

Thermal Design of the Dry Creek Permafrost Stabilization Project

Christopher Stevens, PhD
SRK Consulting, Inc.

Idrees Muhammad, P.Eng, M.Eng;
Kisa Elmer, P.Eng;
Bill Stanley Yukon Government, Highways and Public Works

Yukon Highways and Public Works Transportation Engineering Branch

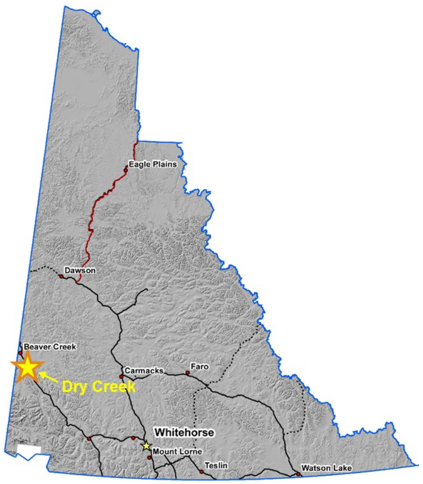
srk consulting

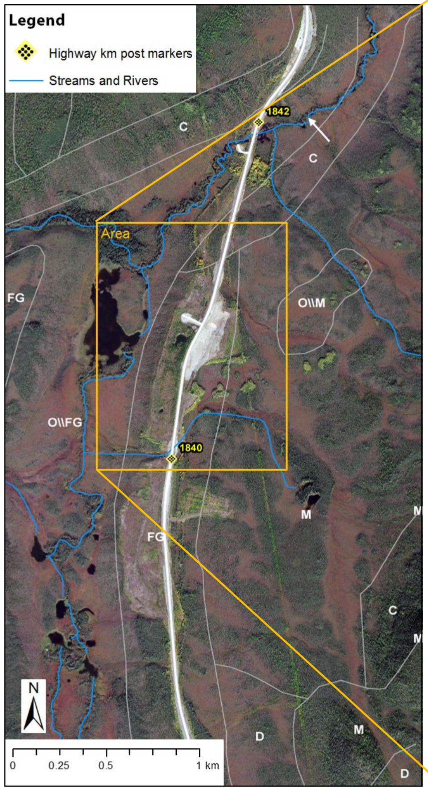
Outline

- Dry Creek Section, Alaska Highway
- History of the Site and Stabilization Project
- Geotechnical & Permafrost Conditions
- Preliminary Design Options Evaluated
- Sloped Thermosyphon Design
- Thermal Performance (modeled)
- Monitoring Plan

Dry Creek Highway Section

- Alaska Highway
- Hwy. km 1840.5 (+400 m)
- Approx. 30 km S. of Beaver Crk.
- Glaciofluvial deposit



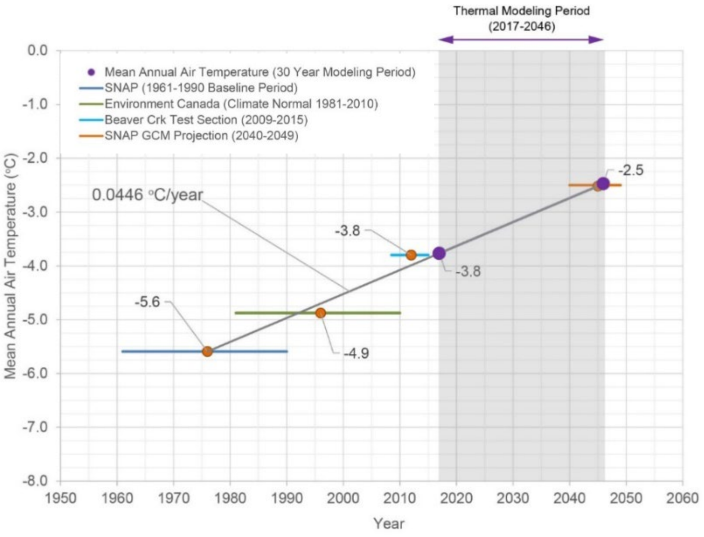


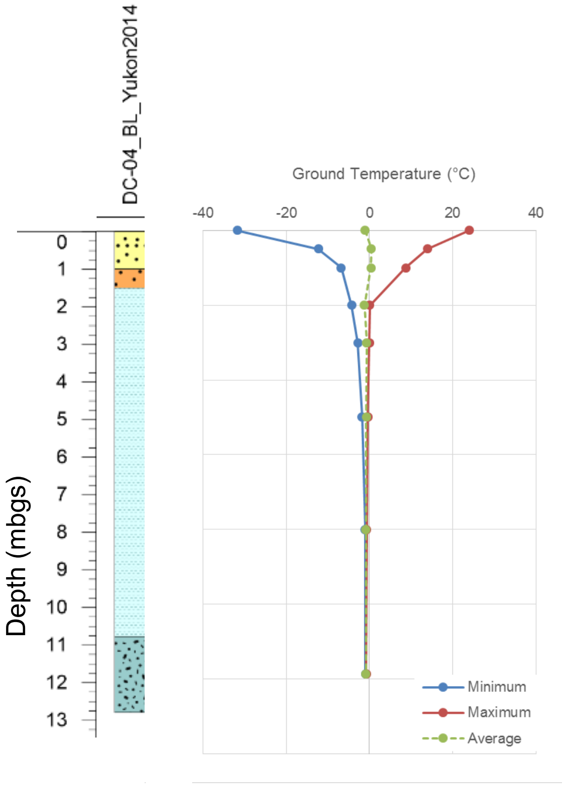
History of Site & Project

Year	History of Site and Project
1995	Site development for borrow material, massive ground ice identified (excavation and drillholes)
1996	Construction of current highway alignment
1997 - Present	Highway distress observed and general maintenance
2012	Massive ground ice identified by SRK following review of Yukon Highway geotechnical data
2014	Site rehabilitation & ROW backslope protection
2017	Preliminary design: Evaluation of air convection embankment and thermosyphon designs to stabilize permafrost (Funded by YHPW & Transport Canada)
2018	Additional geotechnical drilling, advancement of thermosyphon design, optimization of the design, issue design report and IFC, installation of monitoring system
2019	Construction scheduled for October

Site Climate & Ground Thermal Regime

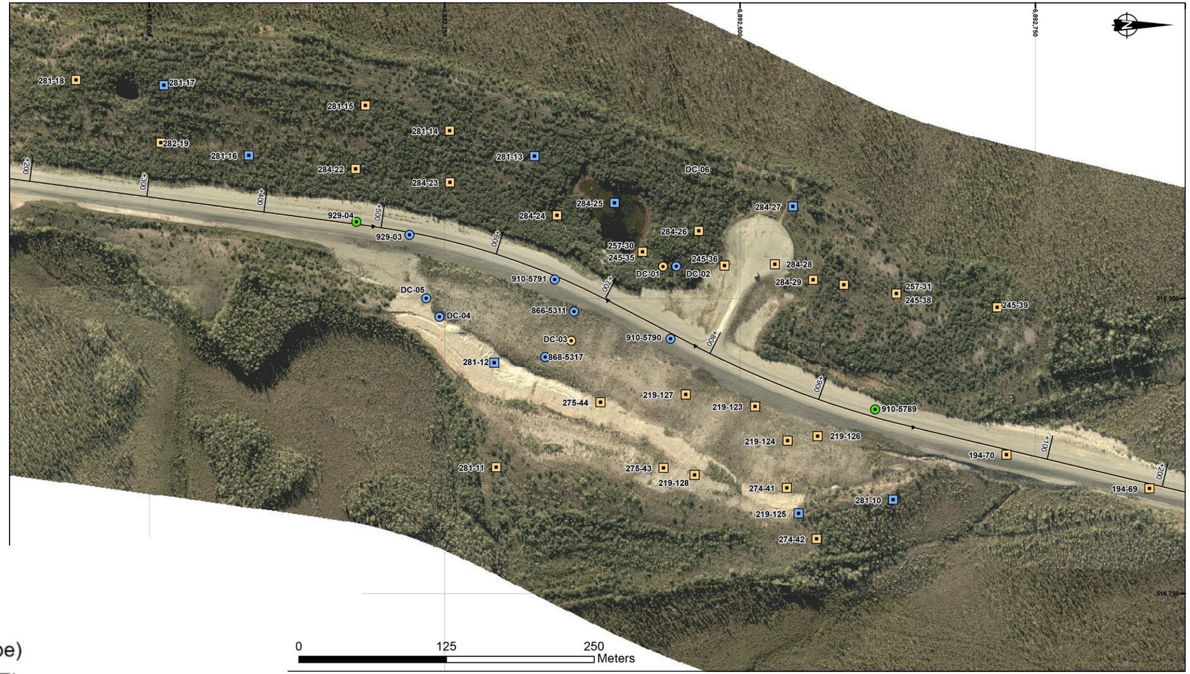
- Recent MAAT approx. -3.8°C (2009-2015)
- MAAT approx. -5.6°C (1961-1990)
- MAAT approx. -4.9 °C (1981-2010)
- Warm permafrost (>-1.0°C)
- Talik beneath sideslopes





Historical Drill Data

- Drilling in mid-1990s to support borrow development
- Adequate characterization of index properties & stratigraphy
- Well and poorly graded sand and gravel underlain by silt, interbedded with sand and gravel
- 8 of 33 holes → massive ground ice (blue square symbols)

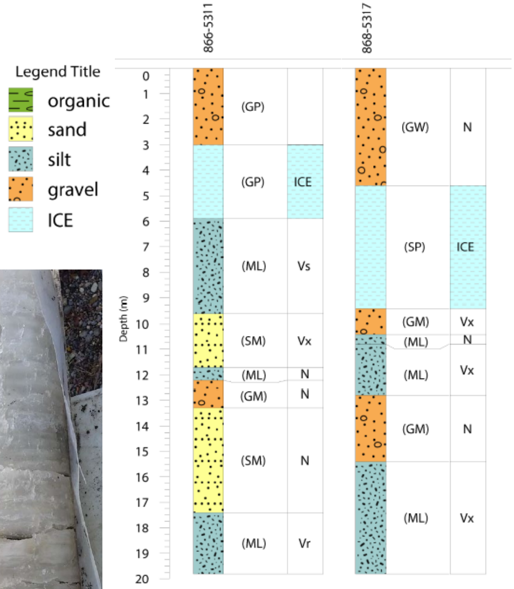


Legend

- Dry Creek Highway Section
- Recent Geotechnical Borehole with Ground Ice Type (Nbe)
- Recent Geotechnical Borehole with Ground Ice Type (ICE)
- Recent Geotechnical Borehole with Ground Ice Type (Vx,Vr,Vs)
- Historic Borehole wt (ICE)
- Historic Borehole wt (Vx,Vr,Vs)

Recent Geotechnical Drilling

- Focus on characterization of foundation & ROW conditions
  - 2011 -2018 (21 holes)
- Massive ice
  - At least 9 m thick (variable thickness)
  - ROW 3 to 5 m bgs
  - ~3 m below base of embankment
- Yukon College geophysical surveys



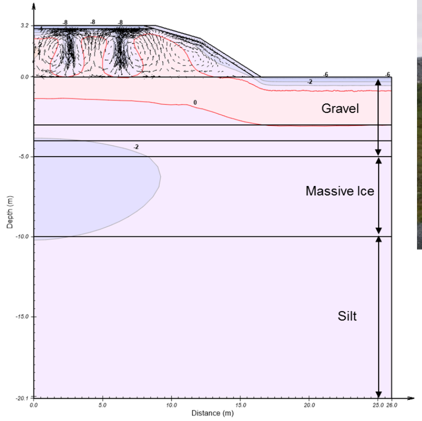
Consideration & Design Criteria

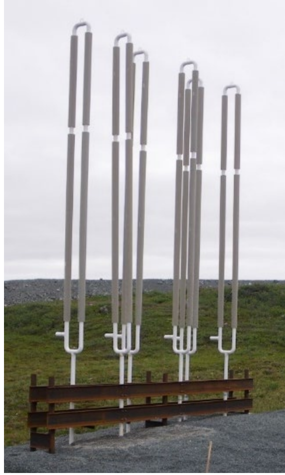
- Maintain current travel corridor and embankment geometry
- Minimize thermal disturbance from construction
- Limit need for re-routing of traffic during construction

- Design life of 30 years
- Minimum ground temperature of -2°C for the foundation (over specified area)
- Consideration of climate change within the design

Preliminary Design Options

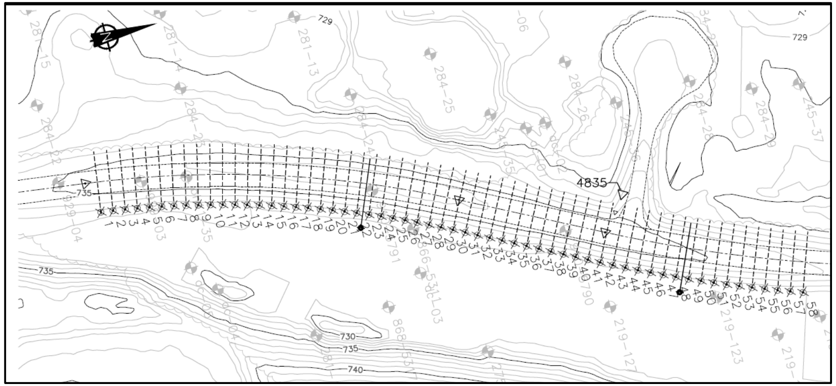
- Two options evaluated during preliminary design stage
- Air convection embankment (full ACE)
  - Reconstruction of embankment required
  - Unknown rock source / costly rock development
  - Marginal ground cooling early-on
  - Potentially less control on thermal performance
- Thermosyphons
  - Existing embankment with minor amount of earthwork
  - Rapid and dependable ground cooling to stability massive ground ice
  - Greater control over thermal performance



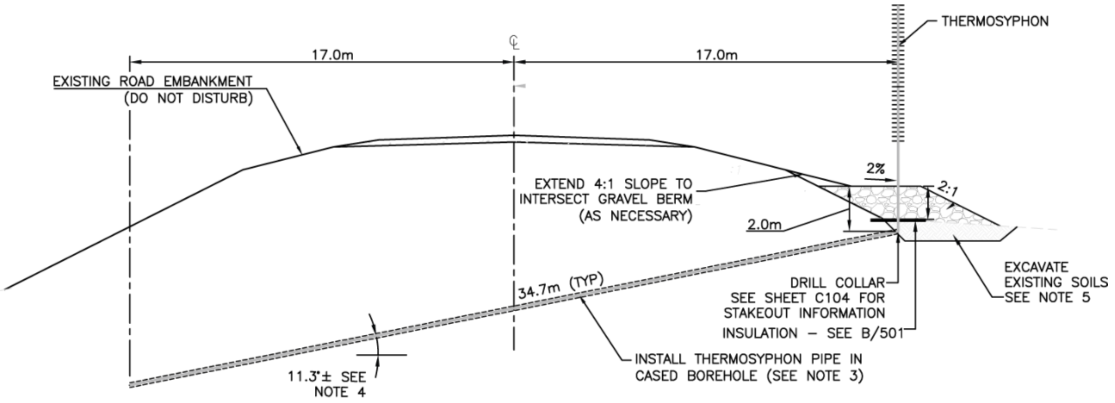


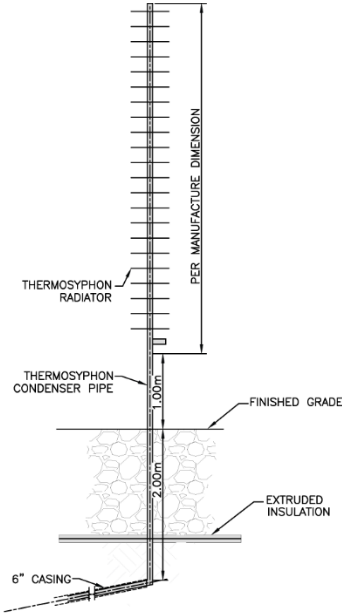
A thermosyphon-based design was predicted to provide more immediate and dependable ground cooling to stabilize the permafrost and massive ground ice with a more predictable project schedule and acceptable costs.

Design Section



- Sloped thermosyphon evaporator pipe (11.3°)
- Evaporator pipe 34.7 m long, with 7 m offset between pipes
- Minor excavation eastern embankment toe (fall construction)
- HDD & install of steel casing, installation of evap. pipe with slurry
- Construction of toe berm, with riser 1 m above design grade

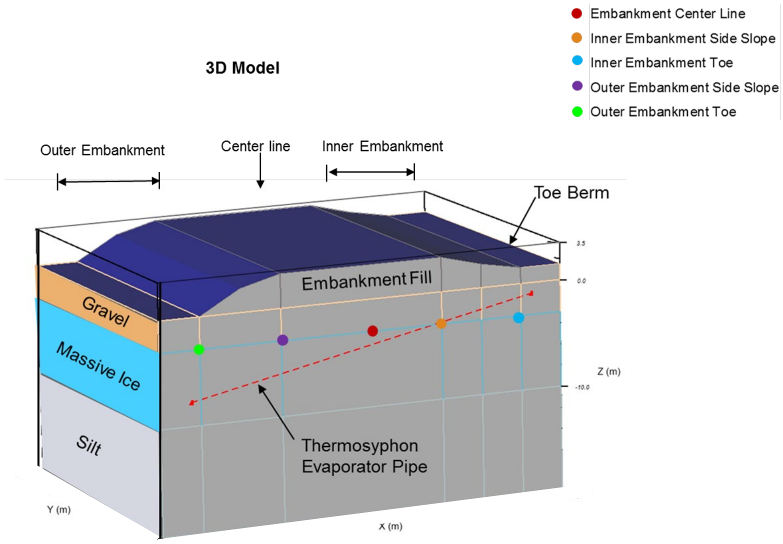




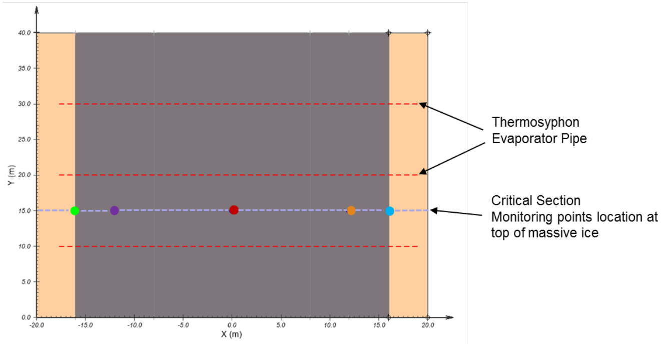
Thermal Model

- Thermal modeling to evaluate thermal performance
- Major considerations
  - Site climate
  - Climate change (winter air temp. & wind)
  - Material properties based on drill data
  - Thermosyphon radiator surface area
  - Evaporator pipe (length, install angle, pipe offset)
- Critical section to evaluate
  - Top of permafrost / massive ice
  - Mid-point between two evaporator pipes
  - Warmest position at inner-embankment toe

3D Model



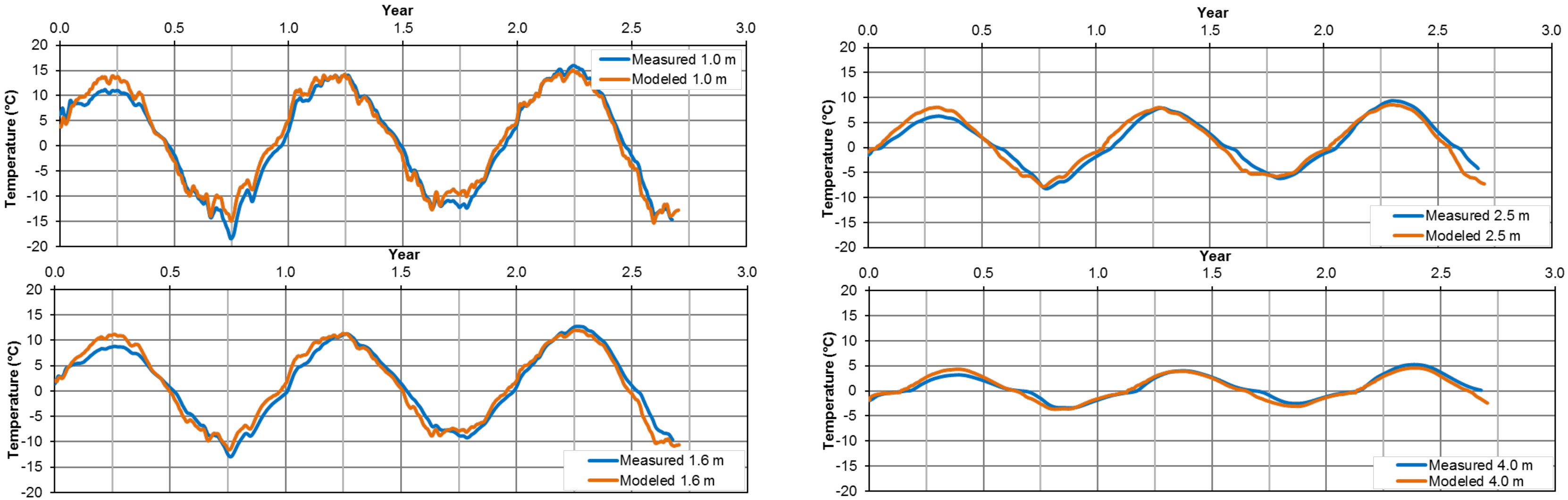
2D Plan View



Validation of Thermal Model

Measured ground temperature from Beaver Creek Test Section 5 (Control YG5)

Model ground temperature (thermal conduction model)



Building on data from nearby Yukon Government Test Section…value added data

Model Results

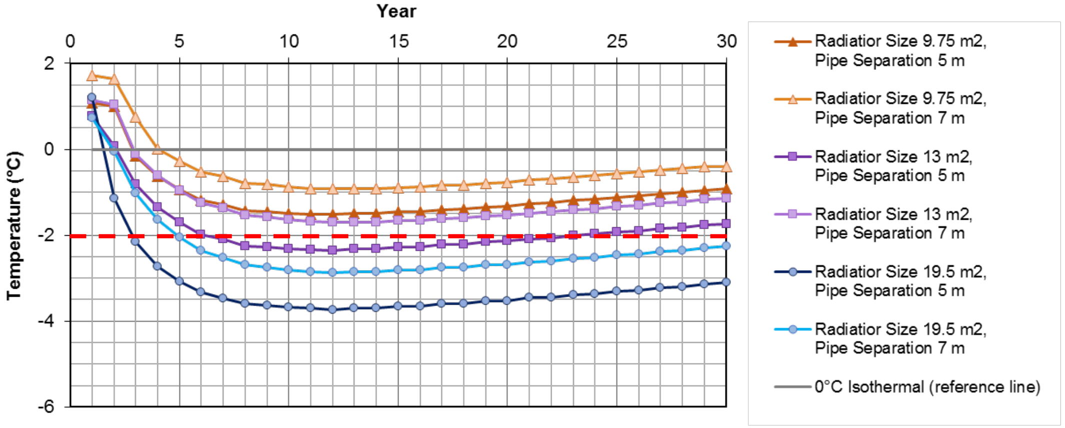
Maximum Annual Ground Temperature

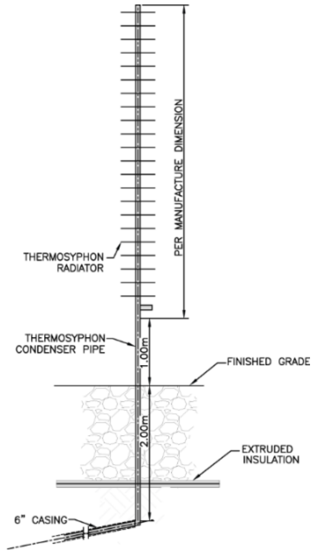
Warmest Monitoring Location

- Inner embankment toe
- Shallowest location of evaporator pipe
- Greater sensitivity to surface heat transfer

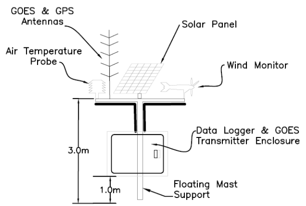
Warmest Monitoring Location

Model Scenario	Radiator Surface Area (m^2)	Evaporator Pipe Separation (m)	Years before Thermal Criteria Reached	Years Less than -2°C
1A	9.75	5	30	0
1B		7	30	0
2A	13.00	5	5	19
2B		7	30	0
3A	19.50	5	2	28
3B		7	4	26

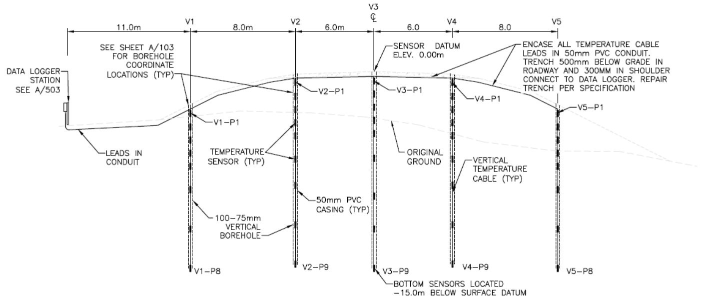




Monitoring



- Verify thermosyphon function and need for repair / replacement
- Verify thermal performance of design at representative locations
- Collect data that can be used to support similar designs



Monitoring Component	Location	Purpose	Data Collection Frequency
Ground Temperature Monitoring	Monitoring Station 1 & 2	Verify thermal performance	Every four hour
Meteorological Monitoring	Monitoring Station 2	Support validation of thermal performance	Hourly
Thermal Infrared Images	Thermosyphon Radiators	Verify thermosyphon function	Annually, Air temp <-5°C
Visual Inspection	Design Section	Thermosyphons & highway distress	Annually, Early September

Summary

- Dry Creek located along the Alaska Highway is characterized by warm permafrost with massive ground ice.
- Past development of borrow material, thermal forcing from the highway embankment, and long-term changes in climate are inferred to be the cause of permafrost warming and thaw that contribute to highway distress and increased maintenance costs.
- Preliminary design demonstrated that sloped thermosyphons would provide more immediate heat loss from the ground and stabilization of permafrost compared to an air convection embankment.
- Accepted thermal design is based on the installation of sloped, passive thermosyphons is expected to limit permafrost thaw and improve highway performance.
- Thermosyphons have been procured with plans for installation in the fall of 2019
- Long-term monitoring will be completed to evaluate performance over the 30-year period and to provide information that will support similar designs

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