality associated with wildfires and airborne dust due to high winds). High risks were also identified for surface drainage and culverts in association with wildfires (impacts related to increased runoff due to loss of vegetation) and for culverts in association with icing (impacts related to ice buildup in the culverts requiring melting by maintenance staff). Adaptation recommendations for the three additional climate parameters include the following:

- Routine inspection of roadway for erosion and undertake maintenance actions as necessary.
- Design and install permanent erosion control measures in areas anticipated to be suspectable to erosion.
- Work with communities in the region to establish evacuation plans which take into consideration the possibility of road closure due to climate and weather-related events.
- Establish O&M policies for working in adverse conditions and include contingency plans in the event of wildfire and/or road closure.
- Continue to use the established public notification system to communicate with road users and report on maintenance activities, road conditions, and weather conditions.

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Appendix A Climate Profile for the Mackenzie Valley Highway Project – Updated for 2024 CCRA Addendum

Climate Profile for the Mackenzie Valley Highway Project – 2024 CCRA Addendum

Prepared for:

Government of the Northwest Territories Department of Infrastructure

Prepared by:

K'alo-Stantec Limited

June 19, 2024

Project No.: 123514886

K'alo-Stantec

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1 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 (e.g., a 30-year period or longer[1]). Climate profiles are important tools that describe what climate trends have been occurring in recent history, and also describe future climate conditions to help inform planners, stakeholders and decision makers in managing the climate change risks and planning for appropriate adaptation measures. 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: the performance of the infrastructure from the past can be compared to both historical and future climate to better understand what (if any) adaptation measures should be implemented to ensure better performance in the future.

When developing a profile of the historic climate, meteorological data from a recent 30-year period (e.g., 1981-2010 or 1991-2020) is preferred to provide a representative estimate of the recent climate at a given location – though longer periods are of 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. For locations that do not have good coverage from weather stations (e.g., remote locations), or when completing a regional scale assessment, gridded data products are also used. Natural Resources Canada (NRCan) has produced the NRCANmet gridded dataset, which includes daily maximum and minimum temperature and total precipitation data on a ~10 km grid resolution over Canada for the 1950-2017 time period (Hopkinson et al., 2011; McKenney et al., 2011). The NRCANmet data is interpolated from quality-controlled but unadjusted station data from the National Climate Data Archive of Environment and Climate Change Canada and is widely used by industry and researchers (Hutchinson et al., 2009). Although observational data from a weather station is preferable, gridded datasets such as NRCANmet are well accepted and researched and can provide reasonable approximations for locations when historic data is not inadequate for climate assessment.

Climate projections are descriptions of plausible future climate, dependent on assumptions about future economic, social, technological, and environmental conditions which will drive greenhouse gas concentrations in the atmosphere. Climate models are the primary tools used to develop three-dimensional climate projections. Since 1995, the Coupled Model Intercomparison Project (CMIP)[2] has coordinated the international design and distribution of global climate model (GCM) simulations of past, present, and future climate. It is not recommended to rely only on one or two of these GCMs to estimate future climate. Instead, an average of several GCMs (i.e., a multi-model ensemble) tends to give a more reliable estimate of future climate (Cannon et al., 2020; IPCC, 2021). Additionally, the use of a multi-

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[1] A timespan of 30 years is the classical period for defining climate, as established by the World Meteorological Organization (WMO). Calculating climate over a 30-year period removes short-term variability, e.g., year-to-year weather variability, and reveals long-term averages, trends, variability, and other statistical values, often referred to as the climate signal.

[2] https://www.wcrp-climate.org/wgcm-cmip

model ensemble provides information on the range of model output (inter-model spread) and, therefore, insight into inter-model uncertainty. Most recently, GCMs have contributed to CMIP Phase 6 (CMIP6; Eyring et al., 2016), which forms the basis of the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6; IPCC 2021). Previous to this, a similar set of GCMs contributed to CMIP Phase 5 (CMIP5; Taylor et al., 2012), which formed the basis of the IPCC Fifth Assessment Report (AR5; IPCC, 2013). CMIP model performances have undergone evaluation and validation, both individually and collectively (IPCC, 2013). When possible, model evaluations are completed by comparing model output with observations and analyzing the resulting difference. In cases when observations are not available or insufficient, model evaluations are completed through intercomparison of model results, providing quantification of model uncertainty via inter-model spread.

Downscaling methods are often used to produce finer spatial resolution projections from GCMs. Approximately 35 Global Climate Models (GCMs) have contributed to CMIP6. The Pacific Climate Impacts Consortium (PCIC)[3] uses a subset of 26 of these models to produce reliable, high-resolution (~10 km) downscaled climate projections localized to specific areas of interest in Canada, referred to as the Canadian Downscaled Climate Scenarios – Univariate (CMIP6) (CanDCS-U6) (Cannon, 2015; Cannon et al., 2015). PCIC-downscaled CMIP6 climate projections are the primary source of climate projections data for this climate profile and CCRA for the Mackenzie Valley Highway. For climate hazards with limited or no CMIP6 SSP-derived climate projections available, CMIP Phase 5 (CMIP5) RCP-driven projections and specialized studies/scientific literature were utilized. CMIP5 projections form the basis of the IPCC's Fifth Assessment Report publications and a subset of 27 of the CMIP5 GCMs have been downscaled by PCIC, referred to as Canadian Downscaled Climate Scenarios – Univariate (CMIP5) (CanDCS-U5). For both CanDCS-U5 and CanDCS-U6, PCIC produced the downscaled projections for the simulated period of 1950-2100 using the hybrid Bias Correction/Constructed Analogues with Quantile delta mapping reordering, version 2, or BCCAQv2, downscaling method (Cannon, 2015; Cannon et al., 2015).

Actual climate conditions in the future will depend on the concentration of greenhouse gases (GHGs) in the atmosphere. Across multiple iterations of IPCC assessments, various scenarios have been developed to estimate GHG trajectories (emissions- or concentrations-driven) into the future, with focus on anthropogenic emissions. While these GHG scenarios provide a range of plausible futures for anthropogenic emissions, the exact rate of change and eventual concentrations in year 2100 (and beyond) can never be precisely predicted. As such, a large source of uncertainty in all future climate projections is based in the future trajectory of global GHG emissions as controlled by societal actions. The IPCC's Fifth Assessment Report (IPCC, 2013) presented climate change assessments using Representative Concentration Pathway (RCP) scenarios (van Vuuren et al., 2011)[4]. There are four RCP scenarios which were adopted by the IPCC for its Fifth Assessment Report, ranging from low emissions (RCP2.6) to moderate emissions (RCP4.5 and RCP6.0) to high emissions.

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[3] https://www.pacificclimate.org/

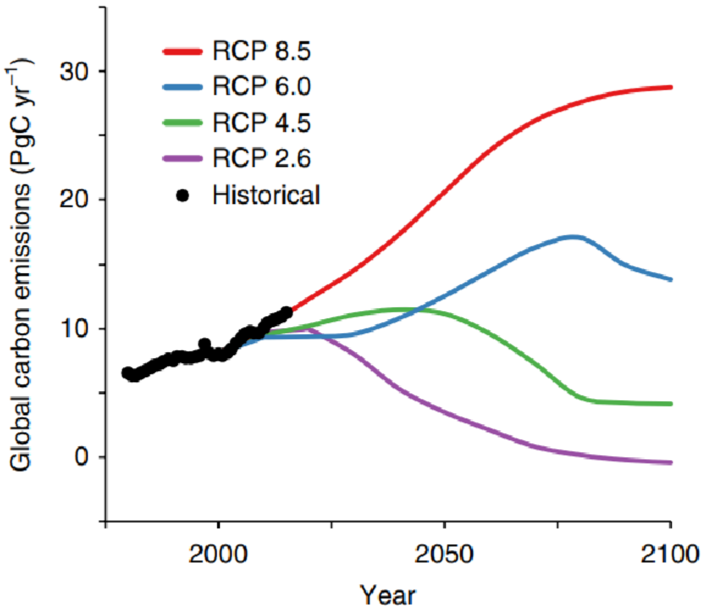
[4] RCP: Representative Concentration Pathways – a greenhouse gas concentration (not emissions) trajectories adopted by the Intergovernmental Panel on Climate Change (IPCC) for its fifth Assessment Report (AR5) in 2013/2014.

(RCP8.5) trajectories. The IPCC's Sixth Assessment Report (IPCC, 2021) presents the latest global and regional assessments of climate change and its impacts using a set of five new illustrative emissions scenarios, referred to as Shared Socioeconomic Pathways (SSPs; Riahi et al., 2016). There are five SSP scenarios which were adopted by the IPCC for its Sixth Assessment Report, ranging from very low emissions (SSP1-1.9) to low emissions (SSP1-2.6) to intermediate emission (SSP2-4.5) to high emissions (SSP3-7.0) to very high emissions (SSP5-8.5). The SSP5-8.5 trajectory more closely aligns with historical and current emissions and represents a plausible emissions track into the future (Figure 1) (Smith and Myers, 2018; Pedersen et al., 2020; Schwalm et al., 2020). While recent studies (Hausfather and Peters, 2020) suggest that the higher emissions scenarios (e.g., SSP5-8.5) may have become less likely due to technological developments and emerging climate policies, the higher emissions scenarios remain plausible trajectories and provide insight into "high-end" risks of climate change (IPCC, 2022). The SSP5-8.5 very high emissions scenario was therefore recommended for use in the CCRA to present a conservatively high estimate of projected climate change and its associated impacts in the climate assessment.

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 1 Historical CO2 emissions for 1980-2017 and projected emissions trajectories until 2100 for the four RCP scenarios (Figure from Smith and Myers, 2018)



1.1.1 Levels of Confidence in Projections

Future climate conditions for the 2020s (2011-2040), 2050s (2041-2070), and 2080s (2071-2100) under the SSP5-8.5 emissions scenarios were retrieved from climate projections produced with the downscaled Global Climate Models (GCMs), as well as from specialized literature, and professional judgement of Stantec's climate scientists. Some climate variables can be projected into the future with more confidence than others. The level of confidence in climate projections is dependent on the understanding of the processes involved in the climate phenomena, ability of climate models to simulate the phenomena, the degree of agreement among the climate models (e.g., range of uncertainty), and the supporting evidence (e.g., theory, specialized literature, expert judgement). In general, projections based on Global Climate Models (GCMs) and downscaling of such models are considered:

- Adequate (high confidence) for general temperature and precipitation projections,
- Less adequate (moderate confidence) for extreme parameters, and
- Inadequate for combined events (low confidence) such as wildfires.

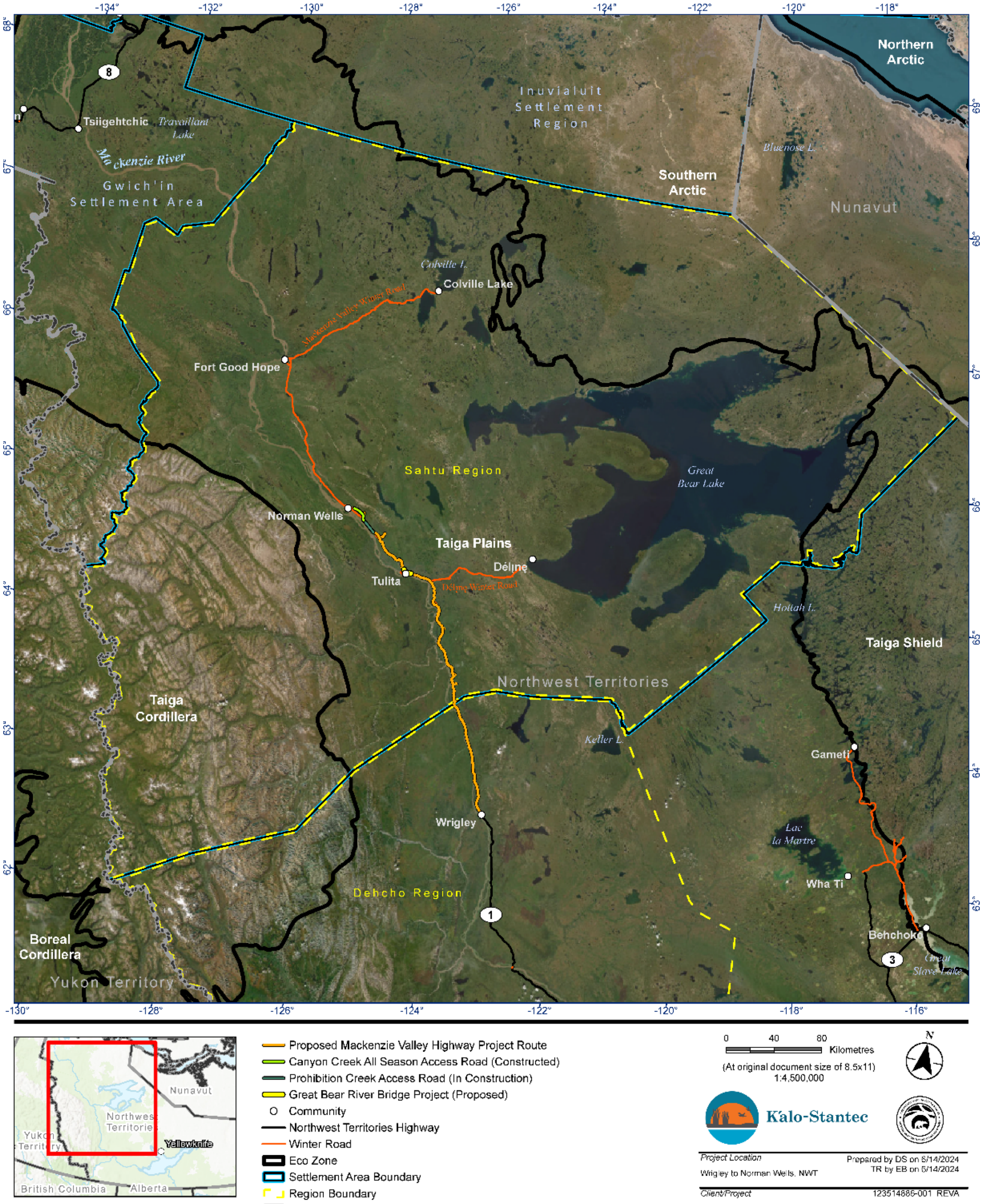
Combined or complex climate variables are normally inferred from other climate variables and result in lower confidence for projections. For example, wildfire is a complex process and the occurrence of wildfires depends on numerous variables, including temperature and precipitation (which influence moisture/dryness conditions), ignition sources (including lightning/atmospheric discharge activity), fuel characteristics, and fire management actions. As a result, the projected changes in wildfire activity under future climate conditions is not as well understood as other variables such as temperature. Confidence may also refer to whether other specialized studies have been done for the climate events projections in the geographical area of interest.

Despite low levels of confidence in some climate projection values, the general projected trend in frequency can provide valuable information for planning purposes (e.g., adaptation strategies). For climate variables with low confidence levels in the projections, additional studies (e.g., sensitivity analyses) can provide further insight into the potential impacts of climate change on infrastructure reliability in different warming and load combination scenarios.

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 (Figure 2). A review of available historical observation data identified various weather stations throughout the region with data archived by Environment and Climate Change Canada (ECCC). Many of these stations, however, either are no longer in operation or have short records and, as such, 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 1). 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 also shown in Table 1. 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 from the proposed terminus of the highway (~180 km to the southeast). The further away Fort Simpson A station was selected over the closer Wrigley A weather station due to the Wrigley A weather station’s poor record, 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.

Figure 2 Mackenzie Valley Highway Project Overview and Eco Zones



Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT. Government of Canada, Stantec
3. Background: World Imagery: Earthstar Geographics
World Topographic Map: Esri, TomTom, FAO. NOAA. USGS, NRCan
World Hillshade: Esri, USGS
Imagery dates: 2015 - 2020

Project Location
Wrigley to Norman Wells, NWT

Prepared by DS on 6/14/2024
TR by EB on 6/14/2024

Client/Project
123514886-001 REVA
Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
2

Title
Mackenzie Valley Highway Project Overview and Eco Zones

Table 1 Observation Stations in the Study Region

Climate Zone	Observation Station Name (Station ID)	Latitude	Longitude	Daily Data Record Coverage (Length in yrs)
Norman Wells – Tulita	Norman Wells A* (ID: 2202800/2202801)	65.2813 N	-126.7986 W	1943-2024 (82)
	Norman Wells Climate▲ (ID: 2202810)	65.2875 N	-126.7534 W	1974-2021 (42)
	Tulita A (ID: 2201700/2201705)	64.9097 N	-125.5694 W	1903-2024 (122)
Wrigley – Fort Simpson	Wrigley A (ID: 2204000/2204005)	63.2094 N	-123.4366 W	1943-2024 (82)
	Fort Simpson A* (ID: 2202101/2202103/2202104)	61.7602 N	-121.2366 W	1963-2024 (62)
	Fort Simpson Climate▲ (ID: 2202102)	61.7603 N	-121.2367 W	1969-2021 (46)

Notes:

* Selected station to represent the respective climate zone

▲ Station with available Intensity-Duration-Frequency (IDF) rainfall data for the respective climate zone; Record range and length in years reflects IDF data availability

In order to characterize the general differences among the two climate zones, below are general comparisons of 1981-2010 Climate Normals values between weather stations available among each climate zone with sufficient data for analysis (where available).

Table 2 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	-2.8
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[5]. This climate profile presents projected climate information for three time horizons: the 2020s (2011 to 2040), the 2050s (2041 to 2070), and the 2080s (2071 to 2100).

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[5] When the 2021 Climate Change Resilience Assessment (CCRA) was completed, 1991-2020 Climate Normals were not available from ECCC and, therefore, the 1981-2010 Climate Normals were used to estimate baseline climate. The scope of the 2024 CCRA update did not include updating the baseline climate period.

Generally, 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 the longer-term climate projections to help inform infrastructure design and adaptation planning.

Climate parameters presented in this climate profile align with the climate parameters assessed for the Climate Change Resilience Assessment. Additional climate-adjusted design criteria which may be of interest for the Mackenzie Valley Highway Project are also available through PCIC's Design Value Explorer (https://pacificclimate.org/analysis-tools/design-value-explorer). The Design Value Explorer provides climate-adjusted design data relevant to the National Building Code of Canada (NBCC 2015) and the Canadian Highway Bridge Design Code (CHBDC/CSA S6 2014). Climate parameters included in the Design Value Explore include hourly design temperatures (e.g., January 2.5% dry bulb), annual maximum 1-day 50-yr return period rainfall, intensity-duration-frequency (IDF) rainfall data, and annual maximum hourly wind pressures (10- and 50-yr return periods). Additional information and details on the methodology used to develop climate-adjusted design data are presented in Cannon et al. 2020.

2 Temperature

2.1 Mean Temperature

Table 3 Projected Average Annual Mean Temperature and Change from Baseline under SSP5-8.5

Time Period	Climate Zone (Station Name; ID)	1981-2010 Baseline (°C)	Projected Annual Mean Temperature* (Change from 1981-2010 Baseline [50th percentile]; 10th percentile, 90th percentile) (°C)		
			2020s	2050s	2080s
Annual	Norman Wells A (ID: 2202800)	-5.1	-3.4 (+1.7; +1.6, +1.9)	-1.0 (+4.1; +3.5, +4.8)	1.8 (+6.9; +6.0, +8.7)
	Fort Simpson A (ID: 2202104)	-2.8	-1.1 (+1.7; +1.4, +1.9)	1.1 (+3.9; +3.3, +4.6)	3.7 (+6.5; +5.7, +8.2)
Winter	Norman Wells A (ID: 2202800)	-24.5	-22.4 (+2.1; +2.0, +2.1)	-19.2 (+5.3; +4.6, +5.8)	-15.4 (+9.1; +8.3, +10.9)
	Fort Simpson A (ID: 2202104)	-22.2	-20.3 (+1.9; +1.9, +2.1)	-17.2 (+5.0; +4.3, +5.2)	-13.8 (+8.4; +7.8, +9.9)
Spring	Norman Wells A (ID: 2202800)	-5.7	-4.2 (+1.5; +1.4, +1.9)	-1.9 (+3.8; +3.4, +4.2)	0.9 (+6.6; +6.0, +7.4)
	Fort Simpson A (ID: 2202104)	-1.6	-0.1 (+1.5; +1.4, +1.6)	1.9 (+3.5; +3.0, +3.8)	4.4 (+6.0; +5.4, +6.6)
Summer	Norman Wells A (ID: 2202800)	15.3	16.7 (+1.4; +1.1, +1.6)	18.5 (+3.2; +2.6, +3.9)	20.8 (+5.5; +4.3, +7.2)
	Fort Simpson A (ID: 2202104)	15.8	17.1 (+1.3; +1.2, +1.7)	19.0 (+3.2; +2.7, +4.1)	21.5 (+5.7; +4.4, +7.5)
Fall	Norman Wells A (ID: 2202800)	-5.6	-3.7 (+1.9; +1.9, +1.9)	-1.4 (+4.2; +4.1, +4.5)	1.0 (+6.6; +6.4, +8.1)
	Fort Simpson A (ID: 2202104)	-3.1	-1.3 (+1.8; +1.7, +1.9)	0.8 (+3.9; +3.7, +4.5)	3.2 (+6.3; +6.0, +7.8)

*Multi-model ensemble average of the CanDCS-U6 downscaled climate projections

2.2 Maximum Temperature

2.2.1 Annual and Seasonal Average

Table 4 Projected Average Annual Maximum Temperature and Change from Baseline under SSP5-8.5

Time Period	Climate Zone (Station Name; ID)	1981-2010 Baseline (°C)	Projected Annual Maximum Temperature* (Change from 1981-2010 Baseline [50th percentile]; 10th percentile, 90th percentile) (°C)		
			2020s	2050s	2080s
Annual	Norman Wells A (ID: 2202800)	-0.4	1.2 (+1.6; +1.5, +1.8)	3.5 (+3.9; +3.4, +4.4)	6.2 (+6.6; +5.6, +8.0)
	Fort Simpson A (ID: 2202104)	2.7	4.3 (+1.6; +1.4, +1.8)	6.3 (+3.6; +3.2, +4.3)	8.9 (+6.2; +5.3, +7.7)
Winter	Norman Wells A (ID: 2202800)	-20.4	-18.6 (+1.8; +1.8, +2.0)	-15.6 (+4.8; +4.4, +5.0)	-12.0 (+8.4; +7.9, +9.6)
	Fort Simpson A (ID: 2202104)	-17.5	-15.7 (+1.8; +1.8, +1.8)	-12.9 (+4.6; +4.1, +4.6)	-9.6 (+7.9; +7.2, +8.7)
Spring	Norman Wells A (ID: 2202800)	0.2	1.6 (+1.4; +1.3, +1.8)	3.7 (+3.5; +3.1, +3.9)	6.3 (+6.1; +5.5, +6.7)
	Fort Simpson A (ID: 2202104)	4.8	6.2 (+1.4; +1.4, +1.5)	8.0 (+3.2; +2.8, +3.5)	10.3 (+5.5; +4.9, +6.1)
Summer	Norman Wells A (ID: 2202800)	20.7	22.0 (+1.3; +1.1, +1.7)	23.9 (+3.2; +2.5, +4.0)	26.3 (+5.6; +4.1, +7.4)
	Fort Simpson A (ID: 2202104)	22.1	23.5 (+1.4; +1.3, +1.9)	25.4 (+3.3; +2.6, +4.3)	27.9 (+5.8; +4.2, +7.8)
Fall	Norman Wells A (ID: 2202800)	-1.9	-0.2 (+1.7; +1.7, +1.8)	2.0 (+3.9; +3.9, +4.1)	4.4 (+6.3; +6.1, +7.2)
	Fort Simpson A (ID: 2202104)	1.3	3.0 (+1.7; +1.6, +1.7)	5.0 (+3.7; +3.6, +4.2)	7.3 (+6.0; +5.5, +7.2)

*Multi-model ensemble average of the CanDCS-U6 downscaled climate projections

2.2.2 Extreme Maximum Temperature Frequency

It can also be 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 in Table 5.

Table 5 Annual Occurrence of Maximum Daily Temperatures > 30°C: Historic (1981-2010) and Projected under SSP5-8.5

Climate Zone (Station Name)	Annual Occurrence of Days with Max. Temp > 30°C (days/year)* 50th percentile (10th percentile, 90th percentile)			
	1981-2010	2020s	2050s	2080s
Norman Wells-Tulita (Norman Wells A)	2.1	4.5 (2.2, 7.7)	11.3 (3.9, 22.0)	24.2 (8.6, 47.0)
Wrigley-Fort Simpson (Fort Simpson A)	4.2	7.8 (4.8, 12.1)	17.7 (8.3, 30.5)	35.4 (14.4, 60.6)

*Multi-model ensemble average of the CanDCS-U6 downscaled climate projections

2.3 Minimum Temperature

2.3.1 Annual and Seasonal Average

Table 6 Projected Average Annual Minimum Temperature and Change from Baseline under SSP5-8.5

Time Period	Climate Zone (Station Name; ID)	1981-2010 Baseline (°C)	Projected Annual Minimum Temperature* (Change from 1981-2010 Baseline [50th percentile]; 10th percentile, 90th percentile) (°C)		
			2020s	**2050s**	**2080s**
Annual	Norman Wells A (ID: 2202800)	-9.9	-8.1 (+1.8; +1.6, +2.1)	-5.6 (+4.3; +3.7, +5.3)	-2.7 (+7.2; +6.3, +9.6)
	Fort Simpson A (ID: 2202104)	-8.2	-6.5 (+1.7; +1.4, +2.0)	-4.2 (+4.0; +3.5, +4.9)	-1.4 (+6.8; +6.0, +8.8)
Winter	Norman Wells A (ID: 2202800)	-28.5	-26.3 (+2.2; +2.2, +2.4)	-23.0 (+5.5; +4.8, +6.2)	-18.7 (+9.8; +8.7, +11.9)
	Fort Simpson A (ID: 2202104)	-26.8	-24.9 (+1.9; +1.9, +2.3)	-21.6 (+5.2; +4.6, +5.6)	-17.8 (+9.0; +8.2, +10.8)
Spring	Norman Wells A (ID: 2202800)	-11.6	-10.0 (+1.6; +1.4, +2.1)	-7.5 (+4.1; +3.5, +4.8)	-4.7 (+6.9; +6.3, +8.3)
	Fort Simpson A (ID: 2202104)	-8.1	-6.6 (+1.5; +1.4, +1.8)	-4.3 (+3.8; +3.2, +4.1)	-1.7 (+6.4; +5.7, +7.2)
Summer	Norman Wells A (ID: 2202800)	9.7	11.1 (+1.4; +1.1, +1.6)	12.9 (+3.2; +2.7, +3.8)	15.2 (+5.5; +4.5, +7.0)
	Fort Simpson A (ID: 2202104)	9.5	10.8 (+1.3; +1.1, +1.6)	12.7 (+3.2; +2.8, +3.9)	15.1 (+5.6; +4.6, +7.1)
Fall	Norman Wells A (ID: 2202800)	-9.3	-7.4 (+1.9; +1.9, +2.1)	-4.9 (+4.4; +4.3, +5.0)	-2.4 (+6.9; +6.8, +9.0)
	Fort Simpson A (ID: 2202104)	-7.6	-5.8 (+1.8; +1.8, +2.0)	-3.5 (+4.1; +3.9, +4.8)	-1.1 (+6.5; +6.3, +8.4)

*Multi-model ensemble average of the CanDCS-U6 downscaled climate projections

2.3.2 Extreme Minimum Temperature Frequency

It can also be 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 in Table 7.

Table 7 Occurrence of Minimum Daily Temperatures < -30°C: Historic (1981-2010) and Projected under SSP5-8.5

Climate Zone Station Name)	**Annual Occurrence of Days with Min. Temp < -30°C (days/year)* 50th percentile (10th percentile, 90th percentile)**			
	1981-2010	**2020s**	**2050s**	**2080s**
Norman Wells-Tulita (Norman Wells A)	51.0	37.6 (38.6, 37.0)	21.2 (25.1, 21.8)	7.0 (17.7, 4.4)
Wrigley-Fort Simpson (Fort Simpson A)	37.5	27.2 (27.8, 27.2)	14.4 (18.1, 13.8)	2.9 (12.7, 0.0)

*Multi-model ensemble average of the CanCDS-U6 downscaled climate projections

3 Precipitation

3.1 Total Annual & Seasonal Accumulation

Table 8 Projected Average Total Precipitation and Change from Baseline under SSP5-8.5

Time Period	Climate Zone (Station Name; ID)	1981-2010 Baseline (°C)	Projected Total Precipitation (mm)* (Change from 1981-2010 Baseline (%) [50th percentile]; 10th percentile, 90th percentile)		
			2020s	2050s	2080s
Annual	Norman Wells A (ID: 2202800)	294.4	322.8 (+9.6%; +9.6%, +11.8%)	355.2 (+20.7%; +19.2%, +24.0%)	400.5 (+36.0%; +34.1%, +44.4%)
	Fort Simpson A (ID: 2202104)	387.6	415.7 (+7.3%; +5.1%, +7.6%)	452.8 (+16.8%; +16.6%, +17.2%)	486.8 (+25.6%; +24.1%, +30.4%)
Winter	Norman Wells A (ID: 2202800)	48.7	54.9 (+12.8%; +9.1%, +12.8%)	58.9 (+21.0%; +17.5%, +21.0%)	65.8 (+35.1%; +26.8%, +37.8%)
	Fort Simpson A (ID: 2202104)	55.6	59.0 (+6.1%; +6.1%, +8.1%)	64.1 (+15.3%; +11.8%, +18.0%)	67.8 (+22.0%; +20.6%, +27.1%)
Spring	Norman Wells A (ID: 2202800)	40.8	43.2 (+6.0%; +3.1%, +10.7%)	48.6 (+19.1%; +14.8%, +25.5%)	54.7 (+34.1%; +25.4%, +42.0%)
	Fort Simpson A (ID: 2202104)	61.8	64.2 (+3.8%; +2.3%, +6.4%)	71.8 (+16.2%; +13.9%, +20.6%)	78.2 (+26.6%; +22.8%, +31.9%)
Summer	Norman Wells A (ID: 2202800)	126.3	133.7 (+5.9%; +2.7%, +7.9%)	143.1 (+13.3%; +11.8%, +17.3%)	153.3 (+21.4%; +16.2%, +26.8%)
	Fort Simpson A (ID: 2202104)	173.8	179.6 (+3.3%; +0.5%, +5.9%)	186.6 (+7.4%; +7.4%, +14.5%)	187.4 (+7.8%; +4.6%, +20.3%)
Fall	Norman Wells A (ID: 2202800)	78.5	87.6 (+11.7%; +9.4%, +11.7%)	94.8 (+20.8%; +14.4%, +24.0%)	111.3 (+41.7%; +34.4%, +43.2%)
	Fort Simpson A (ID: 2202104)	96.4	104.3 (+8.2%; +8.1%, +11.7%)	118.2 (+22.6%; +21.3%, +22.6%)	131.4 (+36.3%; +36.2%, +39.5%)

*Multi-model ensemble average of the CanDCS-U6 downscaled climate projections

3.2 Intensity-Duration-Frequency (IDF)

In the following subsections, total precipitation amount (mm) in 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 intensity-duration-frequency (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.

Historical IDF data generated by Environment and Climate Change Canada (ECCC) from the Norman Wells Climate (Station ID: 2202810) and Fort Simpson Climate (Station ID: 2202102) weather stations are used. ECCC derives IDF curves from rate-of-rainfall observations by fitting a Gumbel extreme value distribution to the annual maximum series of each rainfall duration. Extreme value distributions are theoretical statistical descriptions of the probability of extreme events.

To prepare projected IDF data for future climate, the Canadian Standards Association's (CSA) Rainfall Intensity-Duration-Frequency Guide (CSA PLUS 4013:19) and ECCC both recommend (Cannon et al., 2020) using the Clausius-Clapeyron relation method for estimating projected changes to short duration storm events. The Clausius-Clapeyron relation is founded on the atmospheric physics theoretical relationship between air temperature and the amount of water the air could potentially contain, otherwise known as its holding capacity. The Clausius-Clapeyron relation indicates that there is an average of 7% increase in the air's holding capacity per 1°C of local warming. Therefore, when using the Clausius-Clapeyron relation method, rainfall intensity projections are calculated using temperature scaling where, for every 1°C increase in temperature, rainfall intensity increase by 7%; Projected rainfall intensity (Rp) is calculated as follows:

$$R_p = R_c \; x \; (CC_{adj})^{\Delta T}$$

where Rc is the current (historical) rainfall intensity or IDF value, CCadj is the rainfall intensity vs. temperature relationship adjustment factor, and ∆T is the projected change in local temperature. When using the general recommendation of 7% per 1°C warming, CCadj = 1.07 and the equation becomes Rp = Rc x 1.07T. Rainfall vs. temperature relationships close to the Clausius-Clapeyron relation have been detected globally and regionally in observational studies (Westra et al., 2013; Panthou et al., 2014; Prein et al., 2016; Barbero et al., 2017). IDF projections for this assessment therefore follow the Clausius-Clapeyron relation method. In addition to the IDF projections presented below, IDF projections are also available through PCIC's Design Value Explorer[6].

It is recognized that extreme weather events, such as convective heavy rainfall, are often very localized, so it is possible the weather stations used in this analysis may not have captured or may not provide representative measurement of the intensity of some of these extreme rainfall events. This uncertainty is considered by the CCRA methodology during the analysis.

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[6] https://services.pacificclimate.org/design-value-explorer/?dv=IDFCF

3.2.1 Norman Wells – Tulita Climate Zone

For the Norman Wells-Tulita climate zone, historical IDF data from the Norman Wells Climate weather station (ID: 2202810), with 42 years of data spanning from 1974 to 2021, is used. Historical and projected total precipitation amount (mm) in specific time interval (5 minutes to 24 hours) for various return periods (2 years to 100 years) are provided below. Under the SSP5-8.5 scenario, short-duration, high intensity precipitation events are projected to increase 12.2% for the 2020s, 32.0% for the 2050s, and 59.5% for the 2080s, relative to the historical data.

Table 9 Historical Precipitation Event Accumulation IDF data (mm) – Norman Wells Climate (Station ID: 2202810), 1974-2021

T (years)	2	5	10	25	50	100
5 min	3.0	4.7	5.8	7.2	8.3	9.3
10 min	4.3	6.7	8.3	10.3	11.8	13.3
15 min	5.1	7.9	9.8	12.2	13.9	15.6
30 min	6.7	10.4	12.9	16.0	18.3	20.6
1 h	8.8	13.4	16.4	20.2	23.0	25.8
2 h	11.4	16.1	19.2	23.1	26.1	29.0
6 h	16.3	21.6	25.1	29.6	32.9	36.1
12 h	19.6	26.2	30.6	36.1	40.1	44.2
24 h	23.8	34.2	41.0	49.7	56.2	62.6

Table 10 Projected Precipitation Event Accumulation IDF data (mm), Norman Wells Climate (Station ID: 2202810), SSP5-8.5, 2020s

T (years)	2	5	10	25	50	100
5 min	3.4	5.3	6.5	8.1	9.3	10.4
10 min	4.8	7.5	9.3	11.6	13.2	14.9
15 min	5.7	8.9	11.0	13.7	15.6	17.5
30 min	7.5	11.7	14.5	18.0	20.5	23.1
1 h	9.9	15.0	18.4	22.7	25.8	28.9
2 h	12.8	18.1	21.5	25.9	29.3	32.5
6 h	18.3	24.2	28.2	33.2	36.9	40.5
12 h	22.0	29.4	34.3	40.5	45.0	49.6
24 h	26.7	38.4	46.0	55.8	63.1	70.2

Note: IDF projections calculated using the Clausius-Clapeyron relation, using a 7% increase per 1°C of local warming and change in temperature of 1.7°C for the 2020s

Table 11 Projected Precipitation Event Accumulation IDF data (mm), Norman Wells Climate (Station ID: 2202810), SSP5-8.5, 2050s

T (years)	2	5	10	25	50	100
5 min	4.0	6.2	7.7	9.5	11.0	12.3
10 min	5.7	8.8	11.0	13.6	15.6	17.6
15 min	6.7	10.4	12.9	16.1	18.3	20.6
30 min	8.8	13.7	17.0	21.1	24.2	27.2
1 h	11.6	17.7	21.6	26.7	30.4	34.0
2 h	15.0	21.2	25.3	30.5	34.4	38.3
6 h	21.5	28.5	33.1	39.1	43.4	47.6
12 h	25.9	34.6	40.4	47.6	52.9	58.3
24 h	31.4	45.1	54.1	65.6	74.2	82.6

Note: IDF projections calculated using the Clausius-Clapeyron relation, using a 7% increase per 1°C of local warming and change in temperature of 4.1°C for the 2050s

Table 12 Projected Precipitation Event Accumulation IDF data (mm), Norman Wells Climate (Station ID: 2202810), SSP5-8.5, 2080s

T (years)	2	5	10	25	50	100
5 min	4.8	7.5	9.3	11.5	13.2	14.8
10 min	6.9	10.7	13.2	16.4	18.8	21.2
15 min	8.1	12.6	15.6	19.5	22.2	24.9
30 min	10.7	16.6	20.6	25.5	29.2	32.9
1 h	14.0	21.4	26.2	32.2	36.7	41.1
2 h	18.2	25.7	30.6	36.8	41.6	46.3
6 h	26.0	34.5	40.0	47.2	52.5	57.6
12 h	31.3	41.8	48.8	57.6	64.0	70.5
24 h	38.0	54.5	65.4	79.3	89.6	99.8

Note: IDF projections calculated using the Clausius-Clapeyron relation, using a 7% increase per 1°C of local warming and change in temperature of 6.9°C for the 2080s

3.2.2 Wrigley – Fort Simpson Climate Zone

For the Wrigley-Fort Simpson climate zone, historical IDF data from the Fort Simpson Climate weather station (ID: 2202102), with 46 years of data spanning from 1969 to 2021, is used. Historical and projected total precipitation amount (mm) in specific time interval (5 minutes to 24 hours) for various return periods (2 years to 100 years) are provided below. Under the SSP5-8.5 scenario, short-duration, high intensity precipitation events are projected to increase 12.2% for the 2020s, 30.2% for the 2050s, and 55.2% for the 2080s, relative to the historical data.

Table 13 Historical Precipitation Event Accumulation IDF data (mm) – Fort Simpson Climate (Station ID: 2202102), 1969-2021

T (years)	2	5	10	25	50	100
5 min	4.5	6.8	8.3	10.2	11.6	13.0
10 min	6.5	10.2	12.6	15.6	17.9	20.2
15 min	8.0	12.5	15.5	19.3	22.2	25.0
30 min	10.0	15.5	19.1	23.6	27.0	30.4
1 h	11.9	17.7	21.5	26.3	29.9	33.4
2 h	14.7	20.5	24.4	29.3	32.9	36.5
6 h	21.3	28.1	32.6	38.3	42.5	46.7
12 h	26.6	35.1	40.7	47.9	53.1	58.4
24 h	33.7	46.3	54.6	65.1	72.9	80.7

Table 14 Projected Precipitation Event Accumulation IDF data (mm), Fort Simpson Climate (Station ID: 2202102), SSP5-8.5, 2020s

T (years)	2	5	10	25	50	100
5 min	5.0	7.6	9.3	11.4	13.0	14.6
10 min	7.3	11.4	14.1	17.5	20.1	22.7
15 min	9.0	14.0	17.4	21.7	24.9	28.0
30 min	11.2	17.4	21.4	26.5	30.3	34.1
1 h	13.4	19.9	24.1	29.5	33.5	37.5
2 h	16.5	23.0	27.4	32.9	36.9	40.9
6 h	23.9	31.5	36.6	43.0	47.7	52.4
12 h	29.8	39.4	45.7	53.7	59.6	65.5
24 h	37.8	51.9	61.3	73.0	81.8	90.5

Note: IDF projections calculated using the Clausius-Clapeyron relation, using a 7% increase per 1°C of local warming and change in temperature of 1.7°C for the 2020s

Table 15 **Projected Precipitation Event Accumulation IDF data (mm), Fort Simpson Climate (Station ID: 2202102), SSP5-8.5, 2050s**

T (years)	2	5	10	25	50	100
5 min	5.9	8.9	10.8	13.3	15.1	16.9
10 min	8.5	13.3	16.4	20.3	23.3	26.3
15 min	10.4	16.3	20.2	25.1	28.9	32.5
30 min	13.0	20.2	24.9	30.7	35.2	39.6
1 h	15.5	23.0	28.0	34.2	38.9	43.5
2 h	19.1	26.7	31.8	38.1	42.8	47.5
6 h	27.7	36.6	42.4	49.9	55.3	60.8
12 h	34.6	45.7	53.0	62.4	69.1	76.0
24 h	43.9	60.3	71.1	84.8	94.9	105.1

Note: IDF projections calculated using the Clausius-Clapeyron relation, using a 7% increase per 1°C of local warming and change in temperature of 3.9°C for the 2050s

Table 16 **Projected Precipitation Event Accumulation IDF data (mm), Fort Simpson Climate (Station ID: 2202102), SSP5-8.5, 2080s**

T (years)	2	5	10	25	50	100
5 min	7.0	10.6	12.9	15.8	18.0	20.2
10 min	10.1	15.8	19.6	24.2	27.8	31.4
15 min	12.4	19.4	24.1	30.0	34.5	38.8
30 min	15.5	24.1	29.7	36.6	41.9	47.2
1 h	18.5	27.5	33.4	40.8	46.4	51.8
2 h	22.8	31.8	37.9	45.5	51.1	56.7
6 h	33.1	43.6	50.6	59.5	66.0	72.5
12 h	41.3	54.5	63.2	74.4	82.4	90.7
24 h	52.3	71.9	84.8	101.1	113.2	125.3

Note: IDF projections calculated using the Clausius-Clapeyron relation, using a 7% increase per 1°C of local warming and change in temperature of 6.5°C for the 2080s

3.3 1-, 3-, and 5-Day Accumulation

Table 17 Record Maximum 1-, 3-, and 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	85.8	June 30, 1988
	3-day	127.9	July 2, 1988
	5-day	132.4	July 2, 1988

1-day (24 hour) accumulation projections are provided in the Intensity-Duration-Frequency (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. Since climate model grid box precipitation projections are usually interpreted as spatially averaged values, the outputs tend to reduce extreme precipitation magnitudes (Chen and Knutson, 2008; Seneviratne et al., 2012), contributing to the systematic underestimation of precipitation. Nevertheless, considering the Clausius-Clapeyron relation, it is probable an increasing trend in precipitation accumulation would extend to longer rainfall duration events.

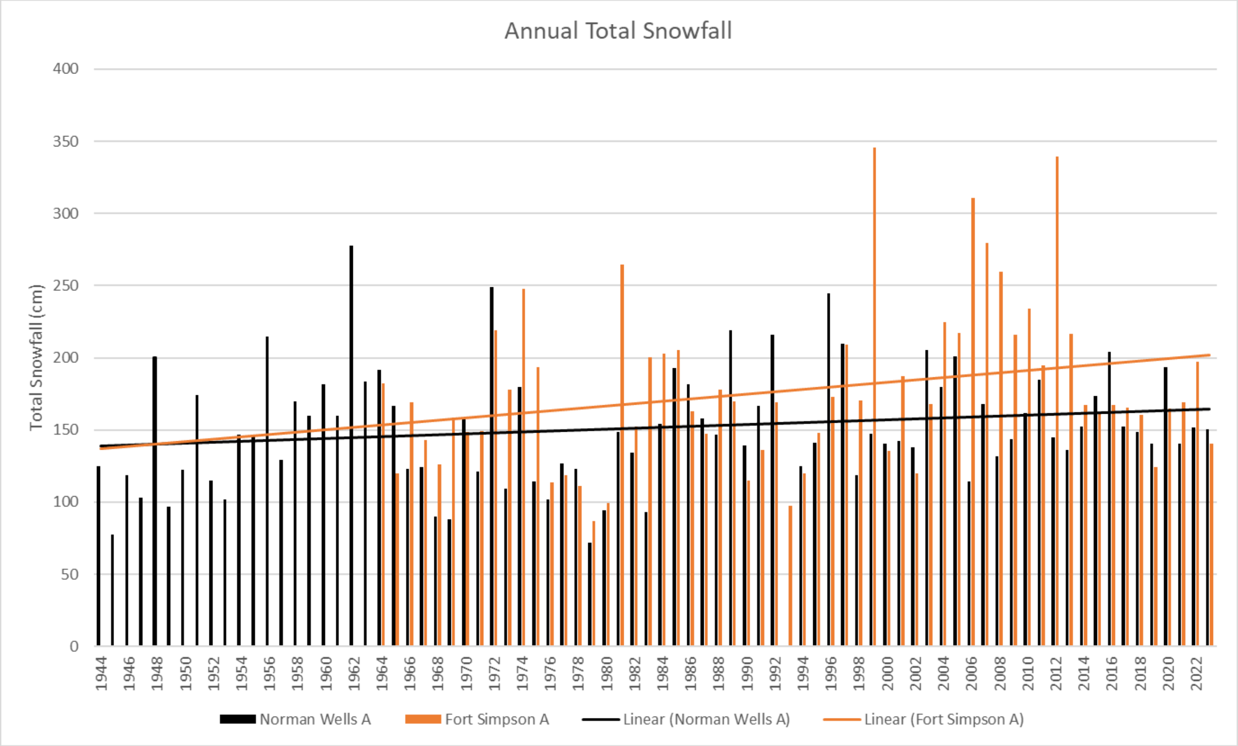
3.4 Snowfall

Total annual snowfall is presented in Figure 3 for historical periods at Norman Wells A from 1944 to 2023 and at Fort Simpson A from 1964 to 2023. The average annual total snowfall for the 1981-2010 time period was 161.5 cm for Norman Wells A and 187.0 cm for Fort Simpson A. Historical trends in precipitation falling as snow are generally observed to increase in this area, especially for Fort Simpson

A. 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.

It should be noted that Figure 3 presents snowfall data as calculated from the in-situ weather station records. Changes in weather station instrumentation, measurement methodologies (e.g., manual observation vs. automated precipitation gauges), and/or location can result in inhomogeneities (non climatic shifts) which can influence precipitation trends. The number of stations with homogenized precipitation data has been decreasing in Canada (Mekis et al., 2018; Wan et al., 2023) and the homogenized data records for Norman Wells and Fort Simpson do not include recent years (e.g., 2018 to present). ECCC and its partners have noted that “extensive data integration” is required to account for the implementation of automated precipitation gauges into long-term historical records[7]. As such, there is lower confidence in the snowfall trends presented in Figure 3.

Figure 3 **Annual Total Snowfall for Norman Wells A and Fort Simpson A for available data between 1944 to 2023 and 1964 to 2023, respectively**



Under a warming climate, the snow cover duration (i.e., the period of the year with snow cover) will reduce, with reduced snow cover particularly during the spring and fall transition seasons (Figure 4) (Mudryk et al., 2018; CCCR, 2019). Small changes in snow accumulation are projected for northern regions of Canada, with no significant change in average annual maximum snow water equivalent (SWE)[8] in the Mackenzie Valley Highway region through mid-century under the RCP8.5 emission scenario (Figure 5) (Mudryk et al., 2018; CCCR, 2019). A decrease of approximately 10 to 20% in annual SWE, however, is projected by the end of the century under the RCP8.5 emissions scenario (Shi and Wang, 2015).

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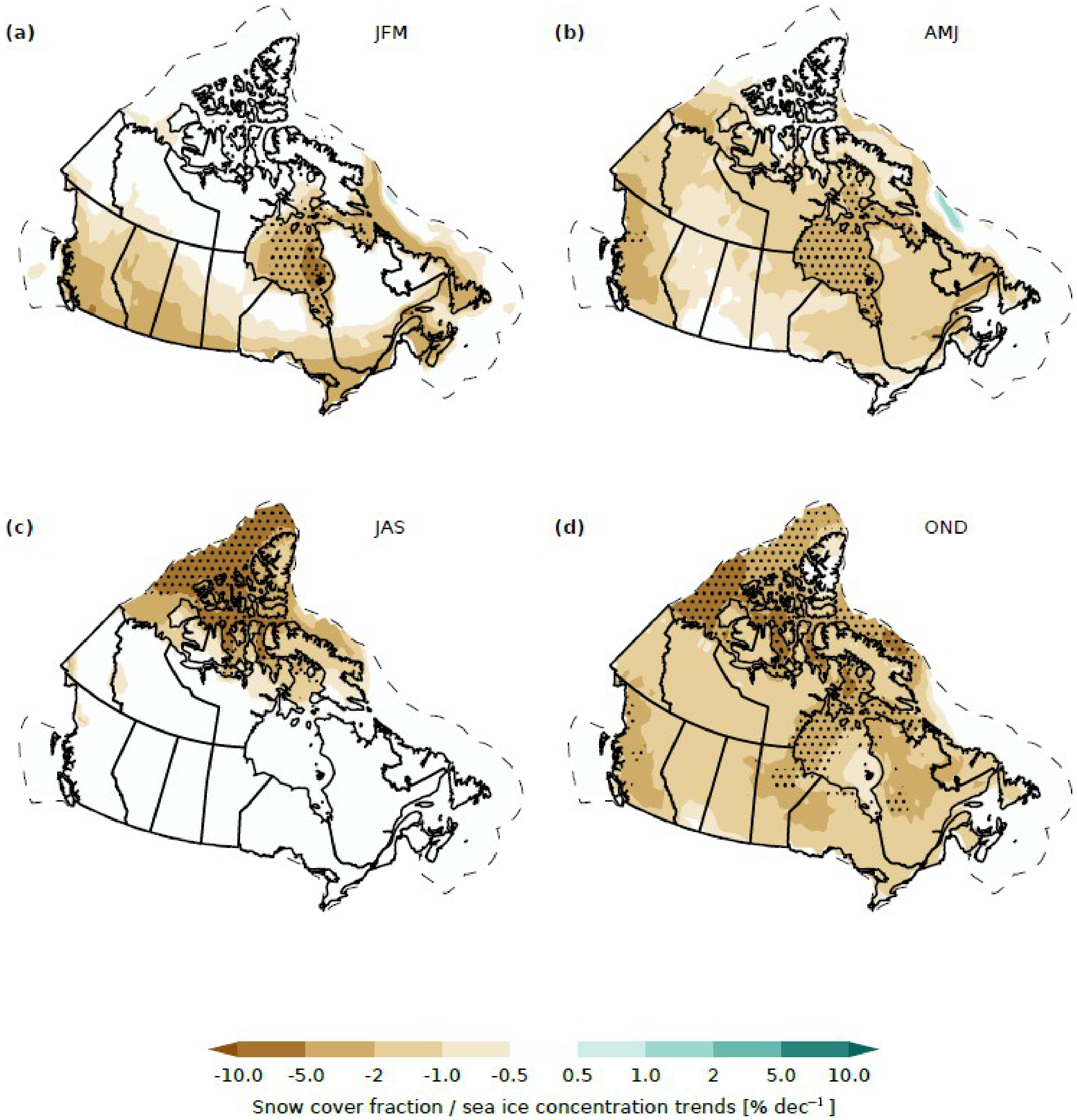
[7] https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/climate-trends-variability/trends-variations.html

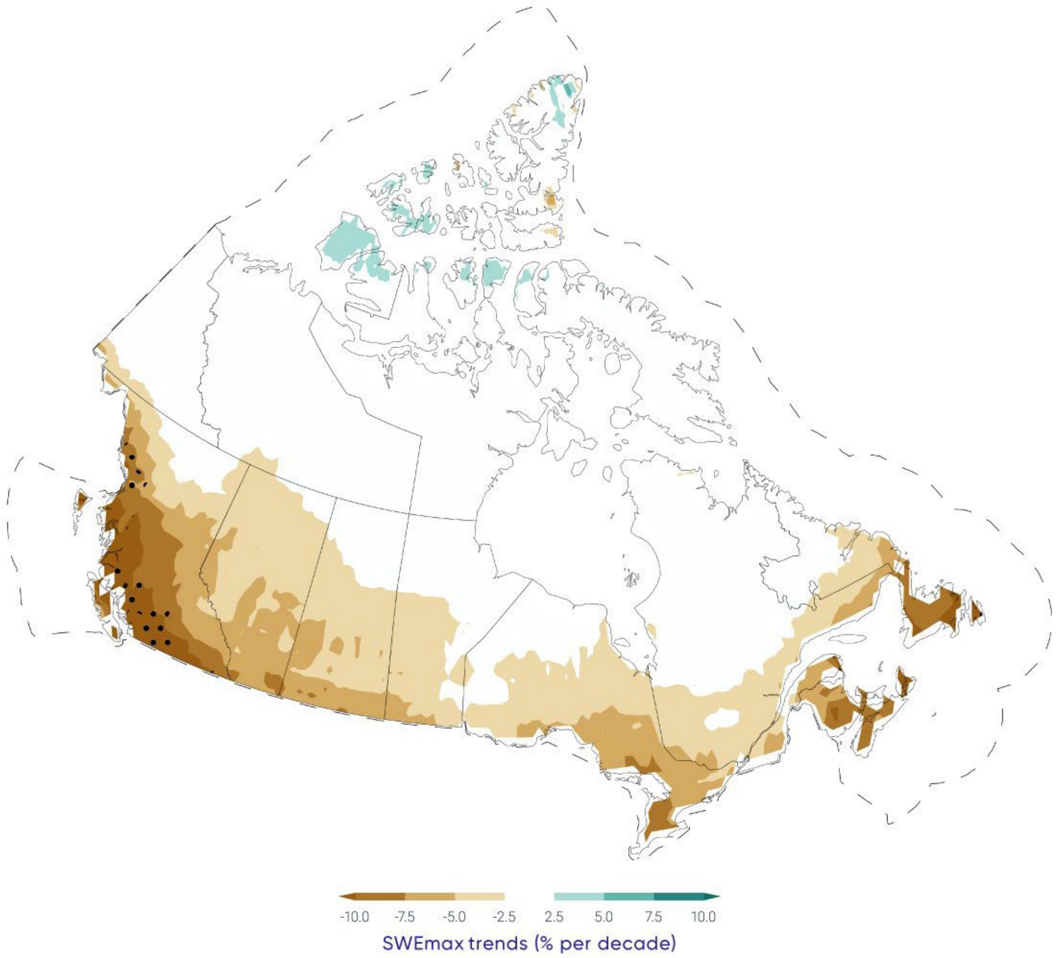
[8] Seasonal maximum snow water equivalent (SWE) represents the seasonally accumulated snow available for spring melt.

Figure 4 **Projected snow cover fraction and sea ice concentration trends for 2020-2050 (Figure source: Mudryk et al., 2018)**



Stippling indicates statistical significance at the 90th percentile.

Figure 5 **Projected trends in maximum snow water equivalent (SWE) for 2020-2050 under the RCP8.5 emissions scenario (Figure source: Mudryk et al., 2018)**



Stippling indicates statistical significance at the 90th percentile.

3.5 Dry Spells

Dry spell is 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 6. It should be noted that there may be more than one dry spell of significant length in a given year but Figure 6 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. Norman Wells' average annual maximum dry spell appears to be stable historically while Fort Simpson is slightly decreasing.

Nonetheless, average maximum dry spell length for the region is generally stable historically. Projected average annual maximum number of consecutive dry days (i.e., average annual longest dry spell duration) are presented in Table 18. The length of the maximum dry spell for both locations is projected to slightly decrease under climate change. The projections for dry spell duration are not made with the same level of confidence as other climate variables in this report.

Figure 6 Maximum Annual Dry Spells, Norman Wells A and Form Simpson A, 1943-2023

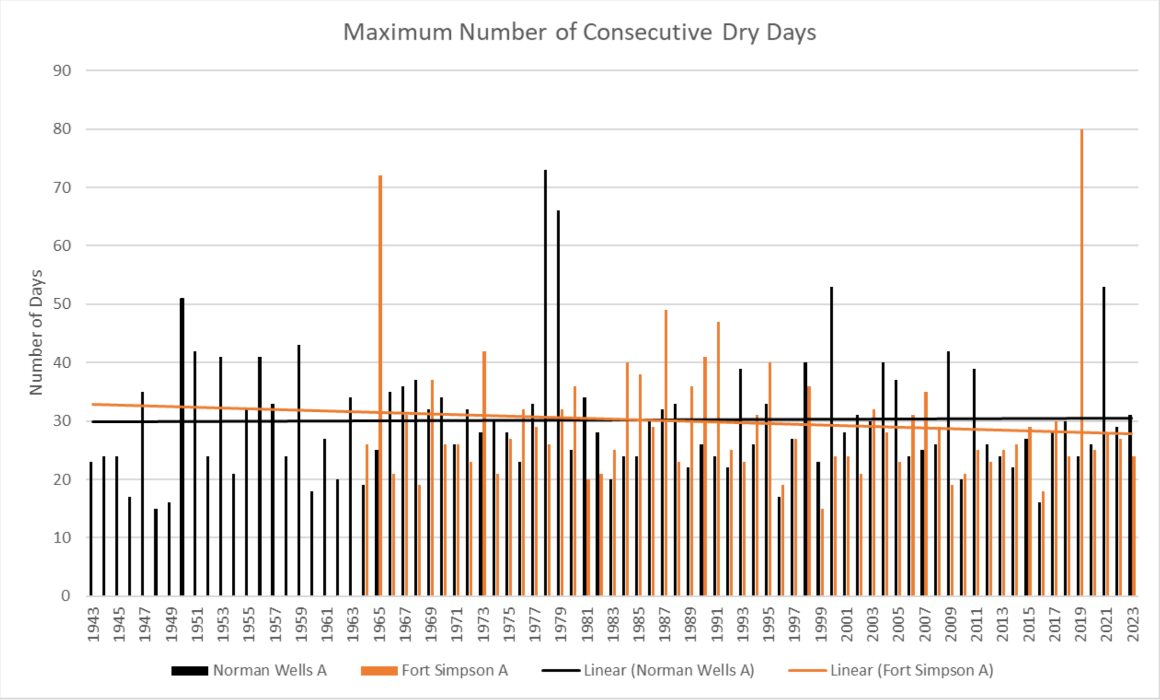


Table 18 Average Annual Maximum Number of Consecutive Dry Days: Historical (1981-2010) and Projected under SSP5-8.5

Climate Zone (Station Name)	Average Annual Maximum Number of Consecutive Dry Days			
	1981-2010	2020s	2050s	2080s
Norman Wells-Tulita (Norman Wells A)	29.3	27.8	27.7	25.2
Wrigley-Fort Simpson (Fort Simpson A)	29.0	28.5	27.6	26.8

4 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 19 Average Annual Number of Frost Days: Historical (1981-2010) and Projected under SSP5-8.5

	Average Annual Number of Frost Days			
Climate Zone	**1981-2010**	**2020s**	**2050s**	**2080s**
Norman Wells-Tulita	240.0	229.0	217.4	202.9
Wrigley-Fort Simpson	224.7	213.5	199.3	185.3

5 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 in Table 20.

Table 20 Annual Freeze-Thaw Cycles: Historical (1981-2010) and Projected under SSP5-8.5

Climate Zone (Station Name)	Average Annual Freeze-Thaw Cycles (Days with Maximum Temperature > 0°C and Minimum Temperature ≤-1°C)			
	1981-2010	2020s	2050s	2080s
Norman Wells-Tulita (Norman Wells A)	43.8	41.7	37.9	36.7
Wrigley-Fort Simpson (Fort Simpson A)	57.1	51.8	47.1	44.7

While the projected overall decrease in the annual number of freeze-thaw cycles, the number of freeze-thaw cycles during the colder months is projected to increase. For example, winter season (December-January-February) average number of freeze-thaw cycles projections are presented in Table 21. With warmer winter conditions projected under climate change, temperature fluctuations around 0°C are projected to become more common during the colder months.

Table 21 Winter Season Freeze-Thaw Cycles: Historical (1981-2010) and Projected under SSP5-8.5

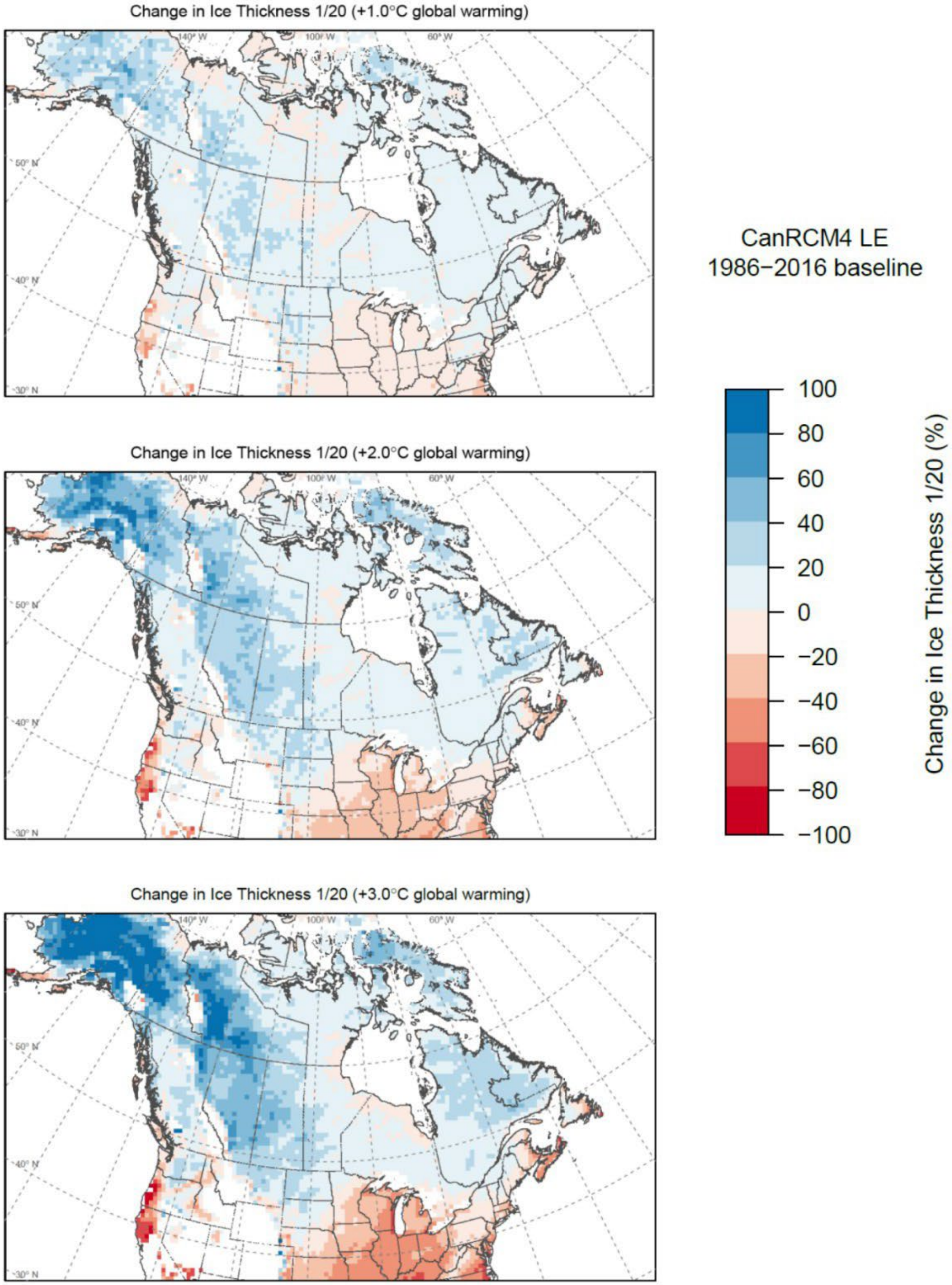
Climate Zone (Station Name)	Average Number of Winter Season* Freeze-Thaw Cycles (Days with Maximum Temperature > 0°C and Minimum Temperature ≤-1°C)			
	1981-2010	2020s	2050s	2080s
Norman Wells-Tulita (Norman Wells A)	~0	0.2	0.6	1.2
Wrigley-Fort Simpson (Fort Simpson A)	1.4	1.7	2.1	3.0

Note:
* Winter season is defined as December-January-February

6 Ice Accretion

Ice accretion loads are specified in the Canadian Highway Bridge Design Code (CHBDC/CSA S6 2014, Annex A3.1) and are mainly the result of freezing rain events across Canada. In the Mackenzie Valley Highways region, freezing rain events are historically short-duration events, with an average of up to ~3 to 4 hours annually of freezing rain, occurring typically in the fall, winter, or spring (Kochtubajda et al., 2017; Mekis et al., 2020). Under a warming climate, the average annual number of hours of freezing rain and resulting ice thickness are projected to increase. Under a +3°C global warming scenario, the average annual number of hours of freezing rain is projected to increase by approximately 5 to 10 hours per year (McCray et al., 2022) and the 1-in-20-year ice thickness is projected to increase by 60-100% (Cannon et al., 2020). Figure 7 shows the projected changes in the 1-in-20-year ice accretion load when compared to the 1986-2016 baseline for the +1.0°C, +2.0°C and +3.0°C global warming levels. Under the RCP8.5 scenario, +1.0°C global warming is projected to be reached by 2035, +2.0°C global warming is projected to be reached by 2059, and +3.0°C global warming is projected to be reached by 2080. In general, the duration and intensity of freezing rain events are projected to increase for the Mackenzie Valley Highway region under a warming climate. It should be noted, however, freezing rain projections have significant uncertainty.

Figure 7 **CanRCM4 LE projected changes to ice accretion loads (20-year return period) for three global warming levels (Figure source: Cannon et al., 2020)**



Under the RCP8.5 scenario, +1.0°C global warming is projected to be reached by 2035, +2.0°C global warming is projected to be reached by 2059, and +3.0°C global warming is projected to be reached by 2080.

7 Wind

Wind data is available from the Norman Wells A and Fort Simpson A weather stations from the early 1960s through 2024. The wind data records are sporadic earlier in the records and then with increasing data frequency in the second half of the record. Historical maximum wind speed and maximum gust records at the Norman Wells A and Fort Simpson A weather stations are presented in Table 22 and Table 23, respectively.

The available wind data from the Norman Wells A and Fort Simpson A weather stations is used to generate windroses[9] for this climate profile. Wind data from the three Norman Wells A stations and the two Fort Simpson A stations were merged, respectively, to generate the windroses. The following windroses contain some amount of missing information as direction information was not recorded when wind gusts were less than 31 km/h; These points were excluded from the plots. The figures below display daily maximum gust wind speed and direction observed at the Norman Wells A station (Figure 8 and Figure 9) and Fort Simpson A station (Figure 10 and Figure 11) annually and seasonally. It should be noted that wind regimes are influenced by topography and, therefore, can vary within a region. For example, wind direction is predominately west-northwest or east-southeast in Norman Wells, which has higher terrain to the northeast and southwest, while north-northeast winds are also commonly observed in Tulita (Fort Norman Airport, ~80 km southeast of Norman Wells), which does not have higher terrain to the northeast.

For the Climate Change Resilience Assessment, high winds (i.e. wind gusts) were considered to account for potential impacts on roadway maintenance and possible temporary road closures (e.g., windblown tree branches and other debris, snow drifts) as well as potential impacts on staff and road users (e.g., reduced air quality due to blowing dust, reduced visibility due to blowing dust or snow, potential for tipping over of tractor trailers). Wind pressure climate-adjusted design criteria may also be of interest to the Mackenzie Valley Highway Project and are available through PCIC's Design Value Explorer[10].

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[9] Windroses show the distribution of wind direction (direct 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, such as those presented in this profile, can also provide information on the wind speeds observed from each direction.

[10] Annual maximum wind pressure 10-yr return period data: https://services.pacificclimate.org/design-value-explorer/?dv=WP10
Annual maximum wind pressure 50-yr return period data: https://services.pacificclimate.org/design-value-explorer/?dv=WP50

Table 22 Canadian Climate Normals, Wind, Norman Wells A Station (source: Environment and Climate Change Canada, 1981-2010 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
Record Length Assessed	1981-2010		1953-2010			1958-2010			1981-2010	1981-2010

Table 23 Canadian Climate Normals, Wind, Fort Simpson A Station (source: Environment and Climate Change Canada, 1981-2010 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
Record Length Assessed	1981-2010		1963-2010			1963-2009			1981-2010	1981-2010

Figure 8 Daily Maximum Wind Gust Speed and Direction from 1958-2024 Observed at the Norman Wells A (Station ID: 2202800 and 2202801)

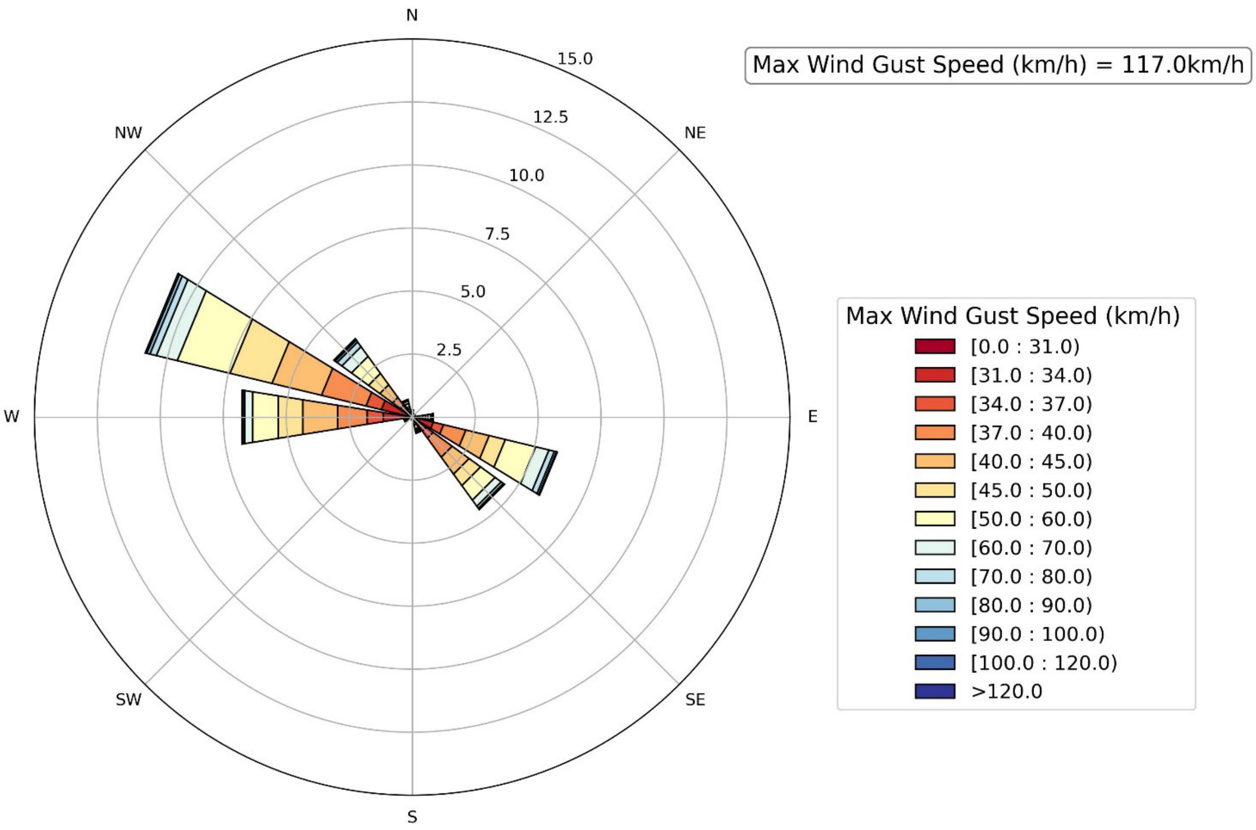


Figure 9 Seasonal Daily Maximum Wind Gust Speed and Direction From 1958-2024 Observed at the Norman Wells A

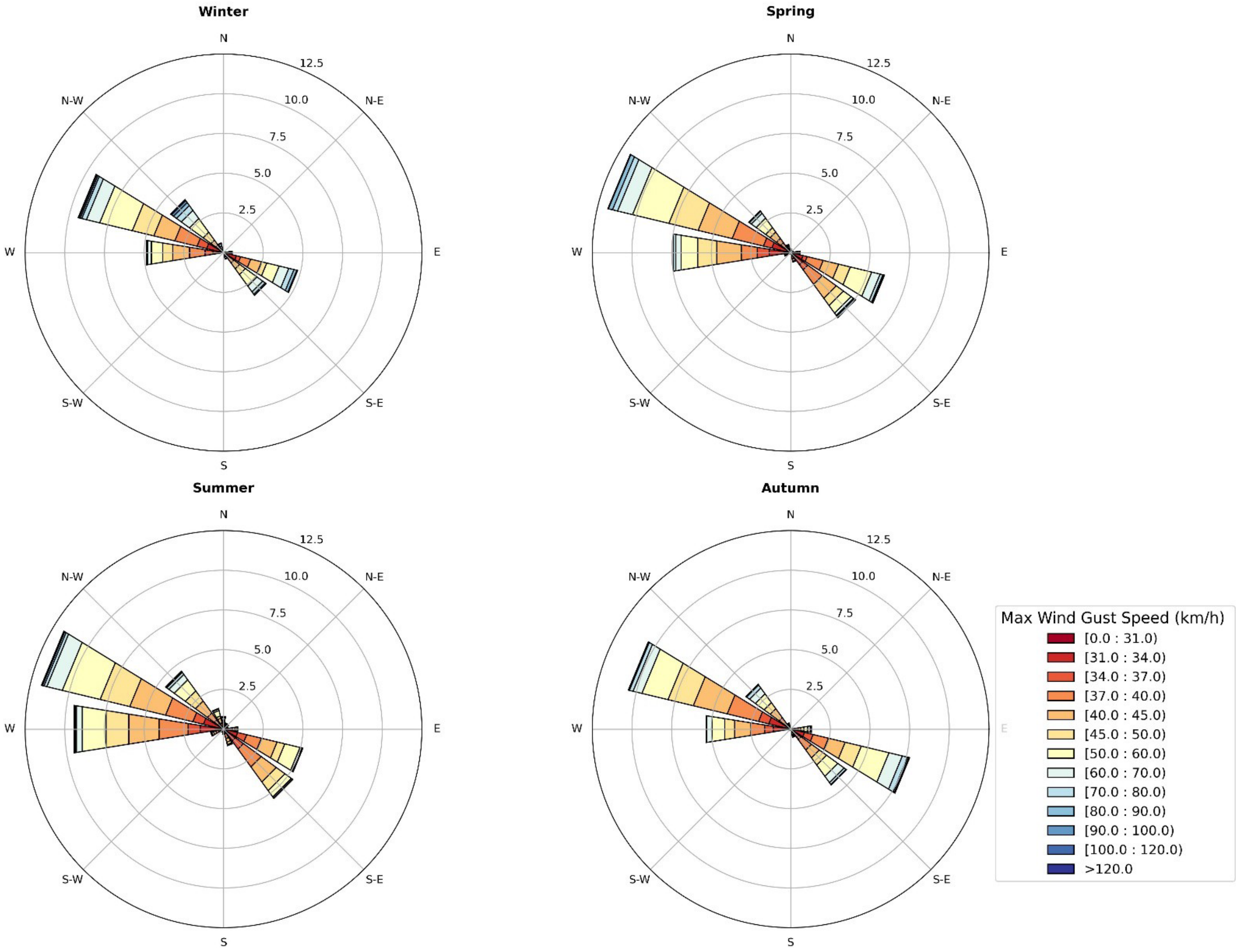


Figure 10 Daily Maximum Wind Gust Speed and Direction From 1963-2024 Observed at the Fort Simpson A (Station ID: 2202101 and 2202103)

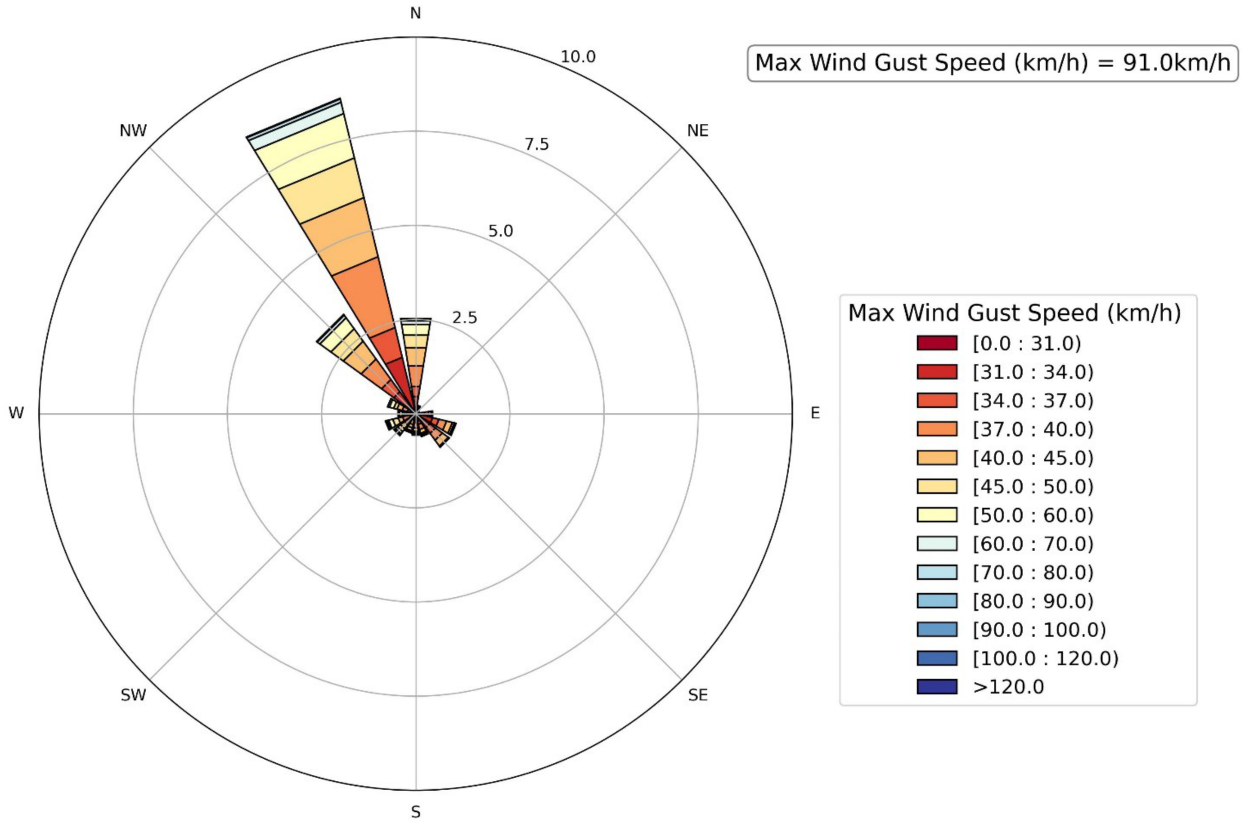
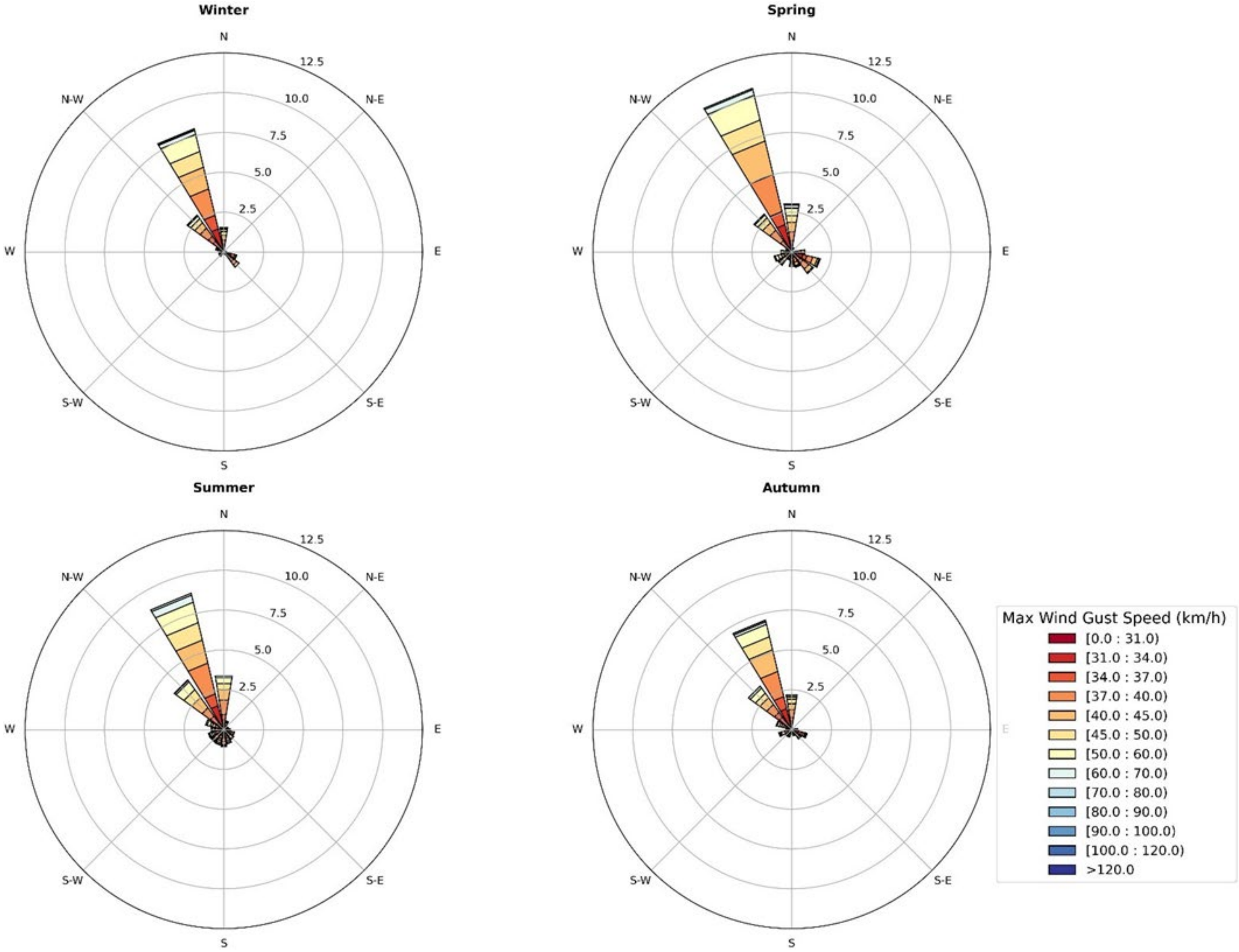


Figure 11 Seasonal Daily Maximum Wind Gust Speed and Direction From 1963-2024 Observed at the Fort Simpson A



The projected changes in wind frequency and intensity have considerable uncertainty compared to other climate variables such as average temperature. However, some general trends have been estimated from specialized research. For example, an analysis of 57 years (1953-2009) of wind gusts at 104 weather stations across Canada indicated that for every 1°C increase in the daily temperature anomaly, the speed of daily wind gust events (≥ 50 km/hr) increased by more than 0.2 km/hr over most regions in Canada (Cheng, 2014). Chang et al. (2014) provides projected percentage changes in the frequency of future daily wind gust events of ≥ 50 km/hr and ≥ 90 km/hr under the SRES A2 scenario (roughly corresponds with RCP8.5 and SSP5-8.5). Cheng et al. (2014) provides regional projections, with Norman Wells located in region N2 and Fort Simpson located in region W1 (Figure 12). Table 24 presents the projected changes for the N2 and W1 regions. Cheng et al. (2014) also indicate that, for the Northwest Territories, the largest projected percentage increases in future daily wind gusts events are expected to occur in the summer (June-July-August) season, suggesting potentially more localized convective windstorms due to warming temperatures.

Figure 12 **Wind Gust Regions and Selected Stations Utilized in Cheng et al., 2014 (Figure Source: Cheng et al., 2014)**

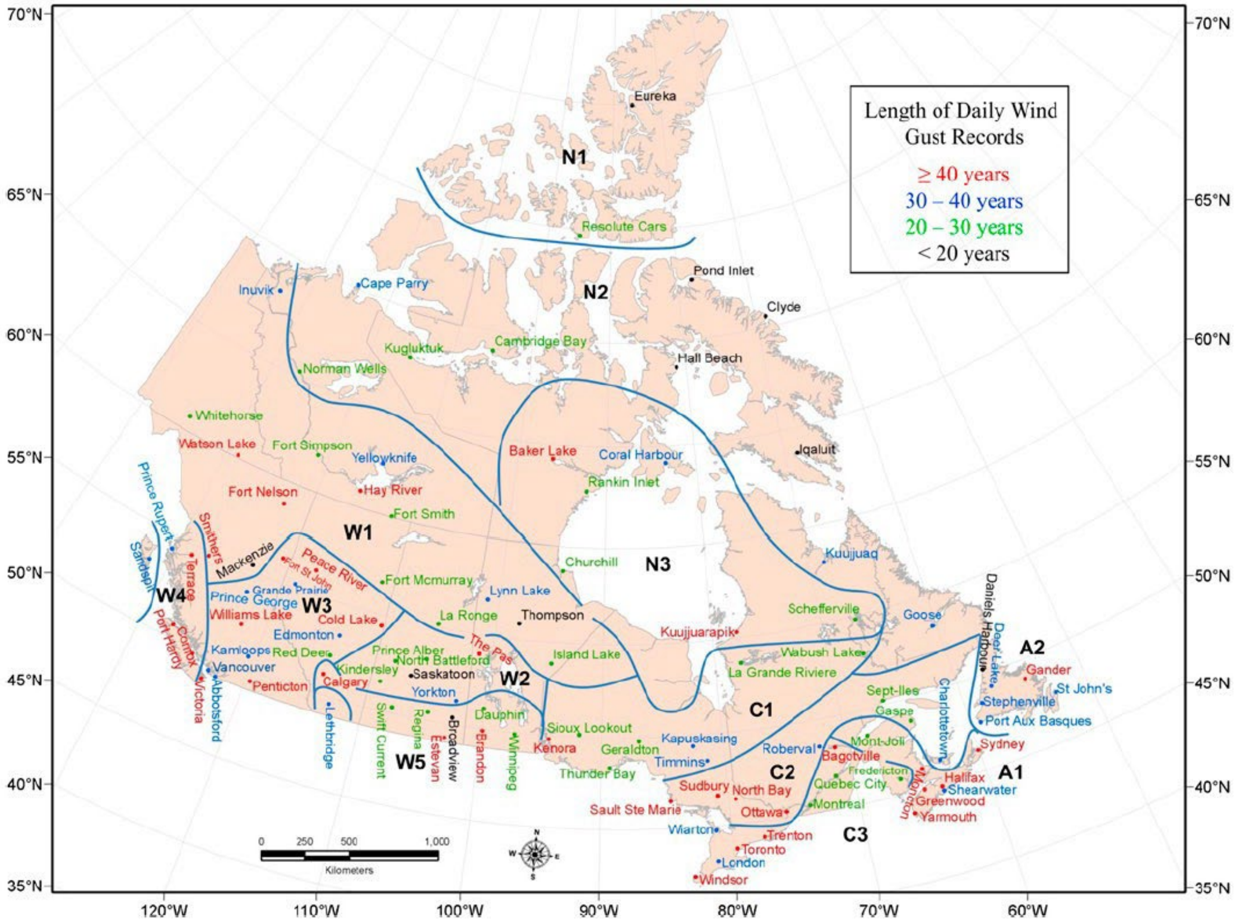


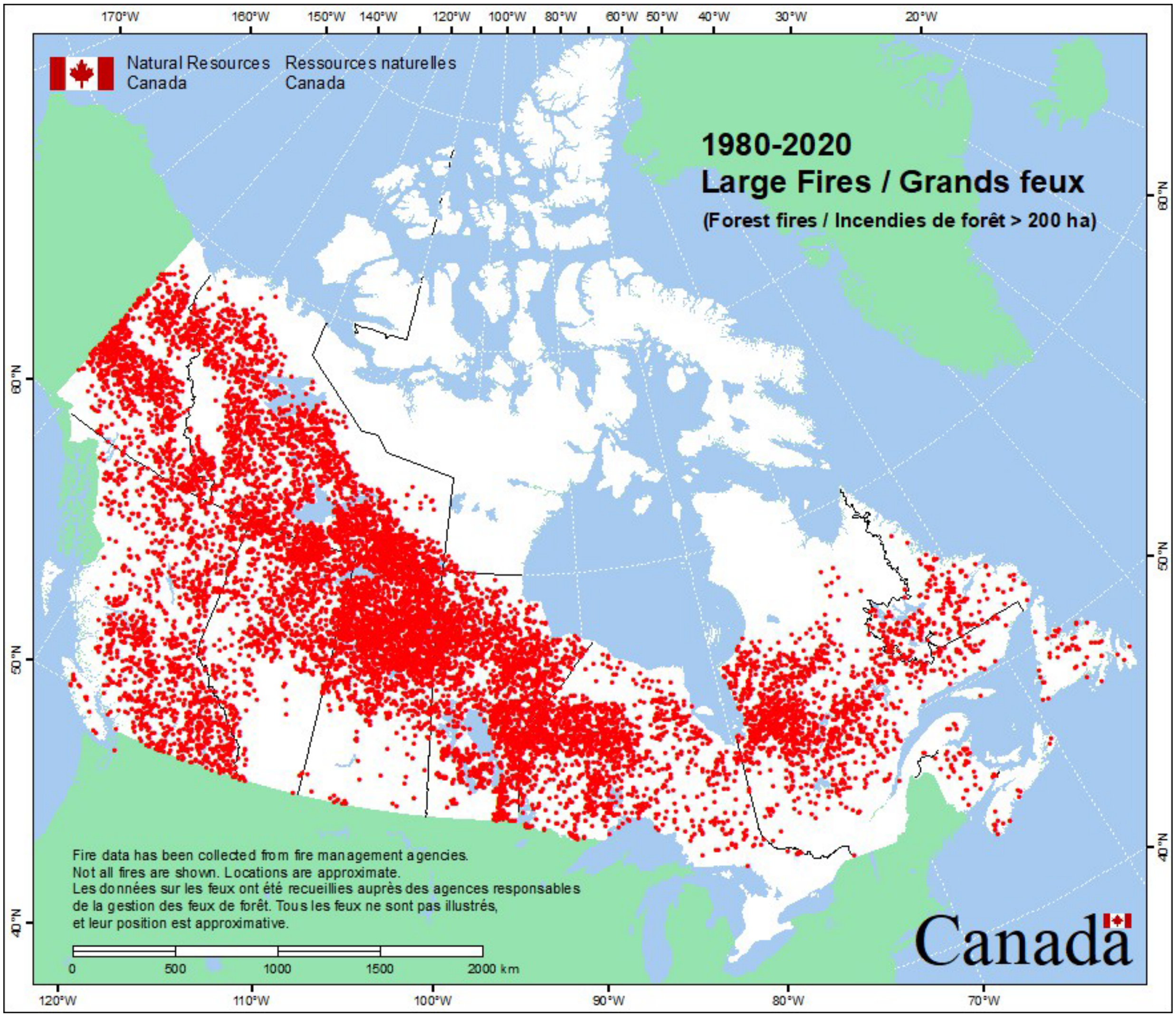
Table 24 Percent Change in Daily Wind Gust Event Frequency (Data source: Cheng et al., 2014)

Climate Zone	Region	Approximate Percent Change in Daily Wind Event Frequency (relative to 1955-2009 baseline)			
		Gusts ≥ 70 km/hr		Gusts ≥ 90 km/hr	
		2050s (2046-2065)	2080s (2081-2100)	2050s (2046-2065)	2080s (2081-2100)
Norman Wells-Tulita	N2	6	22	15	45
Wrigley-Fort Simpson	W1	30	33	95	120

8 Wildfire

The Canadian National Fire Database (CNFDB) provides historical occurrences of large fires (≥ 200 ha) across Canada for the period of 1950 to 2020 (Canadian Forest Service, 2021). Figure 13 presents large fire locations for the 1981-2020 time period.

Figure 13 **1980-2020 Large Fire (> 200 ha) Locations (Figure source: Canadian Forest Service)**



1980-2020
Large Fires / Grands feux
(Forest fires / Incendies de forêt > 200 ha)

Fire data has been collected from fire management agencies.
Not all fires are shown. Locations are approximate.
Les données sur les feux ont été recueillies auprès des agences responsables de la gestion des feux de forêt. Tous les feux ne sont pas illustrés, et leur position est approximative.

The Mackenzie Valley Highway region is located in the Taiga Plains (TP) ecozone and the Great Bear Lake (GBL) homogeneous fire regime (HFR). During the 2011-2020 period, the average annual total number of fires in the Taiga Plains ecozone was approximately 375 fires (Stewart et al., 2023), with an average of ~26 large (> 200 ha) fires annually during the 1981-1999 period (Huberman et al., 2022). The average annual number of large (> 200 ha) fires occurrence was 5 to 10 fires annually per 100,000 km2 in the Great Bear Lake HFR during the 1961-1990 period (Boulanger et al., 2014; Huberman et al., 2022). The number of fires annually, as well as the average annual area burned and fire size, is projected to increase under climate change (Boulanger et al., 2014; Blyth et al., 2016; Wang et al., 2022; Stewart et al., 2023). Projected changes in fire occurrence (FireOcc) for the Great Bear Lake HFR under the SRES A2 emissions scenario (which is roughly comparable to RCP8.5 and SSP5-8.5) are presented in Figure 14 (Boulanger et al., 2014). Projected changes in annual area burned (AAB) are also presented in Figure 14 (Boulanger et al., 2014). Similar changes are projected for the larger Taiga Plains ecozone (Wang et al., 2022) – projected changes in annual number of fires (ANF), annual area burned (AAB), and the maximum fire size (MFS) under the RCP8.5 scenario are presented in Figure 15. Projected changes in wildfire occurrence for the Mackenzie Valley Highway region are summarized in Table 25.

Figure 14 **Projected Changes in Annual Area Burned (AAB) and Fire Occurrence (FireOcc) Compared with the Baseline (1961-1990) Time Period. (Figure source: Boulanger et al., 2014)**

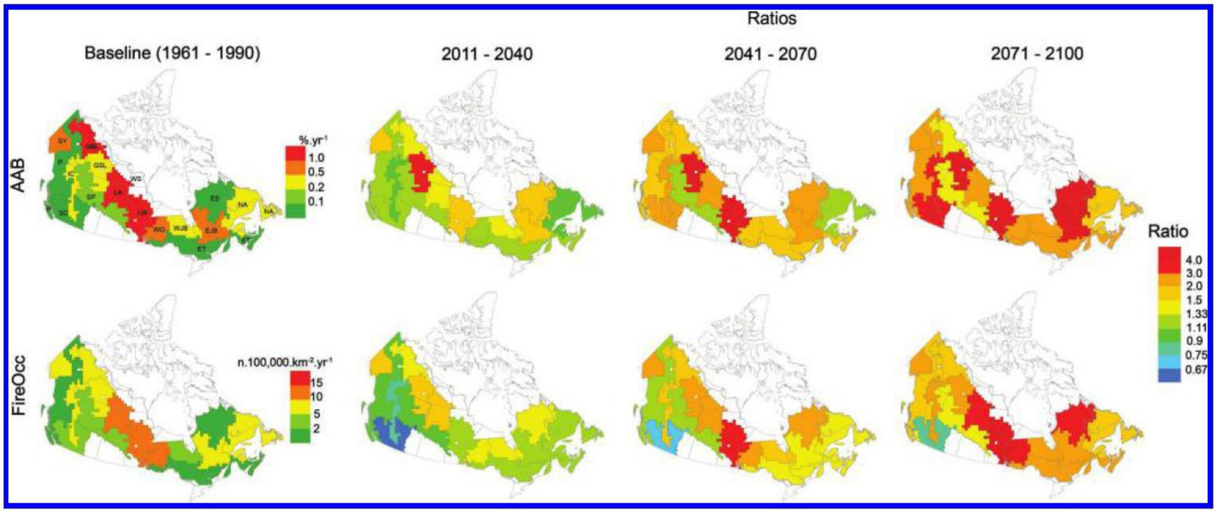


Figure 15 Ratio of Shift (relative to 1981-2010 baseline) for Annual Area Burned (AAB), Annual Number of Fires (ANF), and Maximum Fire Size (MFS) by Ecozone Under RCP8.5 (Figure source: Wang et al., 2022)

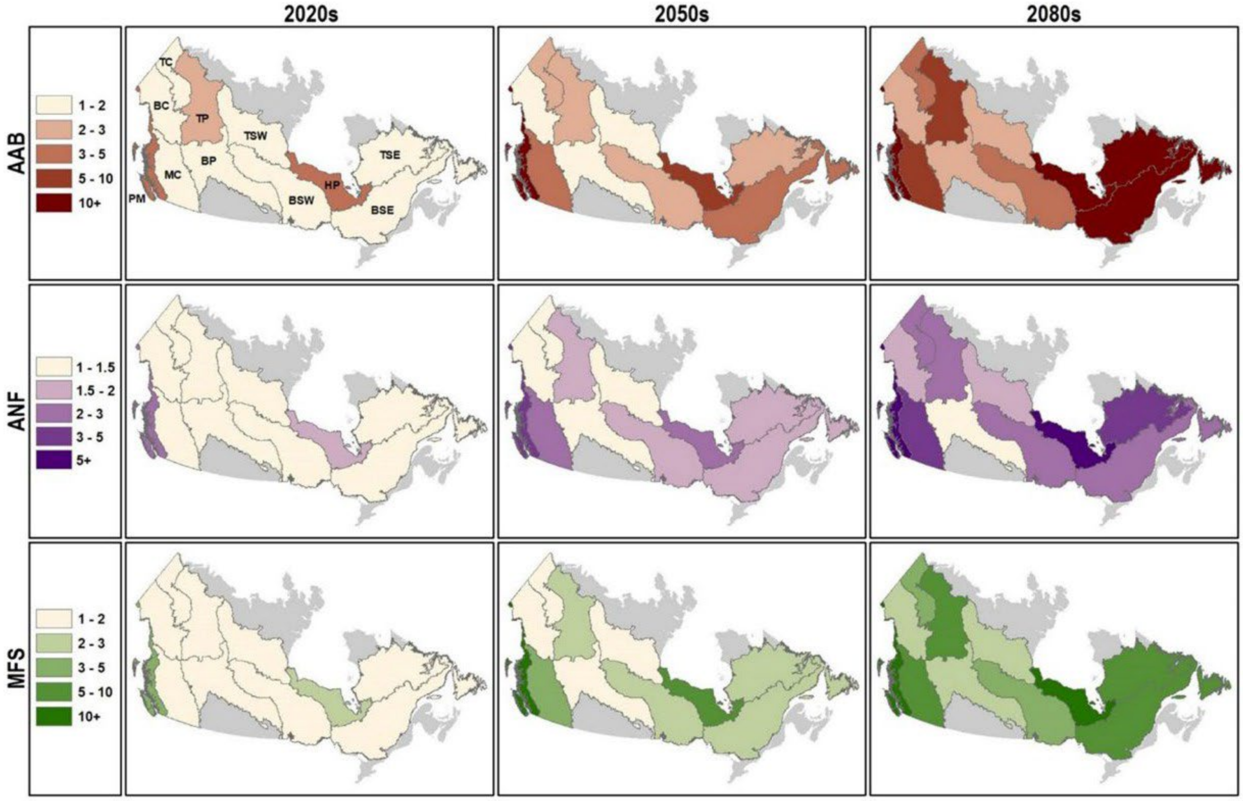


Table 25 Summary of Projected Changes in Large (> 200 ha) Fire Occurrence (Data sources: Boulanger et al., 2014; Wang et al., 2022)

	Average Annual Fire Occurrence (per 100,000 km^2)	Projected Change in Fire Occurrence (ratio of projected fire occurrence under a high emission scenario) (Fire Occurrence Equivalent)		
Region	Baseline (1961-1990)	2020s (2011-2040)	2050s (2041-2070)	2080s (2071-2100)
Mackenzie Valley Highway	5 to 10 fires/yr	1 to 1.5-fold (up to 15 fires/yr)	1.5 to 2.0 (up to 20 fires/yr)	2.0 to 3.0 (up to 30 fires/yr)

In addition to changing frequency of occurrence, wildfire severity (intensity), fire size, and area burned are projected to increase under a warming climate (Wang et al., 2015; 2017; 2020). Furthermore, the fire season length is projected to increase under a warming climate (Gaur et al., 2021; Jones et al., 2022).

The Canadian Forest Fire Weather Index (FWI) system can also be used to evaluate the future fire risk in the region. The FWI represents the potential fire intensity and is based on the Initial Spread Index (ISI) and Build-up Index (BUI). The ISI represents the potential rate of spread of fire without the influence of fuel and BUI represents the availability of total fuel (Whitman et al., 2015). The projected change annual 95th percentile of the FWI (represented extreme fire weather events) for the Great Bear Lake HFR are presented in Table 26. Values in Table 26 reflect combined projected changes for the SRES A2 (roughly comparable to RCP8.5, A1B (halfway between RCP8.5 and RCP4.5), and B1 (roughly comparable to RCP4.5) emissions scenarios (Wang et al., 2015).

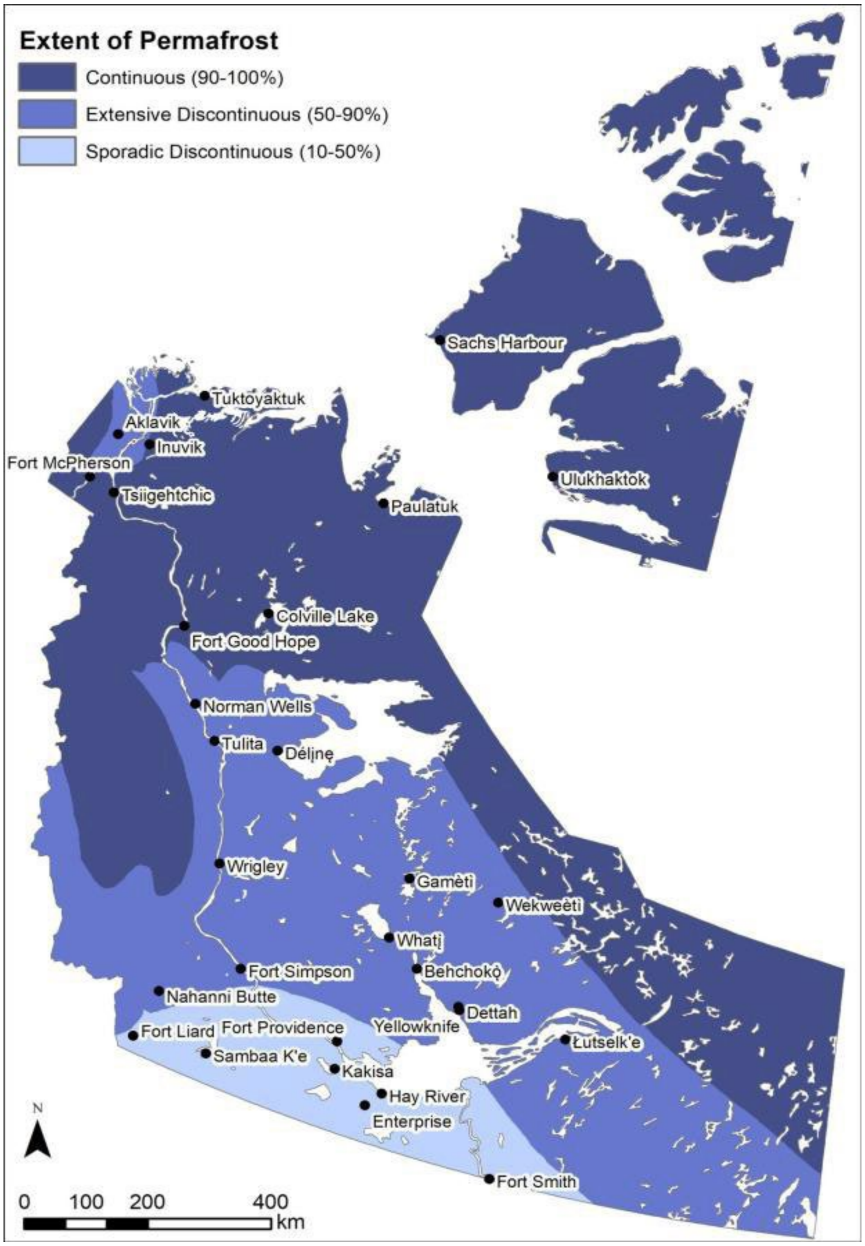
Table 26 Projected Change in the Fire Weather Index (Data source: Wang et al., 2015)

Homogeneous Fire Regime	Projected Percent Change (%) of the 95th Percentile of the FWI Relative to the 1981-2010 Baseline (SRES A2, A1B, and B1 Combined) Median (5th percentile, 95th percentile)		
	2020s (2001-2030)	**2050s (2031-2060)**	**2080s (2061-2090)**
Great Bear Lake	8.7 (1.4, 33.9)	14.5 (0.6, 55.9)	21.7 (7.0, 91.3)

9 Permafrost

The Mackenzie Valley Highway project region is located in the extensive discontinuous (50-90%) permafrost zone (Figure 16) (NWT SOE Report, 2022). Community sensitivity to permafrost is identified as moderate risk in Norman Wells and Tulita and as low risk in Wrigley (GNWT, 2015).

Figure 16 Permafrost Zones in the Northwest Territories (Figure source: NWT SOE Report, 2022)



Permafrost thaw typically occurs through an increase in the depth of the active layer, which decreases the overall thickness of the permafrost, and could result in loss of permafrost entirely. Permafrost thaw is strongly related to increases in air temperature, with increases in precipitation also contributing to the thaw. Permafrost is also vulnerable to other short- and long-term environmental conditions, such as wildfires, changing hydrology, and localized disturbances to organic ground cover, and can thaw rapidly once it is disturbed.

Increases in the permafrost active layer have been observed in the Northwest Territories (NWT SOE Report, 2022). Analysis by Peng et al. (2018) indicates the permafrost in the Mackenzie Valley Highway project region had an active layer thickness (ALT) of 40 to 80 cm during the 1971-2000 baseline period (Figure 17). Work by Garibaldi et al. (2022) indicates that mean ALT in the Boreal and Taiga Cordillera ecological region was approximately 65 cm in the early 2000s, and ALT was approximately 90 cm at that time in the Taiga Plains Low Subarctic (LS) ecological region. These are the primary ecological regions in which the Mackenzie Valley Highway Project is situated (Figure 18) (Ecosystem Classification Group 2007, 2010). Garibaldi et al.'s work also indicates that the ALT has remained generally steady, with limited response to warming air temperatures, at sites in the Project area during the 1993-2014 period. However, the active layer is projected to increase in thickness as permafrost thaws under a warming climate (Peng et al., 2018; CCCR, 2019; NWT SOE Report, 2022). The active layer in the Mackenzie Valley Highway project region is projected to increase 20 to 40 cm by the end of the century (2071-2100) under the RCP8.5 emission scenario (Figure 19) (Peng et al., 2018). Furthermore, studies indicate permafrost will no longer be present in the Mackenzie Valley Highway project region by the end of the century under the RCP8.5 emissions scenario (Figure 20) (Slater and Lawrence, 2013; Guo and Wang, 2016; Cannon et al., 2020).

Figure 17 Spatial Distribution of Multiyear Average in-situ Active Layer Thickness Across the Northern Hemisphere (Figure source: Peng et al., 2018)

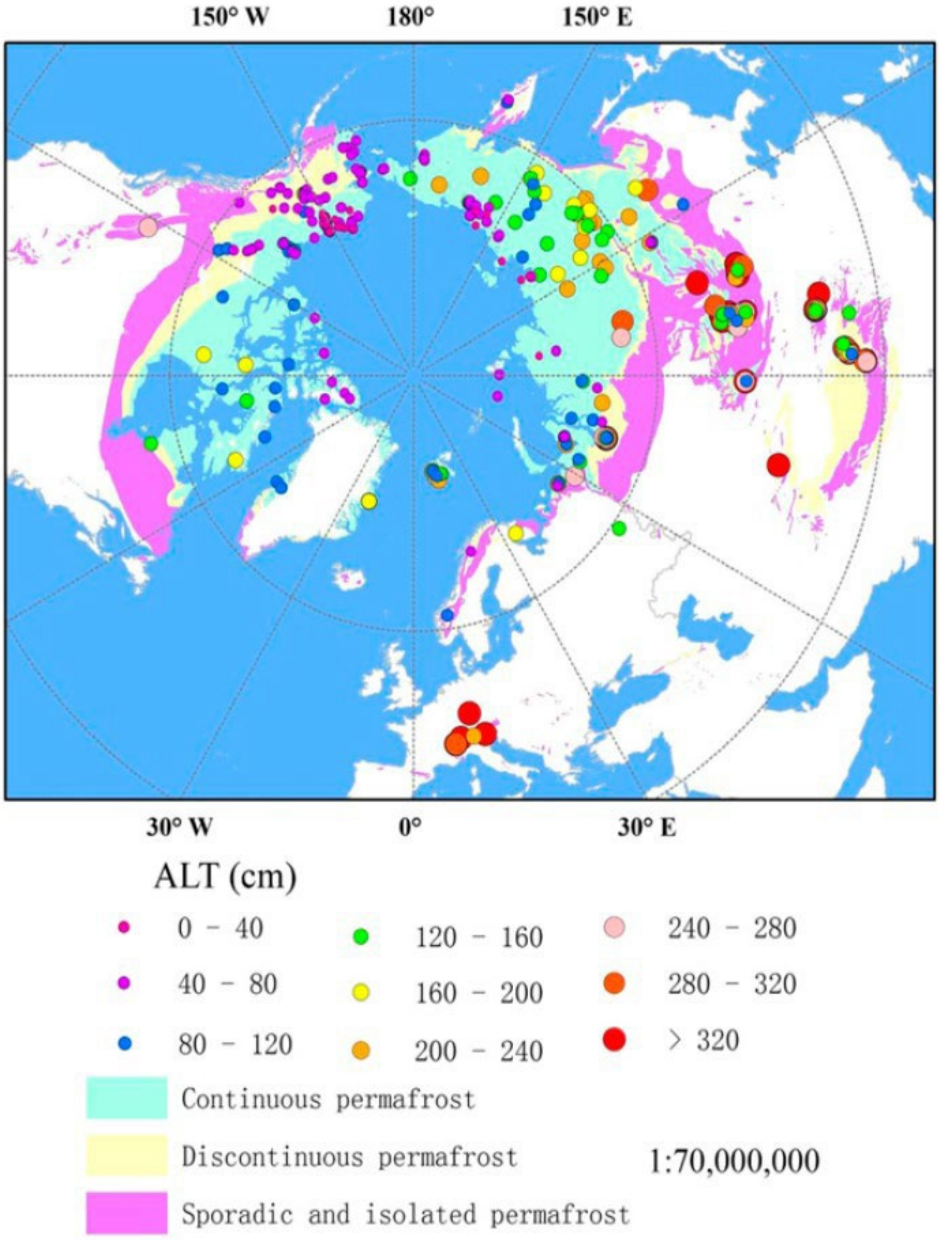


Figure 18 **Mackenzie Valley Ecoregions and Permafrost Active Layer Monitoring Sites (Figure Source: Garibaldi et al., 2022)**

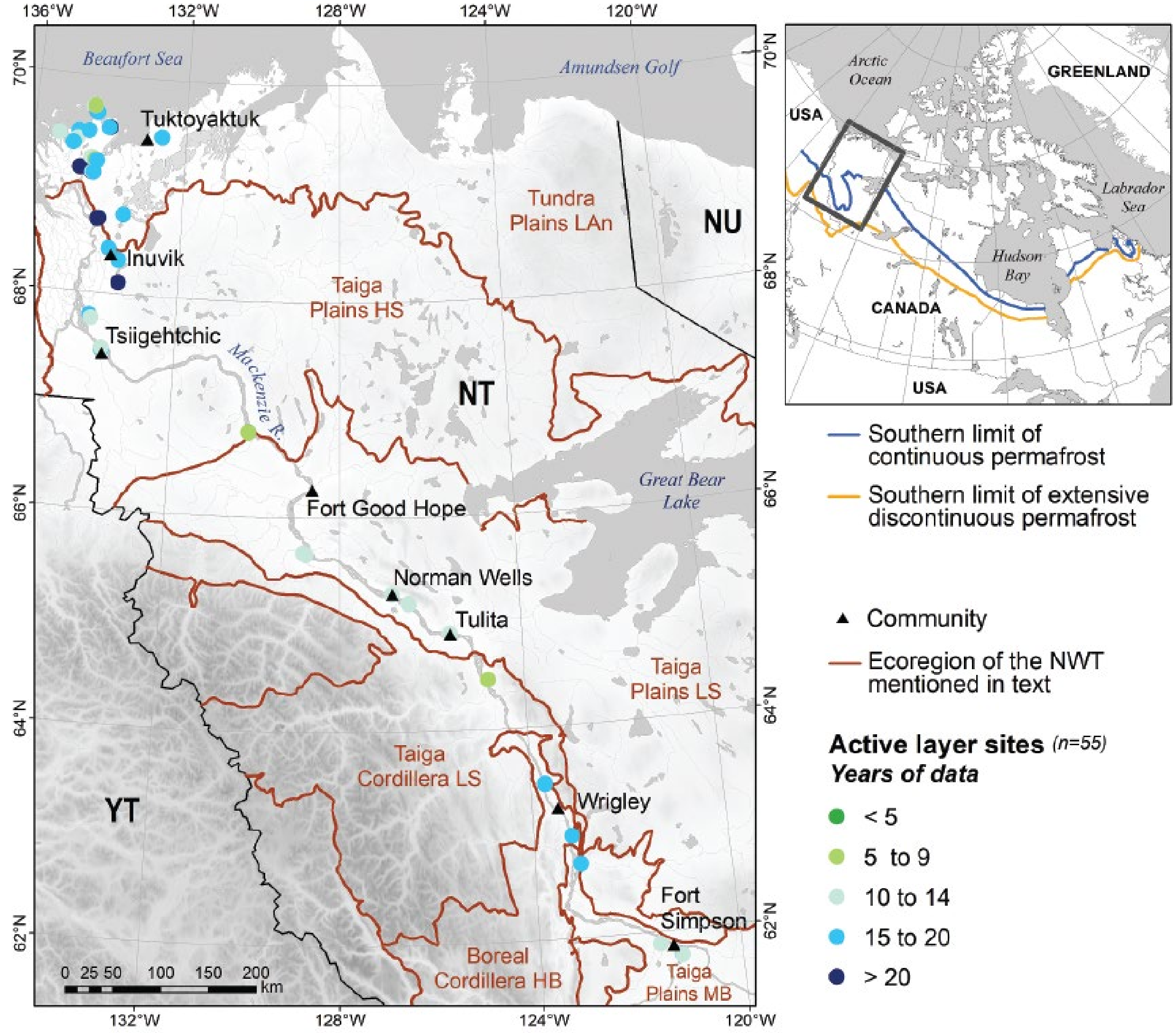


Figure 19 **Projected Change in Active Layer Thickness Between the 2071-2100 Climatology Under the RCP8.5 Emissions Scenario and the Historical 1971-2000 Simulation (Figure source: Peng et al., 2018)**

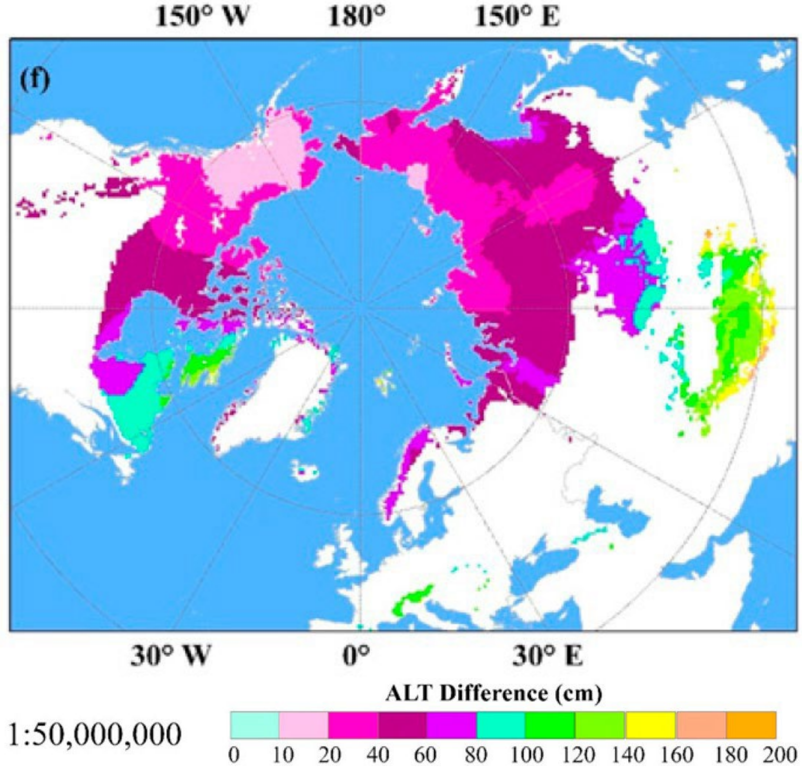
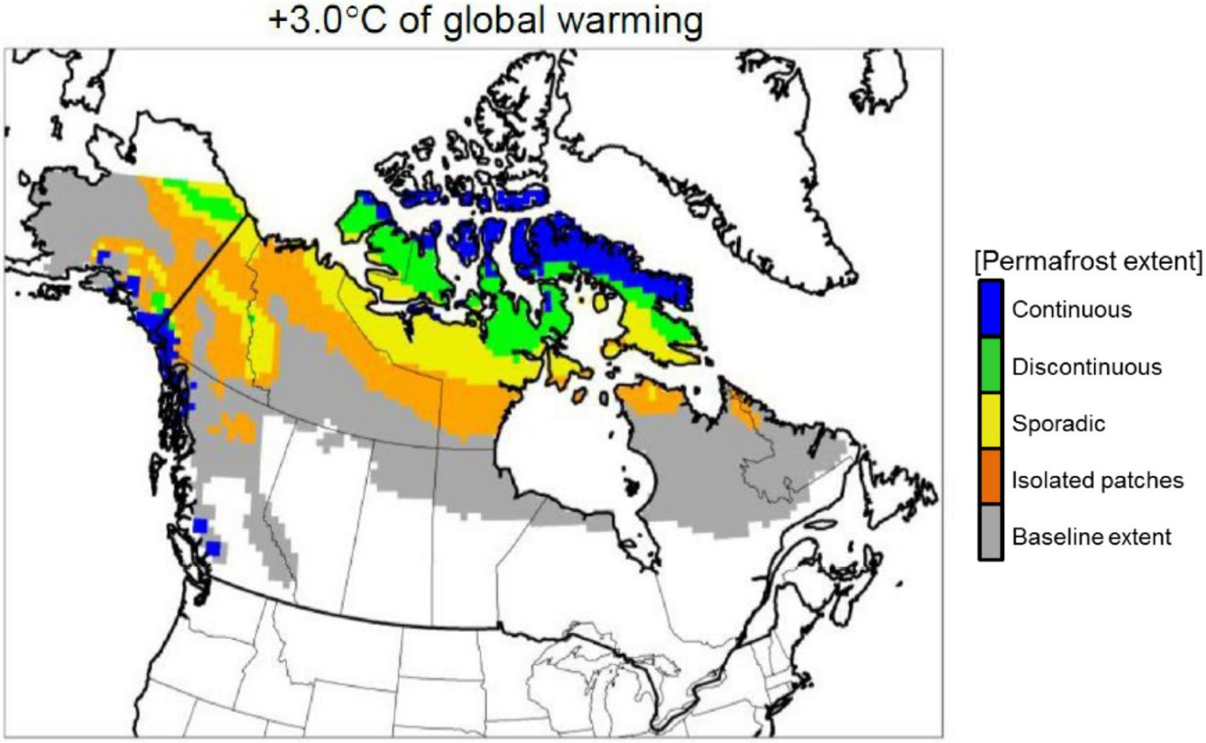


Figure 20 **Projected change in permafrost extent under +3°C of global warming (Figure source: Cannon et al., 2020)**



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Topic: Lessons Learned Tłı̨chǫ Highway

Preamble from the Mackenzie Valley Environmental Impact Review Board (Review Board): On February 27, 2024, the Review Board released a Notice of Proceeding indicating it plans to transfer relevant materials from the Tłı̨chǫ All Season Road EA (EA1617-01) to the Mackenzie Valley Highway EA (EA1213-02). This information request builds on the Notice of Proceeding by asking the GNWT to analyse existing information and provide additional information about the actual and impacts, and the effectiveness of mitigation measures relating to the Tłı̨chǫ highway. In the future, the Review Board may ask additional questions about lessons learned that are specific to individual valued components.

Many of the predicted impacts for the proposed MVH are the same or similar to the impacts that were predicted and occurred during the assessment, construction and initial operations of the Tłı̨chǫ highway. During that environmental assessment for the Tłı̨chǫ highway, the GNWT relied on existing programs and plans to mitigate many of the impacts. Similarly, in the MVH DAR the GNWT appears to rely heavily on existing programs and plans to mitigate impacts of the proposed MVH. Some engagement participants noted that GNWT programs are not adequate to deal with existing social impacts in communities along the route.

When the predicted impacts of the Tłı̨chǫ highway happened, existing programs sometimes proved slow and only partially effective to mitigate the impacts. In addition, experience has shown that the predicted "spike" of social impacts has lasted longer than predicted and some of the impacts have been difficult to detect, monitor, and adaptively manage in a timely and effective manner. Because the Tłı̨chǫ highway project precedes the MVH, it offers an excellent opportunity for lessons that may be applicable for this EA, based on the experiences of Tłı̨chǫ communities and GNWT monitoring and management plans.

Request from the Review Board:

A. Please describe which plans and programs for the Tłı̨chǫ highway were effective in efficiently mitigating impacts when they occurred, and which were not and why not.

B. Please describe how effectively GNWT programs are addressing current and existing impacts on communities and on wildlife that will be affected by the construction and operation of the MVH.

C. For any impacts that were not efficiently or effectively mitigated when they happened during construction and operation of the Tłı̨chǫ highway, please justify:

   i. how GNWT programs will effectively deal with similar impacts on communities and on wildlife caused by or associated with the MVH (referencing key performance indicators where possible)
   ii. why the GNWT believes existing plans and programs are appropriate to mitigate additional impacts caused by or associated with the MVH
   iii. why the GNWT expects that the same or other proposed mitigation measures will work better for the MVH than for the Tłı̨chǫ highway.

Response from the Government of the Northwest Territories:

In its role as a public government, the Government of the Northwest Territories (GNWT) provides programs and services[1] to residents across the territory. Programs and services are executed at local, regional, and territorial levels and evolve in response to the diverse needs of residents, modifications to legislation and guidelines, or other legal requirements. Many of the GNWT's programs and services have also been developed in collaboration with Indigenous governments and community governments and as a result, these programs and services reflect their interests and priorities.

Similar to the approach to mitigating impacts of the Tłı̨chǫ Highway, the GNWT is proposing to leverage existing programs and services, and create collaborative working groups similar to those which have seen success in the Tłı̨cho Highway to mitigate impacts of the Mackenzie Valley Highway (MVH) project. As outlined in Section 9.15.1 of the Developer's Assessment Report (DAR), the mitigations proposed by the GNWT are founded on community readiness and preparedness, collaboration and continued engagement with local peoples to facilitate the integration of local knowledge into the project and develop monitoring approaches collaboratively.

The GNWT understands that the Review Board is attempting to better understand the effectiveness and limitations of this approach. The GNWT has not completed a systematic review of the effectiveness and limitations of each of its programs and plans as they relate to the Tłı̨cho Highway for several reasons including:

1) **GNWT Programs and services are continually evolving**

   The GNWT programs and services are designed to change over time to meet the needs of residents and are regularly adapted to reflect environmental and socio-economic conditions. Programs and services are implemented at territorial, regional, and community levels by the GNWT, Indigenous governments, Indigenous organizations and/or community governments. This approach allows for Indigenous governments and community governments to provide programs and services that people need in their communities and adaptively respond to changing needs. The GNWT provides funding under broad programming areas to provide the greatest flexibility to support defined priorities and objectives[2].

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[1] The IR posed by the Review Board states, "existing plans and programs". The GNWT has interpreted this to mean programs and plans that are associated with the GNWT's role as a public government and not project specific.

[2] Examples include Community Wellness and Addictions Recovery Fund (this funding has replaced the One the Land Healing Fund, the Addictions Recovery Peer Support Fund, and the Gender-Based Violence Community Initiatives Fund). A list of GNWT's programs can be found here.

2) **Social and wellbeing impacts in communities associated with the Tłı̨chǫ Highway are not experienced in isolation.**

The Tłı̨chǫ Highway project was constructed between September 2019 to October 2021 and officially opened in November 2021. During that time, the NWT, along with the rest of the world, experienced the COVID-19 pandemic which impacted the territory in several ways including:

- Reported measures of mental wellness were reported to have declined throughout the pandemic and measures of mental wellness began to recover slightly in 2022[3].
- Alcohol consumption also increased during the pandemic across the NWT and Canada. Alcohol consumption has been documented to exacerbate feelings of loneliness associated with the imposed physical distancing during the pandemic, increase symptoms of anxiety and depression, and increase the risk of intimate partner violence and child neglect[4].
- Closure and/or reduction in access to programs and services due to pandemic related isolation requirements.

With the impacts of COVID-19 and COVID-19 restrictions easing in 2022, it was expected that the pandemic related impacts would decrease (though some experts expect to see impacts of COVID-19 for a decade, if not more[5]). However, 2023 brought other stressors to the Tłı̨chǫ (and other) region(s). Wildfires resulted in the evacuation of Behchokǫ̀ as well as other communities around the territory. The long-term effects of the 2023 wildfire season on territorial residents are not yet fully understood; however, the effects of wildfires in other areas have been documented to:

- Increase rates of post-traumatic stress disorder, depression, generalized anxiety, often in combination with substance abuse and substance use disorder[6]
- Increases in hypertension, gastrointestinal disorders, diabetes, chronic obstructive pulmonary disease, and asthma exacerbations[7].

When considering these impacts associated with the pandemic and the wildfires together, it is clear that there are factors affecting community wellbeing within the Tłı̨chǫ region that are not solely attributable to the Tłı̨chǫ Highway project.

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[3] https://www.hss.gov.nt.ca/sites/hss/files/resources/social-indicators-covid-19-pandemic-june-2022.pdf

[4] World Health Organisation Europe. Alcohol and COVID-19: what you need to know. WHO 2020. http://www.euro.who.int/__data/assets/pdf_file/0010/437608/Alcohol-and-COVID-19-what-you-need-toknow.pdf?ua=1

[5] British Academy. The COVID Decade: Understanding the long-term societal impacts of COVID-19. 2021. doi.org/10.5871/ bac19stf/9780856726583.001

[6] To, P., Eboreime, E., and Agyapong, V.I.O. The Impact of Wildfires on Mental Health: A Scoping Review. Behav. Sci. **2021**,11, 126. https://doi.org/10.3390/bs11090126

[7] Doerr, S.H.; Santín, C. Global trends in wildfire and its impacts: Perceptions versus realities in a changing world. Philos. Trans. R. Soc. B Biol. Sci. 2016, 371, 20150345.

The GNWT does not complete formal project-specific (resource development, large infrastructure project) evaluation of its programs and plans. However, when indicators are trending in a way that is unanticipated, regardless of the cause of the trend, programs can be responsive, or have additional mitigations put in place. Indicator trends may not only be related to project-specific impacts rather they may be connected to broader trends that may be present across the region and/or territory.

In the preamble of the Information Request, the Review Board stated that "*existing programs sometimes proved slow and only partially effective to mitigate the impacts. In addition, experience has shown that the predicted "spike" of social impacts has lasted longer than predicted and some of the impacts have been difficult to detect, monitor, and adaptively manage in a timely and effective manner*". There is preliminary information collected that indicates concerning changes in social indicators are occurring, and while this might suggest that existing programs were unable to mitigate the impacts of the Tłı̨chǫ Highway as predicted, there were other unanticipated factors that may have contributed to these observations. The COVID-19 pandemic and its related restrictions, wildfires and evacuations, etc. occurred at approximately the same time and are likely contributing to the observations of the "spike" extending. As well, it is important to note that not all changes in indicators of concern are directly related only to the Tłı̨chǫ Highway as trends in some of the indicators were observed before construction of the highway began and similar trends are being observed in other regions of the NWT.

3) **From an environmental perspective, the Projects fundamentally differ and therefore direct comparisons are difficult.**

The GNWT has, where appropriate, considered the Tłı̨chǫ Highway project in its design of adaptive management. That being said, there are important differences between the MVH and Tłı̨chǫ Highway projects which make direct comparisons challenging. These differences include:

- The disturbance to the landscape is not the same. The all-season road proposed as part of the MVH project will generally follow the existing Mackenzie Valley winter road which has been in use for many years. The Tłı̨chǫ Highway replaced a winter road that traversed a lake for a significant portion of its length with an all-season road that followed an older winter road alignment that had not been in use for quite some time.
- From a wildlife perspective the MVH is changing from an area where wildlife was already exposed to seasonal winter traffic to a proposed year-round highway but the Tłı̨chǫ Highway was a new road with year-round traffic being established in an area where there was essentially no traffic disturbance at any time of the year at baseline.
- Communities impacted by the MVH are different from the Tłı̨chǫ communities given some of the regional development in the area (e.g. Norman Wells). Further, they have different histories, governance structures, interests, and needs.

As a result of these differences, the baseline conditions for wildlife and socio-economic conditions were/are notably different. For example, the amount of undisturbed caribou habitat in the Sahtu is greater than in the Wek'èezhìı region and the amount of boreal caribou collar information available to inform baseline information is greater for the MVH than for the Tłı̨chǫ Highway environmental assessment (EA). All of the above being considered, it is true that the physical construction activities for the road will be similar. Note, specific regulatory plans will be developed for the MVH as part of regulatory permitting for the highway.

4) The GNWT is working to improve programs and services.

Throughout the COVID-19 pandemic, the 2023 wildfire season, and the opening of the Tłı̨chǫ Highway, the GNWT used existing programs to adaptively manage impacts to the extent possible. There will always be capacity and resource constraints in providing services to diverse people and regions, experiencing different stressors, compounded by the history of imposed colonialism and the residential school system, across the NWT. The legacies of colonization and residential schools have impacted health outcomes of Indigenous residents and shaped the way services are delivered in the territory. The GNWT is working to address these concerns and improve the health outcomes of Indigenous residents.

At the same time, the GNWT is committed to supporting the expansion and diversification of our economy, the strength of which is dependant upon reliable, sustainable and resilient infrastructure such as the proposed Mackenzie Valley Highway, which among other outcomes is intended to improve the quality of life for NWT residents.

Below, the GNWT has provided information, where possible, on select programs and plans from the Tłı̨chǫ Highway project that are relevant to this EA. This information includes examples of:

- Existing GNWT programs and plans relevant to mitigating impacts of the Tłı̨chǫ Highway project (Appendix A, item i).
- Existing GNWT programs and plans that have been adapted in response to commitments and measures resulting from the Tłı̨chǫ All Season Road (TASR) EA as well as from impacts observed during the construction and operation and maintenance of the Tłı̨chǫ Highway (Appendix A, item ii).
- Existing GNWT programs and plans relevant to the MVH Project (Appendix A, item iii).

A. Please describe which plans and programs for the Tłı̨chǫ Highway were effective in efficiently mitigating impacts when they occurred, and which were not and why not.

The GNWT relied on existing plans, programs, and services to mitigate impacts of the Tłı̨chǫ Highway project construction (complete) and operation and maintenance (ongoing), on local communities and the environment. In response to requests from communities and/or the region, the plans, programs, and services were supplemented as appropriate and possible. In addition to the plans, programs, and services, there were actions taken during the project planning phase that resulted in mitigations not being required. These include employment and contracting initiatives put in place through the P3 operator (North Star Infrastructure) that resulted in benefits for the Tłı̨chǫ Government. Safety and awareness training, development of gender-specific employment policies, etc.

It is important to note that GNWT plans and programs that mitigate impacts of the Tłı̨chǫ Highway do not operate in isolation but in conjunction with measures from the TASR EA directed to the GNWT both as the Developer and as a Government and Regulatory Authority, and measures directed to Tłı̨chǫ Government. In the case of the Tłı̨chǫ Highway, the GNWT and Tłı̨chǫ Government worked collaboratively to advance measure implementation.

Measure 14-3 in the Report of EA for the TASR required the GNWT establish the Tłı̨chǫ All Season Road Corridor Working Group (THCWG) "To mitigate significant adverse impacts from the Project to the environment and ***people*** [emphasis added], the developer will implement the TASR Corridor Working Group…". The THCWG provides a forum for information exchange, with the specific objectives to review and provide comment on the design of the GNWT's Tłı̨chǫ Highway project specific monitoring programs, review and comment on project specific monitoring program annual reports and providing advice on monitoring and mitigation results that may contribute to adaptive management and/or regional cumulative effects monitoring programs. The GNWT's Annual EA Measures Report is guided by and reflects feedback from the THCWG and the other working groups.

Socio-Economic Related Impact Mitigation

As part of the implementation of EA Measure 5-1, the GNWT, Tłı̨chǫ Government, Tłı̨chǫ Community Services Agency, and the Community Governments of Behchoko and Whati, established the Tłı̨chǫ Highway Socio-Economic Working Group (formally referred to as the Health and Well-being Working Group). This working group provides a forum for information exchange specific to identifying trends in indicators being monitored for community health and well-being and provide advice on monitoring and mitigation results that may contribute to adaptive management. The working group began in 2019 and has worked collaboratively to develop, monitor, and collect important health and well-being indicators.

The collaborative work of the working group is critical to adaptively managing negative trends. For instance, when the working group identified a need to improve road safety, the GNWT provided satellite phones to Tłı̨chǫ Community Service Agency workers, and Road Safety and Trauma Kits to the Tłı̨cho Government in 2023. The working group also provided information regarding the ongoing syphilis outbreak that resulted in additional work being undertaken by the Tłı̨chǫ Community Service Agency and the GNWT (further details provided in the appendix). As well, GNWT-HSS held a youth painting night in Whati, as a way to engage youth and continue to build relationships that started at the mental health and substance use information session held in the school during the day.

Wildlife Related Impact Mitigation

A Wildlife Management and Monitoring Plan (WMMP) for the Tłı̨chǫ Highway was required under s.95(1) of the *Wildlife Act* and under Measure 10-2 of MVEIRB's Report of EA and Reasons for Decision (Report of EA) for the Tłı̨chǫ Highway. The GNWT's WMMP for the Tłı̨chǫ Highway project was informed by feedback from the THCWG and from the annual public review of the WMMP. The GNWT is compiling findings and results of the monitoring programs advanced under the WMMP during the Tłı̨chǫ Highway project construction, which is anticipated to be complete in the fall of 2024. This report will include an assessment of which mitigation measures and monitoring programs have been effective at mitigating impacts on wildlife and habitat during the construction of the highway and will be made available to the public.

As part of Measure 6-1 of the EA, the GNWT was required to develop and implement a range planning for boreal caribou. Through the Wek'èezhìı range planning working group developed in response to the EA measure, the regional boreal caribou range plans began in 2019, and an interim range plan for the Wek'èezhìı region was completed in February 2022. Development of range plans in the other four regions is still in progress. A range plan for the Bathurst barren-ground caribou herd was completed in August 2019. Outcomes of the monitoring activities completed as part of the project are outlined in the GNWTs Annual EA Measures Report[8].

A specific example of a program that could have been more effective on the Tłı̨chǫ Highway project is related to the ground temperature monitoring installations along the Tłı̨chǫ Highway. Many of the thermistors along the Tłı̨chǫ Highway were unintentionally destroyed during road construction. On the MVH project, the GNWT will incorporate the learnings from the Tłı̨chǫ Highway and ensure that the thermistor installation along the MVH is protected to ensure that ground temperature can be effectively monitored from pre-construction through to operations.

WMMP for MVH Project

A Minister-approved WMMP will be required for the MVH project under s.95 of the *Wildlife Act*. The DAR included a draft WMMP (Volume 5 – Management Plans), with descriptions of new positions and programs (e.g., for harvest monitoring) that will be needed for the MVH project. The draft WMMP for the MVH project was largely based on the WMMP for the Tłı̨chǫ Highway. It is intended that the draft WMMP will be updated and added to during the course of the EA to reflect new developer commitments, measures of EA, and post-EA to reflect the results of a public review of the WMMP before its final approval by GNWT-ECC.

With respect to existing wildlife monitoring and management programs implemented by the GNWT, or in partnership with renewable resources boards and other Indigenous governments and Indigenous organizations, the DAR for the MVH acknowledges that they may need to be expanded upon or enhanced to specifically address impacts from the MVH, and that this will require additional resources. There are several examples including:

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[8] GNWT 2022 Annual Measures Report Tlicho All-season Road Project (EA1617-01).pdf (reviewboard.ca)

For example, Section 10.7.2 - Gaps and Uncertainties of the DAR states that:

> *"The GNWT will work with SRRB and other resource managers to address uncertainty regarding the effects of improved 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."*
>
> *"It is expected that there will be a time lag associated with the implementation of enhancements into exiting harvest management programs to effectively respond to increased harvest pressures on caribou and moose (e.g., new staff would need to be hired, monitoring and enforcement protocols would need to be developed and applied)."*

For example, Section 10.8 – Follow-up Monitoring, and Management states that:

> *"Existing monitoring programs can/will receive support early on to expand and modify them to address questions/provide more information about species near the Project. The programs will require long-term financial and staffing and resource commitment to obtain and analyze results."*

Section 10.2.2.2 of the DAR describes existing monitoring and management plans that are in place for barren-ground caribou. For boreal caribou, a new collar-based monitoring program was initiated to provide baseline data for the MVH DAR, and as proposed in the draft WMMP, this program may continue through the construction phase of the project and into the operations phase, similar to the approach taken in the WMMP for the Tłı̨chǫ Highway.

B. Please describe how effectively GNWT programs are addressing current and existing impacts on communities and on wildlife that will be affected by the construction and operation of the MVH.

The DAR submitted for the MVH EA provides a snapshot of the existing baseline conditions, including existing program and services, and emphasizes ongoing collaboration with Indigenous governments and Indigenous organizations in communities anticipated to be impacted by the project. Where appropriate, the DAR identifies where gaps may exist, and which GNWT programs and plans may need to be augmented to mitigate anticipated impacts, or where monitoring and adaptive management is proposed. Further, as noted above, a project specific WMMP will be developed for the MVH that will be revied and refined as part of the regulatory/public review process prior to permitting, for both the construction and operation phases.

C. For any impacts that were not efficiently or effectively mitigated when they happened during construction and operation of the Tłı̨chǫ Highway, please justify:

  a. How GNWT programs will effectively deal with similar impacts on communities and on wildlife caused by or associated with the MVH (referencing key performance indicators where possible)

  b. Why the GNWT believes existing plans and programs are appropriate to mitigate additional impacts caused by or associated with the MVH

  c. Why the GNWT expects that the same or other proposed mitigation measures will work better for the MVH than for the Tłı̨chǫ Highway.

Learnings from the Tłı̨chǫ Highway project will be integrated into the MVH project based on the outcomes of the Tłı̨chǫ Highway project (e.g. the construction phase WMMP Report anticipated in fall of 2024), the needs/wants of communities, input from Indigenous Governments and Indigenous organizations, resource managers, etc.

The GNWT considers that having a specific WMMP in place for the MVH project, in combination with existing programs, will be effective in mitigating impacts to wildlife and habitat from construction and operations of the MVH. Additional information on the WMMP is provided in Appendix A.

The GNWT is committed to adapting its plans and programs to ensure effectiveness and looks forward to hearing from intervenors during the EA process on ways in which they think impacts to wildlife and communities can be mitigated.

Appendix A –

i. Examples of Existing GNWT Plans and Programs Relevant to Mitigating impacts of the Tłı̨chǫ Highway Project

Project Specific Wildlife Management and Monitoring Plan

A Wildlife Management and Monitoring Plan (WMMP) for the Tłı̨chǫ Highway was required under s.95(1) of the *Wildlife Act* and under Measure 10-2 of MVEIRB's Report of EA and Reasons for Decision (Report of EA) for the Tłı̨chǫ Highway.

The process to prepare the Tłı̨chǫ Highway WMMP[9] was iterative. Since its initial submission in 2016, the WMMP underwent several updates to incorporate developer commitments, address measures from the Report of EA, and integrate feedback from regulators, independent third-party reviewers, and the public. ECC works with the Wek'èezhìı Land and Water Board (WLWB) and the Wek'èezhìı Renewable Resources Board to coordinate an annual public review of the WMMP.

The WMMP will be implemented for the first five years of operations of the Tłı̨chǫ Highway (until 2026), at which time the need for continuing the WMMP programs will be re-evaluated. The GNWT is required to provide annual reports through the WMMP and the annual water licence reports. These are shared with the THCWG, are publicly available on ECC's WMMP Resources website and are submitted to and the WLWB.

A comprehensive report summarizing the findings of the monitoring programs advanced under the WMMP during the construction phase of the TASR is anticipated to be issued in the fall of 2024. This report will include an assessment of which mitigation measures and monitoring programs have been effective at mitigating impacts on wildlife and habitat during the construction of the highway.

Other Northwest Territories Wide Wildlife Related Programs and Plans

The Big Game Hunting Regulations

The Big Game Hunting Regulations set seasons and limits on wildlife harvest. These regulations were amended in 2019 to split mountain woodland caribou and boreal woodland caribou into separate tags to allow for better estimation of Resident and General Hunting Licence (GHL) holder harvest on boreal caribou. The hunting season for boreal caribou for Resident hunters and GHLs was shortened, and Residents were limited to male-only harvesting.

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[9] WMMP is available on GNWT-ECC's WMMP Resources website

Resident Hunter Surveys and Enforcement

The annual Resident Hunter Survey program provides regional-scale information about resident hunter harvest levels. To assist with harvest monitoring and enforcement specific to the Tłįchǫ Highway, a new Renewable Resources Officer position was created in Whatì.

Caribou Range Planning

The regional boreal caribou range plans began in 2019, and an interim range plan for the Wek'èezhìı region was completed in February 2022. Development of range plans in the other four regions is still in progress. A range plan for the Bathurst barren-ground caribou herd was completed in August 2019.

Other Programs advanced by GNWT Partners (Tłįchǫ Government)

GNWT annually provides funding to the Tłįchǫ Government (TG) to support the implementation of TASR EA Measures 7-1 and 9-1, both of which are related to the WMMP. The GNWT also provides contribution agreement funding to the TG to help in the implementation of Measures 5-1 and 5-2 as it relates to monitoring and adaptively management of adverse health and well-being impacts to the Community of Whati.

ii. Examples of existing GNWT Programs and Plans that have been adapted in response to commitments and measures from the TASR EA and community needs

- Wildlife surveys including regional bison and moose population surveys are conducted every three to five years and the survey areas have been expanded to include the area of the Tłįchǫ Highway corridor.
- In response to the opioid crisis, the Health Promotion Division of the GNWT has sent 70 naloxone kits to Tłįchǫ as part of the GNWT surge response activities since 2023. This is over and above the normal naloxone kits made available by the Health Authority (2000 kits were sent out across the territory in response to the opioid crisis; training was also provided in the use of the kits).
- In response to the ongoing syphilis outbreak in the NWT, the GNWT has sent 35 condom dispensers to the Tłįchǫ region since March 2023 as surge programming (266 dispensers were distributed across the territory).
    - Tłįcho Government,̨ GNWT-HSS, TCSA and the Office of the Chief Public Health Officer met in October 2022 to identify health related mitigative actions based on initial changes identified through the monitoring program and qualitative reports from the community. Workshops were held in the Tłįchǫ region in May 2023 to provide additional supports and training for community health centre workers. This mitigation was developed based on surveillance by the GNWT and Tłįchǫ Government, as well as ongoing discussions within the Tłįchǫ Highway Socio-Economic Working Group regarding the outbreak of Sexually Transmitted Infections across the north.

iii. Examples of Existing GNWT Programs and Plans Relevant to the MVH Project

Socio-Economic Related GNWT Programs and Plans Relevant to the MVH Project

The GNWT works closely with communities to provide annual funding for plans, programs, and services based on established community needs. For instance:

- Department of Infrastructure
    - Provides financial contributions to communities toward the construction or maintenance of access roads, trails, docks and wharves as part of the Community Access Program.
- Department of Education, Culture and Employment
    - Provides funding directly to Indigenous Governments, communities, and non-governmental organizations to support Indigenous Language programming, communications, and mentorship programs.
    - Provides support for early learning and childcare throughout the territory and is working to create more high-quality, affordable, and regulated childcare spaces, primarily through support for the not-for-profit and public childcare providers.
- Department of Justice
    - Ministerial Policing Priorities (MPP) are built from community priorities sent to the Department of Justice annually.
        - Communities can consider incoming and completed projects and other issues when establishing their priorities. This allows MPPs to act as adaptive management for project issues.
- Industry, Tourism and Investment (ITI)
    - ITI collaborates with Northwest Territories Tourism to provide marketing for tourism specific to each region in the NWT.
    - Communities have the opportunity to access ITI programming and establish their own priorities. This includes the development of Tourism Plans.
        - These plans and priorities can consider incoming and completed projects which allow them to act to adaptively manage project issues and/or retain benefits.
    - Within the MVH Project Local Assessment Area:
        - Norman Wells has an economic development strategy, community plan, and recreation master plan that speaks to tourism and to develop it in Norman Wells.
        - Tulita has put together an informal community strategic plan and has a community campground plan. A new Economic Development Officer (EDO) was hired and is working with ITI’s Regional Office on future plans for the community.
        - Wrigley has an old Tourism Development Plan from 1990. ITI is interested in following up with Wrigley’s leadership to update the plan as conditions change.
- Department of Health and Social Services:
    - Provides health promotion funding:

  - Community Wellness and Addictions Recovery fund provides funding for Regional and Community Indigenous Governments, Community Governing Authorities (Band Councils, Metis Locals, Charter Community or municipal council) and Non-government Indigenous organizations to deliver culturally relevant, community-based options for individuals living with mental health and addictions in the NWT,
  - Community Suicide Prevention fund provides funding for community-based suicide prevention activities in the NWT,
  - Gender-Based Violence Community Initiatives Fund provides funding for community-based initiatives across the Northwest Territories that support the implementation of the National Action Plan to End Gender Based Violence.

Preventative Programming

The GNWT completes health and well-being promotion and preventative programming which supports the adaptive management of negative social issues, including:

- Housing – Public Housing, Assistance to Homeowners (Homeownership Initiative), Assistance for individuals experiencing homelessness (Homelessness Assistance Fund, Small Communities Homeless Fund, Shelter Enhancement Fund, Northern Pathways to Housing).
- MACA – Sports Funding Programs (Recreational and Sport Contribution Program, Regional Youth Sport Events, After School Physical Activity Program, etc.), Youth Support Programs (Youth Contributions, Youth Centres Initiative Program, NWT Youth Corps Program, etc.), and NWT Outstanding Volunteer awards.
- ECE – Income Assistance program provides financial assistance to NWT residents to help them meet their basic and enhanced needs. Benefits are aligned with the Northern Basket Measure and ECE has developed a performance measurement plan to evaluate the effectiveness of the program. The program also provides assistance with shelter (accommodations) and utilities, based on actual amounts, and additional allowances for persons with permanent disabilities and seniors (e.g., Senior Home Heating Subsidy).
- Justice – Assistance to crime victims (Victim Services, Victim Notification Program, Victim of Crime Emergency fund, etc.), Ministerial Policing Policies, First Nations and Inuit Policing Program[10].
- HSS – Health promotion (Healthy Choices Fund, online information and resource catalogues, surge responses to key public health priorities, etc.), mental health and addictions recovery, online resources addressing addiction recovery and community mental health supports and the 811 Nurse Advice Line which provides 24/7 nurse advice, mental health and wellness supports, and tobacco cessation supports for residents of the NWT. These programs and initiatives are likely to support the mitigation of adverse changes in residents mental and physical health as part of an incoming highway project. A new standard of practice for Child and Family Services

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[10] Agreement with Canada and the DOJ to contract more RCMP to provide policing services that reflect the needs and values of - First Nation and Inuit communities.

was implemented in 2021, where extended family can enter in a Voluntary Support Agreement to receive the financial supports without requiring children to come into care. This aligns with the principles of keeping children with family, community, and culture. As well, in response to the overrepresentation of Indigenous children and youth in Child and Family Services, the Family Preservation Program was expanded across the NWT between 2019 and 2021, and expanded support for youth in 2022-2023.

There are other examples of programming that is preventative more so than mitigative. These are designed to help communities take advantage of potential benefits of the project. These include programs such as:

- The Department of Industry, Tourism and Investment:
    - Programs for Entrepreneurs and business owners under the Support for Entrepreneurs and Economic Development (SEED) Policy (https://www.iti.gov.nt.ca/en/services/sector-support-seed).
    - Tourism Programs (including the Tourism Business Mentorship Program, Youth Mentorship for Tourism Program, Tourism Training Fund etc.).
- The Department of Education, Culture and Employment
    - Small Communities Employment Program is a GNWT funded program that supports small communities and regional centres in developing regional employment and training opportunities. Regional ECE Service Centres engage with communities to provide information, tools and supports towards accessing Small Community Employment Support (SCES) program funding and develop multi-year community labour market development plans.

Community Wellness

From a community health and well-being perspective, as part of the Northwest Territories Northern Wellness Agreement (NWA), communities and the GNWT-HSS work together to develop Community Wellness Plans annually based on current needs and future considerations. These Community Wellness Plans include Community Wellness Initiatives (CWI) which are then funded by the GNWT. The GNWT and communities consider incoming and completed projects, along with changes in monitored indicators when building initiatives and allocating funding. This allows CWIs to act as adaptive management and mitigate for project issues. Two-hundred and twenty-four programs and initiatives in communities were funded in the 2022-23. While Tłı̨chǫ communities are not covered by the NWA, Norman Wells, Tulita, Wrigley and other communities which may be impacted by the MVH will be covered.