Alaska Highway Geotechnical Borehole Database: Investigating Permafrost Terrain

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Background

There is currently a major lack of baseline data describing Yukon's permafrost terrain. Detailed maps of permafrost character, distribution and ground temperature do not exist at a scale adequate for:

- assessing terrain stability hazards for infrastructure and communities;
- assessing impacts of climate change and environmental disturbance on permafrost environments; and
- facilitating responsible planning of infrastructure, transportation and development of hydrocarbon resources

Permafrost can be extremely sensitive to natural (fire or river erosion) and anthropogenic disturbance and climatic trends. The existence and character of permafrost therefore directly influences the cost, design, routing and construction techniques for infrastructure and pipelines.

In southern Yukon's warm, marginal, discontinuous permafrost terrain, frequent transitions between frozen and unfrozen terrain make infrastructure and pipeline engineering extremely challenging.

Frost heave, thaw settlement, slope stability, and uncertainty in the rate of response of permafrost to anticipated climate change and forest fires are major geotechnical concerns.

YGS has been compiling geotechnical borehole data in a GIS-compatible database for the Alaska Highway since 2005. 2010 was the final year of data entry required to complete coverage for the Alaska Highway. The database provides new baseline data that can be applied to a variety of planning efforts within the Alaska Highway corridor.

Yukon Highways Borehole Data

From the 1970s to present, Yukon Highways has operated geotechnical drilling programs to characterize highway alignments and gravel pits.

Every time a highway is realigned in Yukon, boreholes are drilled approximately every 100 m down the centreline, averaging 6 m deep (Fig. 1).

Detailed soil descriptions are logged for each borehole, including changes in texture, colour and soil moisture with depth.

Permafrost conditions are classified according to the presence or absence of visible ice and form of visible ice observed in the frozen ground (Pihlainen & Johnston, 1963).

Logs from highway boreholes drilled since 1992 were originally compiled by Yukon Highways into an older digital database (ESEBASE). This database was not GIS compatible and did not include universal location coordinates or permafrost data for any of the records.

Most of the earlier borehole data from the 1970s to 1992 were never digitally captured, and were simply stored in over 1500 field log books.

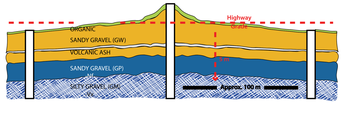

Figure 1. Typical layout of Yukon Highways drilling program.

Database Description

The Alaska Highway borehole database is modelled after a geotechnical borehole database developed by the Geological Survey of Canada (GSC) to store borehole data for the Mackenzie Valley.

The MS Access database structure (Fig. 2) consists of a number of related tables that store soil stratigraphy (Fig. 3), permafrost, geotechnical properties and drilling contract details.

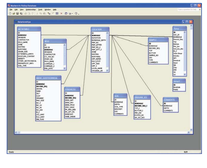

Figure 2. Table relationships in the Alaska Highway borehole database.

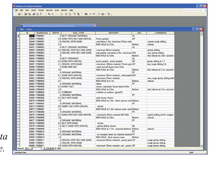

Figure 3. Example of typical data entered in SOIL table.

Compilation Methodology

- Pre-existing digital data from the Yukon Highways ESEBASE database were manipulated and imported into MS Access format.
- Permafrost and soil descriptions for the older borehole data were manually entered into the MS Access database from hundreds of original field logbooks.
- "As built" highway design maps were georeferenced (from scanned images and AutoCAD drawings), and boreholes were manually digitized in ESRI ArcMap to obtain universal location coordinates.
- Unified Soil Classification (USC) codes were assigned to all soil texture descriptions.
- The MS Access borehole data were imported into ESRI shapefile GIS format.

Takhini River Bridge Case Study

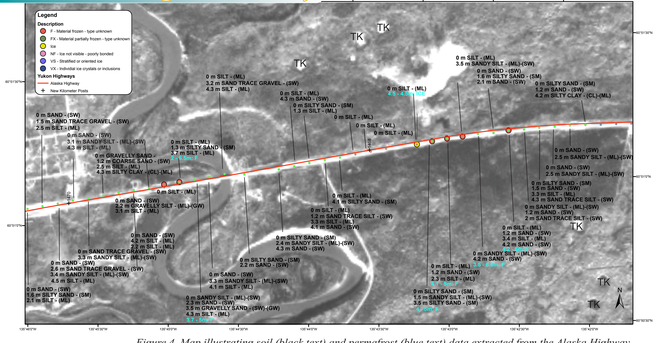

Figure 4. Map illustrating soil (black text) and permafrost (blue text) data extracted from the Alaska Highway borehole database for the Takhini River bridge area, approximately 40 km west of Whitehorse. Boreholes in this area were drilled in 1982 to depths of 5-6.5 m. Soil textures consist of glaciolacustrine silt and sand that is sporadically frozen and ice-rich. Thermokarst thaw depressions (TK) are common in this part of the Takhini Valley (Burn, 1998) and permafrost degradation has caused ongoing damage to the Alaska Highway in this region.

Dry Creek Case Study

Figure 5. Alaska Highway damage near Dry Creek due to local permafrost degradation.

Figure 6. Thermokarst pond at Dry Creek which developed after aggregate removal in the 1990s.

Yukon Highways drilled several boreholes near Dry Creek between 1992 and 1994, prior to the realignment of the Alaska Highway in the area (old km 1906 / new km 1841).

The Alaska Highway borehole database shows that up to 4 m of massive ice existed in gravels between 8 and 12 m depth at this site.

Subsequent removal of surface gravel for aggregate use has since caused major thermokarst subsidence beneath and adjacent to both sides of the highway and ongoing road damage continues to be a problem at this location.

Discussion

Borehole Distribution:

8818 boreholes are contained within the Alaska Highway borehole database, providing nearly complete coverage from Beaver Creek to Whitehorse and from Jake's Corner to Watson Lake (Fig. 7).

Gaps in coverage extend between Whitehorse and Jake's Corner and from the Cassiar Highway Junction to Watson Lake. Drilling occurred in the early 1970s in these sections and the logbooks could not be located.

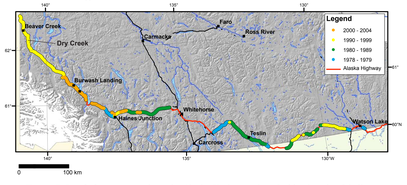

Figure 7. Borehole coverage along the Alaska Highway, classified by decade of drilling.

Permafrost Distribution:

One-third (2970) of the boreholes in the database contain some record of permafrost conditions, with the majority occurring between Beaver Creek and Whitehorse (Fig. 8).

Users must be cautioned that the absence of permafrost records for a particular borehole does not necessarily mean permafrost was not present when drilled.

When ground is only marginally frozen and ice-poor it can thaw by friction during the drilling process and therefore may not get recorded.

In addition, the scope of a particular drilling contract may not have always required that frozen ground be recorded.

Figure 8. Distribution of boreholes containing a record of permafrost in the database.

Take Home Messages

- The Alaska Highway borehole database contains surficial geology and permafrost data from nearly 9000 boreholes drilled along the Alaska Highway between Beaver Creek and Watson Lake between 1978 and 2004.
- The final database and derivative GIS files will be released as a YGS open file in Spring 2011.
- The database provides a wealth of baseline information that can be applied towards:
  - planning future transportation and infrastructure development within the corridor;
  - mapping permafrost distribution, character and temporal change;
  - increasing awareness of permafrost distribution among local engineers, managers, scientists and policy makers;
  - verifying permafrost modeling and geophysical studies;
  - identifying ice-rich permafrost and potential frost heave and thaw settlement zones.

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