Cold Region Covers What Works and What Doesn't?

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16th BC/MEND METAL LEACHING/ACID ROCK DRAINAGE WORKSHOP

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Today's Message

- Revisit why we build covers
- What do we mean when we say "cold region"
- Should cold region cover design be different?
- We don't have all the answers – provide food for thought
- Acknowledgements
  - Financial Support (MEND, INAC, SRK)
  - Vision (Mike Nahir, Gilles Tremblay, Daryl Hockley)

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:

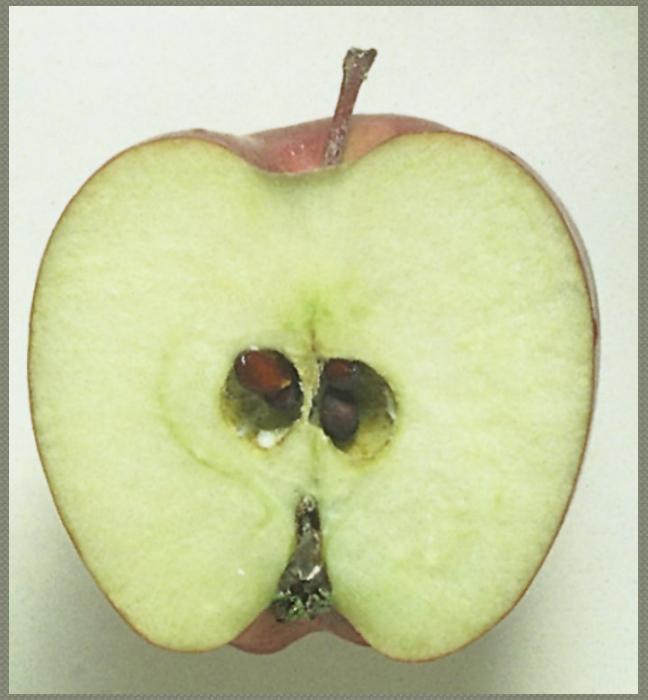
- Remove human/animal health/safety risks
- Prevent/remove/minimize environmental impacts
- Reclaim social/economic land value
- Regulatory compliance
- Release bonds
- Improve corporate image

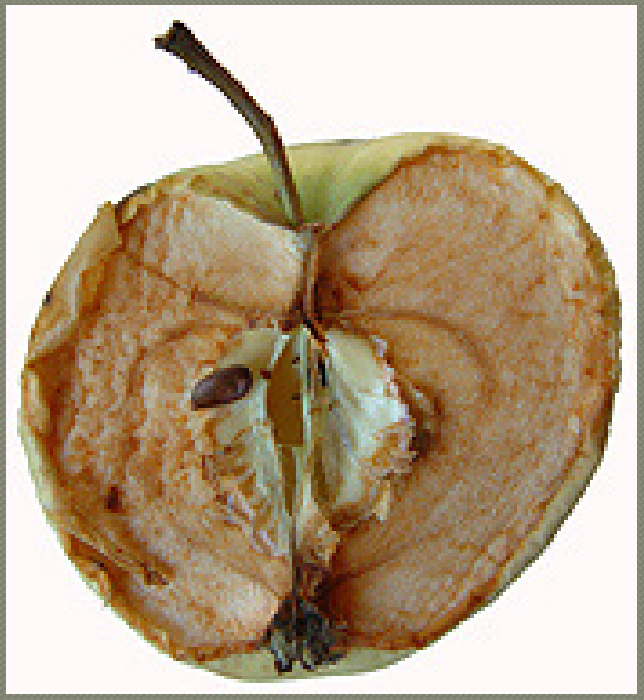
Cover function

- 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)

What is a cover?

(analogy first suggested by Ward Wilson)





Conditions imposed on covers

Parameter	Range
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

Cover Types

- Many definitions of different cover types in use, but none of these are entirely satisfactorily
- Suggest cover types be defined based on **how** they work rather than their intended **function**
- The ultimate choice of a specific cover type may very well consist of a combination of cover types
- Cover type normally dominated by two factors; **material (soil) availability** and **climate**

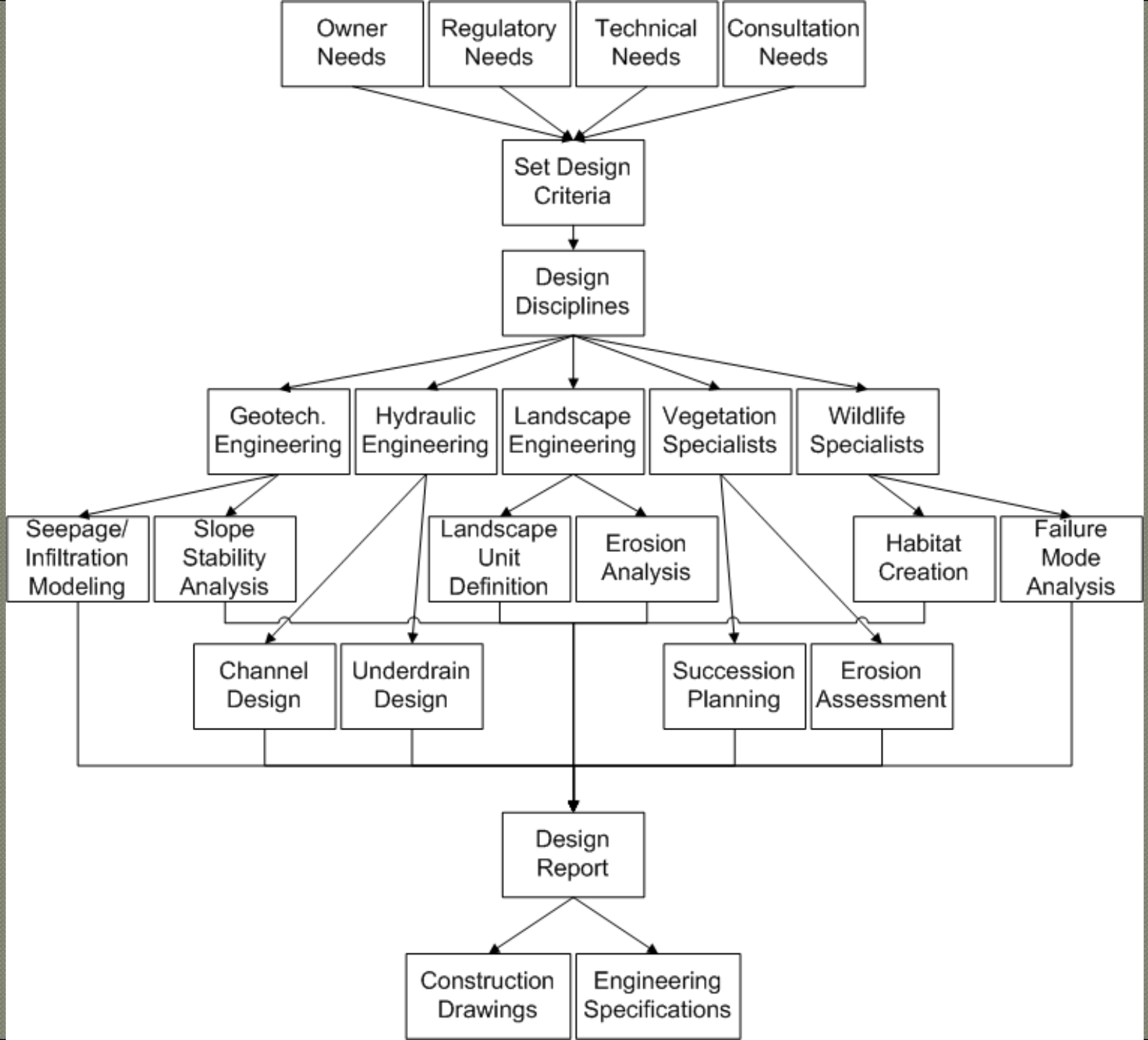
Cover Types Defined

- **Isolation covers** - can consist of any material and is intended only to prevent direct contact of animals and vegetation with the underlying material
- **Barrier covers** - incorporate at least one low permeability soil or geosynthetic layer to physically limit the infiltration of water and, in some case, the ingress of oxygen
- **Capillary break covers** - use contrasts in hydraulic properties to impede infiltration
- **Store-and-release covers** - use of a generally thick layer of soil to store water until it can be taken up and evapo-transpired by plants
- **Water (and saturated) covers** - use of a pond (or saturated soil) to completely cover the underlying waste, typically to prevent oxidation of potentially acid generating materials
- **Insulation covers** - take advantage of cold climates to freeze in, or insulate the underlying waste

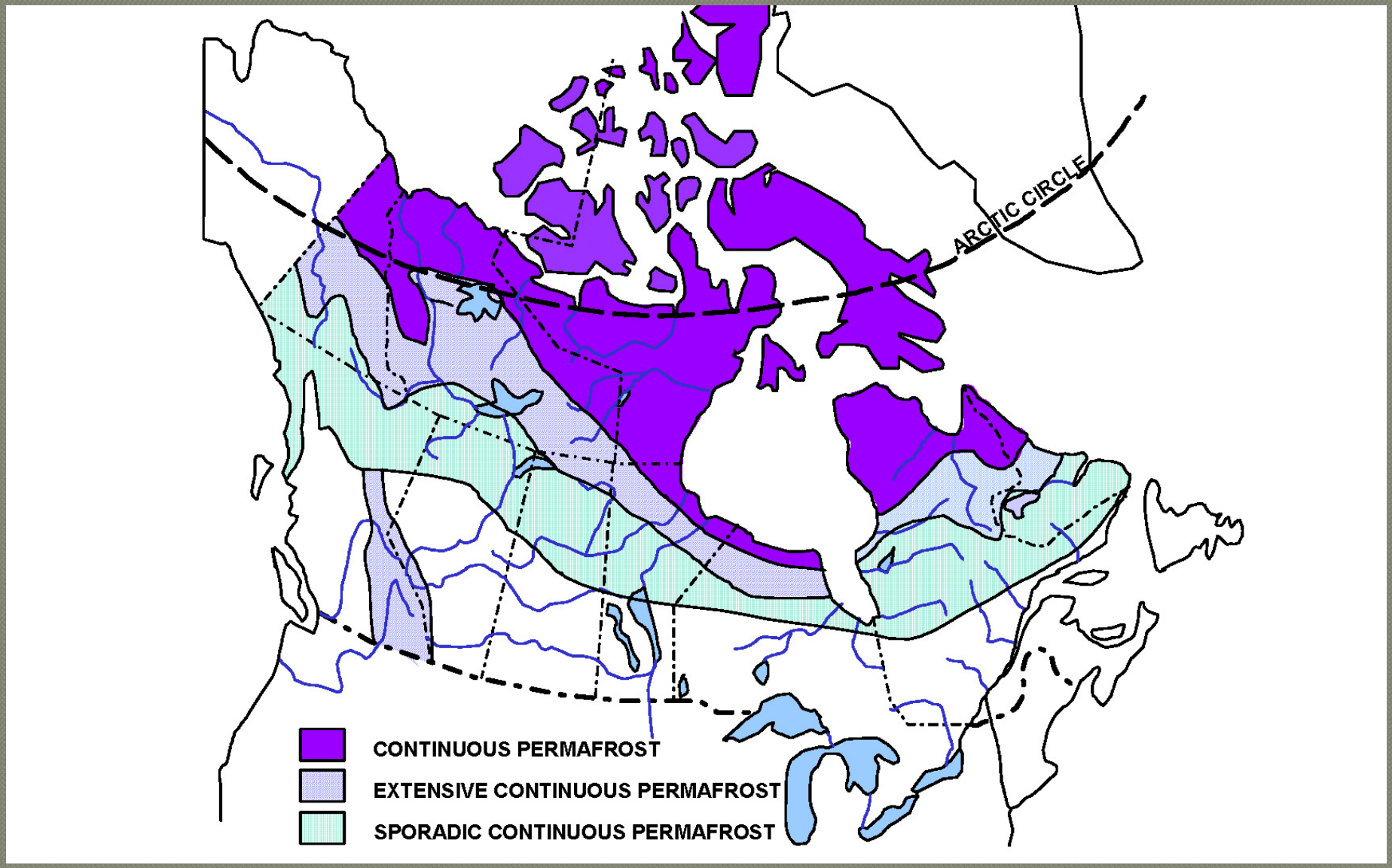
Cover design basis

- 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**

DESIGN PROCESS



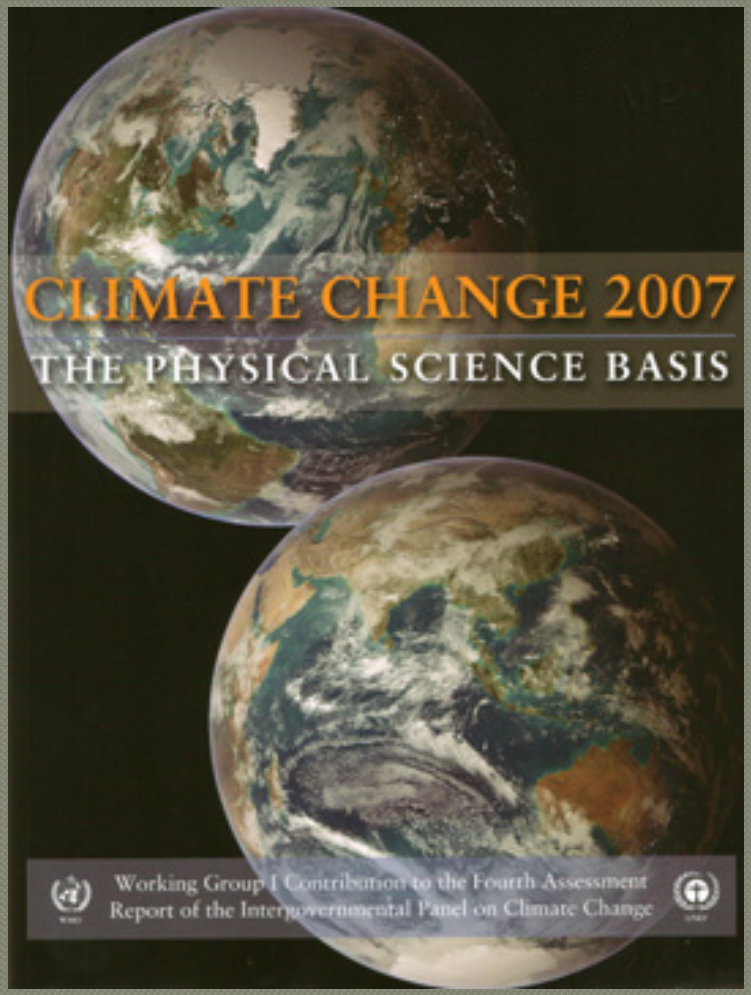
Should cold region cover design be different?

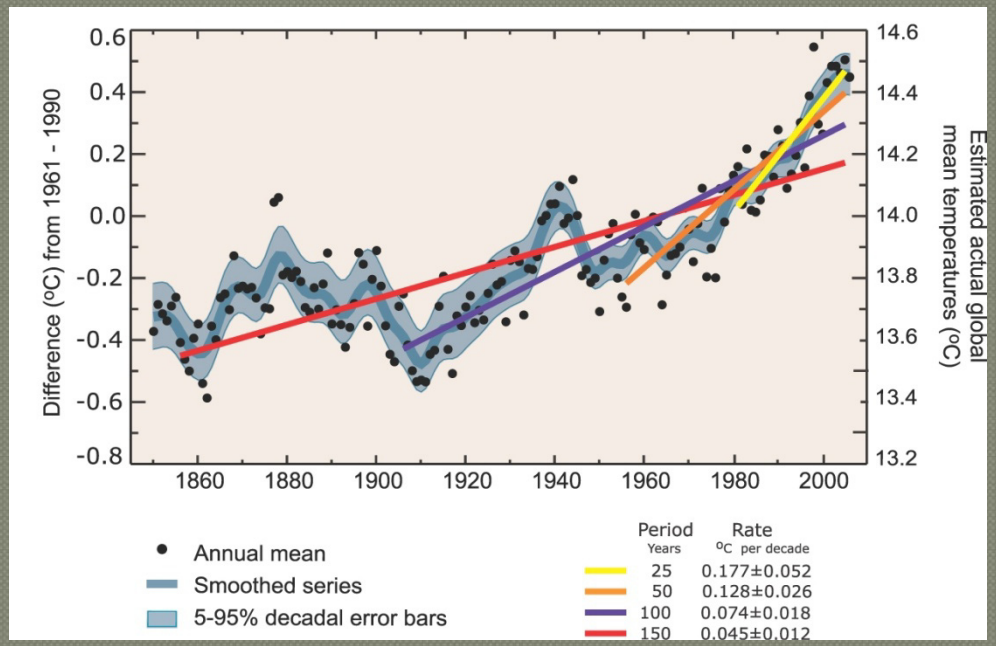


Defining cold regions

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

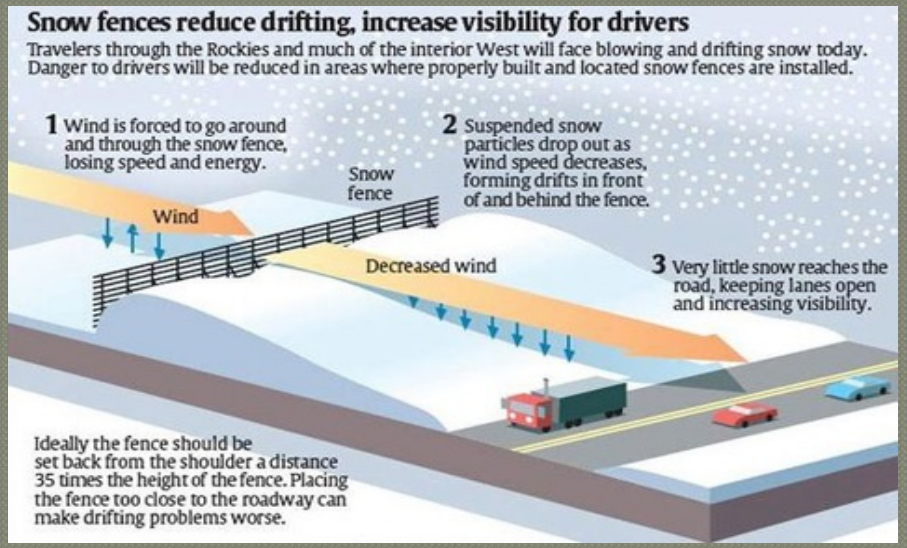
hydrologic phenomena on covers

- 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
- Aspect can greatly change cover design on a single site
- 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

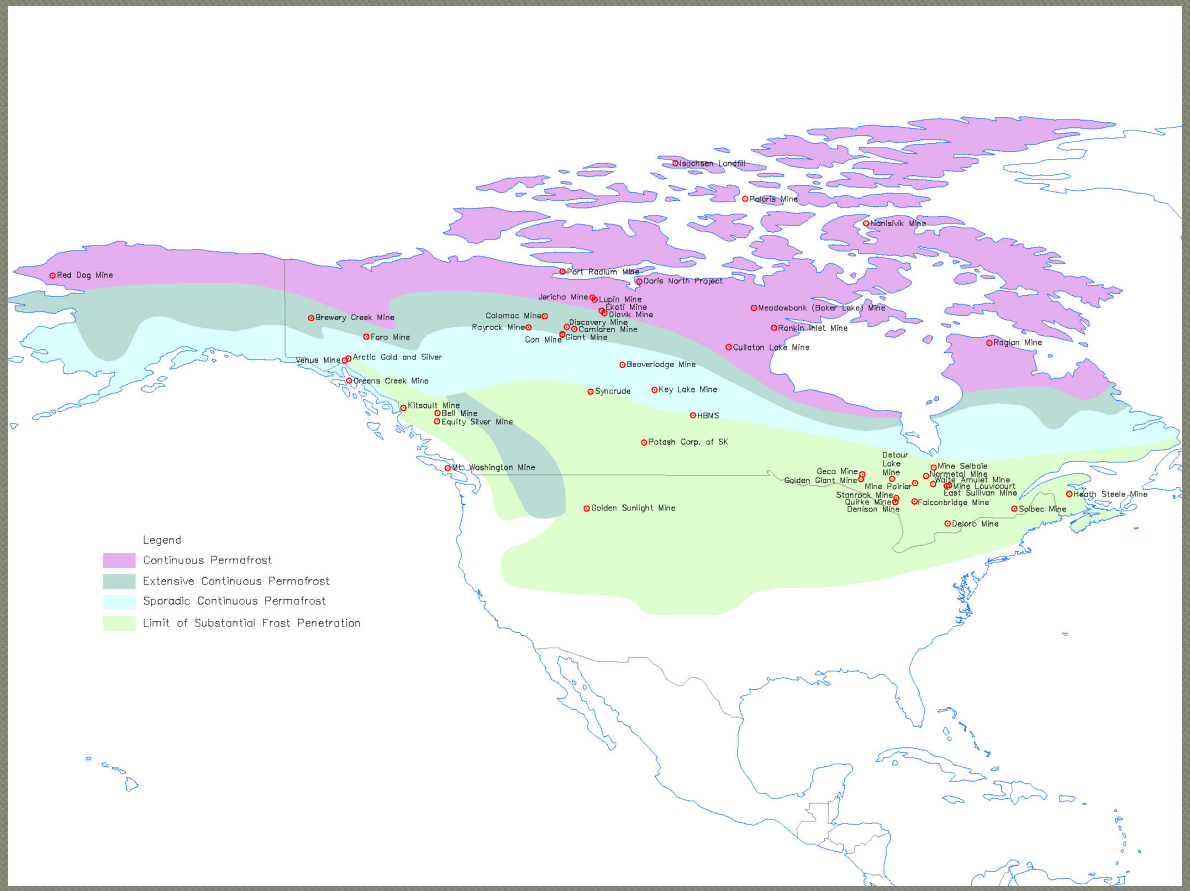
Cold region benefits for covers



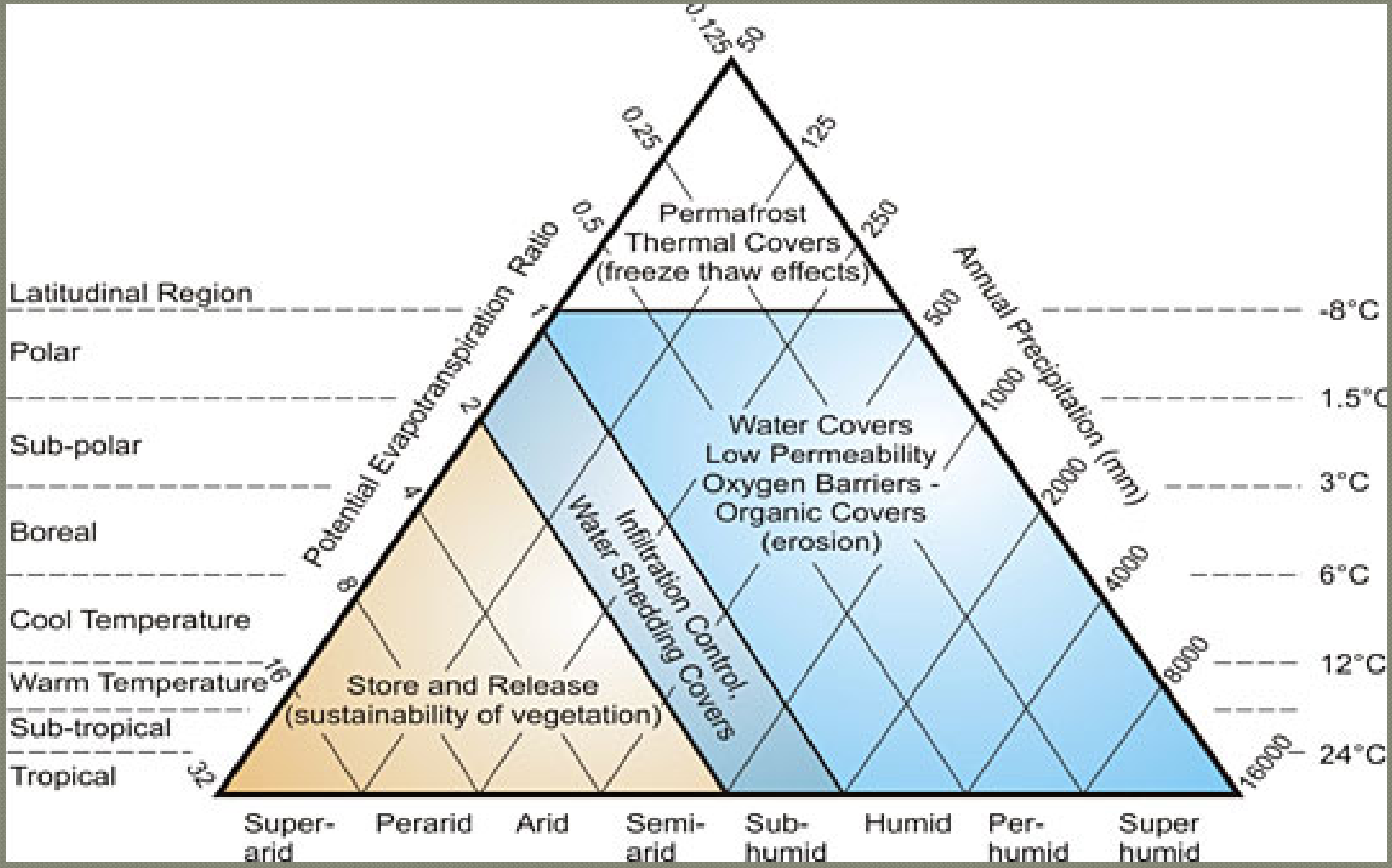
- Constructability on weak/soft unconsolidated tailings
- Permafrost encapsulation
- Possibly manipulate surface hydrology
  - Snowmelt on frozen ground
  - Snow distribution

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

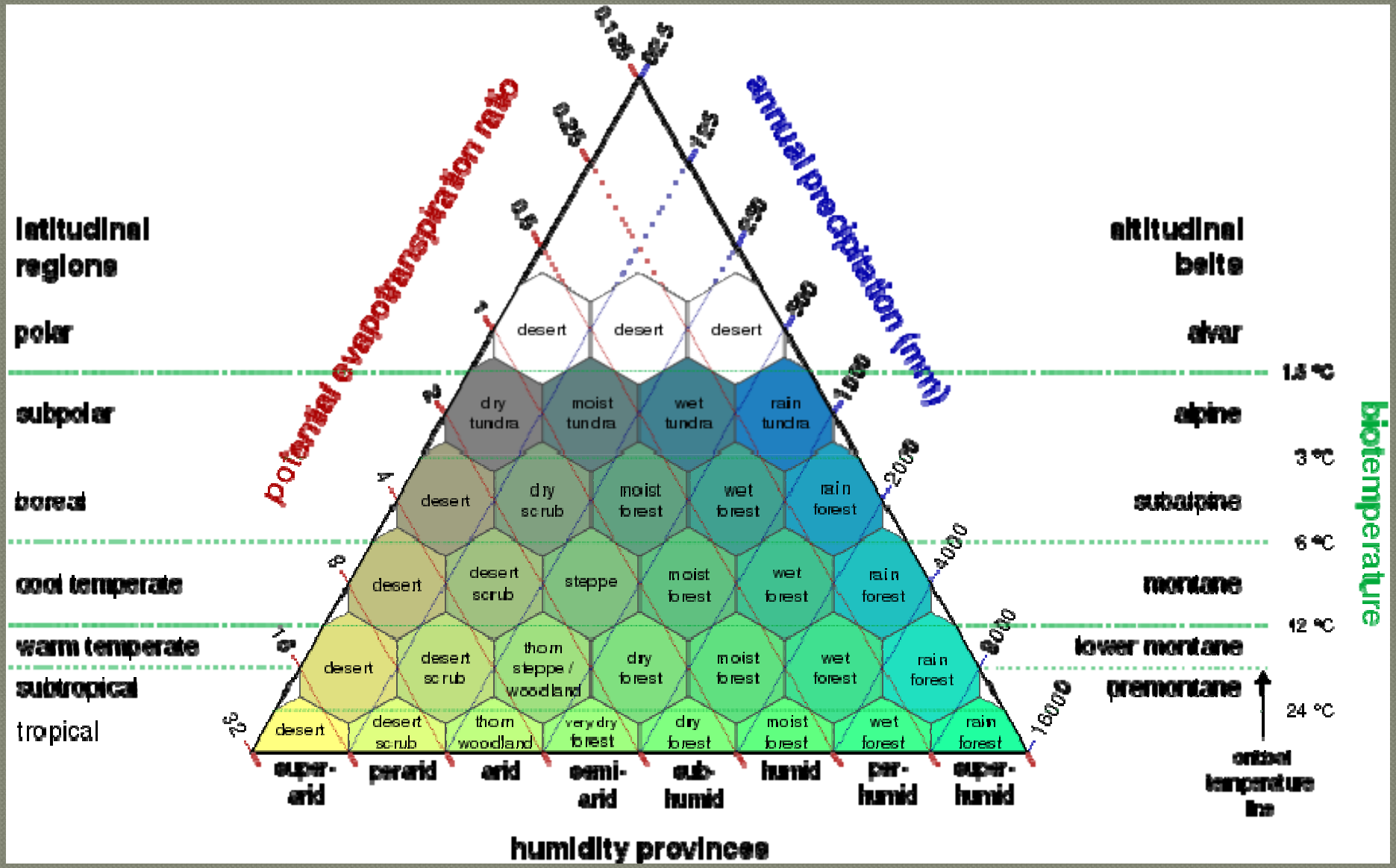


Suggested cover type classification by region *(GARD 2009)*



zones

by L.R. Holdridge (1947)



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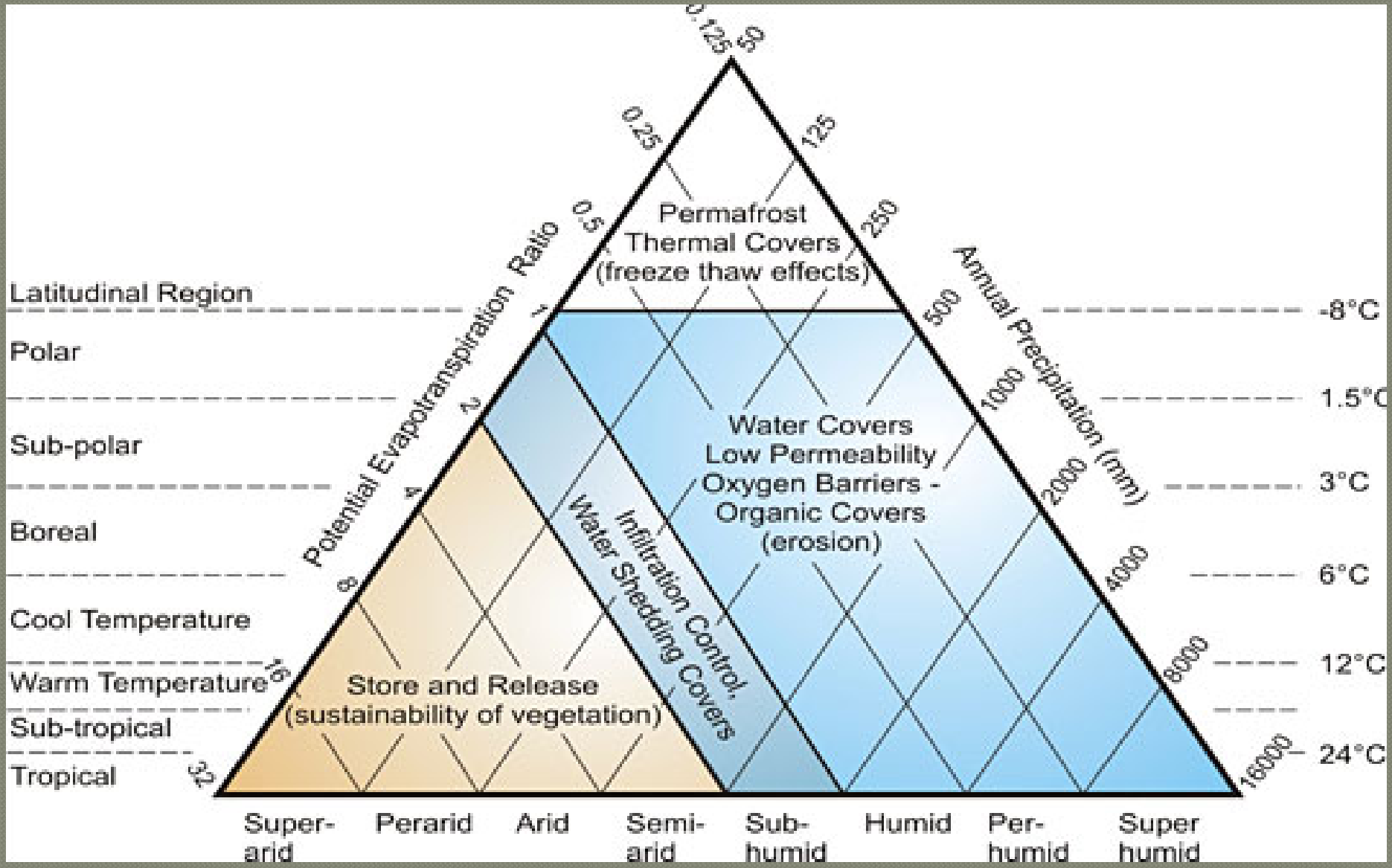
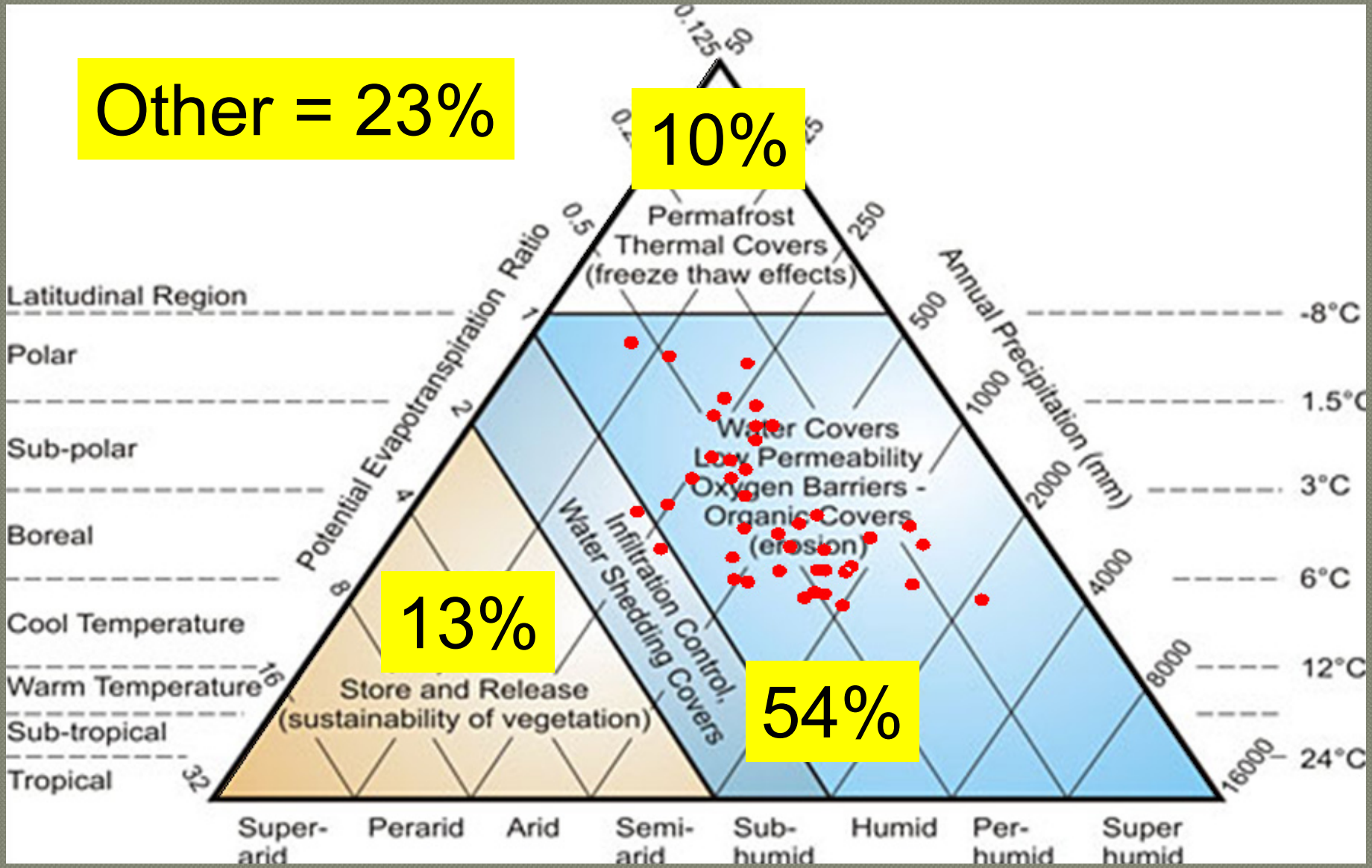


Actual cold region cover distribution



Cold region cover research

- Many cold region covers exist – invaluable archive of "reality"
- 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 but should become more "mainstream"
- Research is being initiated
  - MEND
  - INAC
  - Mining companies

So…what works and what doesn't ?

- Cold region covers remain an appropriate closure tool
- Should make greater use of cold region benefits
- Existing cover design principles remain largely valid, but some additional challenges are lurking
- Many frozen ground processes not well understood
- Cold region hydrologic processes modeling capabilities weak
- Unique (non technical) design criteria apply in cold regions