NORTH YUKON PERMAFROST CONFERENCE
August 21-26 | Dawson City, Yukon Territory, Canada

AN APPROACH FOR QUALITATIVE EVALUATION OF PERMAFROST THAW-SETTLEMENT POTENTIAL

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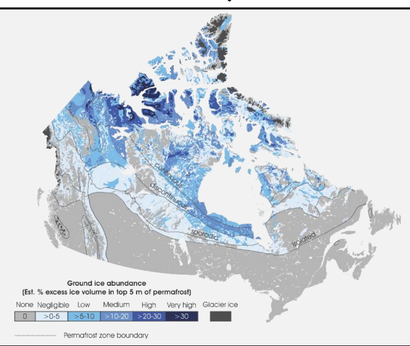
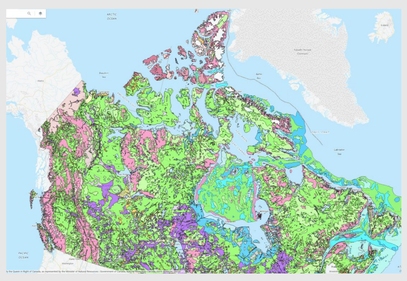
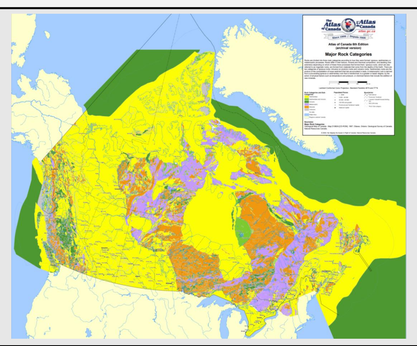
INTRODUCTION & BACKGROUND

- Permafrost degradation under infrastructure has been accelerated by climate warming and construction-induced disturbances
- Thaw-settlement and its associated problems are major contributors to high maintenance costs and compromised safety standards reported for linear infrastructure
- Evaluating thaw-settlement potential at a coarse scale is critical in the early stages of projects with large footprints. This allows for:
  - Comparing and screening multiple possible routes between two points based on thaw-settlement vulnerability
  - Identification of the most vulnerable sections of a route that crosses different types of terrain and permafrost conditions
  - A more effective planning for further investigation at a site scale
- In this study, a systematic approach is proposed for **qualitative evaluation of thaw settlement potential** (TSP) at a regional scale due to near-surface permafrost thaw.

METHODOLOGY

- Ground ice content and soil texture are identified as the main factors defining the thaw-settlement magnitude
- Soil texture is determined by the type of surficial deposit and the type of underlying bedrock:
  - Different surficial geology units are evaluated based on the possibility of having more fine-grained particles and organics, which are more thaw unstable
  - Overburdened cover of sedimentary bedrocks tends to be more fine-grained
- In this study, it is conservatively assumed that near-surface permafrost, if present, eventually thaws.
- Identified factors are compared based on their importance in defining the thaw-settlement magnitude using Analytical Hierarchy Process (AHP)
- A weight is calculated for each factor, and a numeric value is assigned to different categories defined for each factor, then used to calculate Thaw-Settlement Potential Index (TSPI)

THAW SETTLEMENT POTENTIAL EVALUATION

Controlling factors	Reference to obtain data	Maps	Defined classes for each factor	Weights
Ground Ice Content	Ground Ice Map of Canada (O'Neill et al., 2019)		Negligible:1 | Low:3 | Medium:5 | High:7 | Very High:9	0.78
Soil texture: Deposit type	Surficial Geology of Canada (GSC, 2014)		Very low:1: R*, Cv, V; Low:3: Gmn, Gfp, Gfc, Wv, C; Medium:5: Gmv, Tv, w, A; High:7: Gln, Tb, Th, Tm, E; Very High:9: O, Gmo, Glo, Lo, Ln	0.15
Soil texture: Bedrock type	Map of Major Rock Categories (Atlas of Canada, 1997)		Non-sedimentary:1 | Sedimentary:9	0.07

* Refer to Surficial Geology of Canada (CGS, 2014) for the name and description of each surficial geology unit

Overburdened cover of sedimentary bedrocks tends to be more fine-grained

TSP levels for all possible combinations of ground ice content, surficial geology unit and bedrock type classes:

Bedrock type: Non-Sed. (1)	Deposit type \ Ground ice content	9	7	5	3	1
	9	H	H	H	M	L
	7	H	H	H	M	L
	5	H	H	M	M	L
	3	H	H	M	M	L
	1	H	H	M	M	L

Bedrock type: Sed. (9)	Deposit type \ Ground ice content	9	7	5	3	1
	9	H	H	H	M	M
	7	H	H	H	M	L
	5	H	H	H	M	L
	3	H	H	M	M	L
	1	H	H	M	M	L

Thaw-Settlement Potential Index (TSPI):

TSPI = (Ice Content x 0.78) + (Deposit Type x 0.15) + (Bedrock Type x 0.07)

1 — 2.5 — 5 — 9

LOW
There is a low probability of widespread thaw-settlement; however, some sites may experience it due to localized conditions.

MEDIUM
Thaw-settlement is likely to be widespread. In order to minimize problematic settlement risk, an extensive site investigation is required to identify the settlement potential at a site scale.

HIGH
Widespread thaw-settlement is very likely. If construction is unavoidable, design measures should be implemented to keep permafrost intact to minimize the risk of thaw settlement.

APPLICATION OF THE PROPOSED APPROACH

- Performing a preliminary assessment during the route or site selection process, with minimum effort, time and cost
- Guiding city planners in selecting more stable ground for future development in the North

NEXT STEP

- To develop a Canada-wide map for the settlement potential
- To validate the approach by performing the assessment for case studies of thaw-settlement across Canada
- To enable a finer-scaled quantitative assessment using easily acquirable borehole data

REFERENCES

1. Atlas of Canada, "Major Rock Categories, Geological Map of Canada-Map D1860A," Atlas of Canada. Natural Resources Canada, Ottawa, ON, Canada, 1997.
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3. H. B. O'Neill, S. A. Wolfe, and C. Duchesne, "New ground ice maps for Canada using a paleogeographic modelling approach," The Cryosphere Discussions, pp. 1–37, 2019, DOI: 10.5194/tc-2018-200.

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