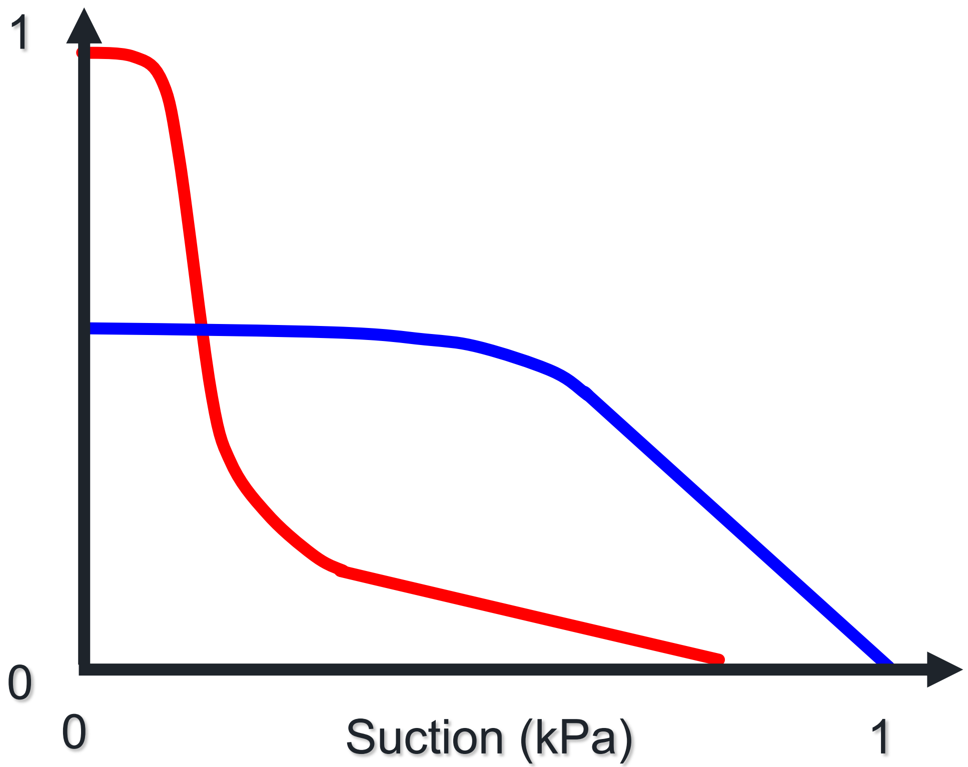
Capillary Break Cover Systems

Challenges in Laboratory to Field and Field to Laboratory Evaluation and Design



Authors:

Greg Meiers, WSP Canada

Jamel Sgaoula, WSP Canada

Sophie Turcotte, Quebec Department of Energy and Natural Resources

Québec

Presentation Outline

1 Capillary Break Cover Systems, The Theory

2 Manitou Mine Closure, Objectives and the Base Case

3 Cover System Materials, A Starting Point for Assessment

4 Preliminary Numerical Simulations, Understanding Risks in the Design

5 Performance Risk Mitigation, Amelioration of the Water Retention Layer

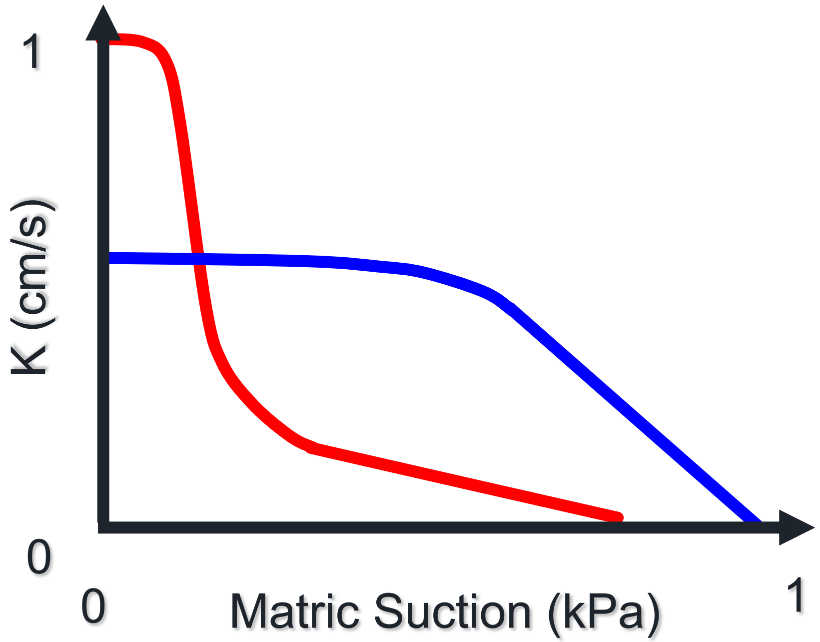
5 Implementation of Test Pads

6 Presentation Summary Points

Capillary Break Cover Systems, The Theory

The WRC and K-function

- The water retention curve (WRC) or the SWCC, defines the energy state and water content of a porous medium
- The hydraulic conductivity function defines the effective permeability for various energy state conditions or water contents
- Do we ever understand the WRC and K-function
- The capillary break is a function of two WRCs that you may not ever really know



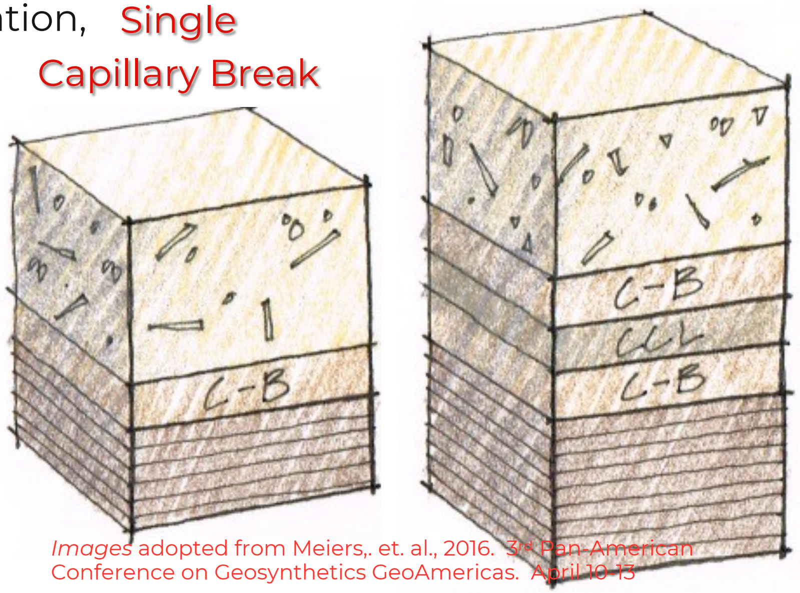
Capillary Break Cover Systems, The Theory

Capillary Break Cover Systems

- Capillary break cover systems are in essence texturally contrasting layers of materials
  - Water retention layers (WRL) and capillary break layers (CBL)
- Single capillary break cover focusses on reducing downward flow
- Double capillary break focuses on reducing downward flow and evaporative losses
- In the mining industry the strategies focus on either reducing net percolation, increasing degree of saturation, or both for managing ML/ARD risks
- What is coarse textured CBL material, probably not what you think
- What is a fine textured WRL

Double Capillary Break

Single Capillary Break

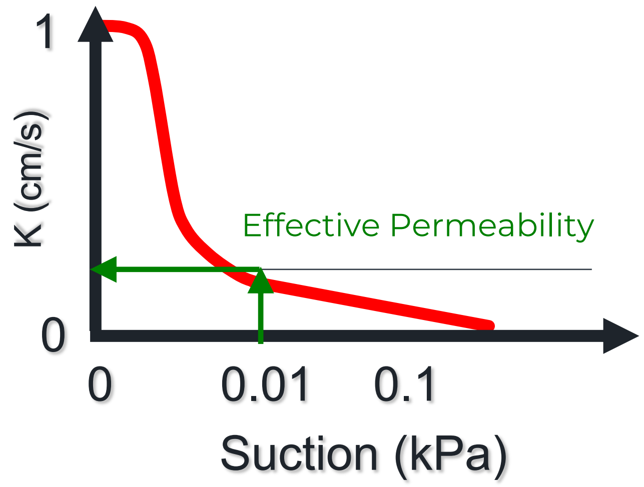


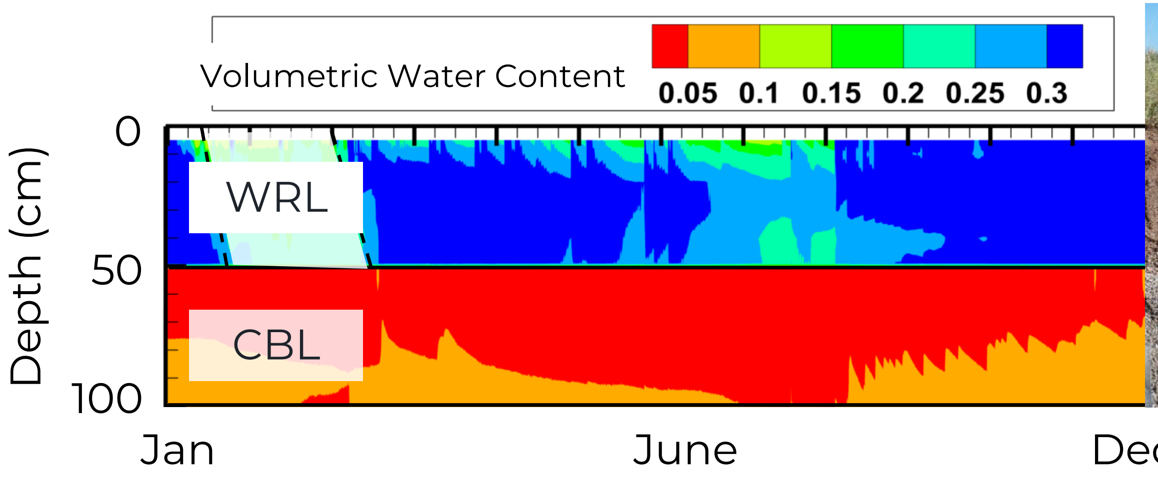
Images adopted from Meiers,. et. al., 2016. 3rd Pan-American Conference on Geosynthetics GeoAmericas. April 10-13

Capillary Break Cover Systems, The Theory

Capillary Break Cover Systems

- Downward flow or breakthrough occurs when the suction at the interface between the WRL and CBL is equal to the water entry value (WEV)
- Evaporative loss from the surface is a function of the k-function and low air entry value (AEV)



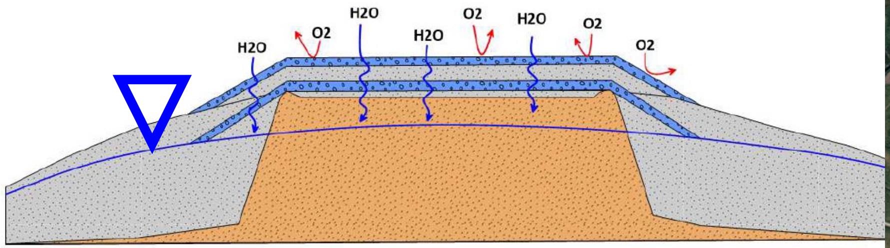


Slide adopted from Meiers,. et. al., . Evaluation of cover systems utilizing geosynthetic layers for closure of coal waste rock piles in a seasonally humid location. CLRA Conference 2014, Wolfville, NS

Manitou Mine TSF Closure

Project Background

- Closure concept includes the placement of Goldex Tailings within the Manitou TSF to encourage the phreatic surface to rise up above the existing acid generating Manitou tailings
- TSF covers and area of about 200 ha
- Within the TSF an oxygen barrier cover system is required to manage oxygen ingress through and area of 20 ha where the phreatic surface is lower and geochemical stability will not be achieved
- Crushed mine rock and tailings from the Goldex site are considered for the cover system
- Site is located in Quebec

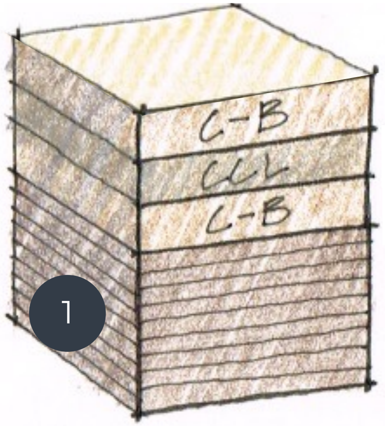


Manitou Mine TSF Closure

Project Background

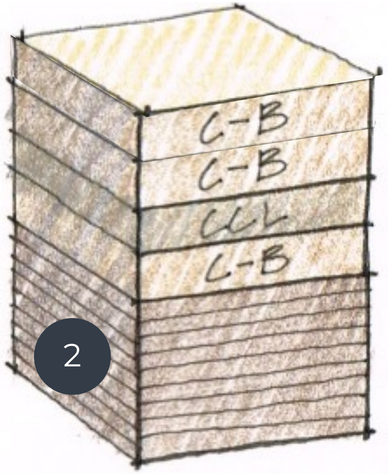
- Initial Base Case cover system design consisted of a double capillary break
- The Base Case was enhanced when considering established closure objectives, end land-use, climate, vegetation, and materials
- Growth medium or upper capillary break was the thinnest layer of the Base Case
- The Base Case design evolved to a single capillary break with a thick water store-and-release growth medium layer

Base Case
Double Capillary Break



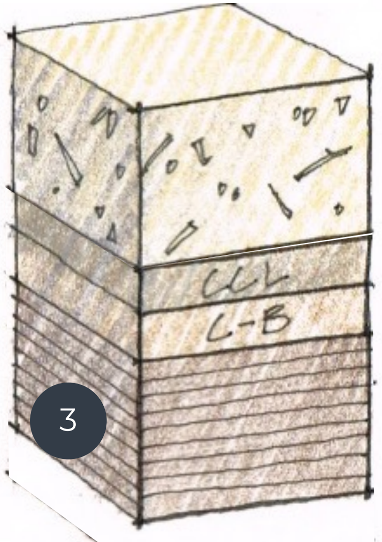
0.3m CBL
0.8m WRL
0.5m CBL

Consider End
Land-Use, Vegetation



1.0m CBL/GM
0.5m WRL
0.5m WRL

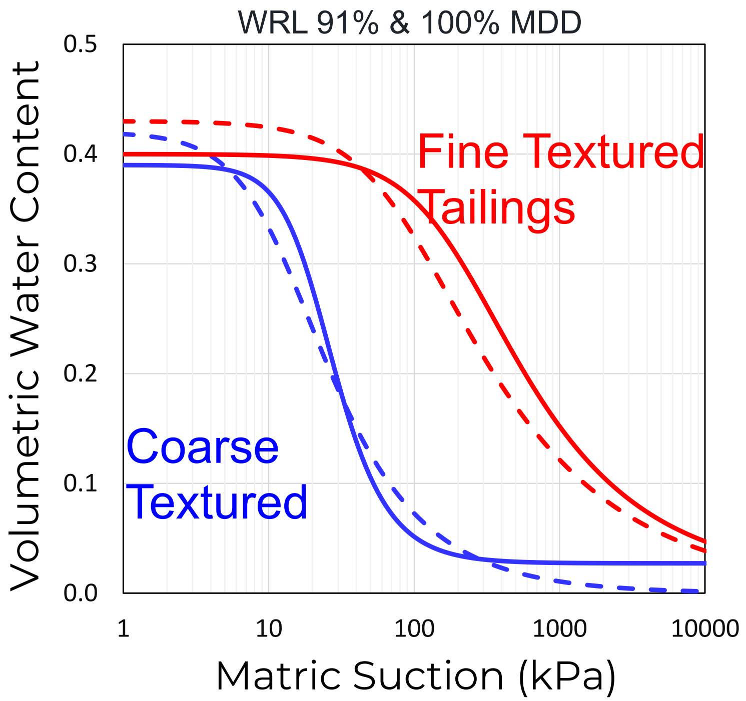
Consider End
Land-Use, Vegetation,
Climate, and Materials

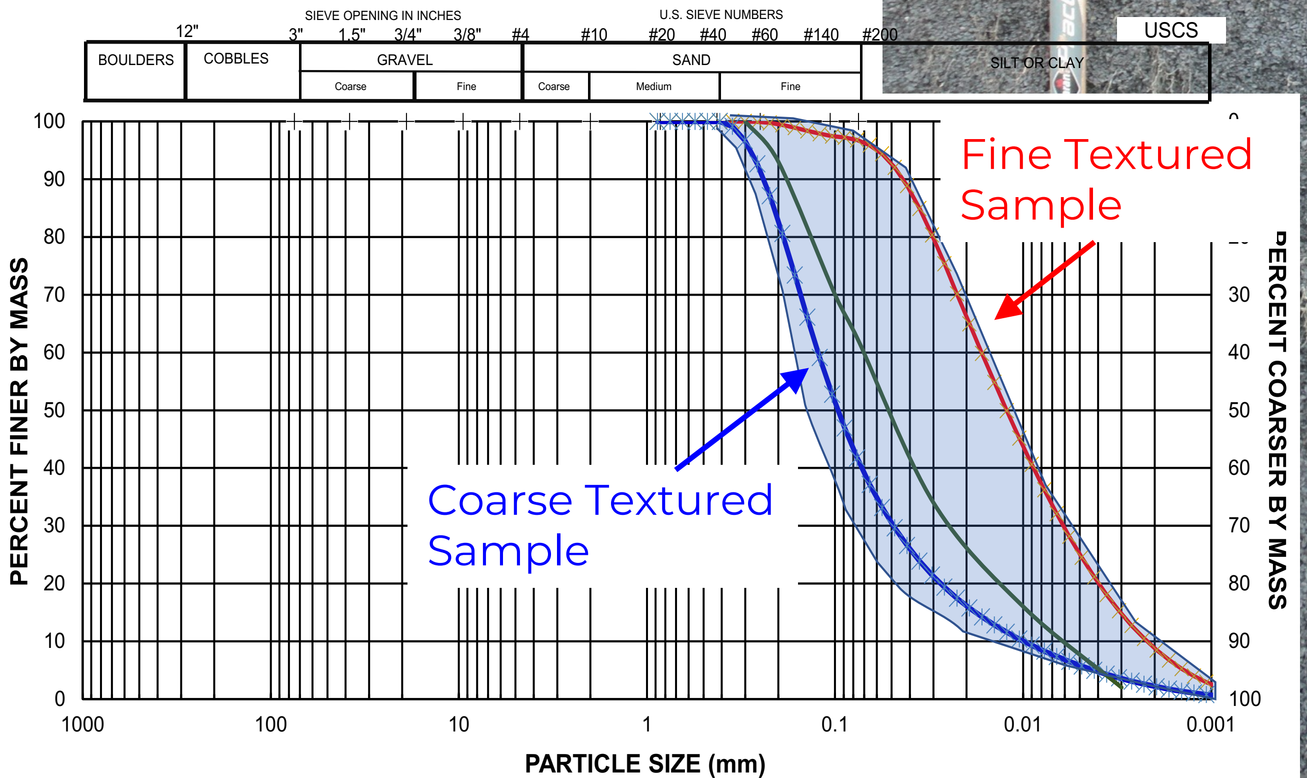


Cover System Materials, A Starting Point

Water Retention Curves – Goldex Tailings WRL

- Goldex tailings used in the WRL has a fines content that varies from 20% to 95%
- Substantial variability in fines and as a result anticipated hydraulic performance
- Anticipated air entry value in the range 8 kPa (Coarse) to 50 kPa (Fine)
- Understanding for potential field variability developed in terms of texture and compactive effort





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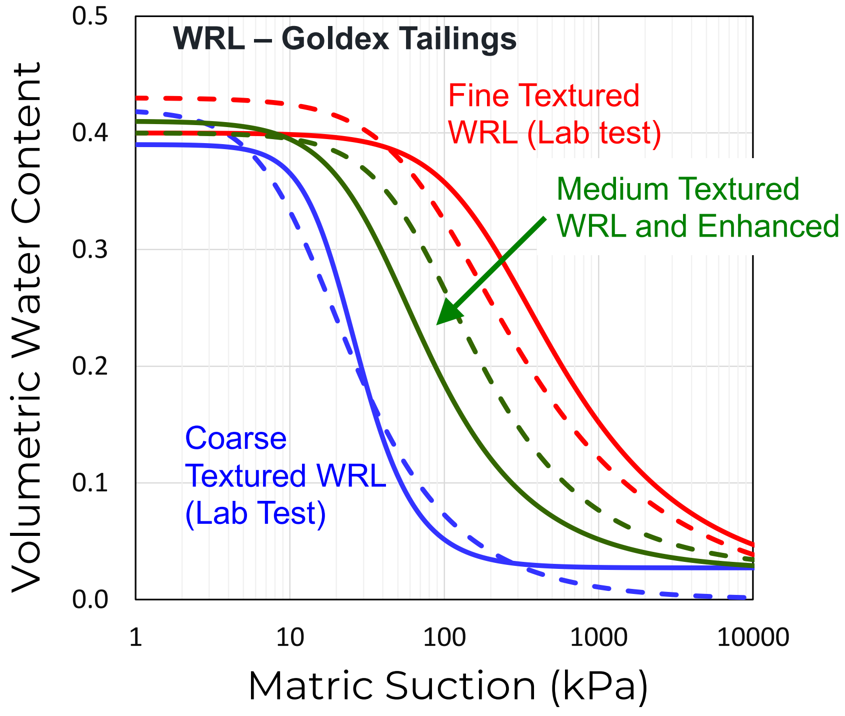
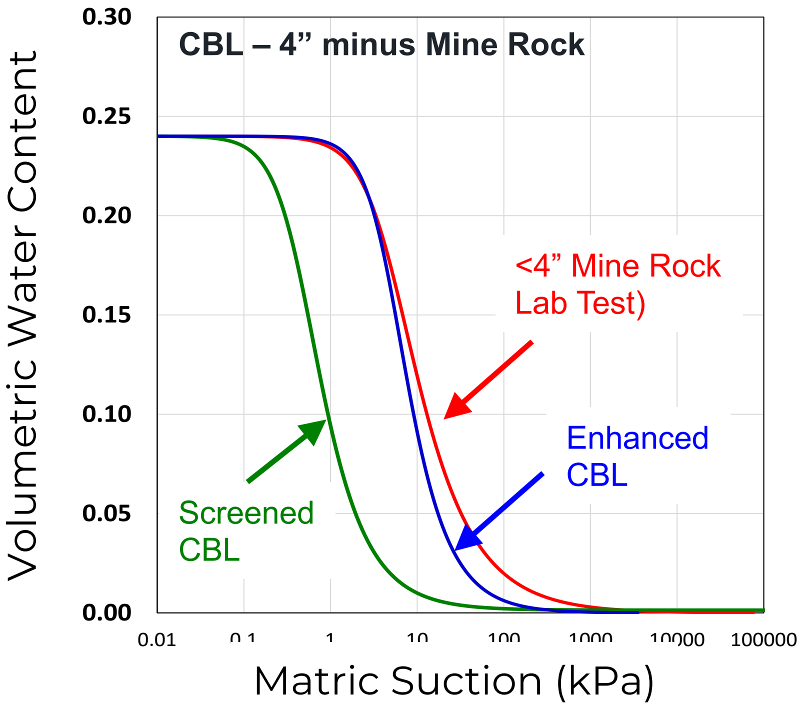
Cover System Materials, A Starting Point

Numerical Simulation Model Inputs, WRCs

- Water Retention Layer – Established a "medium" and "enhanced medium" textured WRL based on anticipated tipping point breakthrough condition
- Find out where the risk is
- Capillary Break Layer – Established "Base Case", enhanced, and screened mine rock to remove

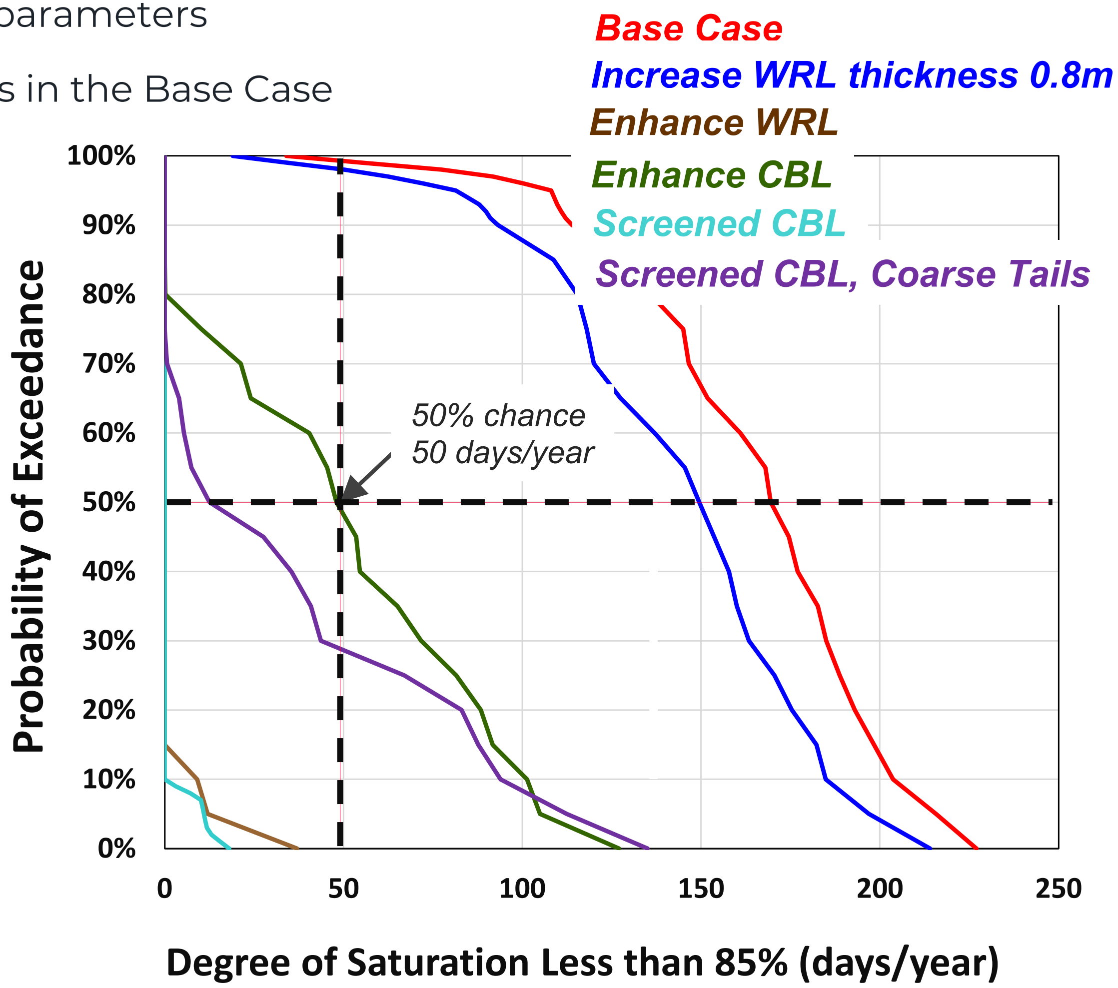




Preliminary Numerical Simulations

Understanding Risk in the Design

- Simulated 40 year climatic database to enhance understanding of performance and influence of key input parameters
- Apparent performance risks in the Base Case
- Slight changes in the WRC of the WRL or CBL resulted in substantial changes in simulated performance
- Lower capillary break allowed for draindown of the WRL
- Need and AEV >28kPa for the WRL to maintain saturation (i.e., >85%)



Preliminary Numerical Simulations

Risks Identified in the Design

- Fines content in the CBL 4” minus crushed mine rock
- Heterogeneity in the WRL Goldex tailings

Challenges in addressing the risk

- Screening and removal of fines from the CBL
  - Allow for fines to be transported from the WRL to the CBL
  - Cost
- Homogenization of the Goldex tailings WRL, would likely not be technically possible

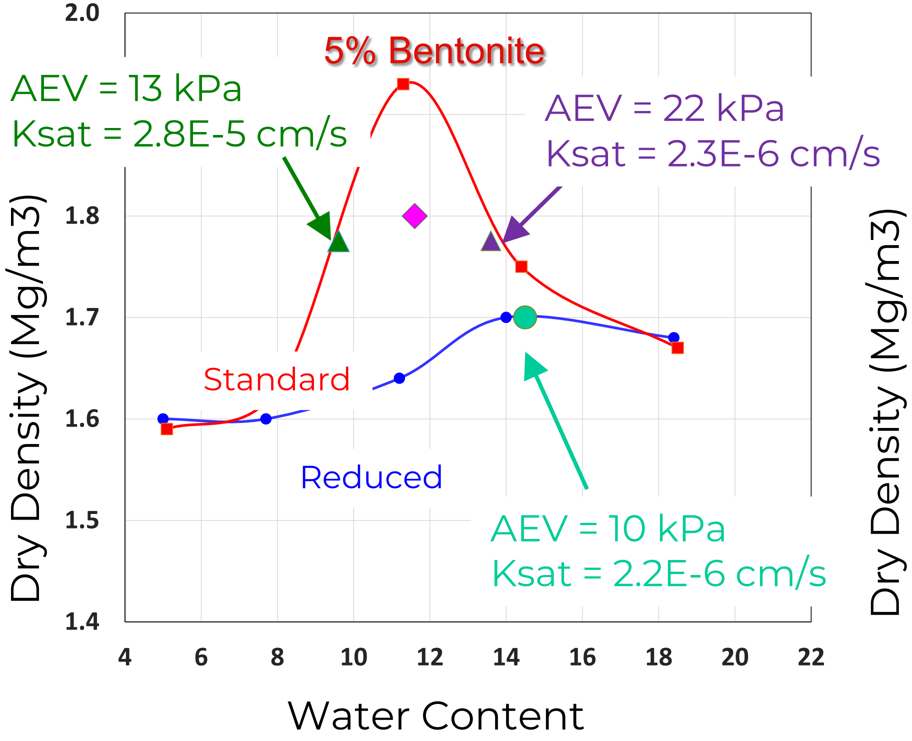
Strategy for addressing performance risks focused on amelioration of the WRL

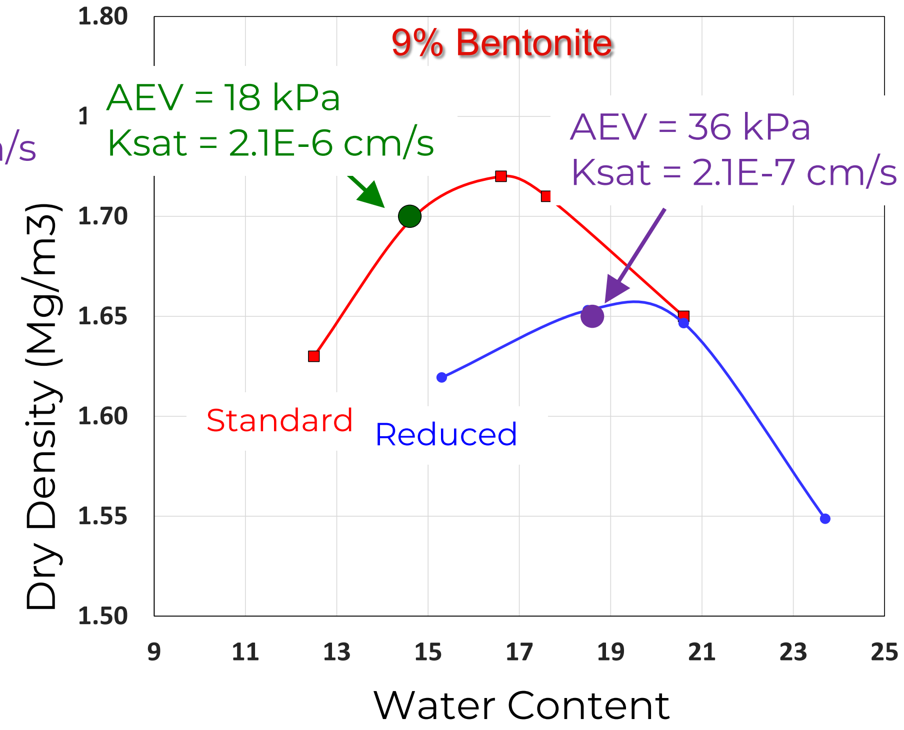
- Laboratory program implemented to evaluate bentonite amelioration of the WRL

Performance Risk Mitigation

Assessment of 5% and 9% Bentonite Amelioration

- Limited benefit obtained from 5% bentonite compared to Base Case WRL
- Moulding water content 2% wet of the OWC provided greater AEV
- Reduced Proctor provided lower AEV
- What can you achieve in the field
- Several re-tests were required in particular for samples dry of optimum





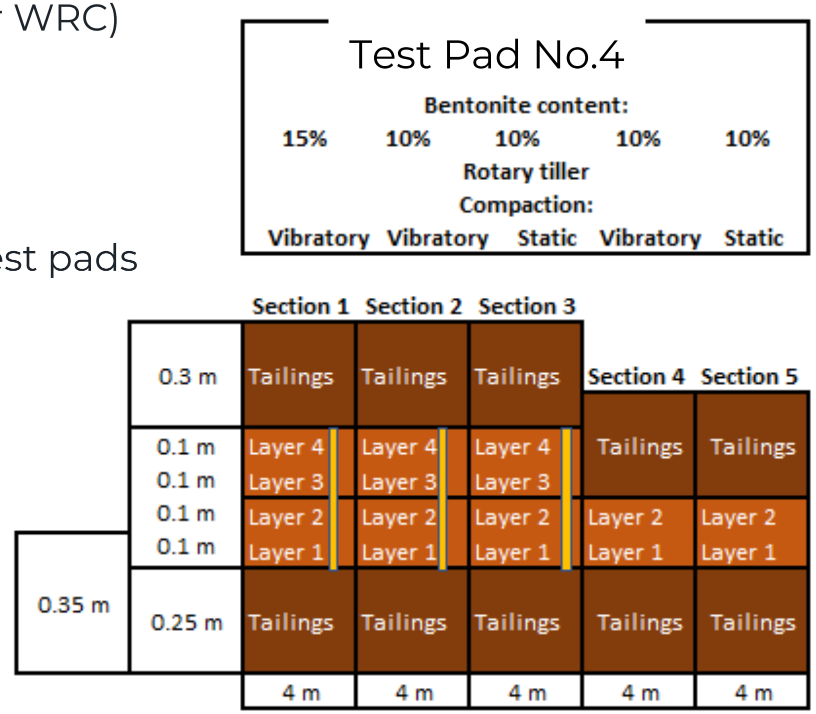
Test Pad Program

Key Objective of the Field Test Pad Program

- Evaluate different types equipment for applying or spreading the bentonite
- Assess different methods of mixing the bentonite and tailings (tiller and disk harrow)
- Assess different methods of compaction (static and vibratory)
- Develop method(s) of assessing achieved as-constructed conditions (density and permeability used as a surrogate to infer WRC)
- Develop construction QA/QC methods

Test Pad Consisted Of

- Test Pad consisted of 1 test strip and 4 test pads



Test Pad Program

Bentonite Application

- Analysis of PSD samples suggest that broadcast spreader provided a more uniform application
- The error associated with pouring bentonite was up to 100% greater than the prescribed amount

Test Pad Program

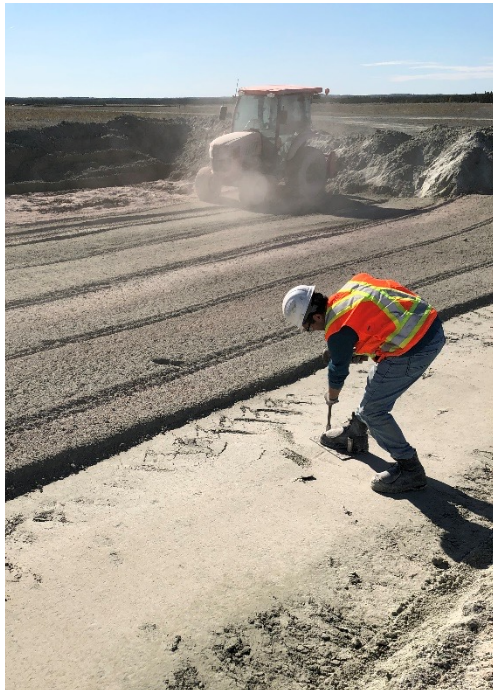
Assessment of Mixing Methods

- Rototiller homogenized the tailings/bentonite, but it did not homogenize on a macro-scale
- Identified a need to increase the thickness of the homogenized lift
- Disk harrow was not able to homogenize the tailings/bentonite at a meso-scale

Test Pad Program

Assessment of As-constructed Conditions – Water Content

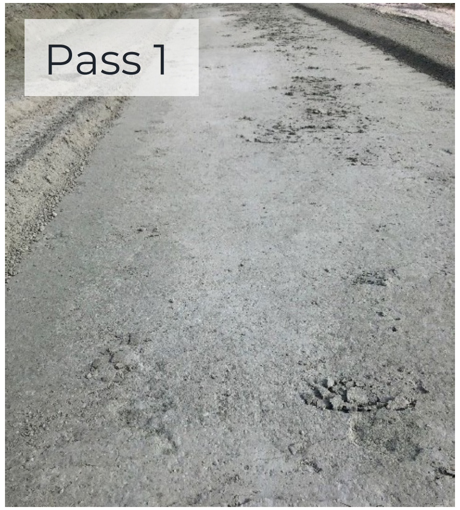
- Nuclear densometers provide a rapid measure of wet density and water content
- Dry density is then calculated
- Suitable calibration is required of a gauge
- Nuclear densometer was utilized to monitor the moulding water content and density of the test pad
- The water content measured in the laboratory was proximately 100% greater than the nuclear densometer

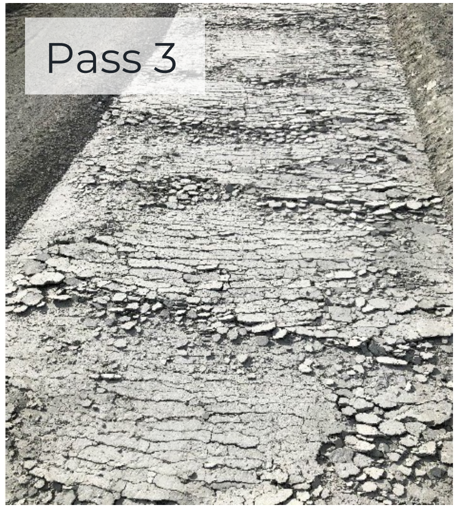


Test Pad Program

Assessment of As-constructed Conditions – Compaction

- Laboratory prepared samples can target any percent of maximum dry density
- In the field you get what you get
- Well-graded and poorly-sorted materials compact well, while poorly-graded and well-sorted materials compact poorly
- Tailings/bentonite amelioration provided a low shear strength, limiting compactive effort





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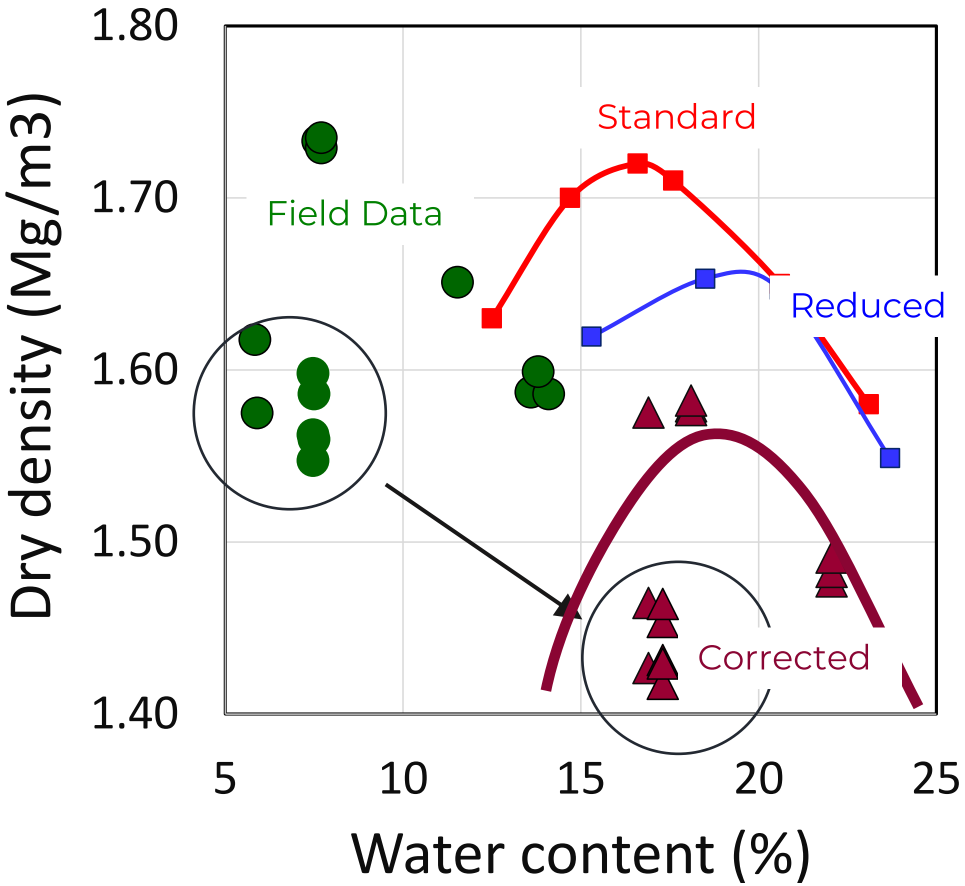
Test Pad Program

Assessment of As-constructed Conditions – Density

- Appeared to be attaining 95% to 100% of Standard Proctor MDD, and dry of the Standard Proctor OWC
- Corrected density values suggest 85% to 91% of Standard MDD, and wet of the OWC
- "Field Compaction" curves suggests lower level of compaction but also likely reflects exceedances of the target bentonite content



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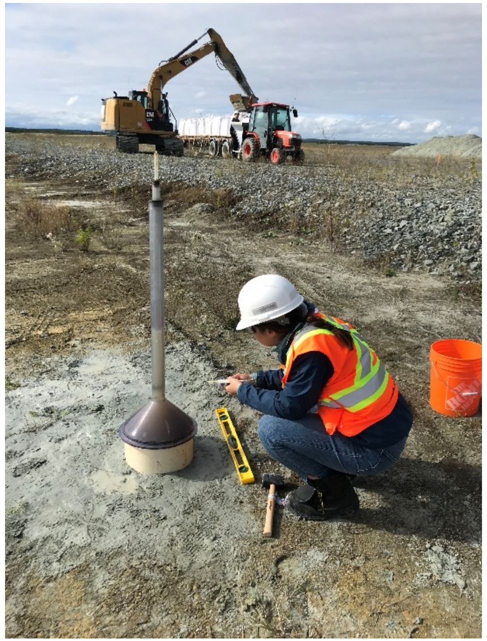
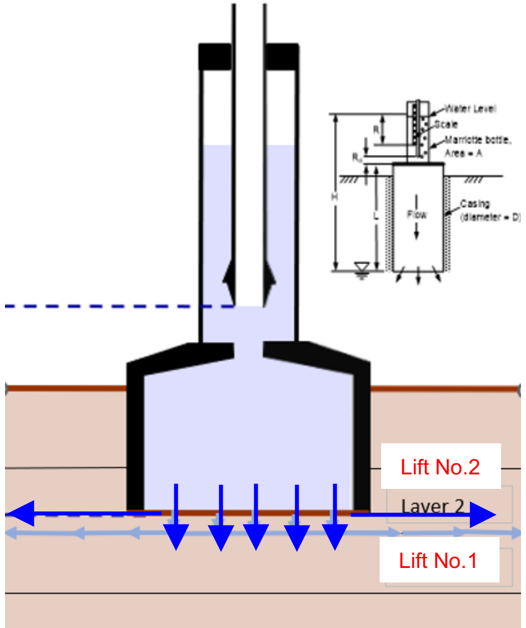
Test Pad Program

Assessment of As-constructed Conditions – Permeability

- Saturated hydraulic conductivity used as a surrogate to infer AEV of tailings
- Measured using ASTM D6391 Bore Hole Permeameter for compacted low permeability clay layers
- Permeability of the ameliorated WRL with 5%, 9% and 15% bentonite was in the range of 1x10-6 cm/s to 1x10-3 cm/s
- The target saturated hydraulic conductivity of less than 1x10-6 cm/s is required, no values met the criteria
- Needed to rethink field test method





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Test Pad Program

Development of Alternate Construction QAQC Method (undisturbed samples)

- Use of steel cutter ring that drops directly into WRC test apparatus
- Ensure sample incorporates field mixing and compactive effort
- Preliminary test results are encouraging providing permeability measurements of about 1x10-7cm/s
- WRC test results are still pending

Key Discussion Points

- As early as possible align the Base Case design with established closure objectives, end land-use, and climate
- Rethink and define what are considered fine and coarse textured materials for capillary break cover systems
- Accept that you may never really know your WRC and k-Function, and focus on risk mitigation
- What you can achieve in the laboratory is not always correlated well to the field or achieved in the field
- Test Pads should be an essential component or any WRL or compacted low permeability clay layer

Thank you

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