Initial Thermal Performance of a Tailings Retaining Frozen Foundation Dam, Nunavut, Canada

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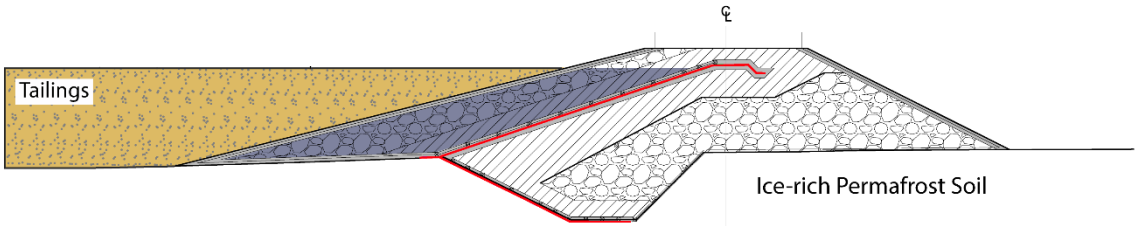
Outline

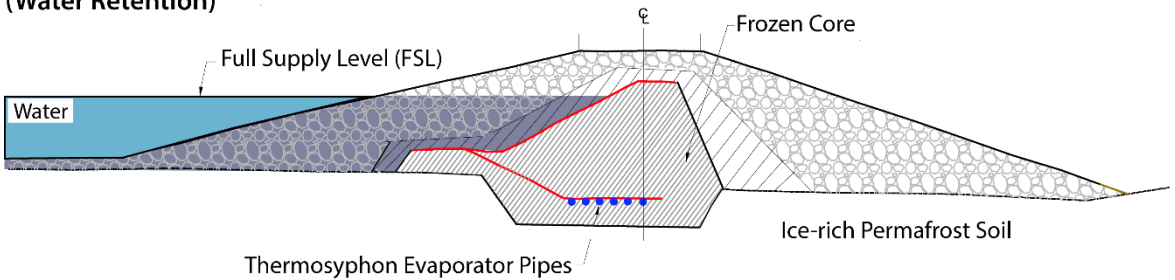
- Dams with frozen components
- Hope Bay tailings impoundment area (TIA)
- South Dam design & construction
- Foundation conditions
- Initial thermal performance (just a glimpse)

Dams with Frozen Components

Frozen Foundation Dam
(Tailings Soilds Retention)



Frozen Core Dam
(Water Retention)



LEGEND

- Upper GCL Liner
- Water
- Tailings
- Water saturated material
- Bedding Material
- Transition Material
- Run of Quarry Backfill

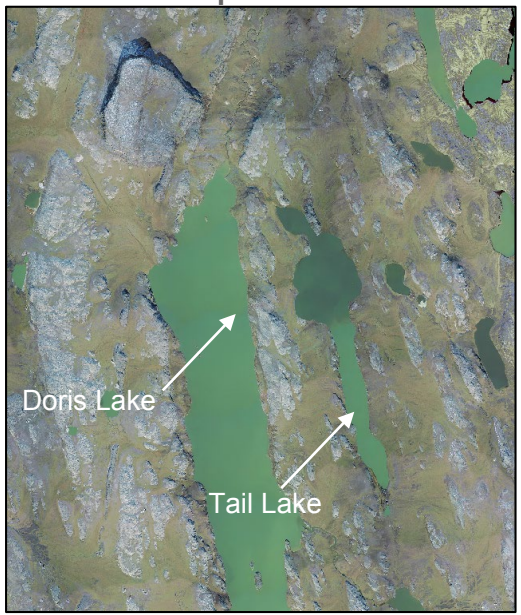
Hope Bay

Hope Bay

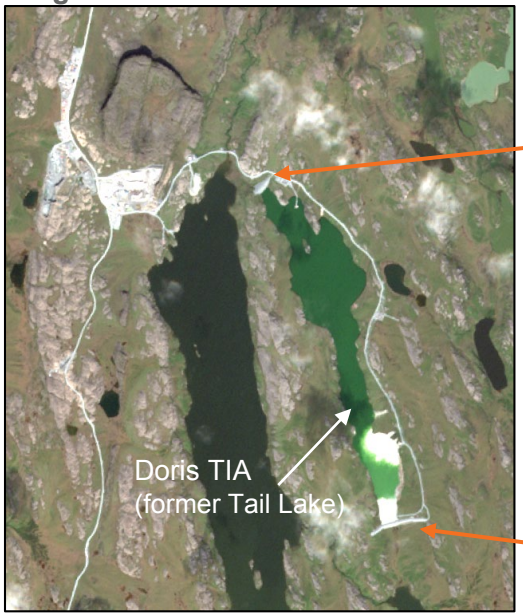
TMAC Resources (100% interest)
Gold mine
Nunavut, Canada
Continuous zone of permafrost

Tailings Impoundment Area

Historical Airphoto
Prior to Development

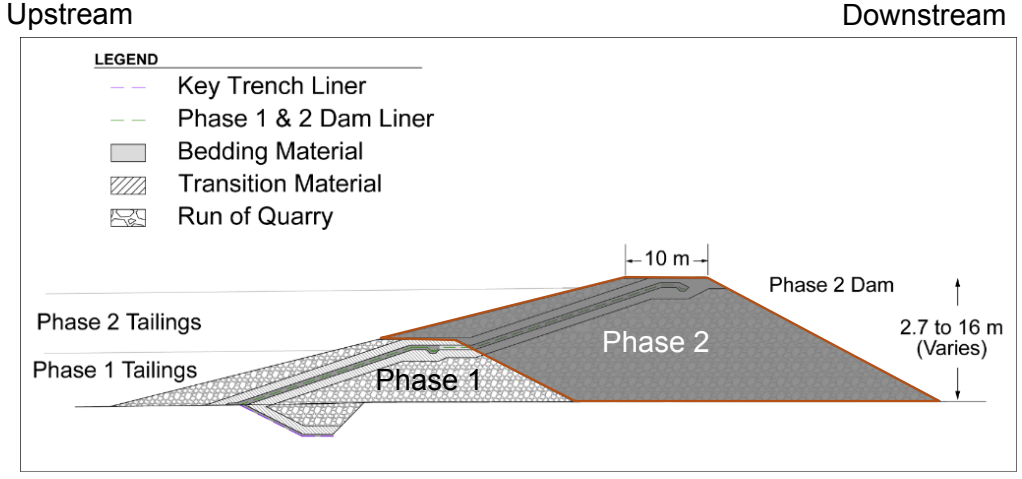


Recent Airphoto
August 2019

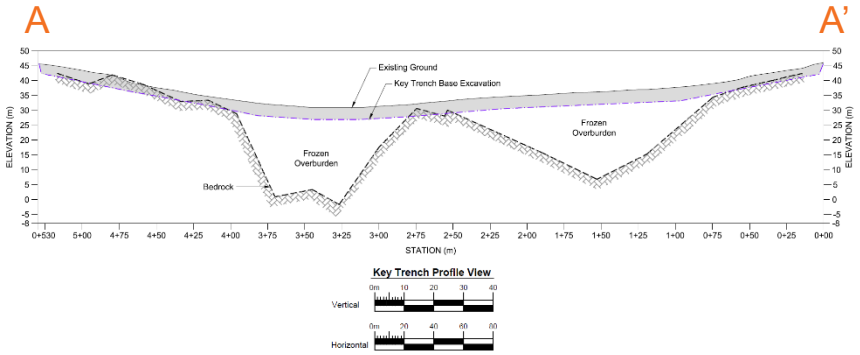


South Dam

- Design life 25 years
- Tailings retaining structure
- Stability and containment relies on permafrost
- Phase 1 – constructed in winter of 2018
- Phase 2 – downstream raise in 2023



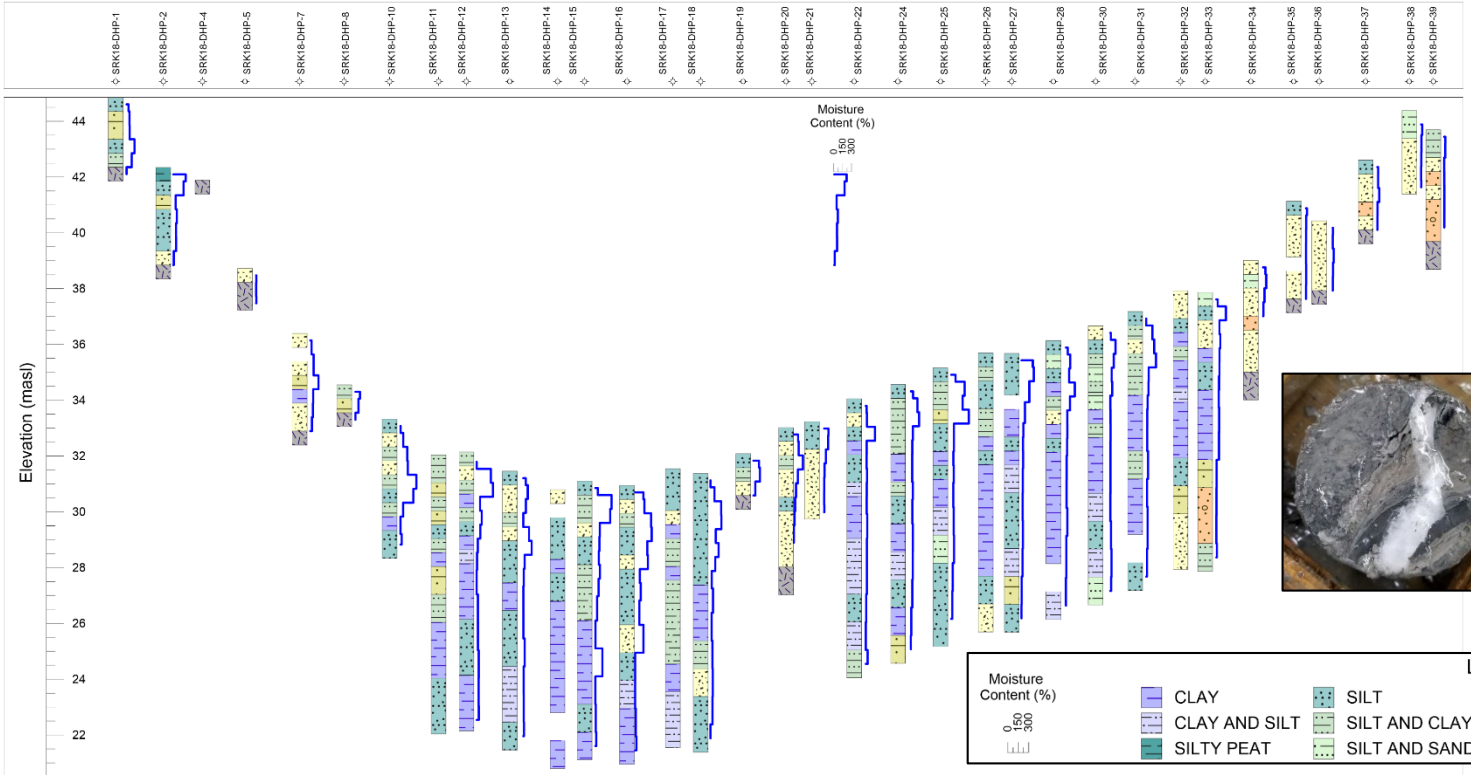
Dam alignment prior to construction

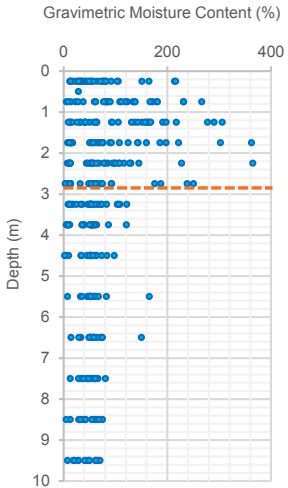


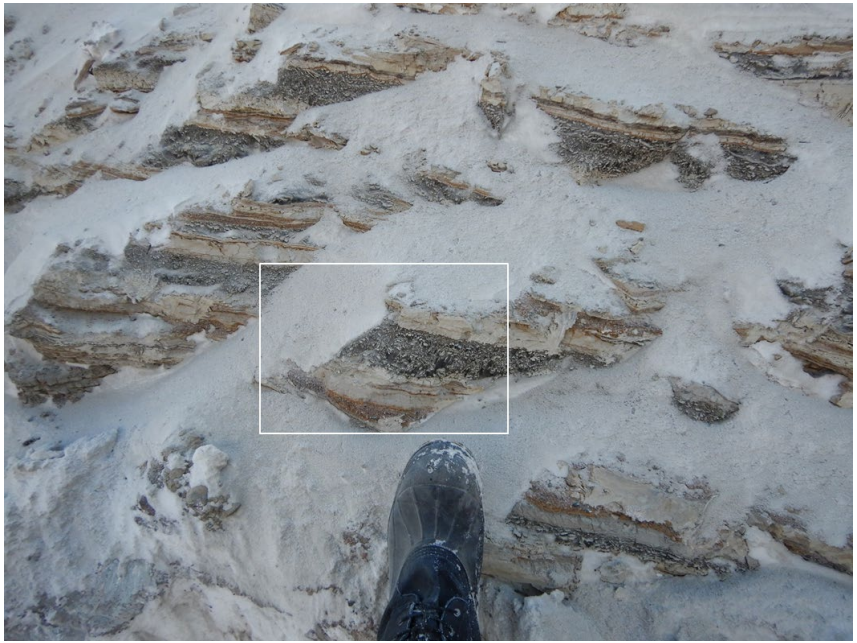
Cross-Section along key trench

Stratigraphy

- Glaciomarine silty clay and clayey silt, underlain by sand and gravel till
- Ground ice increases in upper 3 m, with massive ice
- New FPD of -0.2°C (max. -0.6°C, n=110)







Interbedded silt and clay

Segregated ice lenses

Reticulate ice

Ice Wedges

Design Considerations

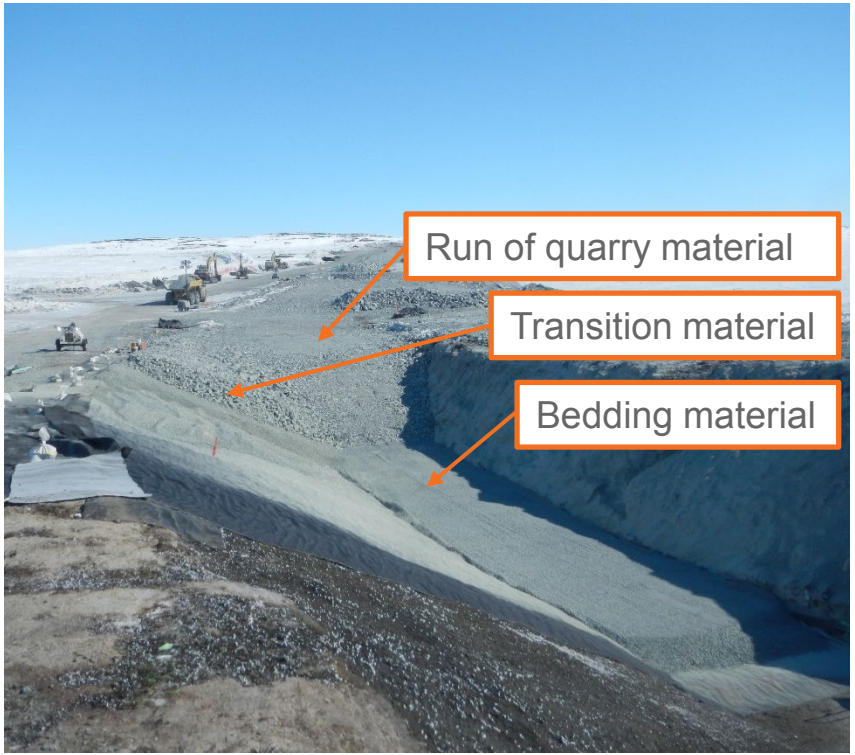
- Foundation conditions
  - Thick permafrost soils
  - Massive ground ice & ice-rich soil
  - Cold permafrost -7.6°C
  - Porewater salinity / depressed freezing point
  - Creep susceptible
  - Low strength soils when thawed
  - Basalt bedrock
- Climate change
- Tailings deposition plan
- Lack of natural borrow materials
- Timing of construction
- Remote location of site

Thermal regime of the dam is largely controlled by atmosphere-to-surface heat exchange, thermal and physical conditions along the upstream face of the dam, and heat transfer through the fill material & foundation

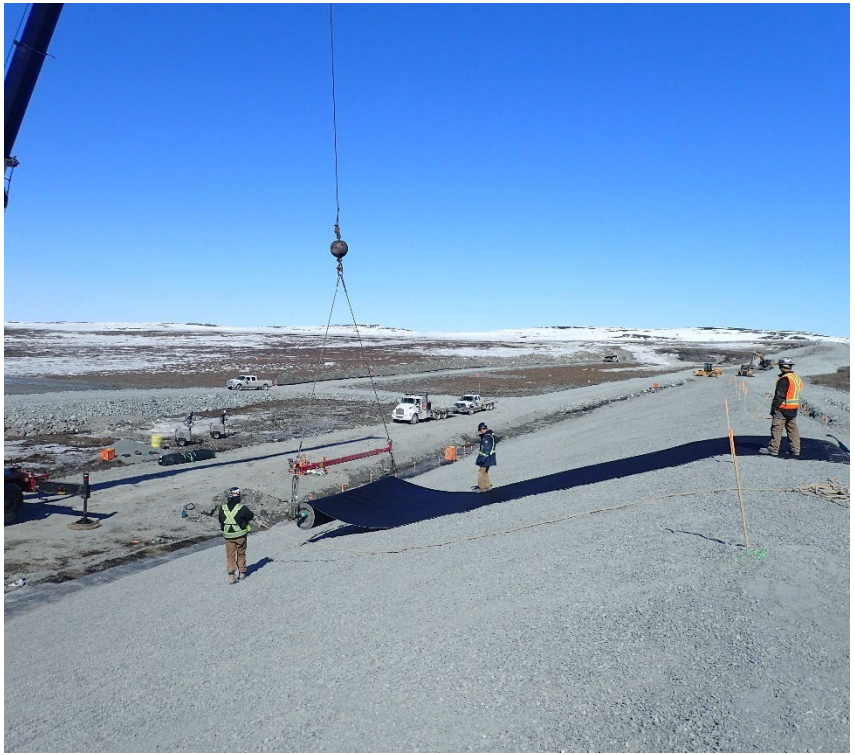
Foreground: Drilling of blast holes
Background: Key trench excavation

Near complete section of key trench

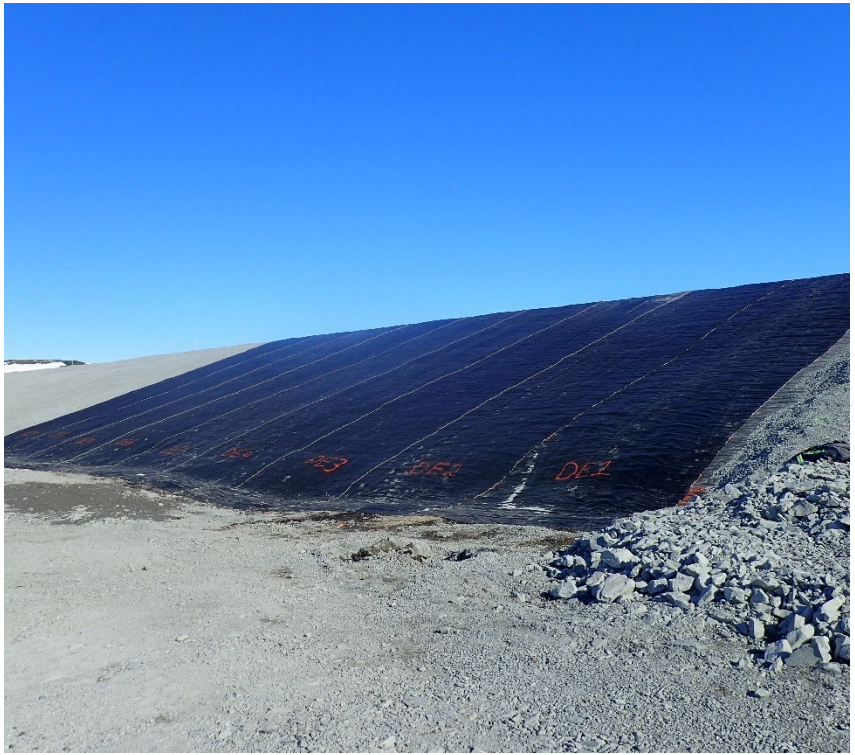
Deployment of liner on upstream slope of key trench



Backfilling of key trench above liner



Deployment of liner on upstream slope of above ground fill



Deployed liner on upstream slope of above ground fill

2018

2019

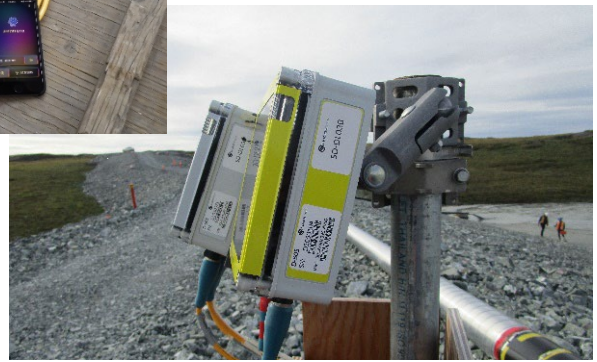
Tailings beach development from the dam ceases in the winter to promote heat loss and to limit ice entrainment immediately upstream of the dam

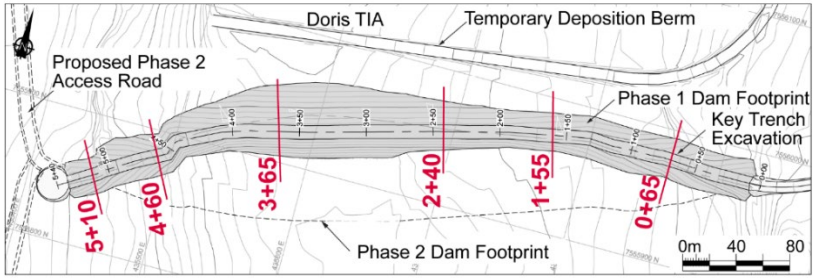
Tailings discharge line along crest of dam

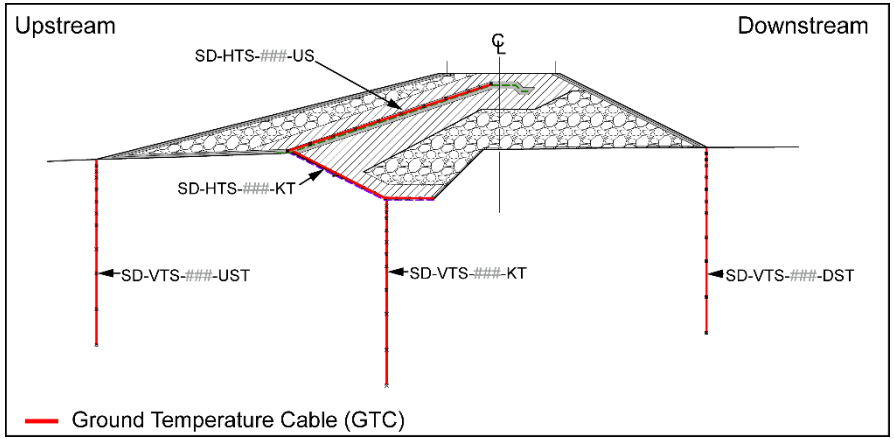
Tailings discharge from spigot along upstream face of dam

Ground Temperature Monitoring

- BeadedStream ground temperature cables and loggers
- Six sections along alignment monitored
- Each section typically 5 cables
- Data transmitted every 12 hours via iridium satellite





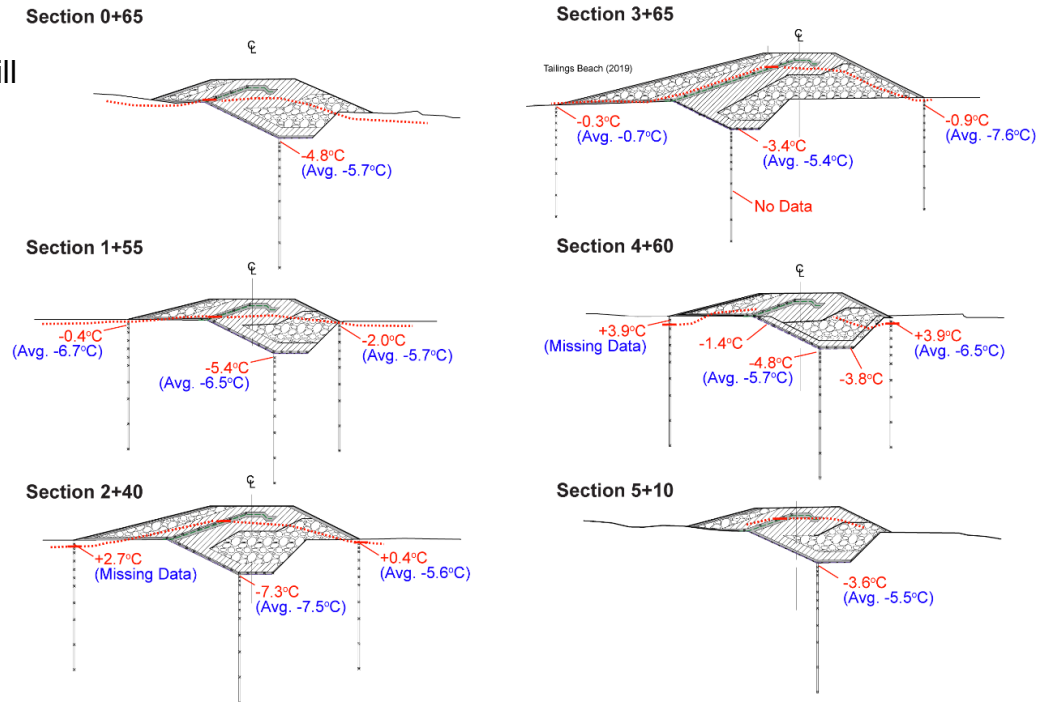


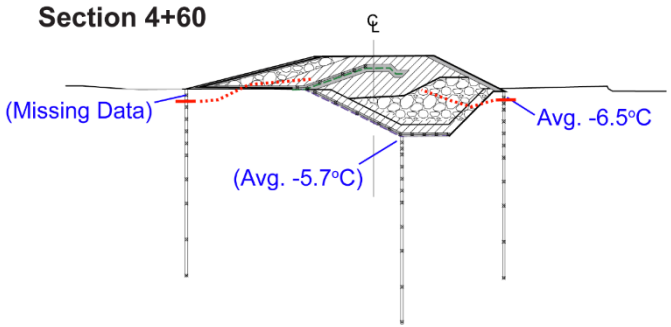
Upstream and Downstream Toe

- Active layer thickness <1 m
  - Influenced by thickness of overlying rock fill
  - Season thaw has not taken place in the foundation beneath the tailings beach

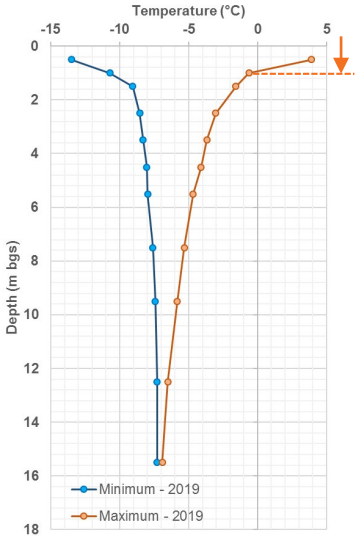
Station	GTC ID	Location	Thaw Depth, 0°C Isotherm (m)
0+155	SD-VTS-155-US	UST	-
	SD-VTS-155-DS	DST	0.0
0+240	SD-VTS-240-US	UST	0.9
	SD-VTS-240-DS	DST	0.6
0+365	SD-VTS-365-US	UST	0.0
	SD-VTS-365-DS	DST	0.1
0+460	SD-VTS-460-US	UST	0.9
	SD-VTS-460-DS	DST	0.9

Active layer <1 m (0°C isotherm)

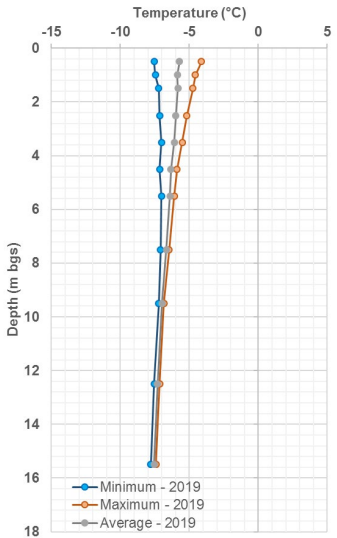




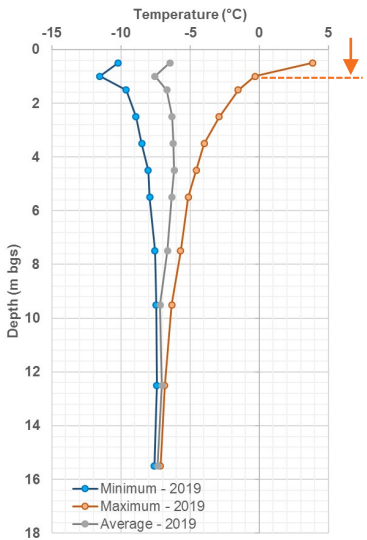
Upstream



Key Trench



Downstream



Active layer

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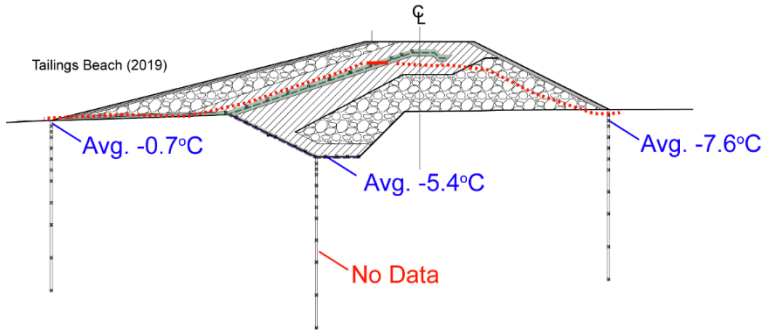
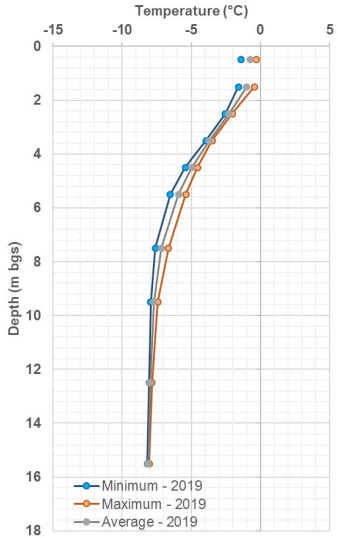
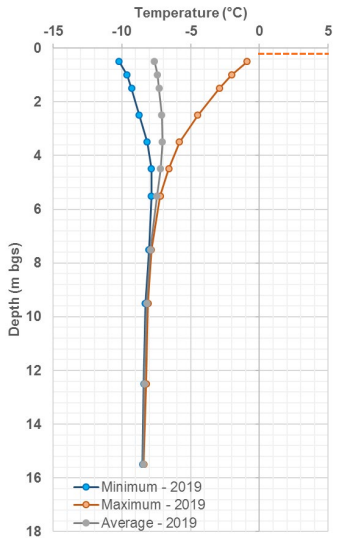
Section 3+65



Upstream



Downstream



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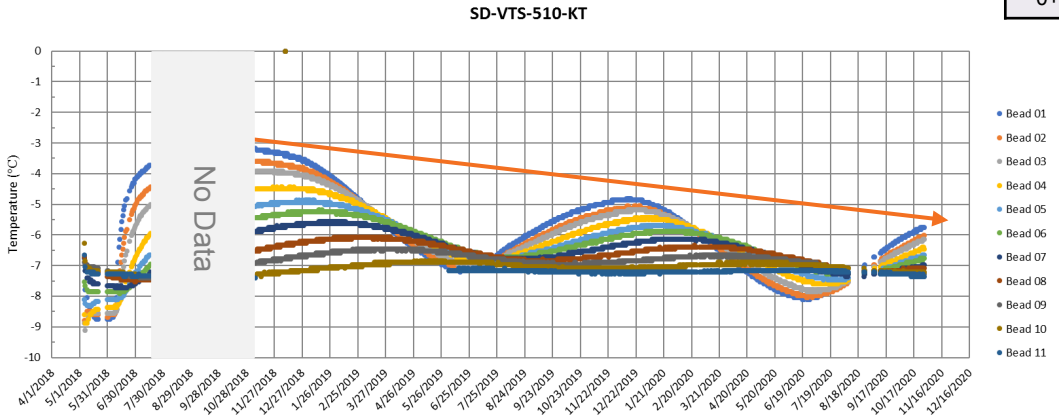
Key Trench

- General reduction in maximum annual key trench temperature compared to 2018
- GCL remains keyed-in to frozen permafrost (critical compliance point)
- Key trench temperatures are within the expected range of model predictions

Station	GTC ID	Maximum Ground Temperature (°C)		
		2018	2019	2020
0+065	SD-VTS-065-KTC	-	-4.7	-6.0
0+155	SD-VTS-155-KTC	-	-5.5	-6.2
0+240	SD-VTS-240-KTC	-7.2	-7.3	-7.6
0+365*	SD-VTS-365-KTC	-6.9	-	-
0+460	SD-VTS-460-KTC	-3.9	-4.7	-5.9
0+510	SD-VTS-510-KTC	-3.2	-4.8	-5.8

2020 ground temperature as of Oct. 28th



Summary

- South Dam was designed as a frozen foundation tailings retaining structure
  - Construction over the winter 2018
- Continuous development of an upstream tailings beach
  - Promote winter heat loss
  - Limit ice entrainment immediately upstream dam
  - Reduce potential for seepage
- Ground temperatures indicate:
  - Dam is thermal performing and within the expected range of model predictions
  - Key trench shows continued cooling and liner tie-in remains frozen (Approx. -5.5°C to -7.5°C)
  - Tailings beach has begun to freezeback, largely attributed to proper tailings management
- Thermal monitoring is only one type of operational monitoring and surveillance of the TIA
  - Surface and deep settlement monuments, UAV and satellite imagery, daily and weekly site inspections, etc.

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