Thermal Cover Design and Performance for Closure of Mine Waste Facilities

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Alaska Miners Association Convention

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Outline

- Freeze strategy for closure of mine waste facilities
- Function of thermal covers and basic designs
- Dominant mechanism for heat transfer
- Review of projects that have adopted thermal covers and the freeze strategy

Freeze Strategy for Closure

- Strategy
  - Natural freezeback waste rock or tailings to limit ARD
  - Freezeback occurs during material placement and closure for sites in cold region
  - Thermal cover is constructed over the final waste surface to maintain frozen conditions

- Freezeback of the material limits key ingredients for sulfide oxidation…
  - Infiltration of surface water
  - Biological activity
  - In-situ pore water within waste
  - Oxygen supply (in some cases)

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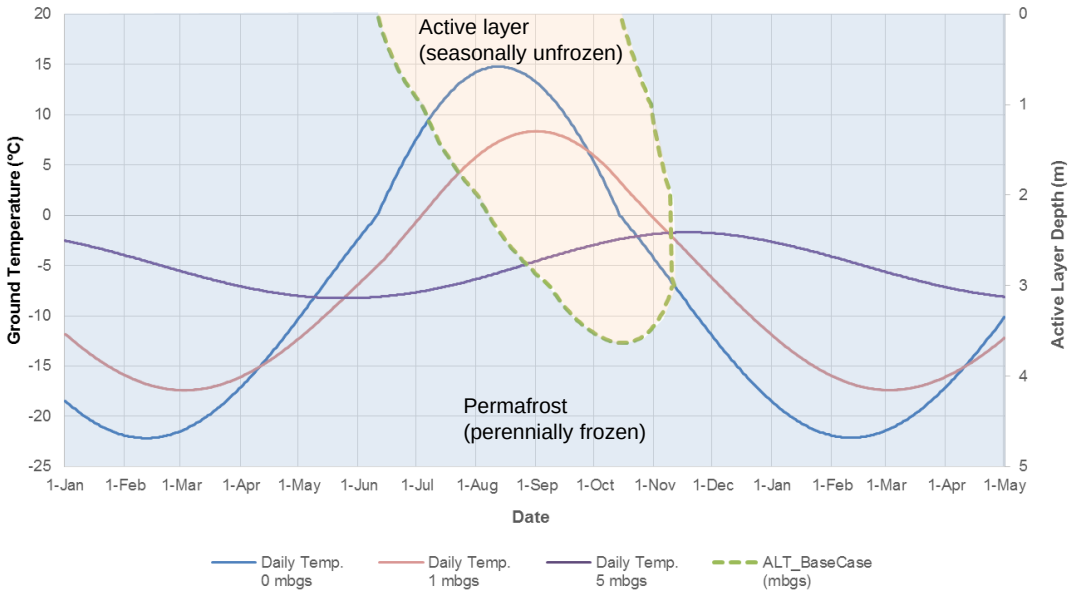
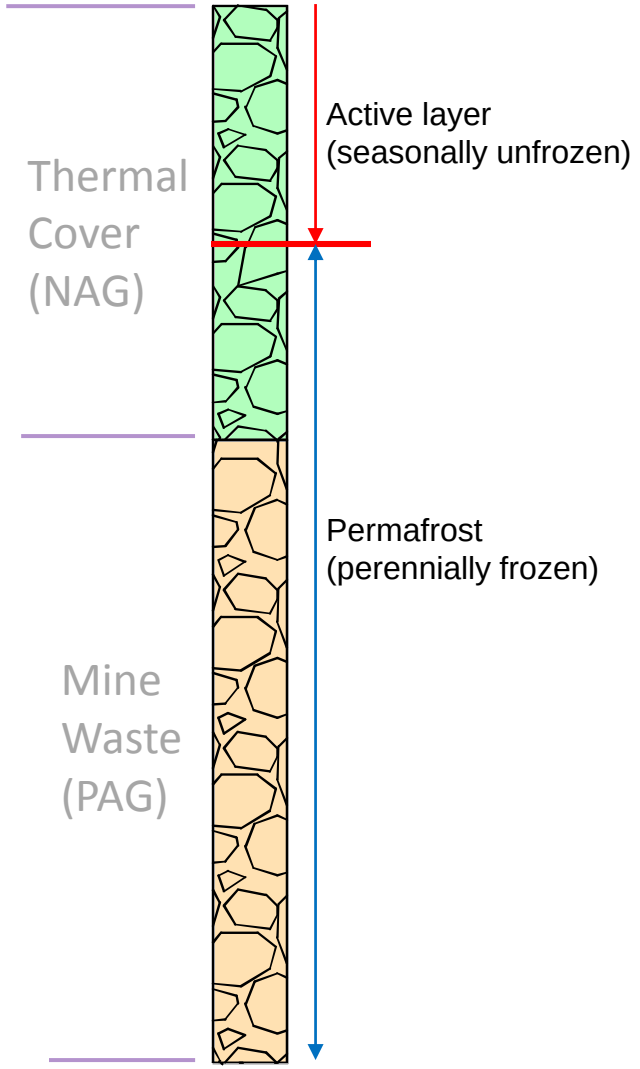
Thermal Cover – Function

- Covers consist of ROM/ROQ or overburden soil
- Maintain seasonal thaw to the cover
- Sustain perennially frozen waste

- Design with thermo-physical-geochemical properties
- Reduce heat gain during the thawing season
- Enhance heat loss during the freezing season





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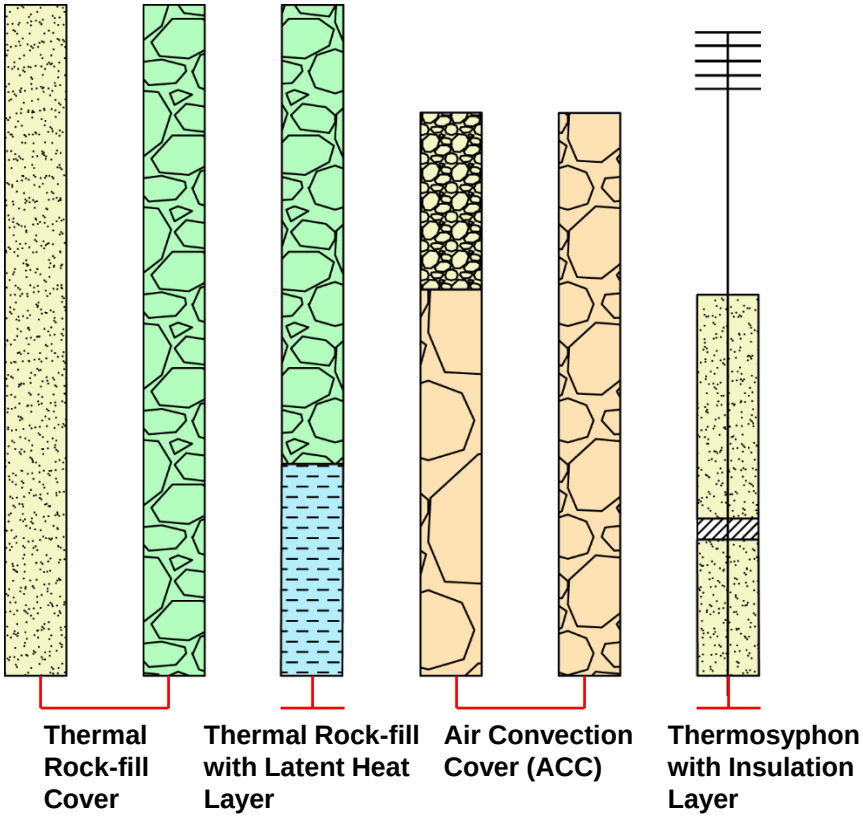
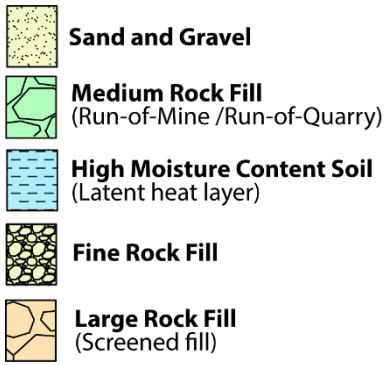
Thermal Cover – Designs

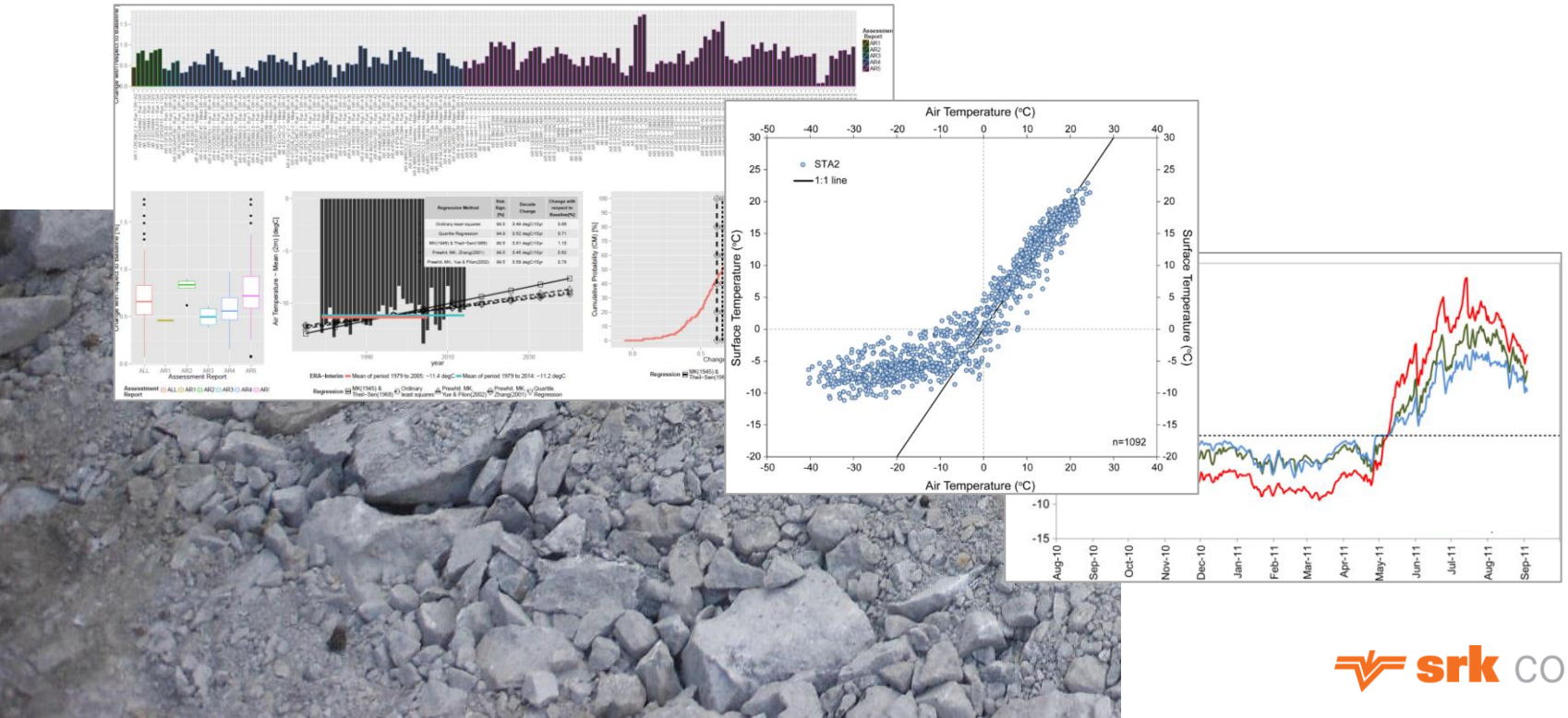
- Thermal rock-fill cover
- Thermal rock-fill with latent heat layer
- Air convection cover (ACC)
- Thermosyphon with insulation layer





Numerical Thermal Modeling

- Model Objectives
  - Timing of waste freezeback
  - Cover active layer thickness
  - Long-term thermal regime
- Major Considerations
  - Local climate (present-day and long-term)
  - Waste physical, thermal, and geochemical properties
  - Material placement during operation
  - Exothermal reactions



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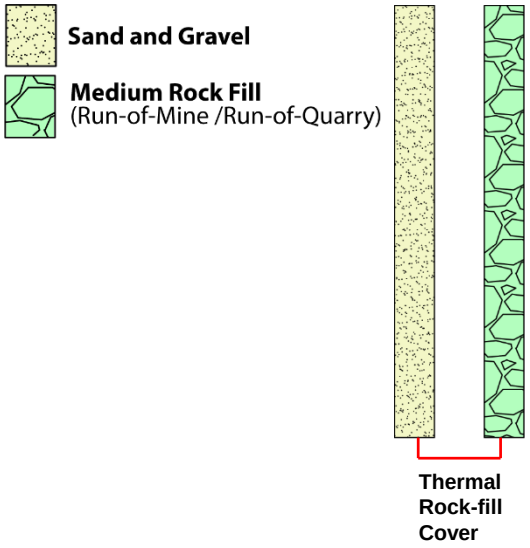
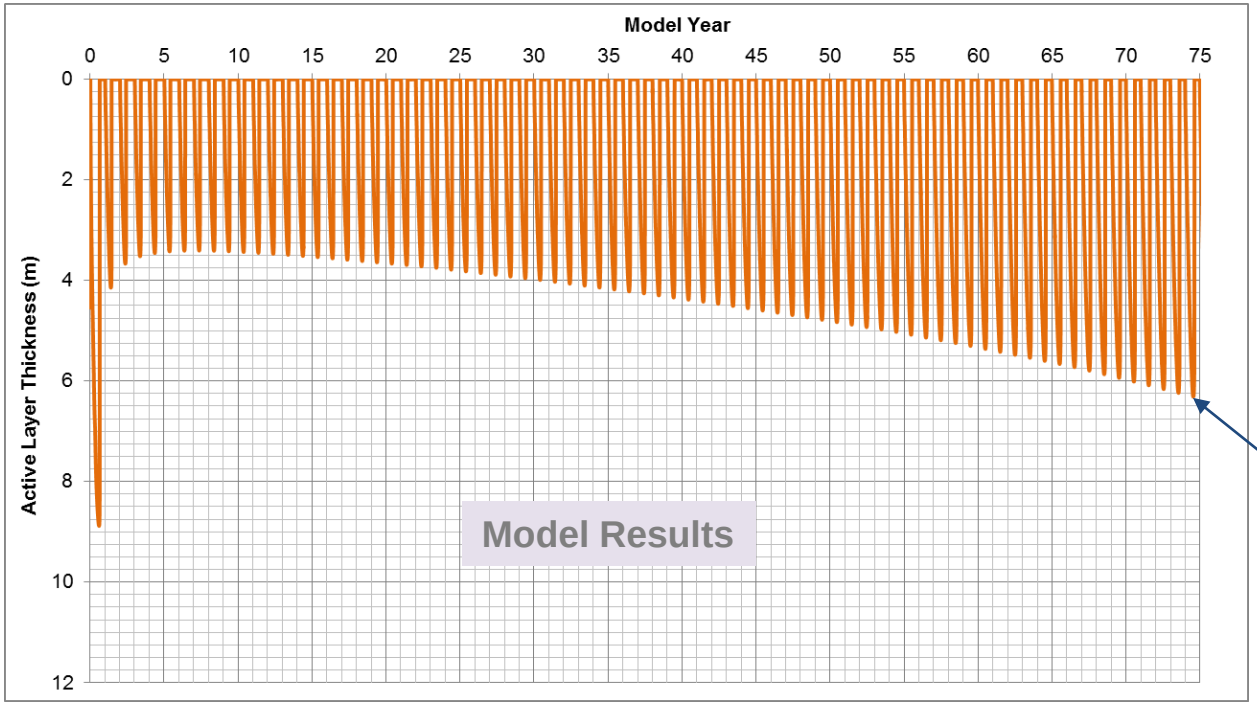
Thermal Rock-fill Cover

- Single-layer cover (ROM/ROQ fill)
- Heat transfer – thermal conduction (Molecular motion)
- Low moisture content – well-drained fill
- Low heat capacity and latent heat requirements
- Greater seasonal thaw compared to other thermal covers
- Thicker cover and large quantity of material required

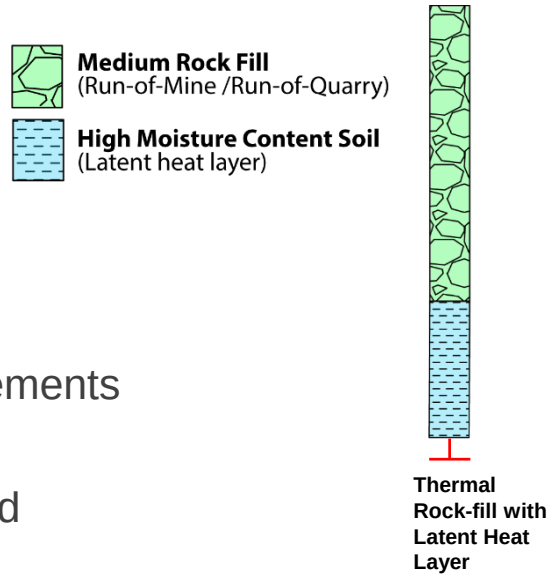


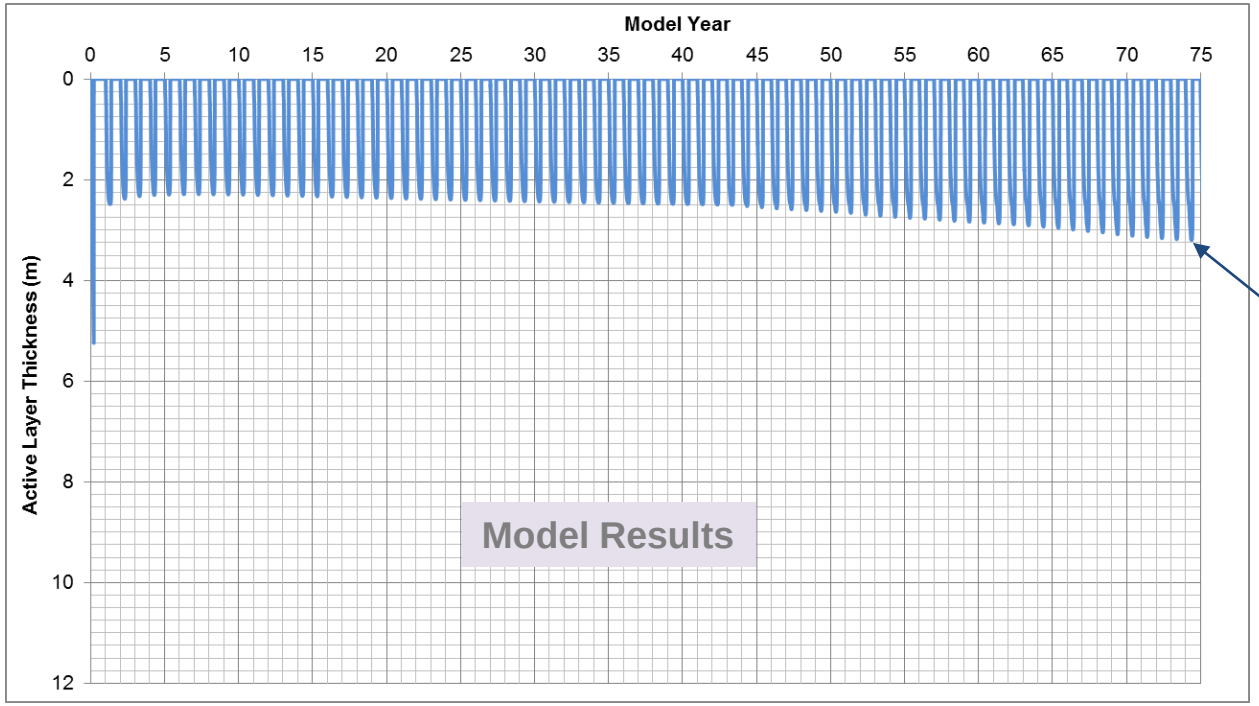


Maximum thaw depth for each year

Thermal Rock-fill Cover with Latent Heat Layer

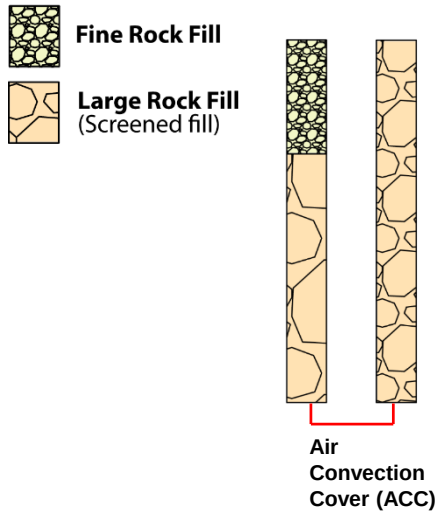
- Double-layer cover system
- Heat transfer – thermal conduction
- High moisture layer – high heat capacity and latent heat requirements
- Seasonal thaw depth is less compared to rock-fill cover
- Reduced cover thickness and lower quantity of material required





Maximum thaw depth for each year

Air Convection Cover (ACC)



- Coarse ROM/ROQ fill
- Material screened to achieve consistent size and remove fines
- Increase air permeability
- Very low moisture content
- Winter heat flow – air convection
- Summer heat flow – thermal conduction

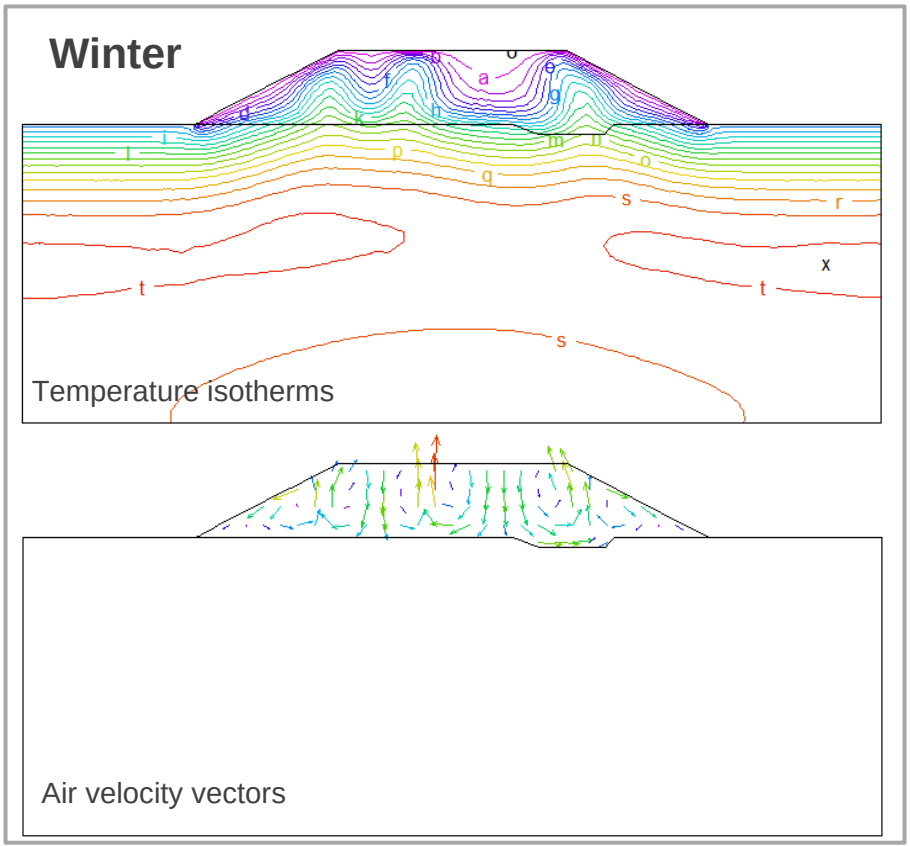
Air Convection Cover (ACC)

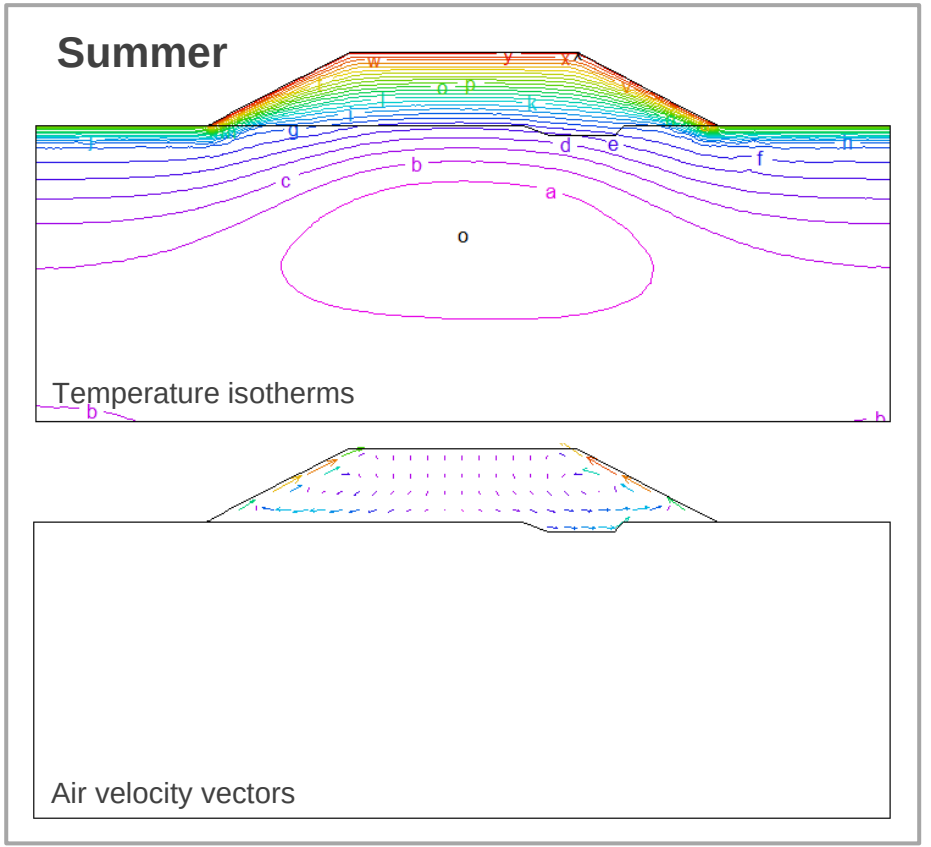
Winter

- Thermal gradient establishes gradient in air density resulting in air displacement
- Air flows leads to mass movement of heat to enhance heat loss (mean temperature 4 to 6°C colder)

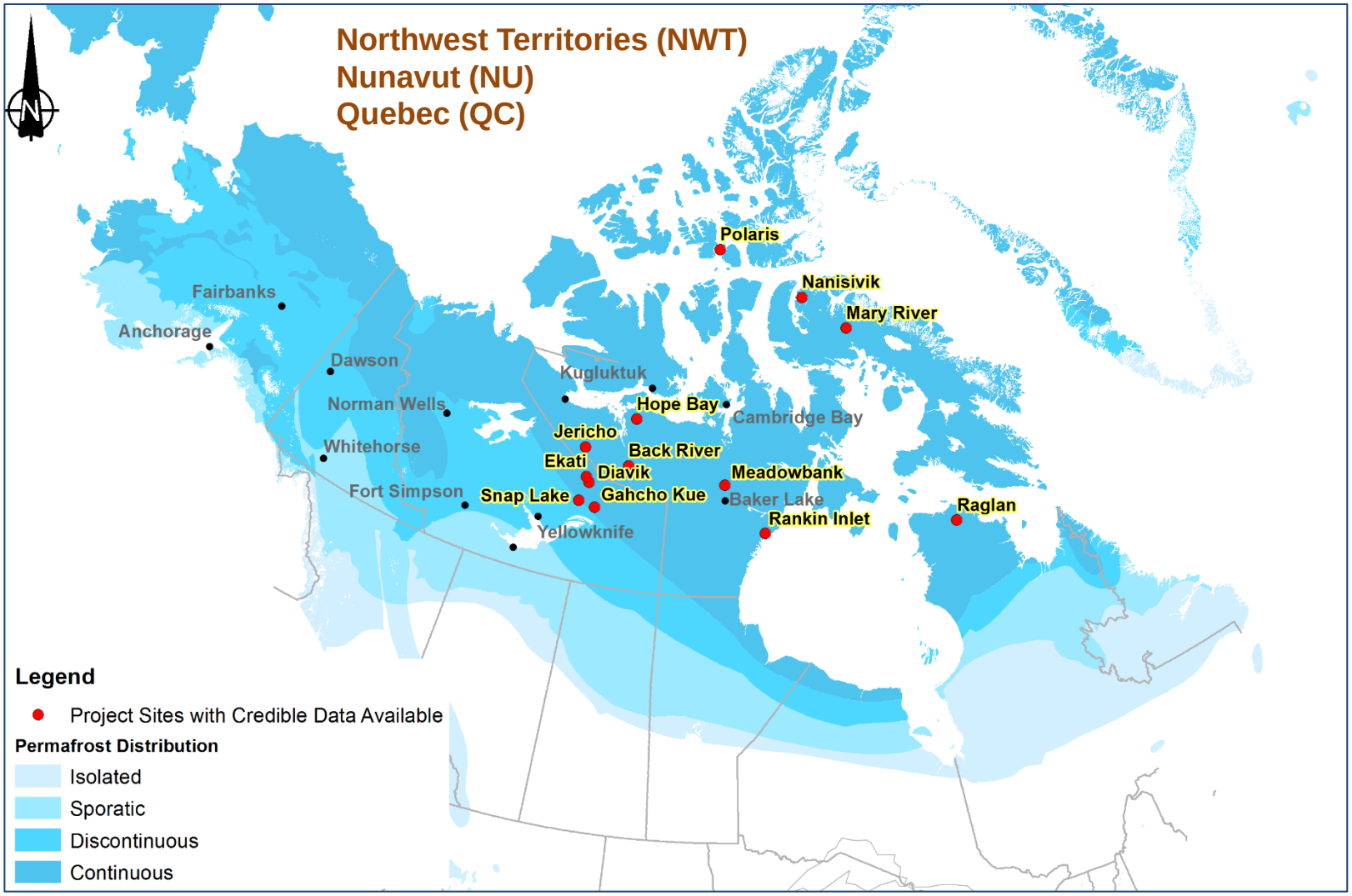
Summer

- Cold air settles in the cover and convective movement is limits
- Coarse, well-drained material results in very low thermal conductivity which limits thaw depth





Mines/Projects with the Freeze Strategy



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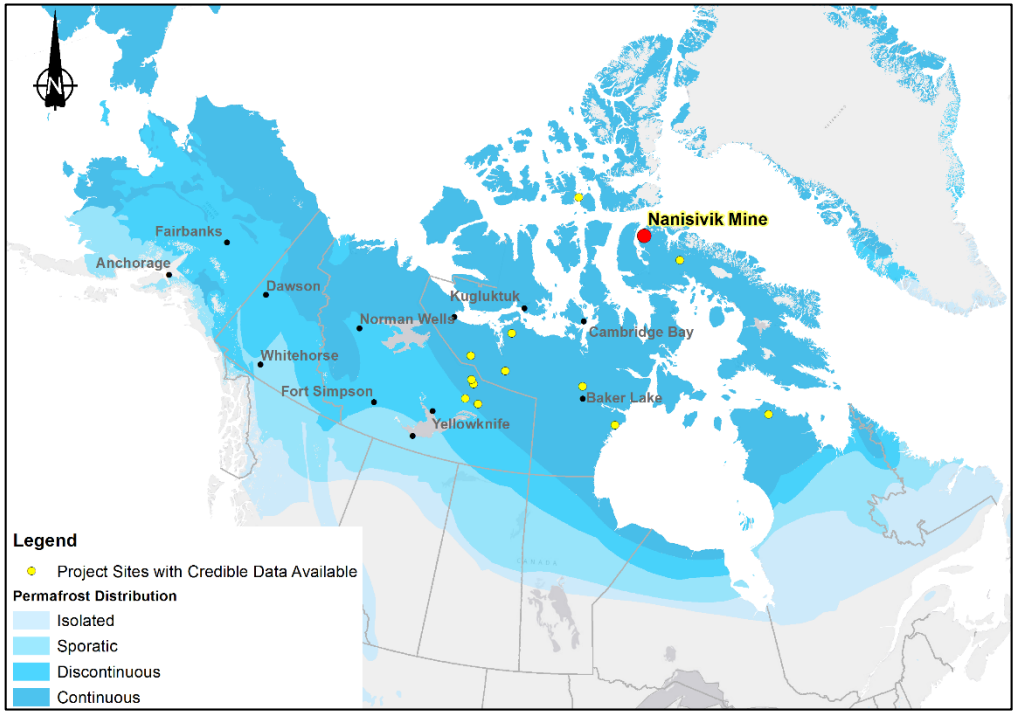
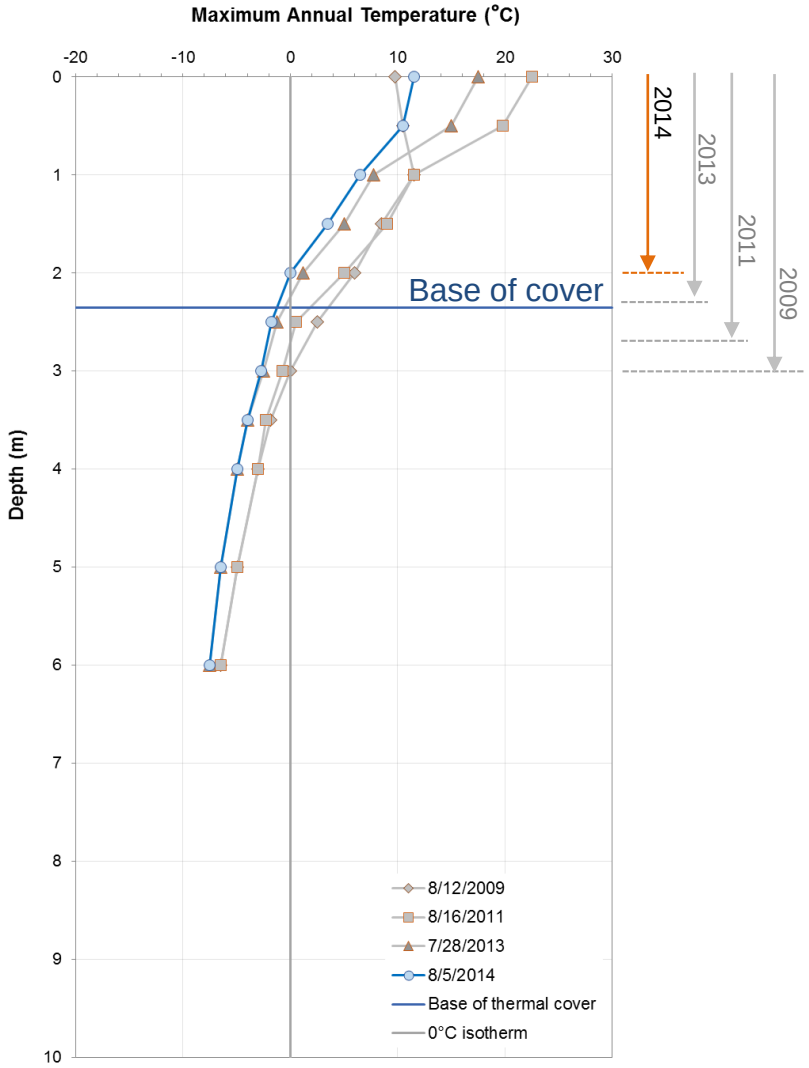
Thermal Performance - Nanisivik

Nanisivik Mine, NU

- Latitude: 73°02‘
- Gold Mine, UG
- MAAT: -14.8°C (5.4°F)
- Cover Design: Thermal rock-fill
- Design thickness: 2.35 m, 2 m shale (NAG) + 0.35 m till
- Permafrost aggrading upward into cover
- Continued heat loss from underlying waste rock
- Ice-saturation observed within the cover





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Major Considerations

- Closure objectives
- Waste properties (thermo-physical-geochemical properties)
- Current and future climate
- Source of cover material
- Constructability and geotechnical stability of cover design
- Waste management during operation
- Cost $

Cover Type	Cost
Thermal rock-fill cover	Low
Thermal rock-fill with latent heat layer	Low
Air convection cover (ACC)	Moderate
Thermosyphon / Insulation layer	High

Concluding Remarks

- Thermal performance of the cover system is directly related to the thermal properties and the dominant mechanism for heat transfer which determines the minimum cover thickness and waste ground thermal regime.
- Different designs and materials result in differences in heat flow and thermal performance.
- The thermal rock-fill cover is the most common design currently used by industry.
- Alternative thermal designs should continue to be pursued to enhance long-term performance, such as air convection covers which are more resilient to increasing air temperature.
- The thermal regime of mine waste is an important consideration for understanding long-term thermal, physical, and chemical stability of waste facilities in cold regions, regardless of whether freezeback is selected as a closure strategy.