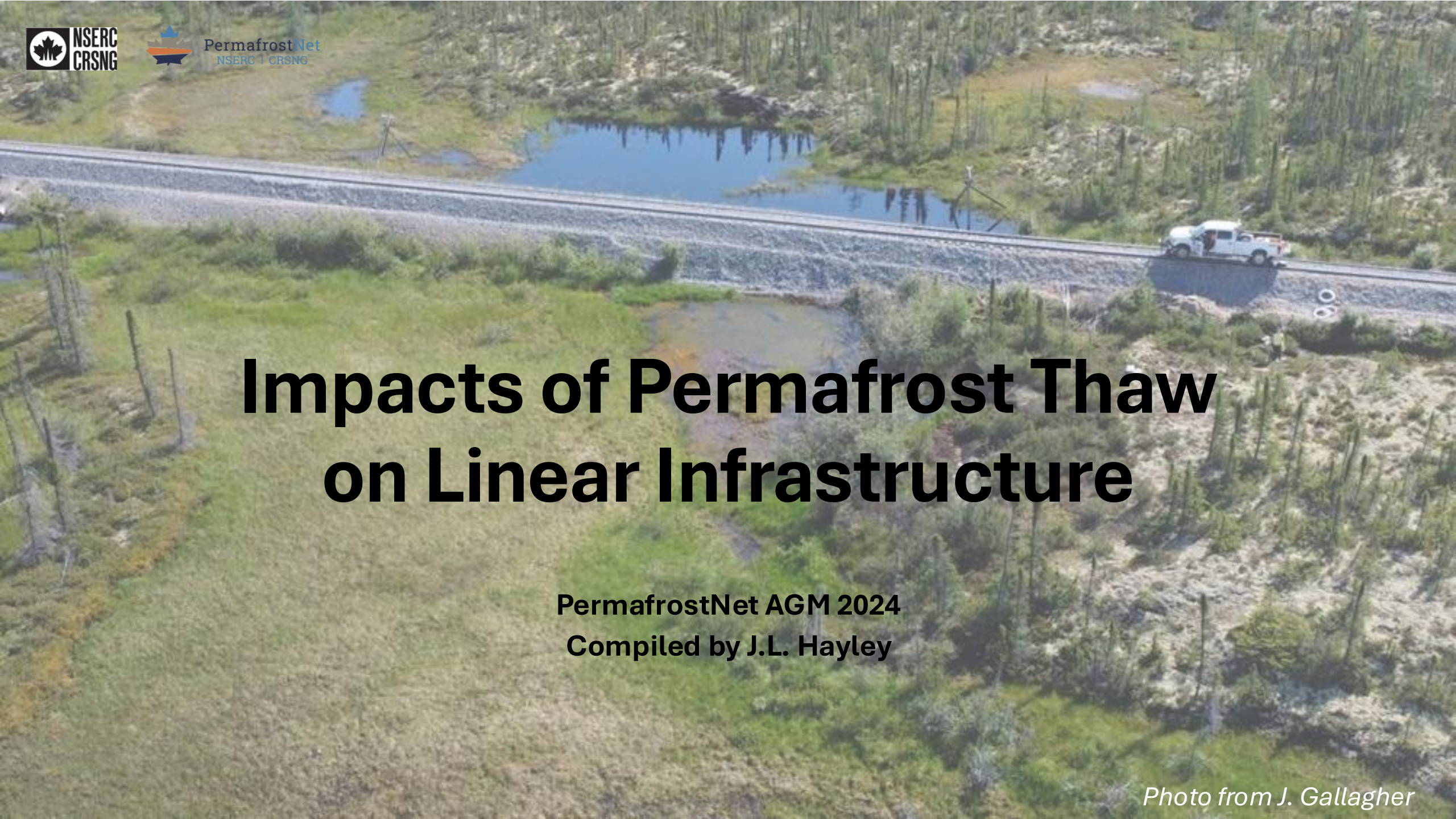


Impacts of Permafrost Thaw on Linear Infrastructure

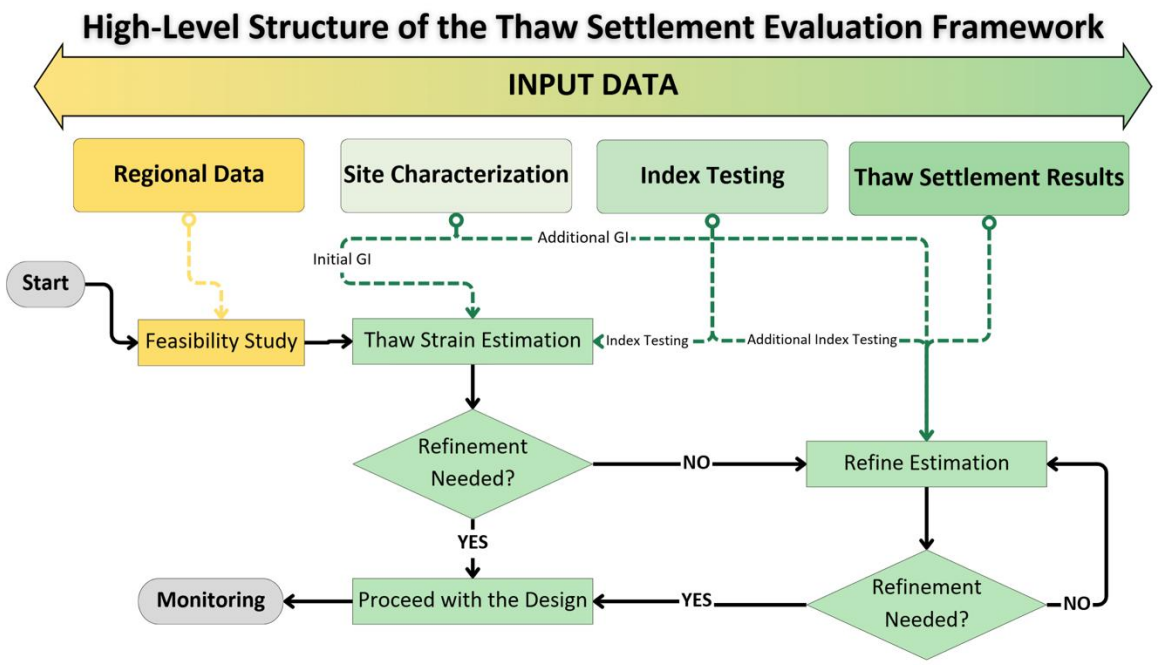
PermafrostNet AGM 2024

Compiled by J.L. Hayley

Photo from J. Gallagher

Theme	Project title	HQP/Student
1	*Building a framework for predicting thaw settlement*	Zakieh Mohammadi
1	*Serviceability analysis of infrastructure embankments on permafrost in a changing climate*	Khatereh Roghangar
1	*Geocryologically-driven landscape responses to climate warming along the Hudson Bay Railway*	Tabatha Rahman
2	*Airborne InSAR and Optical Photogrammetry to monitor linear infrastructure & Permafrost changes*	Usman Ahmed
5	*Risk management of linear infrastructure in remote permafrost terrain: Churchill Railway*	Zhina Rezvani
5	*Lowering ground surface temperatures by compacting snowbanks*	Pat Jardine
5	*Assessing a geocell-supported railway embankment subjected to permafrost degradation and ponding water conditions using numerical modelling techniques*	Payam Sharifi
5	*Sustainable culvert design over degrading permafrost, Hudson Bay railway*	Adeleh Moqadam
5	*Investigating Frost Jacking's Effect on Railway Bridges along the Hudson Bay Railway*	Natalie Arpin
5	*Monitoring climate-induced changes in northern railway infrastructure: an innovative approach using track geometry data*	Jonathan Gallagher
5	*Increases in highway maintenance costs (1994-2022) associated with climate change in Yukon*	Astrid Schetselaar

A Framework for Evaluating Thaw Settlement in Permafrost Regions



- Improved large-scale thaw settlement vulnerability assessment, Canada map
- Enhanced thaw settlement prediction by developing new empirical methods
- Compiled a comprehensive thaw settlement dataset & tested existing tools
- Integrated existing and newly developed tools to create a comprehensive framework
- **Impact:** *support safe infrastructure design and minimize maintenance costs*

Zakieh Mohammadi

Serviceability Analysis of Infrastructure Embankments on Permafrost in a Changing Climate

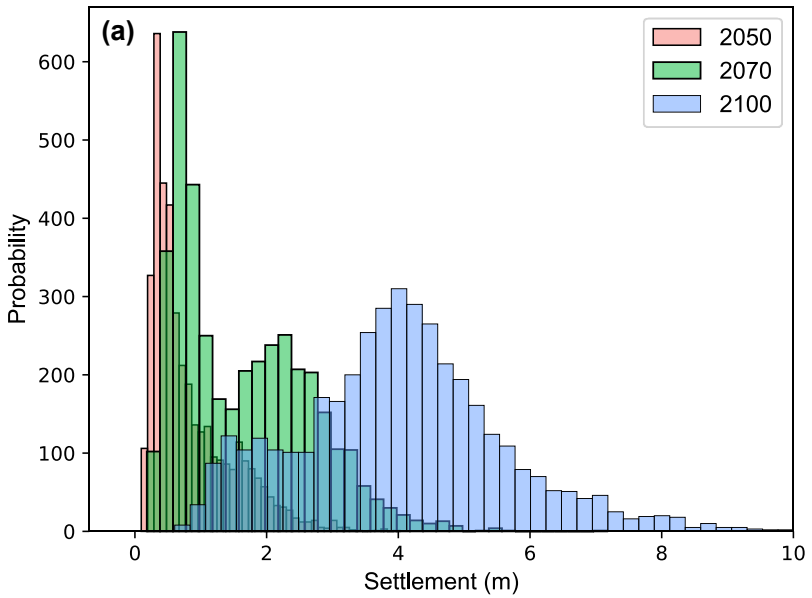


Figure 1: Histogram plots of thaw settlement by 2050, 2070 and 2100. This figure illustrates smaller values in 2050 and 2070 as well as a wider distribution of thaw settlement in 2100.

- Developed an integrated probabilistic approach to predict changes in active layer thickness and thaw settlement
- Incorporates climate change scenarios
- Predicts the serviceability of infrastructure based on anticipated probabilistic thaw settlement

Impact: *develop and maintain infrastructure resilient to future climate scenarios*

Khatereh Roghangar

Geocryologically-driven landscape responses to climate warming along the Hudson Bay Railway

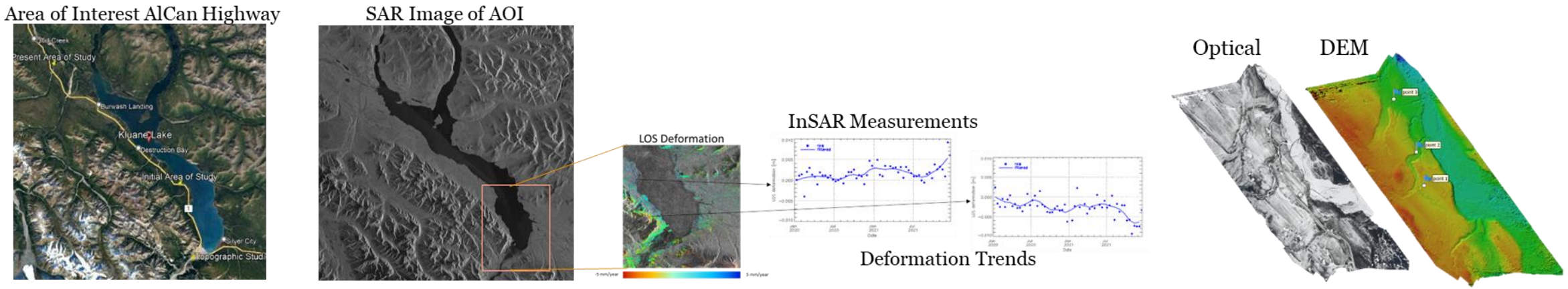
- Collected permafrost cores, ground temperature data, and landscape observations
- Developed a conceptual model of future geomorphological evolution in response to wedge-ice degradation
- **Impact:** *reduced threat to infrastructure stability through understanding and predicting thermokarst processes*

Photos by T Rahman & P Roy-Léveillée

Tabatha Rahman

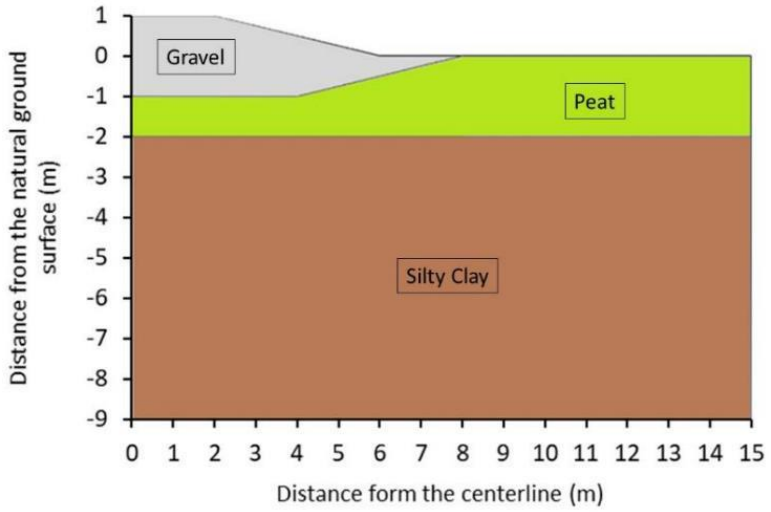
Airborne InSAR and Optical Photogrammetry to monitor linear infrastructure & Permafrost changes

- Utilized inSAR and Optical Photogrammetry methods to monitor changes in permafrost along Al-Can Highway, KNPR region
- Enables precise change detection and deformation trend analysis
- **Impact:** *Provide insight into long-term permafrost degradation where ground-based measurements are difficult to obtain*



Usman I. Ahmed

Assessing Thaw Settlement Vulnerability of the Hudson Bay Railway in the Face of Climate Change

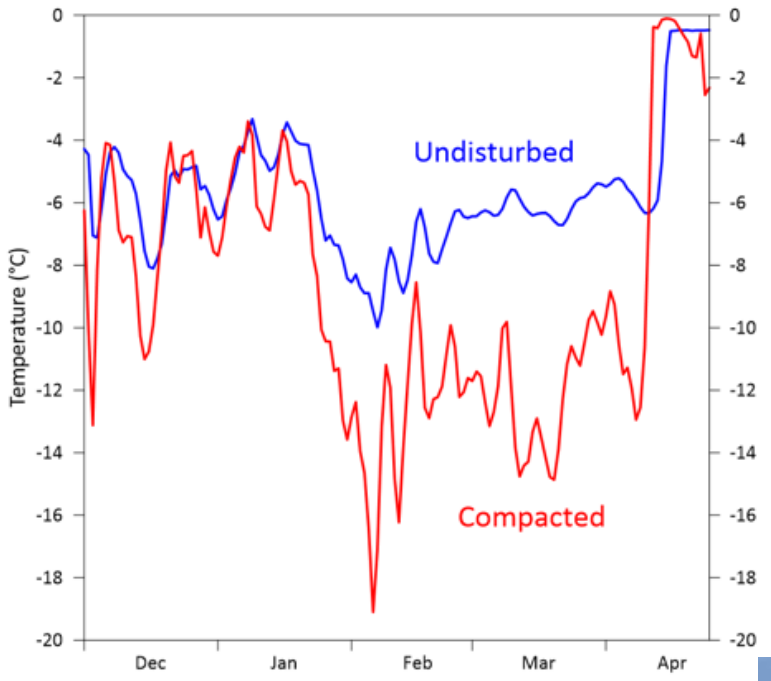


Photos: Zhina Rezvani

- Utilize a coupled thermo-mechanical model, validated by field data, to evaluate sinkhole formation
- Sensitivity analysis will determine key factors
- Vulnerability mapping to identify severity of thaw-related hazards under current and future climate conditions
- **Impact:** *help managers and policy makers make more efficient and informed decisions*

Zhina Rezvani

Lowering ground surface temperatures by compacting snowbanks



Mean daily temp. difference at adjacent roadside plots with monthly compaction at Blackstone Uplands site.

Na-Cho Nyäk Dun workers compacting a plot with snowmobiles at S. McQuesten Road site.

- Field experiments to compact snow alongside two Yukon highways
- Demonstrated a reduction in ground temperature and effectiveness of different regimes and environments
- **Impact:** *provides a simple method of reducing the risk of damage from thawing permafrost to highway embankments*

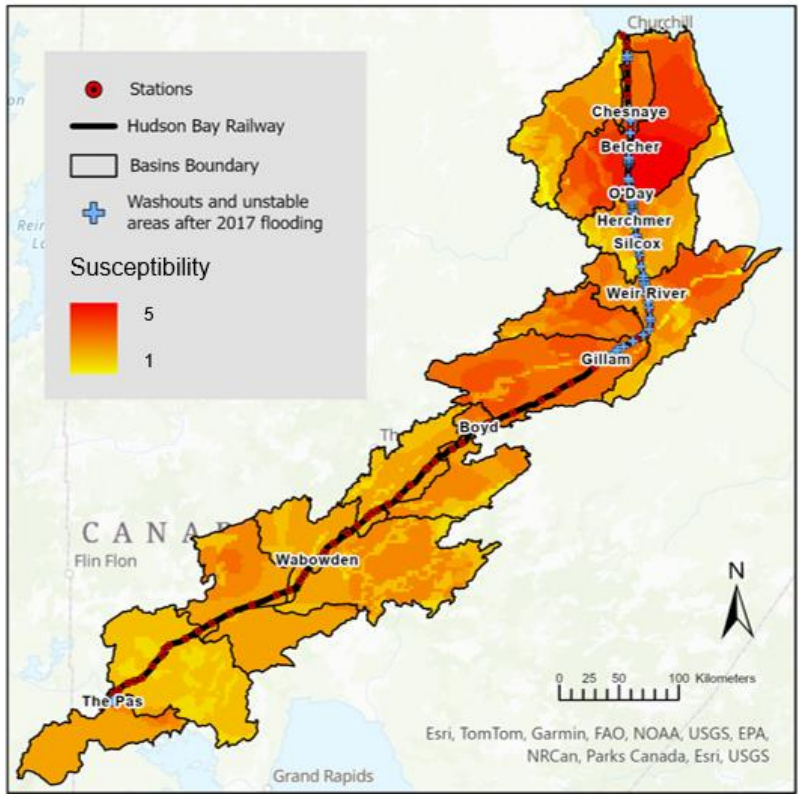
Pat Jardine

Assessing a geocell-supported railway embankment subjected to permafrost degradation and ponding water conditions using numerical modelling techniques

- Determined the optimal placement of geocell in an embankment
- Demonstrated an increase in stability and reduction in settlement with geocell
- **Impact:** *geocell can increase the short and long term performance of road and railway embankments*

Payam Sharifi

Flood Susceptibility Assessment of the Hudson Bay Railway

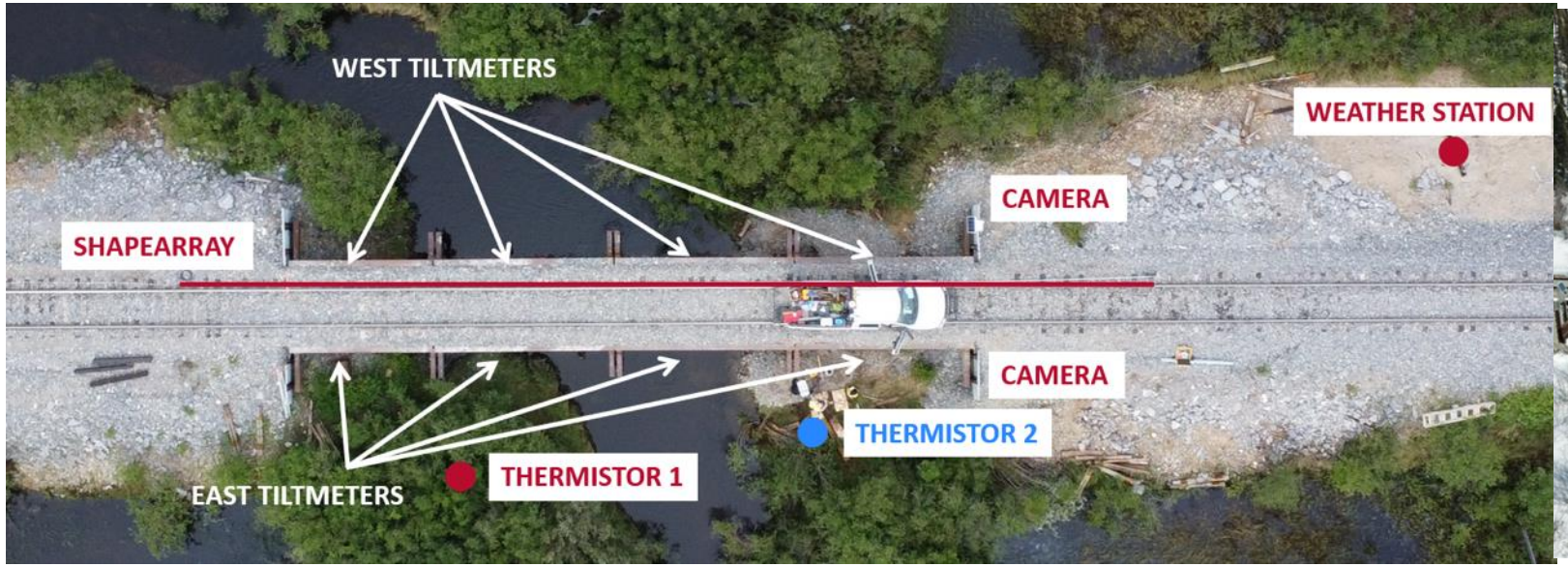


- Performed hydrological modelling to evaluate basins under extreme events
- Developed a flood susceptibility map, identifying areas most prone to flooding under current and future scenarios
- **Impact:** *develop maintenance and adaptation strategies to avoid washouts of infrastructure embankments*

Adeleh Moqadam

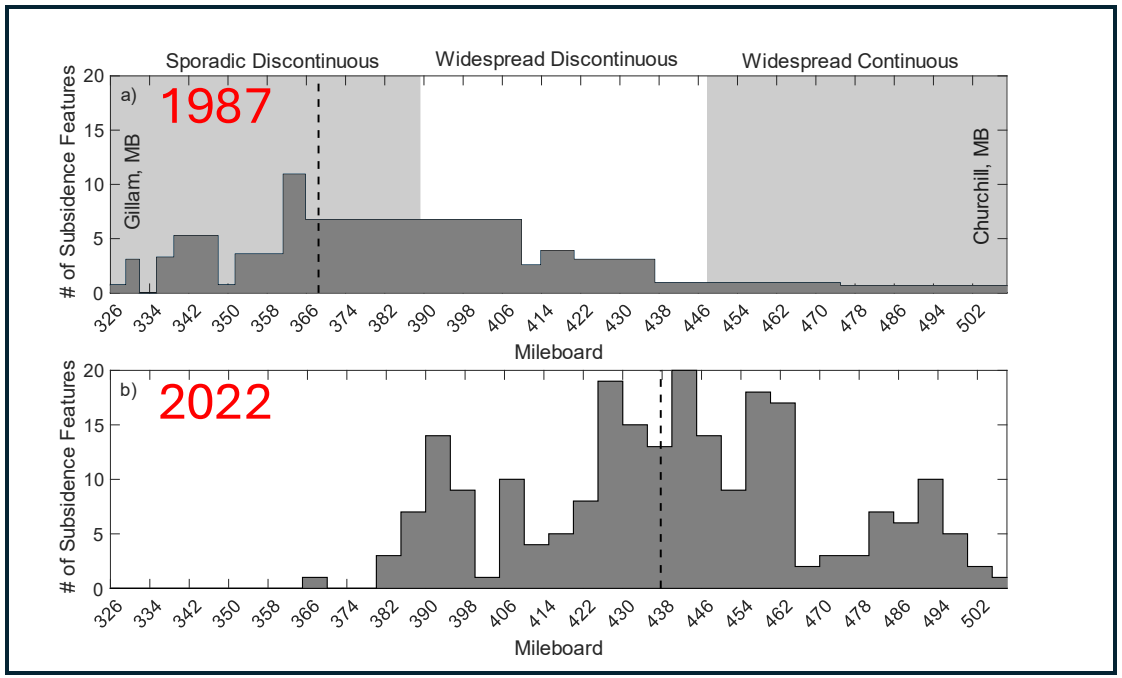
Investigating Frost Jacking's Effect on Railway Bridges along the Hudson Bay Railway

- Developed monitoring methods for frost jacking in remote locations
- Investigate controlling mechanisms through laboratory experiments
- Understand and quantify the system level effects of frost jacking
- **Impact:** *develop and maintain infrastructure resilient to frost jacking*



Natalie Arpin

Monitoring climate-induced changes in northern railway infrastructure: an innovative approach using track geometry data



- Created a workflow converting track geometry parameters into surface profiles
- Monitored the progression of track defects
- Used the railway as a continuous linear sensor to capture climate change effects
- **Impact:** *understand and assess the impacts of climate on infrastructure and degradation rate*

Jonathan Gallagher

Increases in highway maintenance costs (1994-2022) associated with climate change in Yukon

- Performed a retrospective analysis on the increasing infrastructure maintenance costs due to the impacts of climate change in a permafrost environment
- Improved understanding of long-term costs required to ensure functional performance of infrastructure
- **Impact:** *support transportation planners to anticipate the financial requirements for hazard management in the permafrost environment*

Astrid Schetselaar

Bringing it together: A focus on interrelated aspects

1. Understanding Permafrost Behavior
2. Risk and Vulnerability Assessment
3. Technological Solutions
4. Adaptation Strategies
5. Economic and Practical Implications

Together, these projects provide an integrated approach, addressing permafrost issues from basic science and monitoring to practical adaptation and financial planning.

Impacts of Permafrost Thaw on Linear Infrastructure

proactive, data-driven strategies are essential to maintaining and adapting linear infrastructure in permafrost regions as the climate warms

By leveraging predictive models, advanced monitoring technologies, and innovative adaptation techniques, we can mitigate risks, reduce costs, and ensure the long-term resilience and functionality of critical infrastructure like highways and railways.

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