

Cover Design and Construction Practices in the North (Cold Regions)

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Talk intent

Current soil cover design and construction practices are based largely on test and full scale experience from temperate regions and on the theoretical basis provided by agricultural soil physics, which is also derived largely from experience in temperate regions. As a result, they do not take into account many potentially important phenomena that are common in northern (cold) regions. As more northern cover performance data is becoming available, cover practitioners, owners and regulators, and other stakeholders, are in a position to learn from experience, and this talk is aimed at providing some food for thought.

Why covers?

- For every site we need a clear answer to this question
- There is often a disconnect between **site closure goals** and reason for using covers
- Suggest defining two separate terms;
 - Closure **OBJECTIVES**
 - Cover **FUNCTIONS**



Closure objective

Closure **Objectives** are the fundamental reasons/motivations for doing the closure work – they can include:

- Remove human/animal health/safety risks
- Prevent/remove/minimize environmental impacts
- Reclaim social/economic land value
- Regulatory compliance
- Release bonds
- Improve corporate image



Cover function

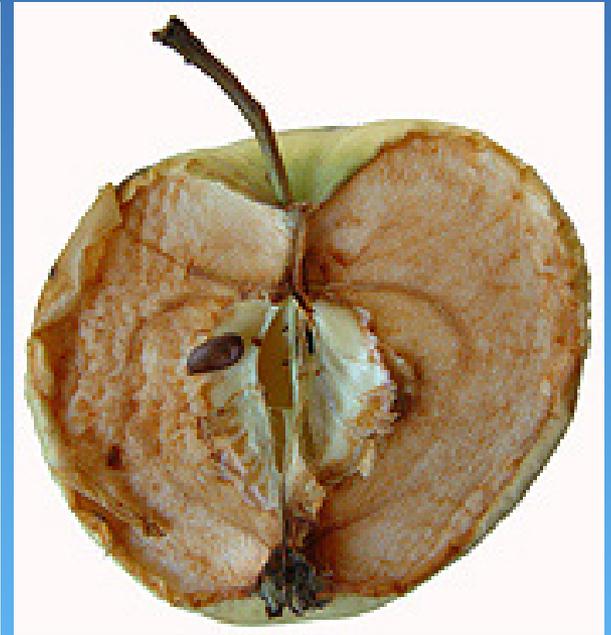
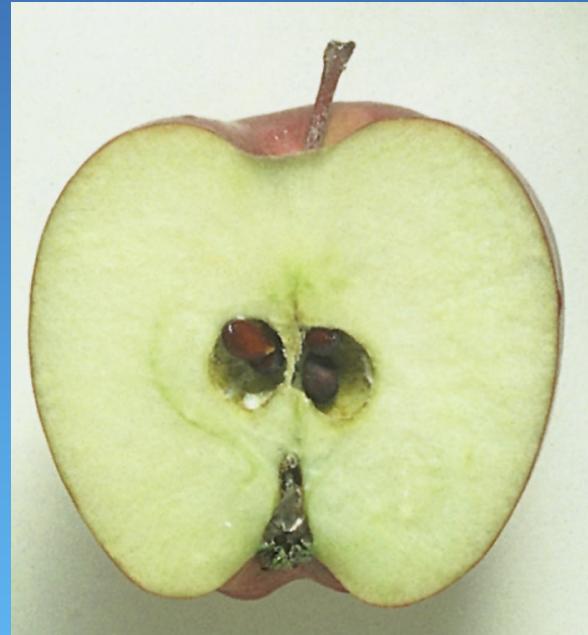
- A cover is one **Tool** that can be used to achieve a closure **Objective**
- Cover **Function** is the “**work**” that the cover must perform in order to achieve part/all of the closure **Objective**
- Typical cover **Functions** include;
 - Radiation control
 - Waste stabilization (i.e. dust, erosion & freeze-thaw)
 - Seepage/leachate management (oxygen/infiltration control)
 - Physical stabilization (slope stability)
 - Thermal control (i.e. promote permafrost)
 - Promote vegetation
 - Access control (i.e. prevent direct contact with waste)

Cover design basis

- Use of mine waste covers evolved from hazardous and municipal landfill liners
- Theory evolved from soil science
- Principles applied to temperate climates
- No standard “recipes” for designing covers
- Site specific designs are promoted
- Designs predominantly influenced by climate & material availability
- Design life an open question



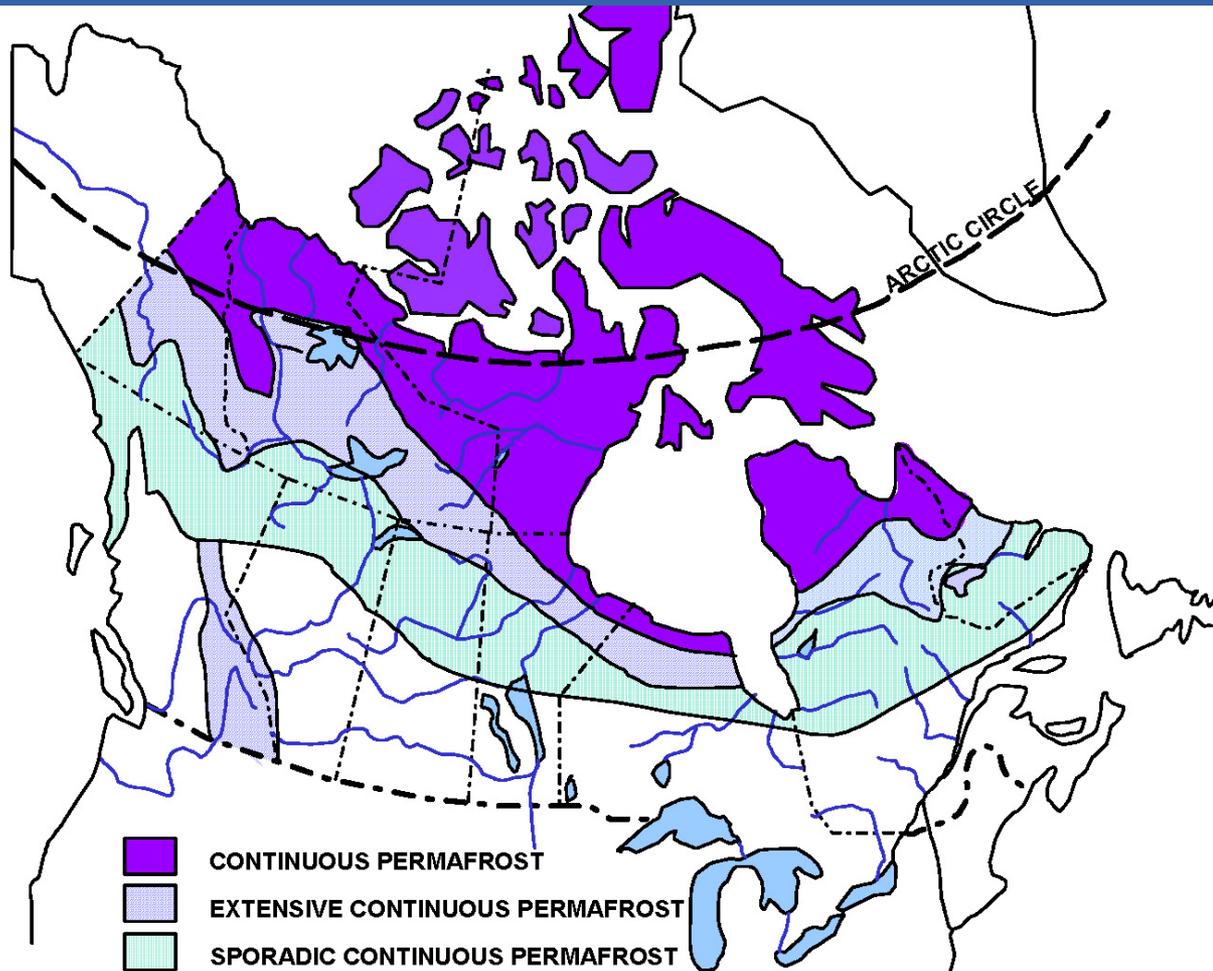
What is a cover?



Conditions imposed on covers

<u>Parameter</u>	<u>Range</u>
Total Stress	Approaches Zero
Temperature	Highly Variable (-50°C to +60°C)
Hydraulic Pressure	Negative (0 to -1,500 kPa)
Degree of Saturation	1% to 100%
Water Phase	Multiphase (Vapor, Liquid, Ice)
Hydraulic Regime	Infiltration, Run-off, Evapotranspiration, Change in Storage
Environment	Microbial Communities, Plants, Roots & Fiber, Animals, Living Systems

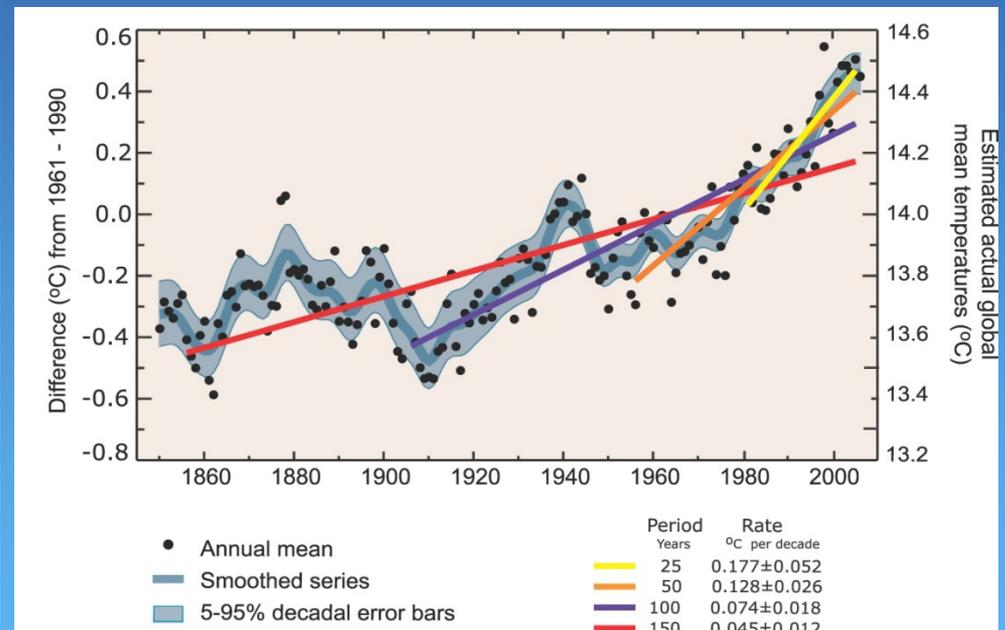
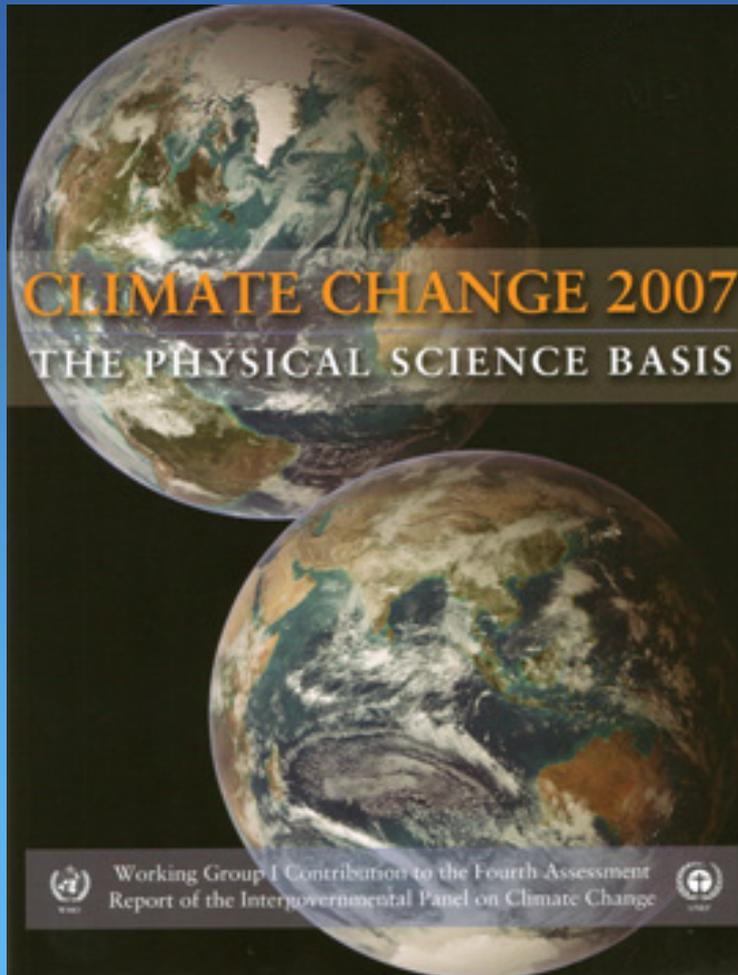
Should cold region cover design be different?



Defining cold regions

There are many definitions for what constitutes a cold region. These include definitions based on air temperature, snow depth, ice cover on lakes, depth of ground freezing and vegetation distribution. The different definitions arise from the different contexts within which various groups have studied cold regions. In the context of mine waste covers, an appropriate definition of cold regions would include any area where there is a regular occurrence of ground frost sufficient to affect cover performance. Ground frost can directly affect the rate at which precipitation infiltrates through a cover system, and can physically alter soil properties and thereby indirectly affect cover performance.

What about climate change?



Cold region effects on mine waste

- Permafrost degradation below mine waste
- Ice entrainment within mine waste
- Freezing of mine waste
- Different rates of geochemical weathering of mine waste



Cold region phenomena

- In cold regions there is distinct link between climate and ground surface
- Where climate is sufficiently cold it will leave physical evidence of its influence
- Cold region phenomena as it relates to cover performance can be categorized as:
 - Frozen ground phenomena
 - Cold region hydrologic phenomena
 - Other factors



Frozen ground phenomena

Ground freezing and ground ice formation, ground thawing and thaw settlement, freeze-thaw cycles, cryoturbation, mass-wasting (including solifluction/gelifluction), convective cooling, ice wedges, palsas, pingos, thermokarst, patterned ground, boulder fields and pavements, mounds and/or hummocks, seasonal frost mounds, mudboils, circles and diapirs, involutions, rock glaciers, ploughing boulders



Effects of frozen ground phenomena on covers

- Freeze-thaw effects on permeability
- Frost susceptibility
- Migration of fines through covers
- Other potential effects
 - Frost heaving
 - Solifluction
 - Boulder fields
 - Plouging boulders
 - Soil heterogeneity
 - Solute concentration



Effects of cold region hydrologic phenomena on covers



- Snow, ground thaw and frost substantially alter water balance
- Snowmelt the most important part of the hydrologic cycle
- Surface runoff factors higher in cold regions
- Rain on snow yield very different design storm events
- High saturation means high ice content which implies lower hydraulic conductivity
- Unfrozen water content increase with salinity
- Ability to model these effects are limited

Other cold regions effects on covers

- Vegetation
- Animals
- Public consultation
- Construction
 - Logistics
 - Productivity
 - Soil sourcing and placement
 - Use of geosynthetics
- Monitoring and maintenance
- Cost



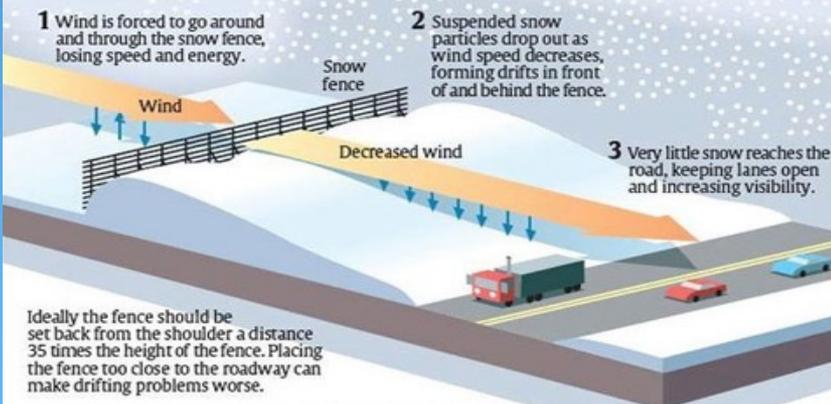
Cold region benefits for covers



- Constructability on weak/soft unconsolidated tailings
- Permafrost encapsulation
- Possibly manipulate surface hydrology
 - Snowmelt on frozen ground
 - Snow distribution

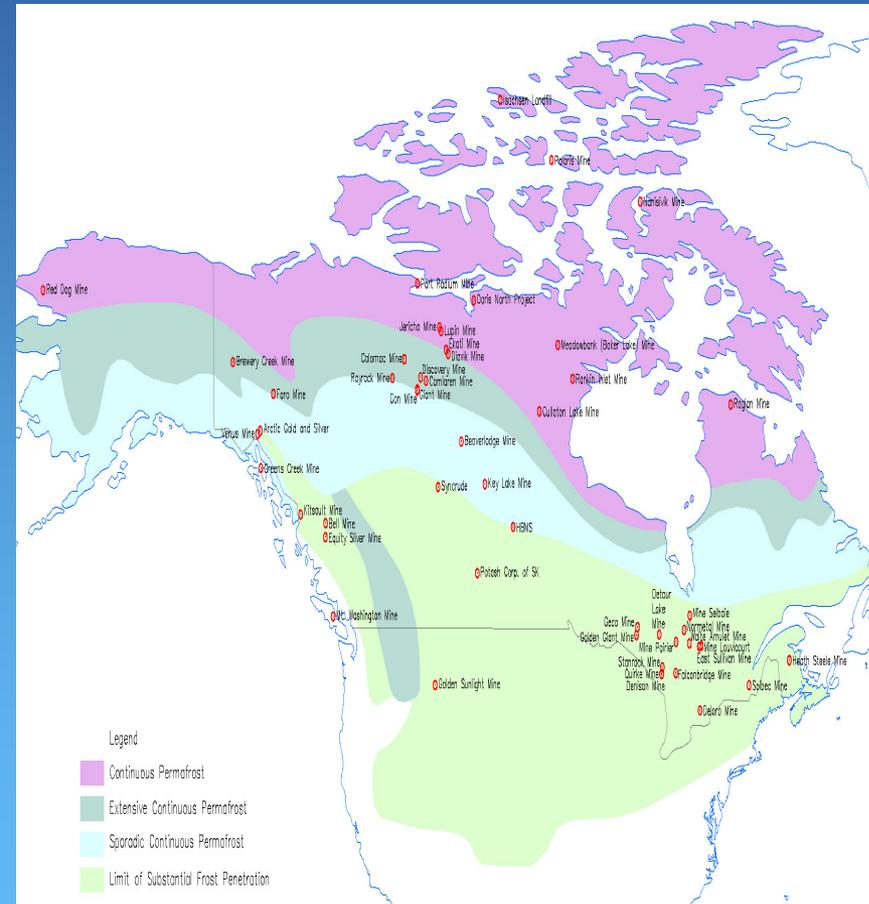
Snow fences reduce drifting, increase visibility for drivers

Travelers through the Rockies and much of the interior West will face blowing and drifting snow today. Danger to drivers will be reduced in areas where properly built and located snow fences are installed.



Cold region cover distribution

- More than 100 covers constructed, or under consideration in cold regions
- Growing number of “older” covers (in place for over a decade)
- Performance data are being collected but not shared
- All types of covers have been used in cold regions
- Some unique requirements (design criteria) has been identified



Cold region cover research

- Numerous active cold region cover trials underway
- Opportunity exists to modify many of these projects to incorporate research focusing on cold region phenomena
- Cold region hydrologic models are being developed
- Research is being initiated
 - MEND
 - INAC



State-of-practice

- Using covers in cold regions remain an appropriate closure tool
- Making use of some of the benefits that cold regions offer, but more opportunities exist
- Existing cover design principles remain largely valid, but some additional challenges are lurking
- Many frozen ground processes are not well understood
- Cold region hydrologic processes modeling capabilities are weak
- Some unique (non technical) design criteria apply in cold regions

