DRY CREEK PERMAFROST STABILIZATION PROJECT, YUKON TERRITORY

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> "The Dry Creek Permafrost Stabilization project contributes to the evaluation of techniques for the adaptation of highway infrastructure to climate change in permafrost environments."

The Dry Creek highway section of the Alaska Highway, approximately 400 metres in length, is located in the Yukon, approximately 40 km southeast of where the highway crosses into Alaska. It was identified as a key section of highway that necessitated permafrost mitigation over the long-term. The section is characterized by well-graded glaciofluvial sand and gravel underlain by glaciolacustrine silt and clay. Permafrost beneath the section is warm (>-1°C) and ice-rich, with massive ground ice layers in excess of 9 m. Yukon's Department of Highways and Public Works identified massive ground ice during investigation and construction of the original alignment in 1994/1995 (Figure 1). The massive ground ice makes this section particularly vulnerable to the effects of climate warming due to the thaw-sensitive nature of the permafrost.

Figure 1: Massive ground ice identifiedat Dry Creek in 1994/1995 (photo by Government of Yukon)

Realignment was not considered a viable option due to the presence of ice-rich permafrost within the surrounding terrain. Over-excavation of the massive ground ice beneath the current alignment was also not considered practical and would be cost prohibitive. The Government of Yukon retained SRK Consulting (Canada) to develop options for thermal stabilization of the permafrost along this section. Thermal modeling of i) an air convection embankment and ii) a thermosyphon-based design with a 30-year design life, both showed potentially positive results, and hence were considered viable options for long-term stabilization of the permafrost. The thermosyphon design was selected due to the potential for more immediate ground cooling with consideration of the overall project cost.

In 2017, Arctic Foundations of Canada (AFC) was selected by the Government of Yukon to construct and install 58 thermosyphon evaporators pipes at 7-m intervals beneath the existing highway embankment (Figure 2). The thermosyphons would provide passive cooling of the underlying permafrost foundation. The design specified 762 mm diameter schedule 80 pipe, approximately 35 m in length, installed in a cased borehole at an ~11° incline beneath the highway embankment. A vertical riser pipe, with a 19.5 m2 thermosyphon radiator installed a minimum of one metre above the designed grade, completed each thermosyphon unit. The inclined boreholes were drilled from a shallow excavation at the embankment toe, so as to maintain the integrity of the existing embankment, allowing for unimpeded use of this vital cross-border transportation route between Alaska and the Yukon.

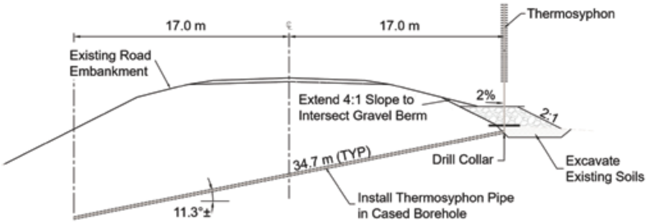

Figure 2: Typical cross section of thermosyphon unit installed beneath highway embankment

AFC supplied and installed its proprietary thermosyphon probes during the fall of 2019 and spring of 2020). Separate contractors drilled and cased the inclined boreholes and completed the final backfill.

The most notable challenge during construction was drilling and casing the inclined boreholes in poorly, ice-bonded gravel without the use of warm drilling muds. Drill muds, for borehole stability and casing installation, were limited due to the potential for thermal disturbance of the permafrost, which had been measured to be only several tenths of a degree Celsius below zero. The challenges with drilling consequently delayed completion of the project and required temporary installation of inclined thermosyphon radiators to ensure heat, induced during drilling, was dissipated (Figure 3).

Thermistor ground temperature readings and thermal imaging verified the immediate heat extraction from the embankment subgrade and the cooling effect of the thermosyphons, respectively (Figure 4).

Final installation of the radiators on the vertical riser pipes and backfill was completed in the spring of 2020 (Figures 5 and 6). A long-term monitoring program was developed by SRK to i) verify the thermosyphon units are functioning, ii) confirm the thermal design criteria is met at representative locations and iii) provide information to support similar thermosyphon-based designs in the future. The Dry Creek Permafrost Stabilization project contributes to the evaluation of techniques for the adaptation of highway infrastructure to climate change in permafrost environments.

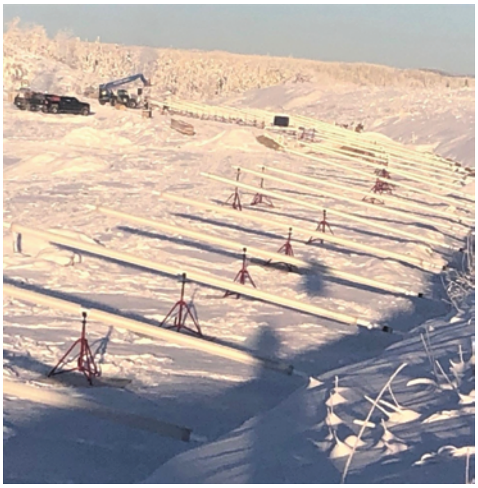

Figure 3: Temporary installation of radiators on extended inclined thermosyphons

Figure 4: Thermal image of temporary radiators showing temperature gradient between functioning thermosyphon radiators (yellow) and ambient background (red-purple)

Figure 5: Final thermosyphon riser piping before installation of radiators and backfill

Figure 6: Completed thermosyphons with vertical radiators installed and backfill complete

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