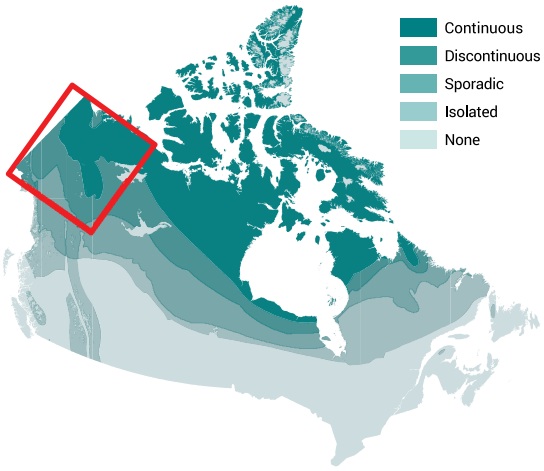
Increasing climate-related highway maintenance costs in permafrost environments of Yukon



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Study locations: Yukon.

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This research provides a retrospective assessment of climate-induced maintenance costs for highways constructed in permafrost environments. This study evaluated the increasing impact of climate change on northern infrastructure, emphasizing maintenance challenges posed by geohazards such as landslides, icings, washouts, and snow management. In addition, the study highlights variabilities in hazard type and magnitude across different terrain characteristics within Yukon. This analysis is important for infrastructure planners to anticipate future costs for transportation infrastructure. For example, planners can utilize this information to develop resilient infrastructure and allocate resources more effectively to mitigate the impacts of climate change on transportation networks.

Figure 1. Part of the Dempster Highway north of Eagle River bridge, northern Yukon.

Figure 2. Part of the Dempster Highway in the Ogilvie River Valley.

Research summary

Yukon's highway network, spanning approximately 4,800 km (about the width of southern Canada) across diverse landscapes, has experienced a notable rise in climate-related maintenance costs, primarily due to hydrologic issues in permafrost environments. Historical operation and maintenance expenditures were examined for 20 maintenance camps from 1994–2022, focusing on four climate-related activities including snow management, icing control, culvert maintenance, and the repair after landslides and washouts. Mean annual costs for these activities increased from $7.1 million to $10.9 million (constant 2021 dollars), rising from 25% to 47% of the total maintenance budget. The frequency and severity of hazardous events, such as landslides and washouts, increased particularly for highways on permafrost. On a per-kilometer basis, expenditures have been twice as costly for highway sections in continuous and extensive discontinuous permafrost terrain. These findings demonstrate the need for targeted maintenance strategies and planning to effectively manage and address the impacts of climate change.

Taking action

For Yukon, the diverse physiographic conditions lead to varying landscape responses to climate change, making a one-size-fits-all approach ineffective for managing the effects of climate change. Strategies should be tailored to the unique conditions and challenges of each region. Incorporating robust climate projections—especially for higher or extreme scenarios—into infrastructure planning that is crucial for ensuring the safety and reliability of highways throughout their service life. Addressing rising maintenance costs due to climate change within a constrained budget could also lead to deferred maintenance, reduced resources for other activities, accelerated infrastructure deterioration, and higher rehabilitation costs. Preventative measures such as increased inspections and timely repairs are essential to mitigate costly damage and maintain infrastructure integrity.

Connections to other projects

1 2 5

This project is part of Theme 5 – *Adaptation to permafrost thaw* and it is related to other network projects that include modelling the impact of surface materials e.g. gravel vs vegetation, on the thawing of frozen ground and subsequent settlement of infrastructure by Khatereh Roghangar (Theme 1), exploring ways of monitoring permafrost thaw near linear infrastructure in the Yukon using Synthetic Aperture Radar and optical data by Usman Iqbal (Theme 2) and project *Reduction of ground surface temperatures beside road embankments by snow compaction in central Yukon* by Patrick Jardine (Theme 5).

Partners, team members and support

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References

Schetselaar, A.B. and Burn, C.R., (2024). 'Increases in highway maintenance costs in a permafrost environment undergoing climate change, Yukon, Canada', in Beddoe, R. and Karunaratne, K. (eds.) 12th International Conference on Permafrost Proceedings. 12th International Conference on Permafrost, 16-20 June 2024, Whitehorse, Yukon, Canada. Available at: https://doi.org/10.52381/ICOP2024.82.1

Schetselaar, A.B., Andersen, T. and Burn, C.R., (2023). 'Performance of climate projections for Yukon and adjacent Northwest Territories, 1991–2020'. Arctic, 73(3), pp. 244–264. Available at: https://doi.org/10.14430/arctic77263

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