Terrain Assessment of the

Proposed Inuvik to Tuktoyaktuk Highway

October 2010

Prepared for: North Mackenzie District

Prepared by: Terrain Sciences Unit

Abstract

An analysis of ice-rich terrain features was conducted for two of the proposed Inuvik to Tuktoyaktuk highway routes using aerial photographs. A one-day field assessment was conducted by helicopter and on the ground to verify some areas of ice-rich terrain. Visible ice-rich terrain features appeared to be less common along the Upland alternative route than in the Husky Lake lowlands to the east. About 14 km of confirmed and suspected ice-rich terrain was identified along the 2009 route, representing about 10% of its 137-km length. Approximately 4 km of confirmed and suspected ice-rich terrain was identified on the Upland alternative route, representing 8% of its 45-km length. The detection of significant areas of ice-rich terrain that were not identified in the Project Description indicates that the Proponent needs to conduct more work to delineate ice-rich terrain and terrain hazards along the proposed route.

1. Background & Objectives

The Inuvik to Tuktoyaktuk Highway is a proposed 140 km all-weather route extending through the uplands east of the Mackenzie Delta (Figure 1). Proponents of the project include the Government of the Northwest Territories, the Hamlet of Tuktoyaktuk and the Town of Inuvik. A Project Description was released in February 2010 that included several routing options. This assessment considers the 2009 Route and the Upland Route.

Indian and Northern Affairs Canada (INAC) is responsible for issuing land use permits on Crown Land under the Territorial Lands Act in the Inuvialuit Settlement Region. If the project proceeds, INAC will be required to issue land use permits and conduct inspections along the right-of-way during construction. A preliminary assessment of terrain hazards along the proposed right-of-way is required by INAC to verify the assessment conducted by the Proponent and to provide a basis for land use permits that are protective of the environment. In this terrain, areas of high ground ice content represent the most significant hazard to geotechnical stability. The purpose of this assessment is to: 1) Identify ice-rich terrain features along the proposed corridors using aerial photographs, and 2) field verify selected ice-rich terrain features.

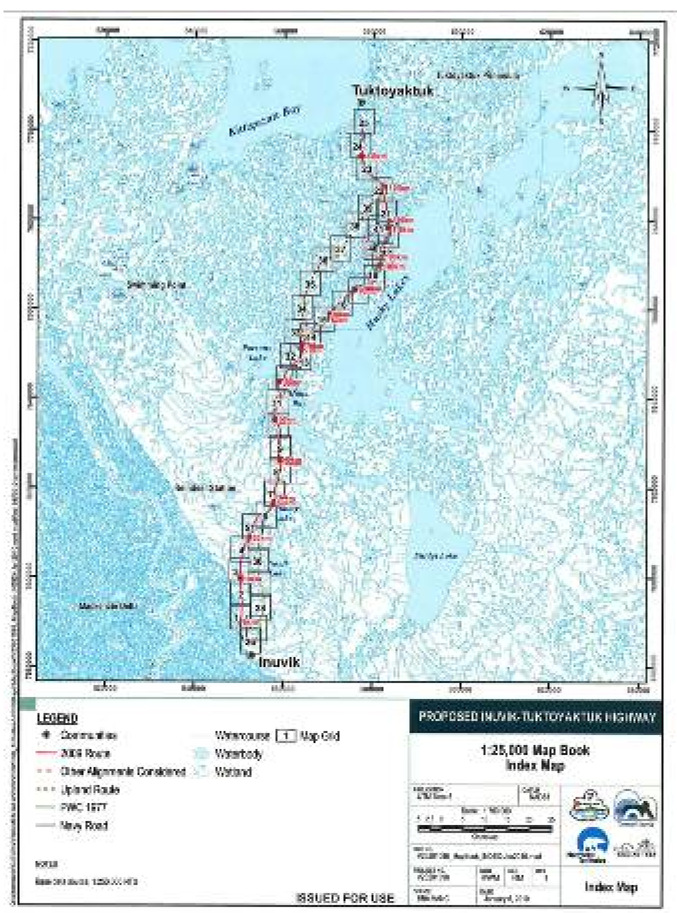

Figure 1 Proposed Inuvik to Tuktoyaktuk highway routes (Kiggiak-EBA Engineering, 2010). The 2009 route is shown in red and the Upland route is shown in brown.

2. Mackenzie Delta Uplands

The uplands east of the Mackenzie Delta are an area of continuous permafrost, with mean annual ground temperatures (MAGT) decreasing northward from -3°C near Inuvik, to -7°C on the tundra near Tuktoyaktuk (Burn and Kokelj 2009). A comparison of current MAGT's with those in the 1970's shows that ground temperatures have increased by 1 to 2°C in association with regional warming of air temperatures (Burn and Kokelj 2009). Surficial sediments are generally fine-grained lacustrine, alluvial or glacial sediments (Rampton 1988). Permafrost is ice-rich throughout the region. Pore ice, wedge ice and segregated ice lenses are present in the upper 2 to 3 m of permafrost (Kokelj and Burn 2004, 2005, Morse et al. 2009). Massive tabular ice bodies are also frequently encountered below the till layer (Mackay 1963, Rampton 1988). Near-surface ground ice is a key factor in the geotechnical sensitivity of this terrain since ground ice that is disturbed can melt and cause subsidence.

3. Methods

a. Aerial Photograph Interpretation

ESRI shapefiles of the proposed highway routes were obtained from EBA Engineering, consultant to the Proponent. The shapefiles were overlain on 2004 1:30,000-scale aerial photographs (Government of the Northwest Territories 2010) using ArcGIS. Ice-rich terrain features located beneath or immediately adjacent to the route were visually identified. These features included polygonal terrain, thaw slumps, and pingos. Results of the assessment were compared with the terrain analysis conducted by the proponent in Appendix B of the Project Description (Kiggiak-EBA Engineering 2010), and sections of ice-rich terrain that were not identified in the Project Description were recorded. The geographic location and length of the affected highway section were also noted.

b. Field Verification

Field verification of selected terrain features that were difficult to interpret with aerial photography was conducted on August 27, 2010. The author was accompanied by two INAC inspectors and an Inuvialuit Land Administration inspector. The 2009 route and Upland route were observed by low-level helicopter flight. Nine sites along the 2009 route were observed in more detail on the ground.

4. Results

a. Aerial Photograph Interpretation

Visual observation of aerial photographs identified 67 areas of ice-rich terrain features located beneath or directly adjacent to the proposed 137-km 2009 route, in addition to the areas identified by the Proponent in the Project Description. The geographic locations and images of these areas are shown in Appendix A. The presence of ice-rich terrain was confirmed by landing or flyovers at many of these areas during the aerial reconnaissance. The additional length of highway affected by ice-rich terrain identified in this analysis totals 10.4 km.

Seventeen areas of suspected ice-rich terrain features were also identified that require further field verification (see Appendix A). At these sites the resolution of the aerial photographs was too low to conclusively determine the presence of ice-rich terrain features, and the sites were not observed during the aerial reconnaissance. If ice-rich terrain was confirmed, these additional areas would represent 3.7 km of ice-rich terrain along the highway.

Analysis of aerial photographs of the 45-km upland alternative route resulted in the identification of 13 areas with ice-rich terrain features; in addition to ice-rich areas identified in the Project Description (see Appendix A). The newly identified areas affect a total length of 3 km along the highway. Two areas of suspected ice-rich terrain, representing an additional kilometre, require field verification.

b. Field assessment

General Observations

On August 27, 2010 a low-level helicopter flight was conducted over the entire length of the 2009 route from south to north, beginning at Navy Road in Inuvik and ending in Tuktoyaktuk, following the road to Source 177. Nine sites were observed on the ground in greater detail, and each is described in the *Site Specific Observations* section. On the return flight to Inuvik, the Upland Route was followed from north to south. No ground observations were made along the Upland Route.

Areas of patterned peatland were present in the forested, tall and short shrub terrain north of Inuvik and south of Parsons Lake. Many of these peatlands could be avoided during route planning. A number of ice-rich terrain features were observed in the lowland region adjacent to Husky Lakes, including drained lake basins, pingos, and thaw slumps with visible massive ice. Much of the ground surface appeared to be covered with saturated organics. The prevalence of ice-rich terrain features in this region could make the avoidance of sensitive terrain difficult. Along the Upland route to the west, relief was more pronounced, active thaw slumps were less common and drained lakes were not observed. Granular materials were exposed in some bare hilltops. Visible ice-rich terrain features appeared to be less common in the Upland region than in the Husky Lake lowlands; however, this observation was not confirmed by examination on the ground.

Site Specific Observations

Site 75: 68º30’39”N 133º46’33”W

A small (60 x 50 m) area of polygonal terrain surrounded by tall shrubs was observed in the southern portion of the route (Figures 2&3). The ice wedges were located in an organic peatland with low shrub and herb vegetation. At the surface, the ice wedge troughs were approximately 1.5 m wide and 0.5 m deep.

In this terrain, polygonal peatlands are widely spaced and can likely be avoided. However, polygonal areas should be identified prior to construction as they would be difficult to identify when snow-covered during the winter construction season.

Figure 2 Site 75, a small polygonal peatland surrounded by tall shrub terrain.

Figure 3 Site 75. Note the relief between polygon troughs and centres.

Site 84: 68º35'57"N 133º41'07"W

Several terrain conditions that could complicate highway construction were observed at this site. A small polygonal peatland was situated on a hilltop bounded on one side by a low polygonal area and on the other by a wide, undefined drainage (Figures 4&5). The small polygonal area on the hilltop was difficult to identify by aerial photograph or flyover. The difficulty in identifying this area emphasizes the importance of examining much of the proposed route on the ground prior to construction.

The wide, undefined drainage is typical of many non-channelized flowpaths that the highway will likely cross. These flowpaths may pose a hazard to the highway due to the warming influence of flowing water. Non-channelized flow is difficult to capture in a culvert. Drains designed to allow water to flow under the highway may transfer heat to the road base and cause subsidence. If the area remains undrained, the highway could act as a dam, resulting in ponding against the highway leading to warming and subsidence of the area. Highway planning will require consideration of how these non-channelized flowpaths will be crossed with minimal disturbance to the highway and surrounding terrain.

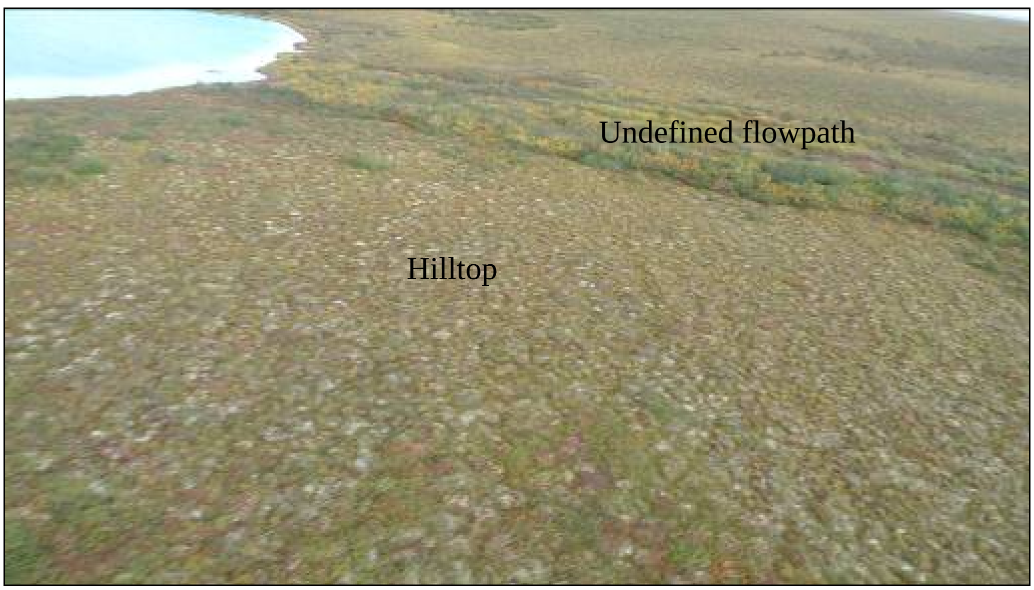

Figure 4 Site 84, Hilltop with a polygonal peatland in the foreground, and an undefined flowpath in the background.

Figure 5 Site 84. An ice wedge trough on the hilltop that was difficult to identify from the air.

Hans Creek: 68º52’04”N 133º33’35”W

Three slumps were observed on the south bank of Hans Creek, adjacent to the proposed route. One 12-m wide slump was likely active since blocks of the fallen active layer covered with live vegetation were situated in the creek below (Figure 6). The exposed sediments at the active slump were gravels and sands with no visible ice content. Two older, revegetated slumps were located immediately east of the active slump, and were each approximately 20-m wide. A large, active slump was located approximately 2 km downstream from the other slumps (Figure 7). All of the slumps were located on steep banks or cutbank slopes. Route planning should account for active and non-active slumps and slump-prone areas along streams and ensure that the highway is located at a safe distance away from them.

Figure 6 Small, active slump next to proposed highway crossing of Hans Creek.

Figure 7 Large, active slump on a cutbank downstream of the proposed crossing of Hans Creek.

Zed Creek: 68º56’24”N 133º25’02”W

Zed Creek has significantly lower banks than Hans Creek; however, even in the gentler terrain, a recently active 25-m wide slump was observed on a cutbank downstream of the proposed highway crossing at Zed Creek (Figure 8). There was no visible ice in the clay and silt sediments. Route planning should account for active and non-active slumps and slump-prone areas even along streams with low banks.

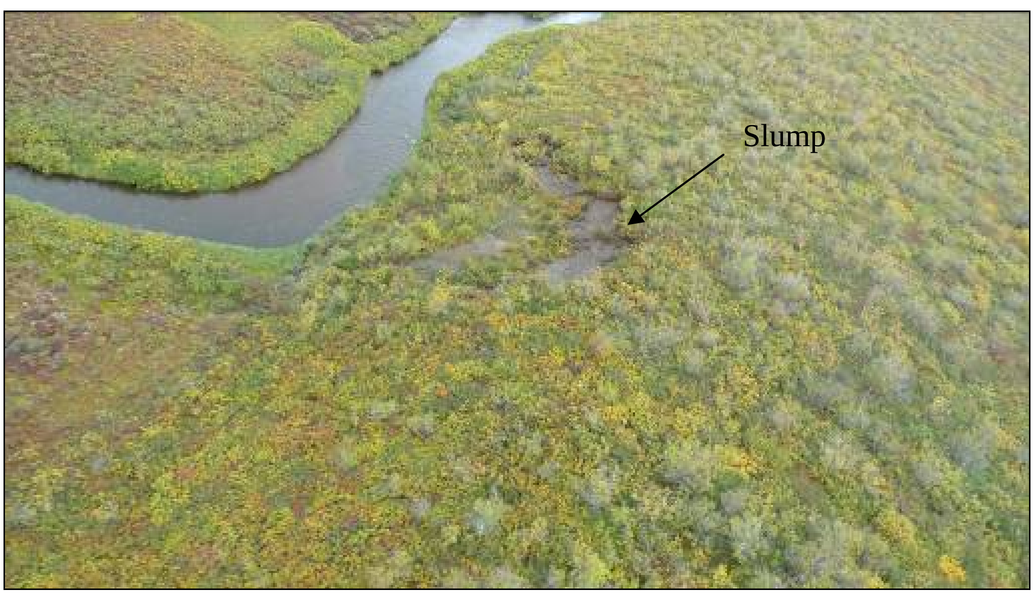

Figure 8 Small, active slump on a cutbank of Zed Creek, downstream of the proposed highway crossing.

IT Highway Slumps: 69º05'11.5"N 133º03'23.5"W
Two active lake-shore slumps and two older, revegetated slumps were observed on the south shore of a lake approximately 150 m north of the proposed highway (Figure 9). Massive ice was observed at the base of the headwall in the active slumps (Figure 10). Thaw slumps retreat backwards as ground ice in the headwall melts. New thaw slumps tend to form adjacent to old, revegetated thaw slumps. Active slumps, their rate of growth and older thaw slumps should be considered when routing the highway.

Figure 9 Active and revegetated slumps on a lake-shore next to the proposed route.

Figure 10 Detail of massive ice in the headwall of one of the active thaw slumps.

Husky Lake Slump: 69º07'49.7"N 132º55'03.4"W
A slump approximately 2 km from the proposed highway was observed to record its configuration and examine ground ice conditions in the slump headwall (Figure 11). The headwall was approximately 83-m long and 6-m tall. Three ice wedges were exposed by the headwall, ranging from 1 to 4 m width at the top of permafrost, and tapering to about 1.5 to 3 m at the base of the headwall (Figure 12). The largest ice wedge exposure was seen in profile, but the other two ice wedges were situated perpendicular to the headwall.

Figure 11 Thaw slump near Husky Lakes. Note that it initiated in previously slumped terrain, as indicated by the tall shrub vegetation.

Figure 12 Ice wedge exposures in the headwall of a slump near Husky Lakes.

IT Highway Pingo: 69º14’13.4”N 132º53’55.2”W,
IT Highway Pingo 2: 69º09’04.7”N 132º55’40.4”W
Two pingos were observed in close proximity to planned highway route (Figure 13). Pingos are thaw sensitive due to a solid ice core. Pingos are often explicitly protected by land use permit conditions that state that no land use operation can be conducted within 150 m of a pingo. Route planning should ensure that pingos are avoided.

Figure 13 Pingo located near the proposed route.

Source 177 Road
Several observations were made on the road extending from Source 177 to Tuktoyaktuk. This road was built in 2010 using similar construction techniques and mitigation measures as proposed for the Inuvik to Tuktoyaktuk highway.

Standing water was observed to be ponding next to the road in multiple locations (Figure 14). Ponded water is a source of heat that can degrade permafrost and cause subsidence of the highway and the adjacent terrain. For example, ponded water may lead to the enlargement of ice wedge troughs next to the road and the melting of ice wedges under the road (Figure 15). At a site next to the road, ice wedge trough widths were approximately 1-2 m and active layers were thicker than at a site located 50 m away from the road where troughs were about 0.5-m wide.

Slumping of embankment materials was observed at several sites along the road (Figures 16&17). The slumping could be due to the use of fine-grained materials to construct the embankments or the melting of ice within the road materials. Ground ice within granular materials should be allowed to melt and drain prior to their use in highway construction.

Figure 14 Multiple areas of water ponded against the Source 177 road.

Figure 15 Ponding of water and enlargement of ice-wedge troughs next to the Source 177 road.

Figure 16 Slumping of Source 177 road embankment material.

Figure 17 Another area of embankment material slumping and flowing across the tundra.

5. Discussion

A basic analysis of ice-rich terrain features was conducted for the 2009 and Upland routes using aerial photographs. A one-day field assessment was conducted by helicopter and on the ground to confirm areas that were difficult to interpret remotely. About 14 km of confirmed and suspected ice-rich terrain was identified along the 2009 route, representing about 10% of its total length. Approximately 4 km of confirmed and suspected ice-rich terrain was identified on the Upland route, representing 8% of the total length of this section. The identification of significant areas of ice-rich terrain that were not identified in the Project Description indicates that the Proponent needs to conduct more work to delineate ice-rich terrain and terrain hazards. Though many of the identified ice-rich areas may be avoided, the additional ice-rich terrain may affect project economics since a greater depth of fill is required in ice-rich areas.

This analysis identified areas with visible surface expressions of high near-surface ground ice content. These surface expressions may be obscured on slopes where slope movement has covered polygonal terrain, or in forested areas where ice-wedge cracking occurs less often and troughs are masked by vegetation. The Proponent should address how these areas will be identified and mitigated.

Lessons learned from the construction and maintenance of the road from Tuktoyaktuk to Source 177 are applicable to the proposed Inuvik to Tuktoyaktuk highway since the roads are to be built in the same environment using similar construction and mitigation techniques. Observations of slumping on the recently constructed Source 177 road may indicate that granular materials were not properly drained prior to their use in construction. Ground ice in granular materials should be allowed to melt and drain in the summer prior to their use. Extensive ponding of water against the side of the road suggests that maintenance of existing drainage control structures and the addition of new structures may be required. In relatively flat permafrost terrain, some flowpaths may not be apparent until after the road is built. Proponents should commit to long term drainage control monitoring and maintenance. Problems such as slumping and ponded water along the Source 177 road suggest that construction techniques and mitigation measures should be evaluated and refined before being directly applied to the Inuvik to Tuktoyaktuk highway.

6. Conclusions

Based on the aerial photograph analysis and field verification of ice-rich terrain features the following conclusions are made:

1. The Proponent should conduct a more detailed analysis of terrain hazards than provided in the Project Description. This analysis should be used to justify the proposed route options and should include an extensive on-the-ground component.
2. Performance of the Source 177 road should be observed and reported since the construction and mitigation techniques are directly relevant to the proposed highway.
3. The Upland alternative route should be examined in more detail since there appears to be less visible ice-rich terrain than in the Husky Lake lowlands.
4. The Proponent should provide a detailed evaluation of proposed mitigation measures to prevent permafrost thaw in areas where ice-rich terrain cannot be avoided.

7. References

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

Government of the Northwest Territories. 2010. Spatial Data Warehouse. http://maps.gnwtgeomatics.nt.ca/portal/index.jsp

Kiggiak – EBA Engineering. 2010. Project Description Report for Construction of the Inuvik to Tuktoyaktuk Highway, Northwest Territories. Prepared for the Hamlet of Tuktoyaktuk, Town of Inuvik and the Government of the Northwest Territories.

Kokelj, S.V. and Burn, C.R. 2004. Tilt of spruce trees near ice wedges, Mackenzie Delta, Northwest Territories. Arctic, Antarctic and Alpine Research, 36(4): 615-623.

Kokelj, S.V. and Burn, C.R. 2005. Near-surface ground ice in sediments of the Mackenzie Delta, Northwest Territories, Canada. Permafrost and Periglacial Processes, 16: 291-303.

Mackay, J.R. 1963. The Mackenzie Delta area, Northwest Territories, Geographical Branch, Memoir 8. Department of Mines and Technical Surveys, Ottawa.

Morse, P.D., Burn, C.R. and Kokelj, S.V. 2009. Near-surface ground-ice distribution, Kendall Island Bird Sanctuary, western Arctic coast, Canada. Permafrost and Periglacial Processes, 20(2): 155-171.

Rampton, V.N. 1988. Quaternary geology of the Tuktoyaktuk Coastlands, Northwest Territories. Memoir 423. Geological Survey of Canada, Energy Mines and Resources Canada, Ottawa.