Permafrost Management Plan

for the

Tłı̨chǫ All-Season Road Project

Prepared for the

Wek'èezhìı Land and Water Board

W2016L8-0001 and W2016E0004

January 2019

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The NSI Environmental Manager is responsible for the distribution, maintenance and updating of the Permafrost Management Plan. Final plan details must be approved by the Government of the Northwest Territories Department of Infrastructure (GNWT-INF) and the Wek'èezhìı Land and Water Board (WLWB).

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Permafrost Management Plan Document History

Revision #	Section(s) Revised	Description of Revision	Prepared by	Issue Date
0	N/A	First version	GNWT-INF and NSI	January 2019

Additional copies of the Emergency Response Plan can be obtained from the NSI Environmental Manager responsible for the Tłı̨chǫ ASR.

Executive Summary

The Tłı̨chǫ All-Season Road (ASR) is a Government of the Northwest Territories (GNWT) 97 kilometre all-season highway project (Project) with the potential to negatively affect the permafrost layer along the road alignment. Construction and operation are being planned to reduce disturbance to the active layer, underlying permafrost, and any ground ice features along the alignment. The GNWT will gain significant experience constructing, maintaining, operating and monitoring highways built on terrain underlain by sporadic discontinuous permafrost during the construction and operation of Tłı̨chǫ ASR.

The Project will involve the construction of a road embankment, 17 water crossings including four bridges over fish-bearing water courses, the development of borrow sources, and pre-construction vegetation-clearing. Such disturbance to the soil layers may lead to degradation of the permafrost layer potentially resulting in soil instability and the erosion of sediments into neighboring watercourses.

This Permafrost Management Plan (PMP) was developed to guide monitoring efforts aimed at ensuring protection of the active layer and permafrost conditions along the highway embankment, at water body crossing structures, and in any exploited borrow sources. The PMP also describes approaches that will be taken to effectively monitor the areas impacted by the Tłı̨chǫ ASR.

The PMP describes ground temperature monitoring activities that will be conducted regularly throughout the construction and operations of Tłı̨chǫ ASR. These monitoring activities will assist in adaptively managing the design and construction elements aimed at protecting ground thermal conditions if and where permafrost is identified. The monitoring efforts will also assist in identifying specific areas where mitigative or restorative efforts will be required. This plan contributes to the adaptive management approach for the Project committed by the GNWT in the regulatory framework.

Information and data collected under the PMP will add value to broad regional sporadic permafrost-related studies in progress by the climate science, geosciences and transportation infrastructure research community.

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Definition and Acronyms

GNWT	Government of the Northwest Territories
GNWT-INF	Government of the Northwest Territories Department of Infrastructure
H	Horizontal
MVEIRB	Mackenzie Valley Environmental Impact Review Board
NRCan	Natural Resources Canada
NSI	North Star Infrastructure (Design-Build-Finance-Operate-Maintain Contractor)
PMP	Permafrost Management Plan
Tłı̨chǫ ASR	Tłı̨chǫ All-Season Road
V	Vertical
WLWB	Wek’èezhìı Land and Water Board

1 INTRODUCTION

The planned construction and operation of the Tłı̨chǫ All-Season Road (ASR) has raised concerns regarding the potential to negatively affect the permafrost[1] layer along the road alignment. The Tłı̨chǫ ASR (Project) will involve the construction of a road embankment, 17 water crossings including four bridges over fish-bearing water courses, the development of borrow sources, and pre-construction vegetation-clearing. Such disturbance to the soil layers may lead to degradation of the permafrost layer potentially resulting in soil instability and the erosion of sediments into neighboring watercourses.

To address these concerns, the Government of the Northwest Territories (GNWT) Department of Infrastructure (GNWT-INF) undertook a geotechnical study in 2017 (Stantec 2017) to investigate the extent of permafrost occurrence along the road alignment to assess the development of measures to minimize and mitigate impacts if needed.

Initially, Canada Permafrost mapping from the National Atlas of Canada (Heginbottom et al. 1995) indicated that the Tłı̨chǫ ASR alignment lies within the zone of extensive discontinuous permafrost, with an estimated 50-90% of the landscape covered. However, no known thermistor or intrusive investigation records existed at the time for the Tłı̨chǫ ASR. Previous reconnaissance by the GNWT did not encounter any permafrost landforms or thermokarst zones within the corridor although a zone affected by thermokarst processes was noted between Whatì, Behchokǫ̀, and the area north of Siemon Lake (Kavik-AXYS Inc. 2008, see also the 2016 Project Description).

During the geotechnical study, 108 single-bead thermistor cables placed at various borehole locations along the alignment and at the crossing sites found permafrost detected at only four locations during the investigations conducted in February and March 2017. Table 1 provides details on the locations and ground temperature ranges for each of these detections.

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[1] Rock or soil that remains below 0°C for at least two consecutive years. Surface conditions including vegetation, organic cover and snow thickness can influence permafrost temperatures. Permafrost thickness is related to the air temperature, soil characteristics and the geothermal gradient as well as the geological history of the area; https://www.enr.gov.nt.ca/en/state-environment/13-permafrost

Table 1: Borehole Permafrost Detections

Borehole	Crossing # / Name	Ground Temperature Range (°C)	
		High	Low
BH-48	n/a.	0	-0.1
BH-33B	8 - Duport River	0	-5
BH-39B	9 - unnamed river	0	-0.2
BH-71B	La Martre River	0	-0.3

Source: Stantec (2017). # = number; BH = borehole; °C = degrees Celsius; n/a = not applicable.

These ground temperature ranges indicate warm to gradually melting permafrost at the sites. No ice-rich permafrost[2] was identified during the investigation. As such, Stantec (2017) suggested that the Project does occur in the discontinuous permafrost zone where 50 to 90 percent (%) of the ground is underlain by permafrost, although not as extensive as previously believed (Heginbottom et al. 1995).

North Star Infrastructure (NSI) has interpreted permafrost likelihood for the Tłı̨chǫ ASR alignment using ground temperature data, ice descriptions from borehole logs, surficial geology mapping and interpretations of additional information from the GNWT's 2018 geophysics data. NSI has estimated that the medium to high likelihood of permafrost occurrence along the route corridor is about 10%. According to Natural Resources Canada (NRCan)'s definitions of permafrost extent, the Tłı̨chǫ ASR alignment corridor would be classified as occurring within sporadic, discontinuous permafrost (10 to 50%).

However, as only a limited number of thermistors were installed along the 97 km of alignment during the geotechnical study, isolated ice-rich permafrost patches, or even isolated ice-rich permafrost areas, may exist in some sections of the alignment and crossing sites. Additional ground temperature data and borehole mapping of ground ice, as noted in the following section, would assist to validate NSI's assessment.

[2] Ground-ice content greater than the saturated moisture content of thawed soil; https://www.enr.gov.nt.ca/en/state-environment/13-permafrost

As a precautionary measure, the Report of Environmental Assessment and Reasons for Decision EA1617-01 (March 29, 2018; PR #286) states that, "the developer will develop and implement a permafrost management plan (PMP) for construction and maintenance of the Project." Hence the reasoning for the creation of this plan. The PMP will assist in adaptively managing the design and construction elements directed specifically at protecting permafrost ground thermal conditions in the Project area and identifying specific sites where mitigative or restorative efforts may be required. Information and data collected under the PMP will also add value to broader regional permafrost-related studies in progress by the climate science, geosciences, and transportation infrastructure research community.

2 MITIGATION AND MONITORING

The initial permafrost assessment in the 2016 Project Description (GNWT-INF 2016) was assessed without field verification to be extensive discontinuous permafrost (Heginbottom et al. 1995) The 2017 geotechnical field study also assessed it as discontinuous permafrost, although not as extensive (Stantec 2017). Based on this, NRCan submitted a technical report in October 2017 where they provided recommendations for the protection of permafrost (NRCan 2017). However, this was prior to the release of the Stantec (2017) report and the follow-up thermistor readings in 2018 which now indicate that the Project occurs in the sporadic discontinuous permafrost zone as noted in Section 1.1. Given this information, there is a medium to high likelihood that any permafrost areas along the alignment are vulnerable to thaw and a risk for thaw settlement.

Although the alignment is no longer considered to be extensive discontinuous permafrost, NRCan's recommendations have been taken into consideration in the development of this PMP. The six main points that NRCan (2017) summarized to the Mackenzie Valley Environmental Impact Review Board (MVEIRB) in the Report of the Environmental Assessment include (MVEIRB 2018):

- *complete detailed geotechnical investigations for the whole roadway*
- *monitor embankment and thermal and hydrologic regimes*
- *complete further investigations for permafrost and subsurface conditions*
- *only remove permafrost/ice after confirming extent of permafrost and thaw unstable materials*
- *deeper geotechnical boreholes, temperature cables, geophysical surveys*
- *provide a final assessment of quality and quantity of borrow material*

These recommendations will be considered, in addition to the following considerations listed below to provide guidance and measures to protect permafrost if encountered along the alignment where construction activities may lead to degradation.

Specialized site preparation to mitigate permafrost degradation, improve stability and reduce settlement of weak consolidating soils may also consist of:

- Protection of permafrost leaving organic layers in place
- Construction of a reinforced soil zone
- Installation of subsurface drainage
- Pre-loading or surcharge of abutment fill regions

2.1 Timing of Construction

As identified by the 2017 geotechnical investigation program, most of the natural ground is not underlaid by permafrost, and where permafrost was identified, no ice-rich permafrost was found (Stantec 2017). The ground along the Project alignment may be suitable for overland travel even during summer season if proper care is taken. Hence construction activities can be conducted during favorable summer seasons with likely no effect to the permafrost layer.

As noted in Section 1.1, the Project is in the sporadic discontinuous permafrost zone and ground ice is poor, traditional cut and fill construction methods may be considered to reduce construction labour. Due to the relative lack of permafrost, the construction of the Tłįchǫ ASR will be different from the approach used in the construction of Inuvik to Tuktoyaktuk Highway, which was built on terrain underlain by continuous ice-rich permafrost.

Ideally the GNWT-INF will continue to monitor and report on the existing thermistor cables as long as they remain functional. This data may be compared with data from the Design-Build-Finance-Operate-Maintain contractor, NSI, to provide a full picture of ground temperature trends before and after construction of the Tłįchǫ ASR.

2.2 Borrow Sources

The Tłįchǫ ASR embankment construction will require materials extracted from borrow sources located within or adjacent to the right-of-way. Even though ice-rich permafrost was not found during the 2017 geotechnical investigation, isolated ice-rich permafrost patches may occur at some locations. If ice-rich permafrost is identified during quarry activities, suitable measures will be taken to protect permafrost and ground ice encountered during material extraction activities as per the Quarry Operations Plan. These measures include covering any ice-rich material so that there is no unintended thaw flows and erosion as a result of permafrost degradation. For the term of the land use permits, the developed borrow sources will be visually monitored throughout the summer and fall to ensure that there is no erosion resulting from degradation of permafrost.

2.3 Highway Embankment

Typically, the design will avoid cuts in permafrost, but where cuts cannot be avoided, a major consideration is the provision of drainage to eliminate the effect of ponding, erosion, and icings along the road alignment that may cause formation of thermokarsts (sink holes) and degradation of permafrost. Various methods have been utilized to limit mass movement within cuts in permafrost zones (Mageau and Rooney 1984), as stated below:

- *Cutting moderate slopes (1.5H:1V to 3H:1V) with the use of covering over-exposed slope surfaces*
- *Building flat cut slopes (3H:1V or flatter) when protective covering is not available*
- *Buttressing exposed cut slopes with free drainage granular material to increase effective normal stress along the potential failure planes*

The embankment will be visually monitored during construction and during highway operations, to ensure that there are no significant erosion and embankment instability issues resulting from degradation of permafrost or other causes.

Where cutting occurs, a detailed geotechnical and/or geophysical investigation should be conducted in advance to confirm the extent of any permafrost or frost-susceptible soils. If permafrost or frost susceptible soils are identified, a detailed assessment and long-term plan of action will be discussed with the GNWT for remediation and further monitoring of the embankment for stability and extent of permafrost.

Where permafrost is encountered and/or with thaw sensitive soils, considerations for reducing risk of degradation and thawing include placing fill directly on undisturbed native surface in areas with permafrost and thick muskeg, in uniformly distributed layers thick enough to support construction equipment. Fill placement and compaction procedures will consider the season, site access, borrow proximity and fill types.

The use of geosynthetic reinforcement, prior to fill placement may also be considered, aligning with NRCan's (2017) recommendation that a non-woven geotextile be placed directly on the subgrade and extend laterally into the embankment footprint from the tow of the embankment. Geotextiles used beneath the embankment (to provide extra strength and prevent water and subsurface materials penetrating into the embankment) will be based on site conditions as assessed by geotechnical field investigations. The specific properties of the geotextile(s) used will be appropriate to the tensile strength, permeability, and weathering resistance requirements encountered.

Despite efforts to preserve permafrost, there may be locations where permafrost will gradually thaw due to thermal disturbance and climate change. The slope stability at these locations may be adversely affected by water released by the melting ground ice that could increase pore pressures and contribute to slope instability. The primary goal is to mitigate the rate of thaw to allow pore pressure dissipation. The embankment design at these locations will incorporate granular fill to provide adequate drainage and prevent the development of excess pore pressures within the embankment.

The main concern will be embankment stability where underlying frozen soils weaken upon melting. Permafrost mapping will allow NSI to identify locations that will be monitored for initial signs of lateral movement and cracking. In special cases, field instrumentation may be used to assess the subgrade pore pressures and monitor movement should embankment creep pose higher risk to the performance and safety of the roadway. Options to mitigate slope instability resulting from melting of frozen subgrade or permafrost include side slope flattening, embankment reinforcement, buttressing with rock fill, and drainage of the subgrade.

Monitoring of embankment performance was also recommended by NRCan (2017) and will include but not be limited to observations of cracking, sloughing, ponding water, aufeis (winter icings) and vegetation changes. Additionally, where permafrost is encountered and where practical, thermal and hydrologic regimes will be monitored to ensure that the embankment performs as designed.

Ideally, more ground temperature sensors will be installed at strategic locations along and adjacent to the right-of-way. These sensors will record ground temperatures at various depths to confirm overall ground temperature regimes, depth of the active layer and temperature of the permafrost. These temperature readings will occur during construction and into the operational phase of the road. This quantitative temperature data will be shared with scientists, geotechnical engineers and permafrost scientists who are undertaking ongoing regional assessments of permafrost, geomorphic, hydrologic and related climate conditions in the NWT and Northern Canada.

2.4 Watercourse Crossing Structures

Ongoing visual inspections will be conducted to ensure that the drainage system is functioning as designed and there is no permafrost damage resulting from crossing structures or bridge abutments. In addition, instrumentation will be installed at bridge abutments to record ground temperatures at various depths to confirm ground temperature regimes, depth of the active layer, and permafrost temperature. These temperature readings will be taken during construction and into the operational phase of the highway.

2.5 Analysis

Quality assurance and quality control of visual and quantitative monitoring results will be maintained through appropriate training of staff, periodic verification of field observations, and monthly review of monitoring results. Metadata and reporting standards will be established so data can be integrated with existing permafrost data collected from the thermistor cables installed in the 2017 geotechnical investigation and any additional thermistors added.

The GNWT-INF will continue to collect thermistor readings at least twice every year (ideally once in winter/spring and another in summer/fall) from the existing thermistor cables, as long as the cables are functional. Data reduction and analysis from the existing thermistor cables, as shown in Appendix A, will continuously be conducted by the Technical Services team of GNWT-INF.

It is anticipated that NSI will conduct data analysis of the temperature readings from the thermistor sensors installed by them during the construction of Tłı̨chǫ ASR. It is further anticipated that other data relevant to permafrost degradation such as data from geophysical surveys or similar to track ground subsidence and any changes in the depth of the active layer, may be used to correlate with the ground temperature data, thus creating a full picture on regional thermal regimes, hydrology and geomorphic events in the Project area. Adaptive management measures can then be undertaken in real time to address any concerns of permafrost degradation during construction, as per the Adaptive Management Framework for this Project.

2.6 Reporting

An annual report of all permafrost monitoring activities will be prepared for the period of construction.

Reports will provide results of permafrost monitoring activities, indicate if any issues were identified, and describe corrective actions to address these issues. The reports will also provide updates on relevant permafrost monitoring work being carried out in the Project area by other parties.

Data will be provided to the WLWB and copies of reports prepared in hard copy and electronic format (PDF format).

An annual review of the PMP will also occur so that relevant updates can be made and the document serving as a living document subject to change as new information is collected. This falls in line with the Adaptive Management framework approach. The annual review will also incorporate recommendations from the Project's Corridor Working Group.

2.7 Climate Change Effects as they Relate to Permafrost

NSI's current opinion is that most of the warm permafrost along the alignment has probably already been thermally disturbed from previous clearing of portions of the alignment or forest fires and is likely thawing. We consider that all warm permafrost will be vulnerable to thawing due to site development. Despite efforts to reduce impacts on permafrost during construction and operations, it is expected that much of the remaining permafrost along the alignment will disappear due to climate warming in the next decades.

3 REFERENCES

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Appendix A: Thermistor Readings along the Tłı̨chǫ ASR Alignment Crossings (2017-2018)