Alaska Highway Geotechnical Borehole Database: Beaver Creek to Kluane Lake

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Background

Currently there is 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 (Figure 7) adequate for:

- Assessing terrain stability hazards for infrastructure and communities
- Assessing impacts of climate change and environmental disturbance on permafrost environments
- 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 (Figure 1).

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.

***Figure 1**. Embankment failure on Alaska Highway near Beaver Creek. Highway construction has altered local hydrology and caused thaw of ice-rich permafrost, resulting in ongoing stability problems.*

Purpose

A wealth of permafrost and surficial geology information (stratigraphy, texture, and ice character and content) exists in borehole logs drilled along the Alaska Highway and pipeline routes.

YGS is contributing to a national borehole database by compiling borehole data collected by Yukon Highways. Addressing the concerns to the left, this will make the data readily available for a variety of users.

The specific objectives of the project are to:

- Compile baseline geotechnical and permafrost data housed in YTG Department of Highways' borehole logbooks into a digital, GIS compatible database format
- Demonstrate some potential uses of this data

YTG Deptment of Highways' Drilling Program

***Figure 2**. Drilling through permafrost.*

***Figure 3**. Drill bit.*

From the 1970s to present, geotechnical drilling programs have characterized alignments and potential gravel pits.

The scope of data collection changed with each project; some borehole logs describe soil moisture content of frozen soils, and classification of permafrost type.

Characterizing permafrost through drilling has its limitations. Material near zero degrees can be thawed by friction with the drill bit, so that ground ice may not always be recorded in the logs.

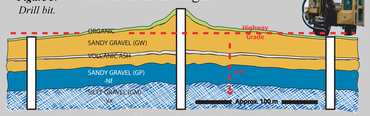

***Figure 4**. Typical layout of Yukon Highways drilling program.*

Database Description

The Geological Survey of Canada (GSC) has developed a geotechnical borehole database in Microsoft Access to create a nation-wide compilation.

The database contains a number of related tables that describe soil stratigraphy, ground ice, geotechnical properties, and drilling details (Figure 5).

The GSC is currently compiling Yukon data from Foothills Pipelines boreholes drilled almost 30 years ago.

YGS is contributing to the national database by compiling data from Yukon Highways boreholes that have been drilled in more recent years.

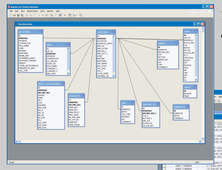

***Figure 5**. Table relationships in borehole database.*

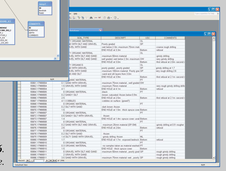

***Figure 6**. Typical entries in SOIL table.*

Compilation Methodology

Over 4000 boreholes have been entered, along a 200 km stretch of the Alaska Highway between the Yukon/Alaska border at Beaver Creek and Kluane Lake.

Digital ESEBASE data (DBase format) was imported into the Access database.

Non-digital records were manually entered from the original field drill log note books.

Borehole locations were digitized from scanned design layout maps or imported directly from AutoCAD drawings.

Koidern Case Study

Figures 8 and 9 show 42 boreholes along a 3 km stretch of the Alaska Highway (km post 1968-1970), just south of the settlement of Koidern (Figure 7).

The permafrost throughout most of this region is reported as probably more than 30 m thick (Rampton, 1978). The highway follows a fluted till plain along the flanks of steep colluvial slopes to the east. Landslide deposits (buried organic layers) from these slopes are evident in some of the cross sections in Figure 8.

In the Koidern River valley in the foreground, numerous thermokarst lakes attest to the widespread distribution of permafrost.

Figure 8 shows a lack of ground ice along the margin of Wolverine Lake (due to thermal heating effects).

A high spatial variability of textures and ice contents even within very small distances (i.e. across the highway) is also evident in Figure 8.

Figure 9 shows that the presence of permafrost is not restricted to fine grained soils.

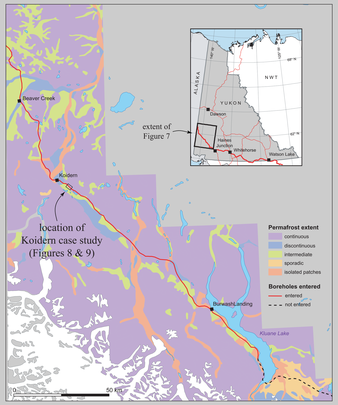

***Figure 7**. Location and index maps showing area covered by the database to date. Background shows the most detailed permafrost data currently available for southwest Yukon (after Heginbottom, 1995).*

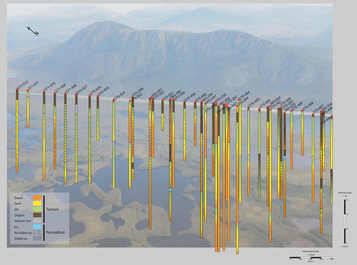

***Figure 8**. Cross section showing variability of soil textures and ice contents found in boreholes near Wolverine Lake / Koidern River area with oblique aerial view in background (Jul. 12, 2003).*

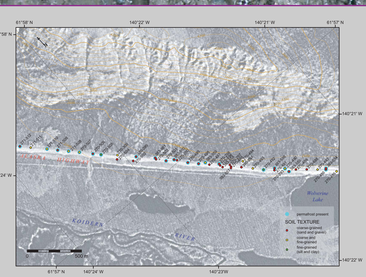

***Figure 9**. GIS analysis allows simple spatial relationships to be easily visualized. In this example, boreholes that encountered permafrost can be compared to soil texture.* *1 m resolution Indian Resource Satellite (IRS) image (September 1, 2000), courtesy of Yukon Highways.*

Discussion

Preliminary GIS and statistical analysis of the borehole data show several interesting patterns to date:

- >80% of the boreholes along the pipeline right of way north of Kluane Lake record the presence of permafrost (Rampton, 1983). Only 50% (2003/4008) of the highway borehole logs record permafrost.
- Presence or absence of permafrost does not appear to be directly correlated with soil texture
- Organic layer thickness does not directly correlate with active layer thickness
- Permafrost distribution is highly variable even on a scale of several metres

Database Applications

The current database and its evolution will improve our ability to:

- Map detailed permafrost distribution (depth and thickness) and character (ice-richness) (Figure 8)
- Identify areas with ice-rich permafrost and massive ice lenses (Figure 9)
- Predict and quantify frost heave and thaw settlement in response to climate change
- Recognize past landslide activity and identify potential slope stability problem areas along infrastructure corridors

It will also provide detailed data to:

- Validate geophysical studies and spatial modelling exercises
- Establish a baseline for regulatory bodies and industry proponents to ensure environmentally sound, safe and economic design, construction and operation of pipelines and transportation infrastructure in permafrost terrain

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