Natural Resources Canada's Draft Technical Submission for Inuvik to Tuktoyaktuk Highway, NWT

Submitted to the

Environmental Impact Review Board

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Non Technical Summary

NRCan's participation in the Tuktoyaktuk Highway Project for the Environmental Impact Review Board is as a leader in science and technology in the fields of earth sciences, and is participating in this review as a Federal Authority under the *Canadian Environmental Assessment Act*.

Key scientific and technical experts from the department have been involved throughout the review process of this project. NRCan's review included the Terms of Reference, draft Environmental Impact Statement (EIS) and supplementary information requests with respect to permafrost and terrain conditions for the proposed construction of the Inuvik to Tuktoyaktuk Highway Project Environmental Impact Review.

In this report, NRCan's specific comments are on permafrost and terrain conditions, as well as surficial geology. Where applicable, NRCan has provided recommendations to the EIRB to assist in the decision making process.

1. INTRODUCTION

Natural Resources Canada (NRCan) involvement in the Environmental Impact Review Board (EIRB) panel review of the Inuvik to Tuktoyaktuk Highway to date is within the context of our capacity as a source of science and technology expertise in the field of earth sciences.

1.1. Regulatory Role

NRCan is responsible for administering the *Explosives Act* and regulations, and pursuing the advancement of explosives safety and security technology. Our principal priority is the safety and security of the public and of all workers involved in the explosives industry in Canada. Through the Explosives Regulatory Division, NRCan provides services and support to the explosives industry, including manufacturers, importers, distributors, and users of explosives.

The Developer including the Hamlet of Tuktoyaktuk, Town of Inuvik and Government of Northwest territories may store explosives at the site during the construction phase. The Developer is unable to confirm whether explosives storage is required until the Government of the NWT makes a procurement decision and the Developer is able to determine an explosives contractor. If the Developer's explosives supplier requires storage of explosives at the site, they will need a licence from NRCan for magazines, and they will be required to follow specific guidelines and standards.

NRCan is not a likely Responsible Authority under the *Canadian Environmental Assessment Act* for this project.

1.2. Expertise

Specific areas of NRCan expertise that have been engaged in this review include:

- Geotechnical Science, Permafrost, Terrain Sensitivity; and
- Surficial Geology, and Stratigraphy.

NRCan reviewers focussed on issues related to the physical environment, including characterization of permafrost and terrain conditions (including terrain sensitivity and stability), surficial geological mapping, borrow resources, impacts of the project on permafrost and terrain, and impacts of the physical environment on the project including the impacts of climate change.

NRCan has participated in:

- Review of the Draft Terms of Reference, Oct. 2010;
- Review of the Draft Environmental Impact Statement and supplemental information regarding permafrost and terrain conditions, January 2012;
- Submission of Information Requests (IRs), February 2012;
- Review of IR Responses, July 2012;

- Submission of Questions and Issues for the Borrow Source Technical Meeting, August 2012;
- Submission of NRCan (ESS) Response to the Developer's Response of March 30, 2012 re: IR141 August 2012; and
- Participation in Borrow Source Technical Meeting, Aug. 22-23, 2012.

NRCan understands that design is an iterative process and more detailed site specific investigations to collect additional information on the physical environment will be required to support detailed and final design.

NRCan is appreciative of the additional information provided by the Developer in response to information requests. NRCan has the necessary information to complete its review of the EIS and offers the following comments and recommendations for consideration by the EIRB.

These recommendations are largely intended to provide guidance on factors that should be considered in detailed and final project design or subsequent monitoring and follow-up plans.

2. SPECIFIC ISSUES

2.1 Issue 1: Terrain conditions and sensitivity along proposed route

Documents Reviewed

- TOR 6, 7, 9.1, 10.1, App. A
- EIS 2.1, 2.2, 2.3, 2.4, 2.7, 3.1, Terrain Evaluation Report and Surficial Mapbook
- Response to IR 90, 91, 130, 131, 135, 136, 139, 148, 149
- Transcripts of Technical Meetings August 22-24, 2012

General Comments

Adequate information on terrain conditions including topography and characteristics of surficial materials (including thermal conditions, moisture and ice content) is required to support the design of the road. This information is required for route selection and to determine adequate embankment heights to limit thawing of the frozen ground. Identification of sensitive terrain and the assessment of environmental impacts will also require adequate information on terrain conditions along the proposed highway corridor.

2.1.1 Developer's Conclusion

The Developer has utilized a combination of historical data from previous geotechnical investigations and their own air photo interpretation to characterize terrain conditions along the route (e.g., EIS 2.3, 3.1, Response to IR 130, 131, 135, Terrain Evaluation Report and Map book). To date there has been limited field verification and the route has been selected, utilizing the information available to avoid ice-rich and sensitive terrain (EIS section 2.2). The Developer indicates that although the information utilized in the terrain evaluation is sufficient for preliminary design (and estimates of required borrow resources) and route selection, further site specific investigations will be required to finalize the route to avoid potential geotechnical challenges and to support detailed design (EIS 2.2, Response to IR 90, 91, 94, 100, 131, 132, 136, 149, Terrain Evaluation Report).

2.1.2 NRCan's Conclusion and Rationale

NRCan generally agrees that the level of detail provided in the Terrain Evaluation Report and accompanying maps is sufficient for preliminary design and identification of potentially sensitive terrain. However, there is a lack of detailed site-specific information for the corridor, particularly in areas of sensitive terrain including hill slopes and areas underlain by massive ice. Geotechnical investigations consisting of borehole drilling, geophysical investigations and installation of temperature cables will be required to support detailed design including final route selection. This information will also be required to determine what mitigation may be required to minimize environmental effects such as ground settlement, changes to drainage and ponding, erosion and slope instability. The Developer has indicated in response to IR 91, 94, 131, 132, 149 that further geotechnical investigations will be conducted to support detailed design.

Identification of ice-rich terrain, in particular areas underlain by massive ice, will be important for detailed design. Although the alignment sheets provided with the Terrain Evaluation Report do identify areas where massive ice may be an issue, including areas of potential instability (e.g., slope instability), further field verification will be required to better delineate potentially sensitive terrain. This will be important where the route is adjacent to water bodies such as lakes and ponds where thaw slumping may occur in ice-rich sediments (e.g., Kokelj et al. 2009). Field verification of ground ice conditions on hill slopes will also be required. The Developer has acknowledged the difficulty in identifying ice wedges and other massive ice on hill slopes from air photos (e.g., response to IR 91, 149). Detailed geotechnical investigations and the use of LiDAR (Light Detection and Ranging) are proposed to better identify ice-rich terrain (Response to IR 91). Geophysical investigations (response to IR 91, 136) including use of Ground Penetrating Radar (GPR) and capacitive coupled resistivity (CCR) are also proposed to identify areas of massive ice. NRCan is supportive of this approach as GPR and CCR are useful tools for delineating ice-rich terrain (e.g., Kneisel et al. 2008; Moorman et al. 2003) and notes that these techniques have been used in the region for mapping massive ice including resolving ice wedges (e.g., De Pascale 2008; Angelopolous et al. 2010; Wolfe et al. 2010).

NRCan notes that a topographic profile along the corridor has not been provided with the alignment sheets. This information could also aid assessments of potential impacts and support detailed design especially for slopes and water crossings. The Developer has also indicated that LiDAR surveys have been conducted (e.g., response to IR 135) and more detailed topographic surveys are planned to aid stream crossing design (response to IR 134). These surveys along with the detailed air photos could be utilized to support detailed mapping of drainage direction, potential drainage diversions, delineate areas susceptible to ponding and erosion and determine where culverts may be required. The Developer has indicated during the technical session (Aug. 22, 2012 transcript, p. 67-71) that these surveys will be utilized during detailed design to support water crossing design and identify locations where culverts may be required.

2.1.3 Recommendations

NRCan is supportive of the Developer's approach for further investigations to provide additional field verification of the terrain mapping and to better characterize terrain sensitivity. NRCan offers the following recommendations to support final route selection, detailed and final road design and to ensure environmental impacts are minimized:

1. NRCan recommends the Developer conduct additional detailed site specific field investigations including, but not limited to, geotechnical boreholes and geophysical surveys such as GPR and CCR to better characterize subsurface materials and identify locations of ice-rich sediments. It is also recommended that detailed field investigations focus on particularly sensitive terrain including potentially ice-rich terrain on hill slopes, at stream crossing and adjacent to water bodies to delineate areas of potential instability including areas prone to thaw slumping, solifluction or creep.

2. To support water crossing design and identify locations where culverts may be required, NRCan recommends that results of LiDAR surveys and proposed detailed topographic surveys along with the results of the air photo analysis be utilized to improve characterization of drainage direction and potential sites of ponding and erosion.

2.1.4 References

Angelopoulos, M., Pollard, W.H. and Couture, N., 2010. Integrated geophysical approach for the detection and assessment of ground ice at Parsons Lake, Northwest Territories, GEO2010, 63rd Canadian Geotechnical Conference and the 6th Canadian Permafrost Conference. GEO2010 Calgary Organizing Committee, Calgary, Sept 2010, pp. 1345-1352.

De Pascale, G.P., Pollard, W.H. and Williams, K.K. 2008. Geophysical mapping of ground ice using a combination of capacitive coupled resistivity and ground-penetrating radar, Northwest Territories, Canada. Journal of Geophysical Research, 113: F02S90, 15 p.

Kneisel, C., Hauck, C., Fortier, R. and Moorman, B., 2008. Advances in geophysical methods for permafrost investigations. Permafrost and Periglacial Process, 19: 157-178.

Kokelj, S.V., Lantz, T.C., Kanigan, J., Smith, S.L. and Coutts, R., 2009. Origin and polycyclic behaviour of tundra thaw slumps, Mackenzie Delta region, Northwest Territories, Canada. Permafrost and Periglacial Processes, 20(2): 173-184.

Moorman, B.J., Robinson, S.D. and Burgess, M.M., 2003. Imaging periglacial conditions with ground-penetrating radar. Permafrost and Periglacial Processes, 14: 319-329.

Wolfe, S.A., Smith, S.L., Chartrand, J., Kokelj, S.V., Palmer, M., and Stevens, C. 2010. Geotechnical database and descriptions of permafrost monitoring sites established 2006-10 in the northern Mackenzie Corridor, Geological Survey of Canada Open File 6677.

2.2 Issue 2: Analysis conducted to support road design and assessment of impacts

Documents Reviewed

- TOR 9.1, 10.1, 10.4, App A
- EIS section 2.4, 2.6, 3.1, 4.0, 4.2, 4.5
- Response to IR 90, 94, 95, 96, 99, 100, 132, 133, Attachment 2
- Terrain Evaluation Report and Map Book

General Comments

Information on ground thermal conditions is required for adequate design of the highway, assessment of impacts associated with the highway and granular resource extraction and also for determining the effects of climate change on the project. Thermal analysis is often conducted to determine the effects on the ground thermal regime, including changes in thaw depth (and associated ground movements) resulting from project activities such as road construction. These analyses can be utilized to support project design (e.g., determination of embankment height) and environmental assessment and also to determine effects of climate change on the project.

2.2.1 Developer's Conclusion

The Developer has largely relied on existing information such as Burn and Kokelj (2009) to describe the ground thermal regime in the proposed corridor (EIS section 3.1). Preliminary cross-sections for the road embankment for representative terrain have been based on preliminary information collected on subsurface conditions. The Developer indicates that a risk-based approach has been utilized to support project design including incorporation of climate change effects (EIS section 2.6, 4.5.1) and they have followed the guidelines in TAC (2010) (e.g., response to IR 96, 99). The Developer has indicated that at this stage the information available is sufficient for preliminary design including assessments of potential subsidence and the borrow requirements for embankments (response to IR 90, 94). More detailed geotechnical investigations are proposed including installation of thermistor cables as well as thermal analysis to support detailed design and selection of mitigative measures to minimize both the impact of the environment on the road and the impact of the road on the environment (Response to IR 91, 94, 96, 132, 133).

2.2.2. NRCan's Conclusion and Rationale

NRCan understands that design of the highway is an iterative process and that more detailed analysis is not required at the preliminary design stage. NRCan is supportive of the risk-based approach and use of the guidelines for incorporation of climate change as outlined in such documents as TAC (2010) and CSA (2010). However more detailed information on ground thermal conditions as well as detailed thermal analysis will be required to support detailed design and determine appropriate mitigation to be implemented to minimize environmental effects. The TAC (2010) guidelines indicate that roads constructed in permafrost regions are moderately sensitive to climate change and moderate consequences are associated with failure. This classification suggests that a semi-quantitative analysis is required and NRCan suggests that thermal analysis for representative terrain types in the project area could be useful. NRCan is supportive of the Developer's proposed detailed field investigations including installation of thermistor cables and their plans to conduct detailed thermal analysis. This will be particularly important in ice-rich and sensitive terrain including hill slopes and other areas of potential instability.

The thermal analysis will need to consider the impacts on the ground thermal regime of vegetation clearance and ground disturbance during construction of the right-of-way as well as the impact of the embankment and any effects on drainage (e.g., Burgess and Smith 2003, Darrow, 2011). Analysis should also consider issues such as increased snow thickness at the base of embankments, migration of surface and subsurface water (cross drainage) into the base of the subgrade and infiltration through the thawed embankment, all of which may affect the ground thermal regime (and result in permafrost degradation) particularly of the side slopes (e.g., Kondratiev, 2010; de Grandpré et al. 2010, 2012). Impacts including permafrost thaw and changes in drainage may be further exacerbated by climate warming (Smith and Riseborough 2010) and the thermal analysis will need to consider the combined effects of both the construction of the road and a changing climate. Recent studies (e.g., Smith et al. 2005, 2010; Burn and Kokelj 2009) have shown that permafrost in the project region has warmed recently at a rate of 0.5° to 1.0°C per decade and the changes in permafrost conditions adjacent to the road over time need to be considered in design of the embankment, especially the side slopes. The Developer has indicated that they will consider climate change in their thermal analysis and have provided scenarios that will be incorporated in their detailed analysis (Attachment 2, Response to IR 95, 96).

Table 4.2.1-1 in the EIS outlines mitigation measures that may be implemented to reduce the effects on the terrain due to construction and presence of the road. The detailed site investigations and analysis to be conducted during detailed design will better identify areas where such mitigation measures may be required. NRCan suggests that although these measures will be implemented during construction, ongoing monitoring will be required to assess the performance of the road and the impacts on the surrounding terrain. Monitoring will be required especially in areas of sensitive terrain and areas of potential instability including ice-rich slopes. Additional mitigation measures, in addition to ongoing maintenance, may be required during the lifetime of the road to ensure the integrity of both the road and the environment. An effective monitoring program will be required that includes, in addition to visual inspections, ground temperature measurements, installation of inclinometers on sensitive slopes, settlement measurements etc. The Developer has provided (e.g., response to IR 91) some information on the type of instrumentation and measurements that will be included in the monitoring program and NRCan supports the approach. Also required in the environmental monitoring and management plans are the definition of criteria for the need for mitigation and the selection of the mitigation techniques. In addition to the mitigation techniques provided in the EIS (section 4.2.1, Table 4.2.1-1), other techniques currently being evaluated elsewhere such as air convection embankments and heat drains (e.g., Lepage and Doré 2010; Lepage et al. 2012) may need to be considered during the project life.

2.2.3. Recommendations

NRCan recommends the following to support detailed design and ensure that environmental effects are minimized:

3. The Developer conduct the detailed investigations proposed, including installation of temperature cables and ground temperature measurements, to better characterize the ground thermal conditions in the corridor. It is recommended that these measurements be made for representative terrain types in the corridor.

4. The Developer conduct the more detailed thermal analysis that is proposed to improve assessments of potential impact of construction and presence of the road on surrounding terrain and to support final embankment design. This analysis should incorporate climate change and consider the range of climate conditions likely to occur over the project lifetime. It is also recommended that the thermal analysis be conducted for representative terrain types and that it also include varying snow depths along the shoulders and also the potential effects of subsurface water flow on the side slopes.

NRCan also recommends the following with respect to environmental monitoring and management plans:

5. Environmental monitoring and management plans include installation of instrumentation (e.g., thermistor cables, slope inclinometers) in addition to visual inspections, to monitor changes to the ground thermal regime and ground movements especially in sensitive areas including ice-rich terrain and hill slopes.

6. Monitoring and mitigation/management plans be developed that define the criteria for the need for mitigation and selection of the appropriate mitigation technique.

2.2.4. References

Burgess, M.M., and Smith, S.L. 2003. 17 years of thaw penetration and surface settlement observations in permafrost terrain along the Norman Wells pipeline, Northwest Territories, Canada. In Proceedings of 8th International Conference on Permafrost. Edited by M. Phillips, S.M. Springman, and L.U. Arenson. Zurich Switzerland. July 2003. A.A. Balkema, pp. 107-112.

Burn, C.R., and Kokelj, S.V. 2009. The environment and permafrost of the Mackenzie Delta area. Permafrost and Periglacial Processes, 20(2): 83-105.

Canadian Standards Association 2010. Technical Guide - Infrastructure in permafrost: a guideline for climate change adaptation, Report Plus 4011-10.

Darrow, M.M. 2011. Thermal modeling of roadway embankments over permafrost. Cold Regions Science and Technology, 65 (474-487).

de Grandpré, I., Fortier, D., and Stephani, E. 2010. Impact of groundwater flow on permafrost degradation: implications for transportation infrastructures. In GEO2010, 63rd Canadian Geotechnical Conference and the 6th Canadian Permafrost Conference. Calgary, Sept 2010. GEO2010 Calgary Organizing Committee, pp. 534-540.

de Grandpré, I., Fortier, D., and Stephani, E. 2012. Degradation of permafrost beneath a road embankment enhanced by heat advected in groundwater. Canadian Journal Earth Sciences, 49. doi: 10.1139/E2012-018

Kondratiev, V.G. 2010. Some geocryological problems of railways and highways on permafrost of Transbaikal and Tibet. In GEO2010, 63rd Canadian Geotechnical Conference and the 6th Canadian Permafrost Conference. Calgary, Sept 2010. GEO2010 Calgary Organizing Committee, pp. 541-548.

Lepage, J.M., and Doré, G. 2010. Experimentation of mitigation techniques to reduce the effects of permafrost degradation on transportation infrastructures at Beaver Creek experimental road site (Alaska Highway, Yukon). In GEO2010, 63rd Canadian Geotechnical Conference & 6th Canadian Permafrost Conference Calgary. GEO2010 Calgary Organizing Committee, pp. 526-533.

Lepage, J.M., Doré, G., Fortier, D., and Murchinson, P. 2012. Thermal performance of the permafrost protection techniques at Beaver Creek experimental road site, Yukon Canada. In Tenth International Conference on Permafrost Edited by K. Hinkel. Salekhard, Russia. The Northern Publisher, Salekhard, Vol.1, pp. 261-266.

Smith, S.L., and Riseborough, D.W. 2010. Modelling the thermal response of permafrost terrain to right-of-way disturbance and climate warming. Cold Regions Science and Technology, 60: 92-103.

Smith, S.L., Burgess, M.M., Riseborough, D., and Nixon, F.M. 2005. Recent trends from Canadian permafrost thermal monitoring network sites. Permafrost and Periglacial Processes 16: 19-30.

Smith, S.L., Romanovsky, V.E., Lewkowicz, A.G., Burn, C.R., Allard, M., Clow, G.D., Yoshikawa, K., and Throop, J. 2010. Thermal state of permafrost in North America - A contribution to the International Polar Year. Permafrost and Periglacial Processes, 21: 117-135.

Transportation Association of Canada (TAC). 2010. Guidelines for development and management of transportation infrastructure in permafrost regions. May 2010. TAC. Ottawa, ON.

2.3. Issue 3: Surficial geology and related ground ice assessment

Documents reviewed

- TOR 6, 9.1, 10.1, 10.4, App A
- EIS section 2.4, 2.6, 3.1.1, 4.0, 4.2, 4.5
- Response to IR 90, 91, 94, 96, 99, 100, 130, 131, 132, 133, 135, 136, 139
- Terrain Evaluation Report and Surficial MapBook
- Transcripts of Technical Meetings August 22-23, 2012
- Terrain Assessment of the Proposed Inuvik to Tuktoyaktuk Highway, INAC, 2010

General Comments

Surficial geology describes the type of sediments and landforms, and their modes of deposition (e.g., glacial, fluvial, lacustrine) that comprise the unconsolidated drift material overlying bedrock. An understanding of this is important for determining availability of granular aggregate resources, engineering properties, and the proclivity of different materials to contain ground ice and massive ice deposits. The last of these criteria, ground ice and massive ice content, has significant bearing on embankment thickness design, road alignments selected, and susceptibility to thermal erosion. An accurate depiction of the surficial geology within the development corridor, and field-based verification of ground ice and massive ice contents is thus required to ensure stable and sustainable road detailed design and construction practices.

2.3.1. Developer's Conclusion

For the preliminary design and route selections, the Developer, largely based their initial surficial geology classifications (excluding potential borrow sites and previous detailed studies conducted around Inuvik, Parsons Lake and Tuktoyaktuk; Response to IR 136) on published maps and reports by Rampton (1981, 1987, 1988). Embankment thicknesses were calculated based on established relationships between different types of surficial geology materials and representative ground ice contents (e.g., TAC, 2010), ensuring that the proposed embankment thicknesses would be sufficient to ensure that the underlying permafrost would remain insulated, and thus stable. Subsequent undertakings by the Developer using colour 1:30 000 scale airphotos, provided a more detailed assessment and mapping of surficial geology, geological processes, drainage and permafrost features along the proposed route alignments 1 and 3 (Terrain Evaluation report and surficial mapbook). This assessment also included airphoto-based identification of areas of ice-wedge polygons and suspected ice-rich terrain. Ground-truthing exercises which were to support this mapping effort were cancelled due to weather restrictions (Terrain Assessment Report). Recent field and geophysical surveys examining sensitive terrain (including ice wedges) and massive ice records in targeted locations over two, five day periods were reported by the Developers, but have yet to be filed with the Board (Aug. 23 transcript, p. 53-55). The Developers do report that based on their airphoto-based surficial geology mapping, significantly less areas of glaciofluvial outwash than suggested by Rampton (1987) occur within the development corridor, indicating instead that much more of this terrain is characterized as till (Terrain Evaluation Report and Surficial Mapbook, p.3-18). The Developer indicated that they do not consider that revisions to the surficial geology will have any substantial impact on the volume of borrow materials required to build the road embankment (Aug. 23, 2012 transcripts, p. 55-57).

2.3.2 NRCan's Conclusion and Rationale

NRCan recognizes the published surficial geology maps and publications used by the Developer to produce a preliminary road design, but notes the absence of integration of existing borehole (Chartrand et al., 2002; Smith et al. 2005) (excepting that discussed in Response to IR 136) and shothole drillers' log data (Côté et al. 2006; Smith 2011; Smith and Lesk-Winfield 2012) for areas outside of potential borrow locations (Response to IR 90, 131, 136). NRCan also acknowledges the Developer's subsequent undertakings to produce more detailed mapping in support of the detailed design stage and realignments of the route to avoid, where possible, sensitive terrain (Terrain Evaluation Report and Surficial Mapbook, Table 3-2). NRCan, however, notes the absence of systematic or extensive ground-truthing and field study beyond potential borrow sites used to instruct and verify the mapping process.

NRCan notes that the terrain through which the proposed development corridor will proceed is particularly difficult terrain to map in, owing to its generally low relief, vegetation cover, and post-depositional alteration brought about by thermokarst activities. In the absence of ground-truthing, it is uncertain to what degree different deposit types, and transitions between materials, particularly in areas where thin and discontinuous veneers of material may exist, could be accurately identified from 1:30 000 scale airphotos. More extensive integration of existing borehole (Chartrand et al. 2002; Smith et al. 2005) and shothole lithostratigraphic information (Côté et al. 2003; Smith, 2011; Smith and Lesk-Winfield 2012) could be used by the Developer during the detailed design stage to identify areas of surficial materials and terrain sensitivity that would warrant field study through boreholes and/or geophysical investigation.

On the issue of ice-wedges, NRCan accepts the Developer's airphoto-based mapping of large ice wedge polygon networks as sufficient to identify this type of particularly sensitive terrain (Terrain Evaluation Report and Surficial Mapbook, Table 3-2). However, as demonstrated by INAC (2010, p.7) smaller ice wedges, including those on hill slopes are unlikely to be identified from airphotos, and may be equally difficult to identify from helicopter-based aerial surveys. Geophysical techniques employed by the Developer in their recent study of massive ice (Aug. 23 2012 transcripts, p. 55-57; Response to IR 91), if employed in a systematic manner could reliably identify areas of ice-wedges, including smaller forms and those obscured by the vegetation.

Regarding massive ice, as previously noted by NRCan in issue 2.1, the Developer's use of geophysical techniques such as Ground Penetrating Radar (GPR) and capacitive coupled resistivity (CCR) are well suited to the identification of massive ice bodies. However, in the absence of the report on the Developer's recent field activities, it is uncertain which sites and terrain types the Developer chose to assess for the presence of massive ground ice, or if this has only been restricted to areas deemed to be ice-rich patterned ground (EIS, 3.1.1.4). NRCan notes comments by the Developer (Response to IR 136) that "massive ice at depth is not anticipated to be a hazard to embankment performance," noting further the exception of where thaw-flow slides are prevalent and may lead to exposure of such ice bodies. However, to NRCan's knowledge, no study has been undertaken by the Developer to determine the occurrence and extents of near-surface massive ice in areas outside of those defined by surface ice wedge polygons.

NRCan notes that previous studies in the development area utilizing borehole and seismic shothole records to identify and characterize ground ice and massive ice distributions have intentionally omitted all ice layers within the upper 4-6 m, classifying these instead as potential "wedge ice" (Rampton and Mackay 1971; Mackay 1973; Côté et al. 2003). More recent and extensive compilations of lithostratigraphic data (Smith and Lesk-Winfield, 2012), and analysis of this data have identified 679 massive ice records within the proposed highway 15 km buffer area, and that within the shothole massive ice data set, up to 41% of such deposits started at depths within the upper 4 m, and 33.4% started within the upper 2 m. Further, the majority (40.8%) of these massive ice records occur within till terrain, which characteristically has the lowest terrain sensitivity rating under the embankment thickness categories (EIS, Table 3.1.1-1).

2.3.3. Recommendations

NRCan recommends the following to support detailed design and ensure that environmental effects are minimized:

7. The Developer undertake more systematic and extensive field surveys, including borehole and sample analysis in order to better ground truth their airphoto-based surficial geology classifications. Further, that any changes to surficial material classifications be integrated and considered in the detailed design.

8. The Developer undertake additional and more extensive focussed field surveys and sample analyses to assess the location of smaller ice-wedges, particularly on hill slopes and adjacent proposed stream crossings, and to accurately determine the near-surface ground ice and moisture content in different surficial materials throughout the length of the proposed alignment. In the absence of any other information (e.g., borehole or shothole records), it is recommended that more widespread application of geophysical assessment (e.g., GPR, CCR) along the proposed development centerline would be of particular benefit.

9. The Developer undertake a more deliberate study of massive ice bodies (beyond those correlated with surface ice wedge polygons) within the proposed development area to better determine where such deposits occur at sufficiently shallow depths as to pose risk to road stability and sustainability. This course of action is recommended, but not limited to all areas of historical thaw-flow slide activity, and where the road passes in close proximity to lakes and other water bodies.

2.3.4. References

Chartrand, J., Lysyshyn, K, Couture, R., Robinson, S. and Burgess, M. 2002. Digital geotechnical borehole databases and viewers for Norman Wells and Tuktoyaktuk, Northwest Territory, Geological Survey of Canada, Open File 3912.

Côté, M.M., Wright, J.F., Duchesne, C. and Dallimore, S.R. 2003. Surficial materials and ground ice information from seismic shotholes in the Mackenzie – Beaufort region, Yukon and Northwest Territories: digital compilation. Geological Survey of Canada, Open File 4490, 1 CD-ROM.

Indian and Northern Affairs Canada (INAC) 2010. Terrain Assessment of the Proposed Inuvik to Tuktoyaktuk Highway. 15 p.

Mackay, J.R. 1973. Problems in the origin of massive icy beds, western Arctic, Canada. In: Permafrost, North American Contribution to the 2nd International Conference, National Academy of Sciences, Washington, D.C., p. 223-228.

Rampton, V.N. 1981. Surficial geology, Mackenzie Delta, District of Mackenzie. Geological Survey of Canada, Preliminary Map 32-1979, scale 1:250 000.

Rampton, V.N. 1987. Surficial geology, Tuktoyaktuk Coastlands, Northwest Territories. Geological Survey of Canada, Map 1647A, scale 1:500 000.

Rampton, V.N. 1988. Surficial Geology of the Tuktoyaktuk Coastlands, Northwest Territories. Geological Survey of Canada, Memoir 423, 98 p.

Rampton, V.N. and Mackay, J.R. 1971. Massive ice and icy sediments throughout the Tuktoyaktuk Peninsula, Richards Island, and nearby areas, District of Mackenzie. Geological Survey of Canada, Paper 71-21, 16 p.

Smith, I.R. 2011. The seismic shothole drillers' log database and GIS for Northwest Territories and northern Yukon: an archive of near-surface lithostratigraphic surficial and bedrock geology data. Geological Survey of Canada, Open File 6833, 1 DVD.

Smith, I.R. and Lesk-Winfield, K. 2012. An updated assessment of ground ice and permafrost geology-related observations based on seismic shothole drillers' log records, Northwest Territories and northern Yukon. Geological Survey of Canada, Open File 7061, 1 DVD.

Smith, S.L., Burgess, M.M., Chartrand, J. and Lawrence, D.E. 2005. Digital borehole geotechnical database for the Mackenzie Valley/Delta region. Geological Survey of Canada, Open File 4924, 30 p., 1 CD-ROM.

Transportation Association of Canada (TAC). 2010. Guidelines for development and management of transportation infrastructure in permafrost regions. May 2010. TAC. Ottawa, ON.

3. CLOSING

NRCan appreciates the opportunity to participate in this review and is willing to respond to any questions regarding our technical review by the EIRB, the Developer, and other parties involved in the project in support of the environmental assessment process.