22nd BC MEND Metal Leaching and Acid Rock Drainage Workshop

December 2 - 3, 2015 I Vancouver, British Columbia, Canada

Performance of Cover Systems With Geosynthetic Barrier Layers

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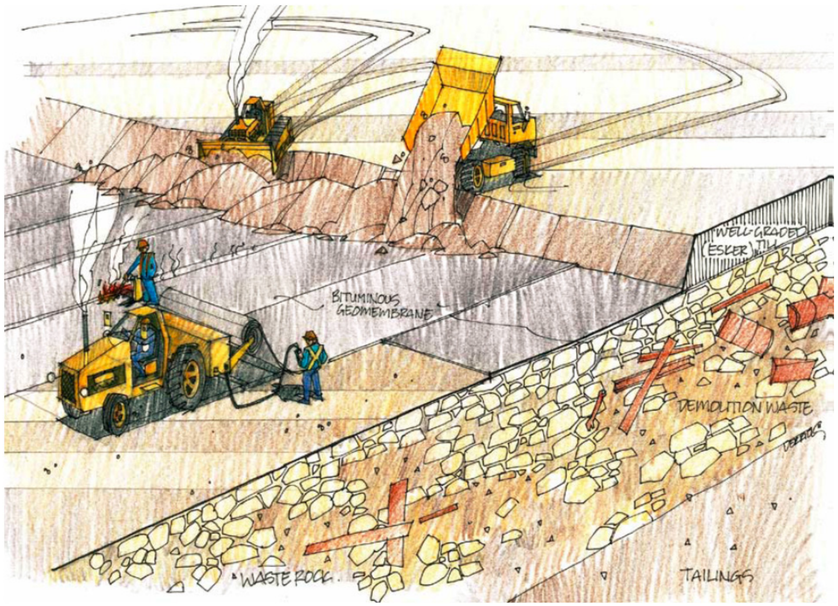
Presentation Discussion Points

- Project Background
- Geosynthetic Barriers
  - Defects
  - Simulated Net Percolation
  - Understanding For and Risk of Net Percolation
- Cover System Design with Geosynthetics
  - Climate, Materials, and Landform
  - Cost, Complexity and Performance



MEND 2011

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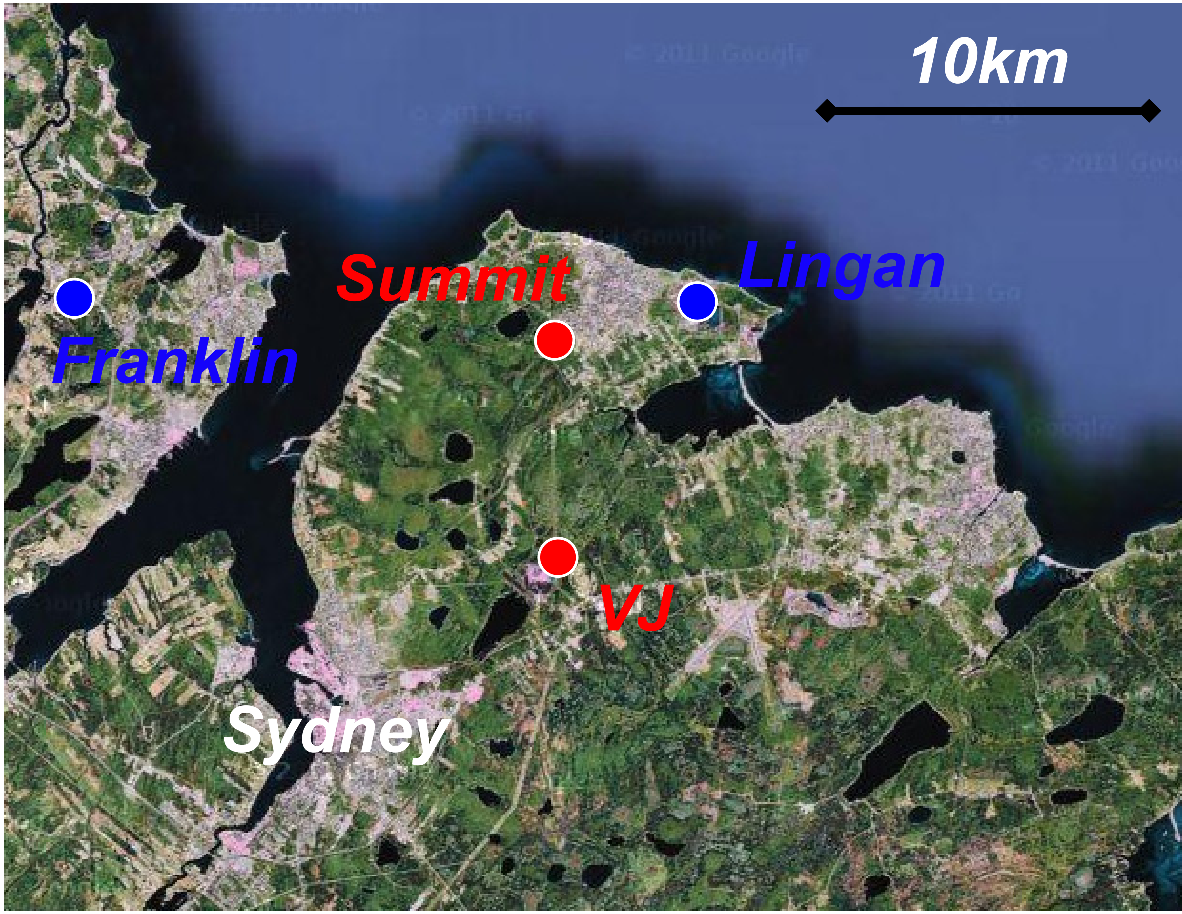
Historical Mine Sites: Sydney, N.S.

Remediation: Enterprise Cape Breton Corporation

Current Management: Public Works and Government Services Canada

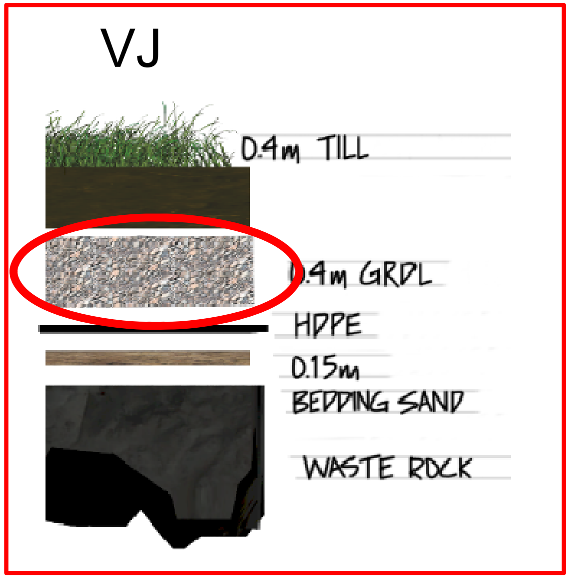
ecbc | secb
Inspire. Build. Succeed. | Inspirer. Bâtir. Réussir.
Canada

- Victoria Junction (VJ)
- Scotchtown Summit (Summit)
- Franklin
- Lingan



Background – Cover System Profiles

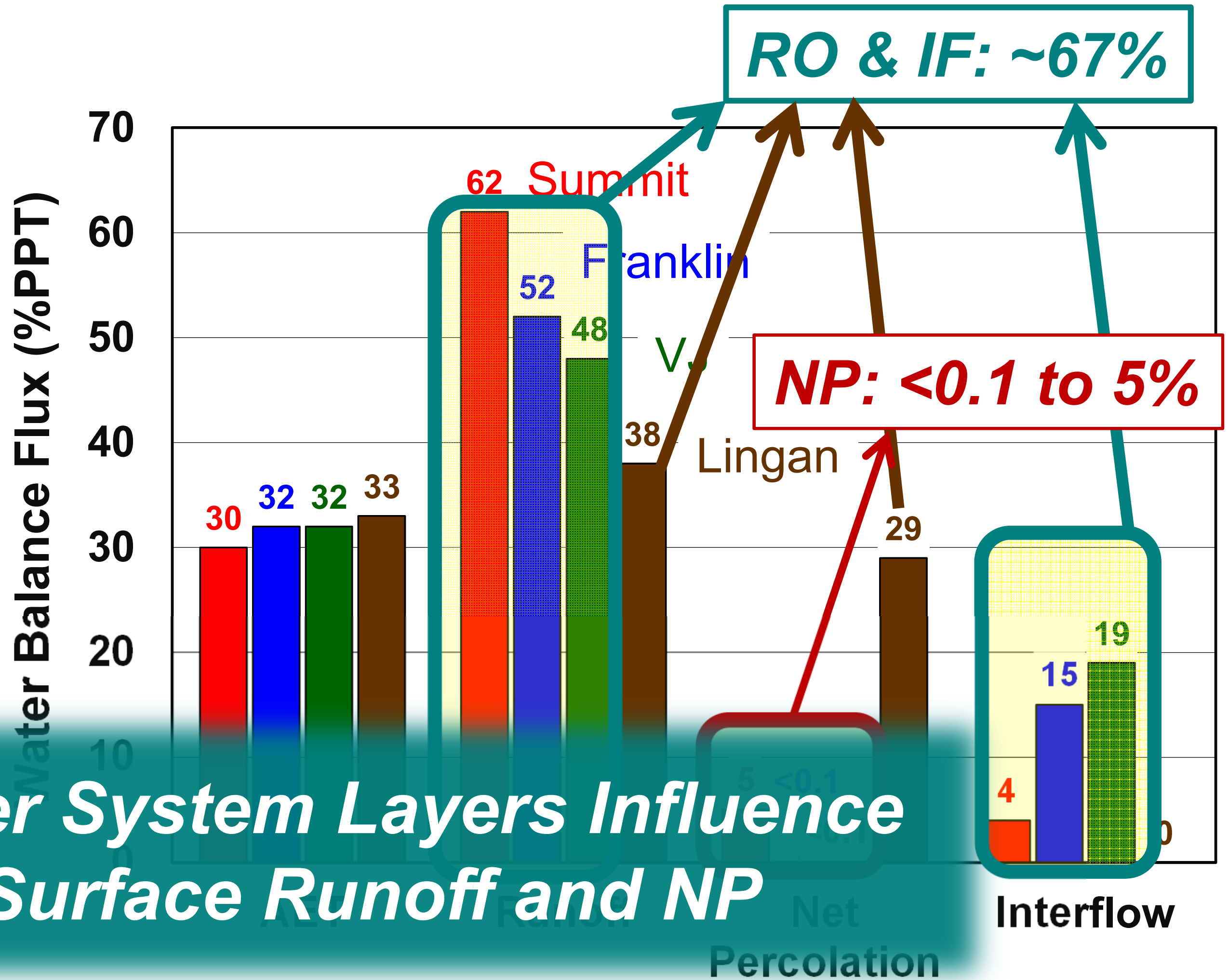
- **Similarities:**
  - Growth medium ~ 0.5 m thick
  - Geomembrane
- **Difference:**
  - Drainage layer



Meiers et al 2014

Water Balance

- Surface runoff and interflow ~67% for the geomembrane cover systems
- NP offsets proportional runoff volume
- NP
  - Lingan ~29%
  - ***Summit ~5%***
  - ***VJ <0.1%***
  - ***Franklin <0.1%***



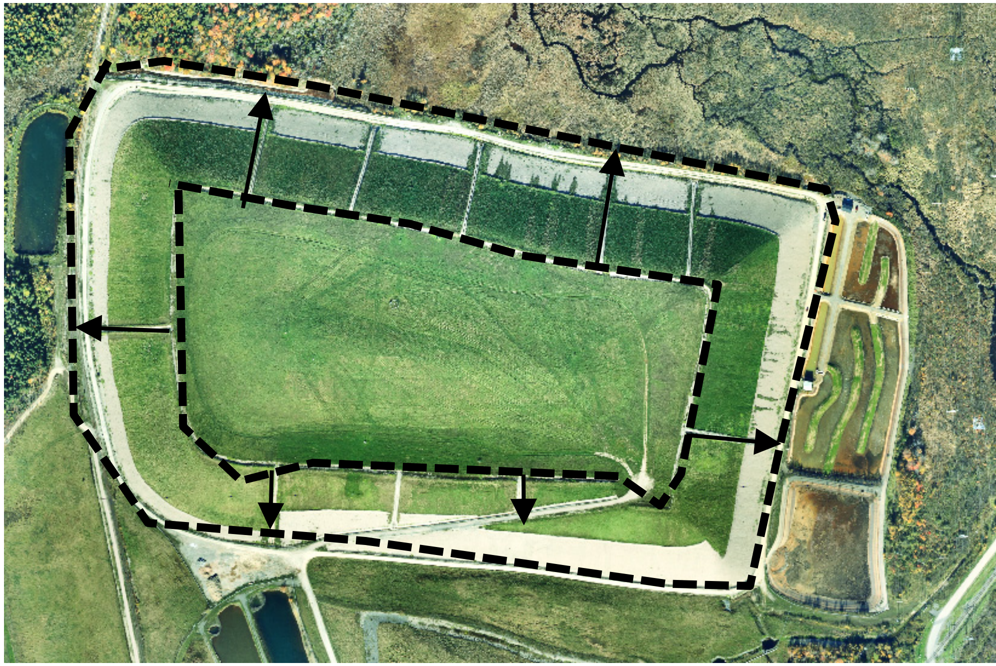
Cover System Layers Influence Surface Runoff and NP

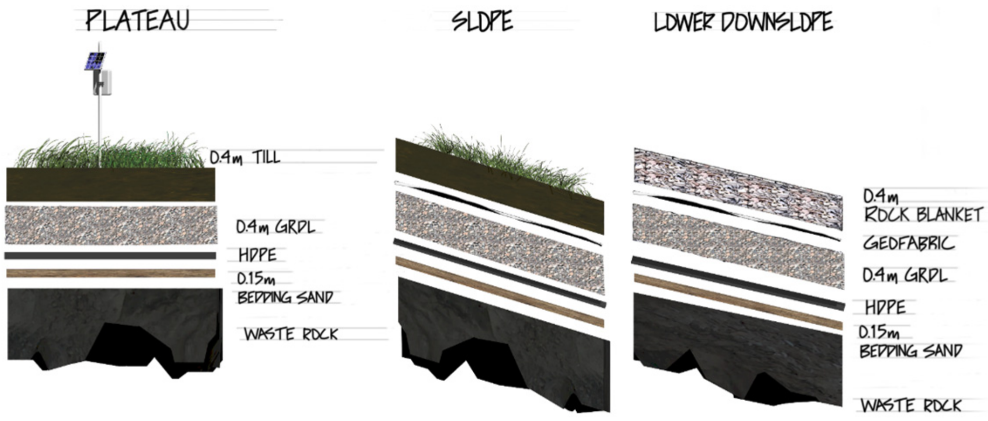
Reclaimed Summit WRP

- Footprint of ~44 ha
- Thickness of 1.5 m to 10 m
- Plateau 3% slope transitioning to 7:1 side slopes
- Runoff ditch constructed around the perimeter

Reclaimed VJ WRP

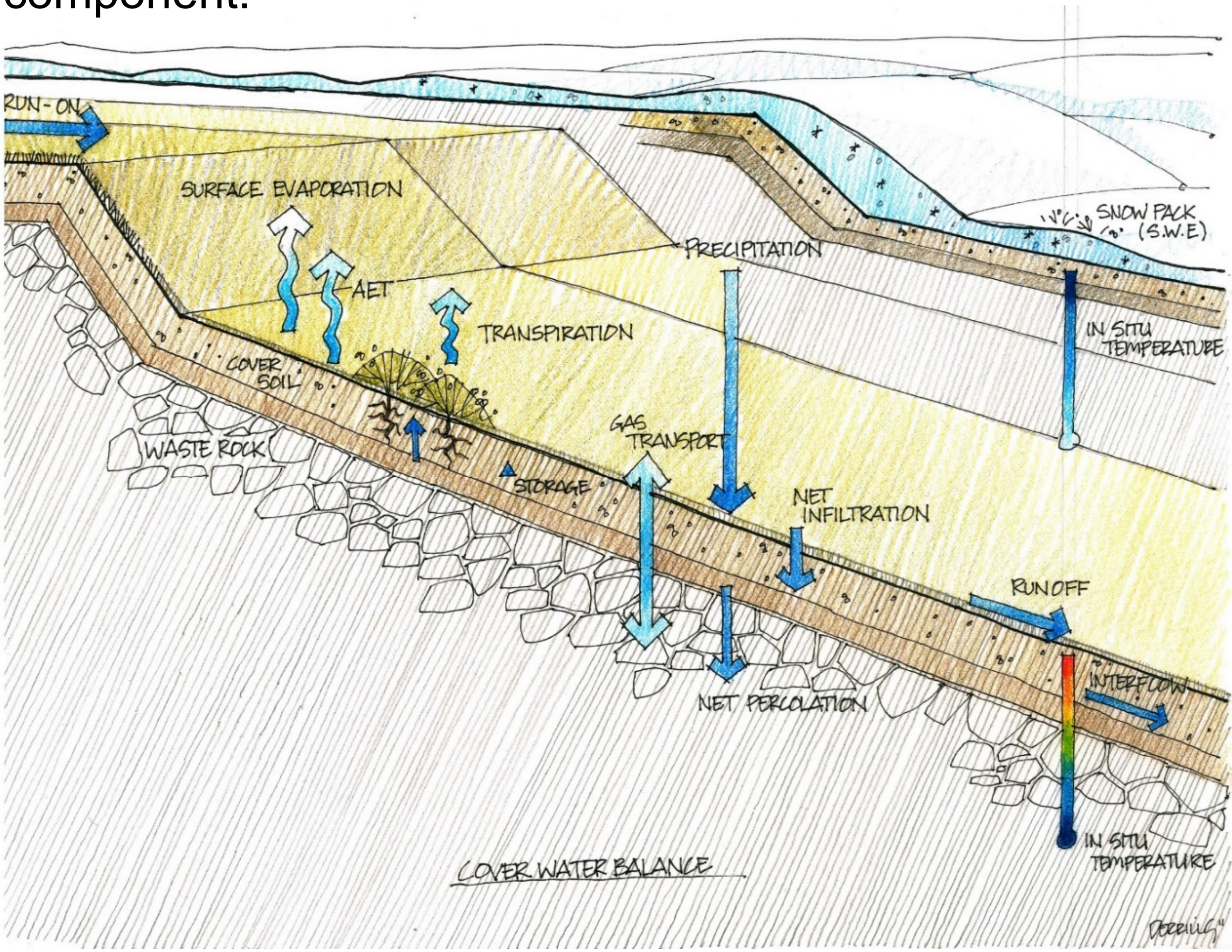
- Footprint of ~26 ha
- Height of 40 m
- Plateau 7%
- Side slope 3:1
- Runoff ditch constructed around plateau channels flows to drop structures on side slopes





WRP Monitoring System

- Monitored water balance component:
  - AET
  - PPT
  - Runoff
  - Interflow
  - Water Storage
  - Net Percolation (NP)
- NP Estimated through:
  - Water Balance
  - Analytical Estimates
  - Conservative Tracer
- Internal WRP Monitoring System:
  - Temperature
  - Pressure
  - GW Elevations
  - Pore-Gas Concentrations
  - Pore-Water Quality



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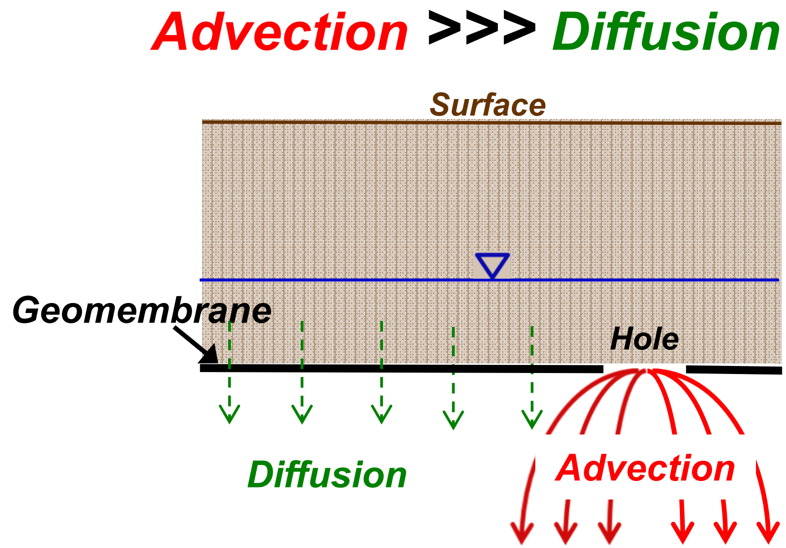
Simulate Net Percolation

- The head of water that develops above a geomembrane is a key parameter for ***estimating*** and ***understanding risk*** of leakage and can be:



  1) Measured directly
  2) Estimated using measured lateral drainage above the geomembrane and transmissivity of drainage layer
  3) Estimated using water balance and transmissivity of drainage layer

- Simulate net percolation over a range of defects
  – 2 and 30 defects/ha each 9 mm diameter

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Geomembrane Defects

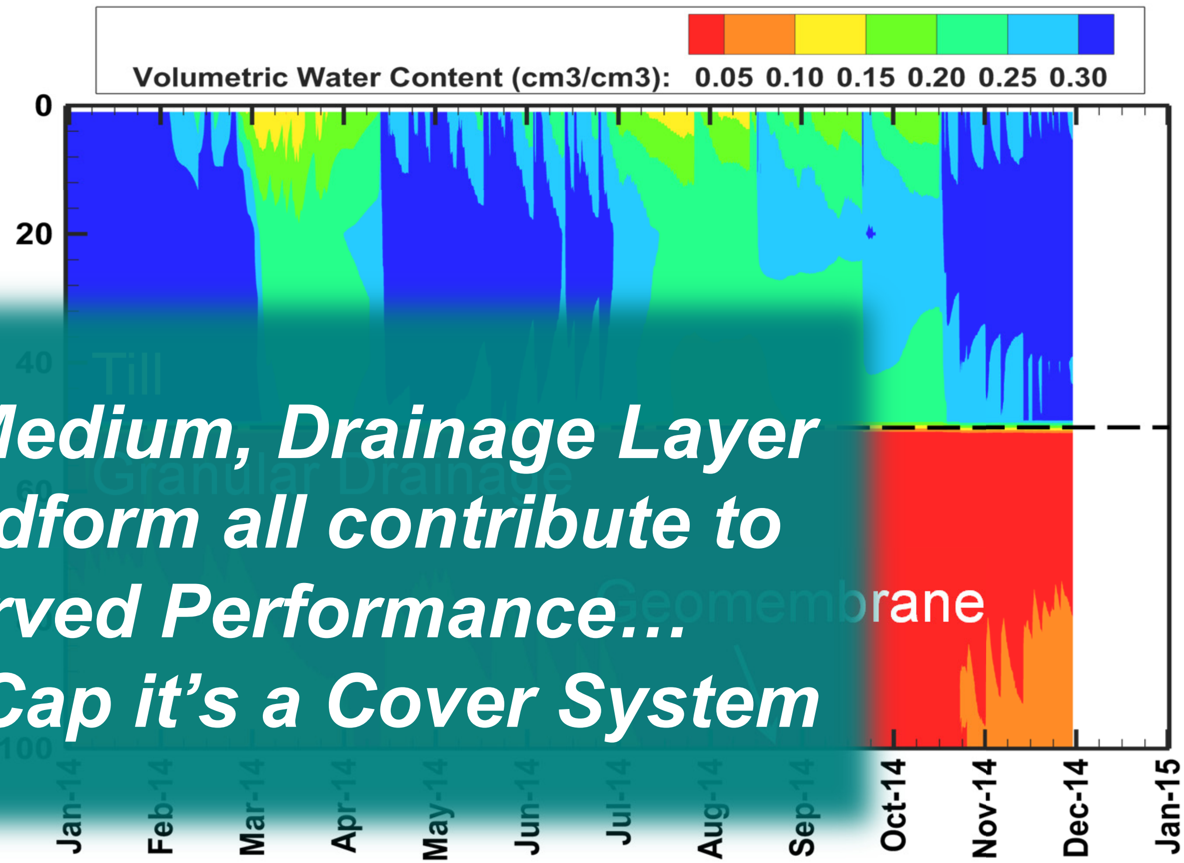
- Construction (wrinkles, tears, welds, punctures, ***imperfections***)
- Post Construction
  - Service stress (differential settlement, Δ temp)
  - Anthropogenic (e.g. artisanal mining)
  - Bioturbation
  - Vegetation (roots, blow down, etc.)

http://heapsolutions.com/applications/heap-liner-leak-detection/

O'Kane and Meiers 2014

Measured Performance – VJ

- ***Conceptual understanding*** of cover system performance is developed
- Adequate lateral ***drainage capacity*** demonstrated
- ***Growth medium attenuates flow*** to drainage layer 0.3 mm/hr



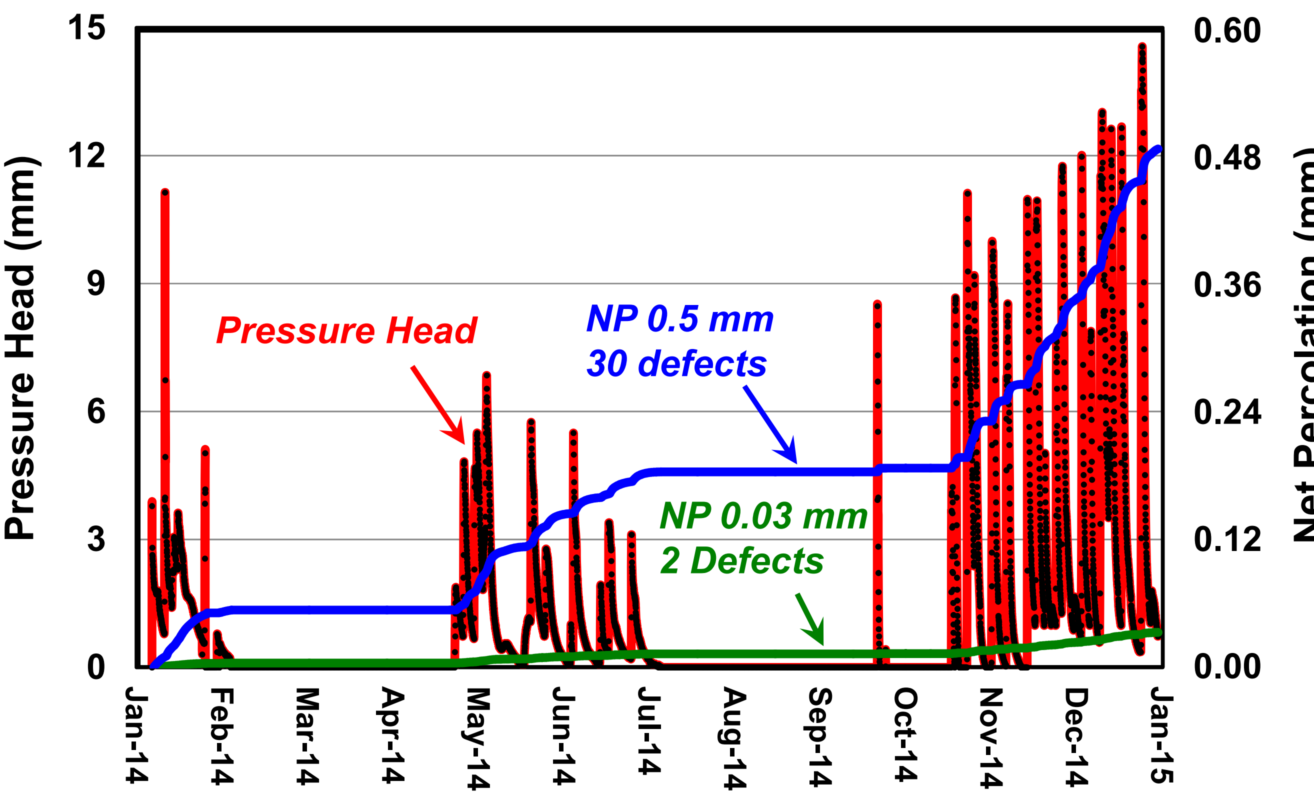
Risk Ass
With Leak
is Low

Growth Medium, Drainage Layer and Landform all contribute to Observed Performance…
Its not a Cap it's a Cover System

Simulated Net Percolation – VJ

- Simulated pressure head using measured lateral drainage
- Maximum pressure head ~12 mm
- ***Risk for NP is low*** under range of defects

But need to consider restriction to flow at the drainage layer outlet



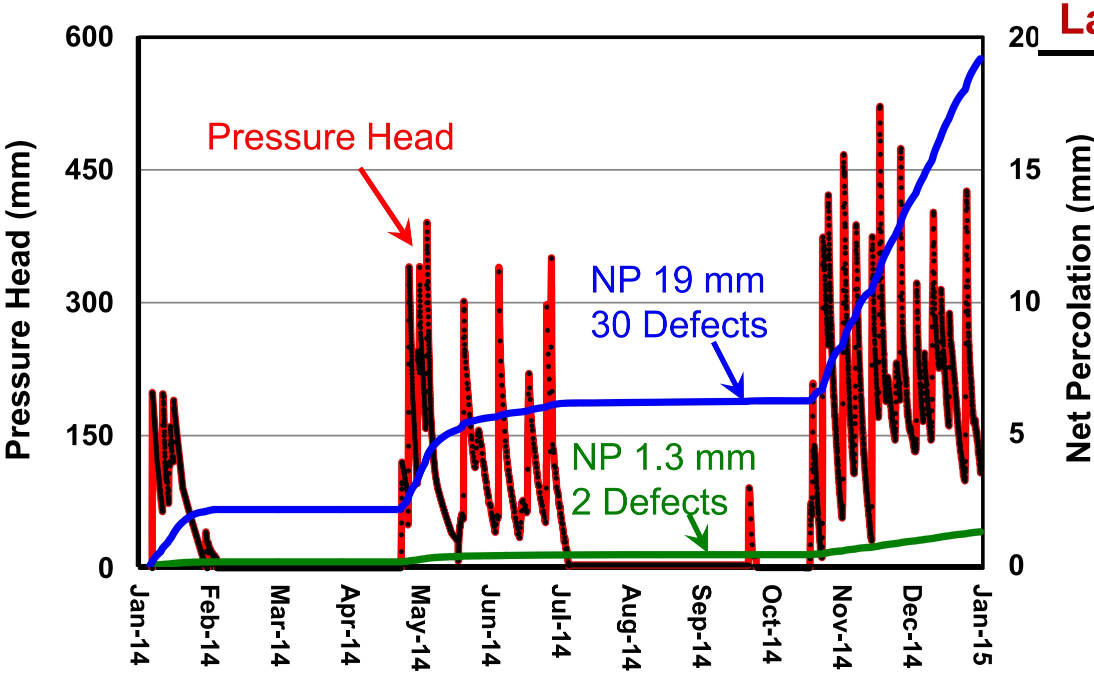
Measured Performance – VJ

the outlet to the

Simulated Net Percolation – VJ

- Measured pressure head reaches ~450 mm
- Simulated ***NP for the landform is very low*** < 2 mm
- ***~6%*** of surface area contributes to ***70% of NP***

Daily Flux Rate (cm/s)	Head (mm)	Defects per hectare		
		2	15	30
		Net percolation (mm/yr)		
Adequate drainage (94% of surface and 30% of total NP)				
transient	transient	0.03	0.2	0.5
Inadequate drainage (6% of surface and 70% of total NP)				
transient	transient	1.2	10	19
Landform		0.1	0.8	1.6



- Engineer adequate lateral drainage capacity:
  - Transmissivity and reduction factors
  - Outlet flow

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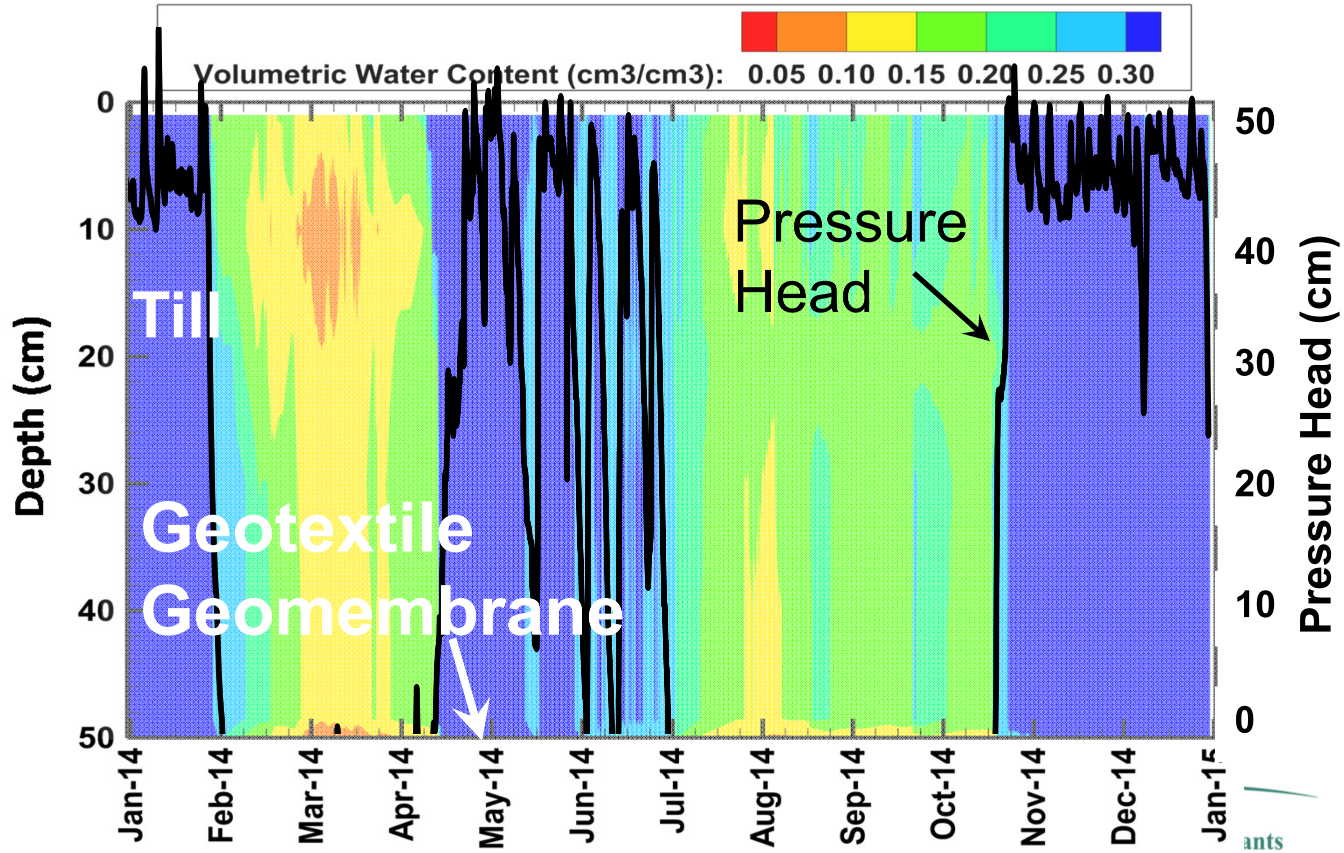
Measured Performance – Summit

- ***Conceptual understanding*** for cover system performance is demonstrated
- ***Inadequate*** lateral ***drainage capacity***
- Transitions rapidly from neg- to pos+ pressure

Carries a Greater Risk for Leakage

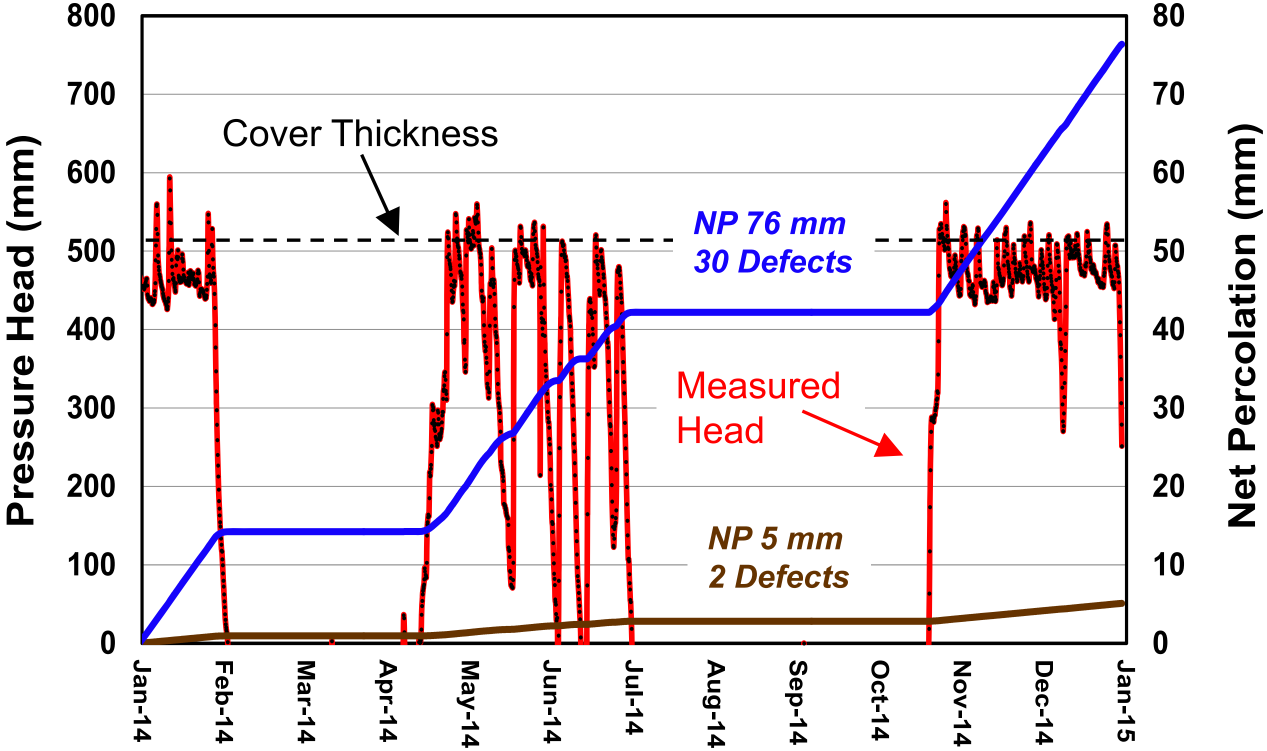


Measured Performance – Summit

- Maximum head is ***~500 mm over prolong periods***
- NP is ***76 mm or 5% of PPT*** for 30 defects
- ***Loading*** to receiving environment would be ***different under the simulated range of NP***

Risk Associated With Leakage is High

…Defects are a Concern! Number, Size, Distribution



Conceptual Understanding – Summit

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Seepage Erosion – Summit

- Monitored performance provides understanding of ***mechanism causing erosion*** (i.e. seepage erosion >> runoff) and ***approach used to stabilize*** cover system

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Biological Monitoring Example

Millions of spiderwebs cover Scotchtown field

Sharon Montgomery-Dupe
Published on November 19, 2014

Sharon Montgomery-Dupe
Published on November 19, 2014

SCOTCHTOWN — There might not be a Spider-Man in Cape Breton but apparently there was a spiderland.

Allen McCormick recently took a picture of a field at the summit in Scotchtown covered with spiderwebs.

"It was like a cotton field — all white."

He estimated the field to be a couple of square kilometres.

"They are saying millions," he added.

© Photo by Al McCormick
A field in Scotchtown was covered with millions of spiderwebs. The curator of the Nova Scotia Museum says this is rare, having heard of three such incidents over the past 20 years. Submitted by Allen McCormick

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Biological Monitoring Example

Millions of spiderwebs cover Scotchtown field

Sharon Montgomery-Dupe
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Hebda explained these are not webs for catching food but rather webs for "ballooning" by small spiders.

"They basically produce a long single strand and let the wind catch it and carry them."

He said if there conditions make the place no longer suitable — such as flooding or drastic change in temperature — spiders will disperse.

"It's got to be something fairly large scale that covers a relatively large area. They will all move at the same time and travel the same distance."

© Photo by Al McCormick
A field in Scotchtown was covered with millions of spiderwebs. The curator of the Nova Scotia Museum says this is rare, having heard of three such incidents over the past 20 years. Submitted by Allen McCormick

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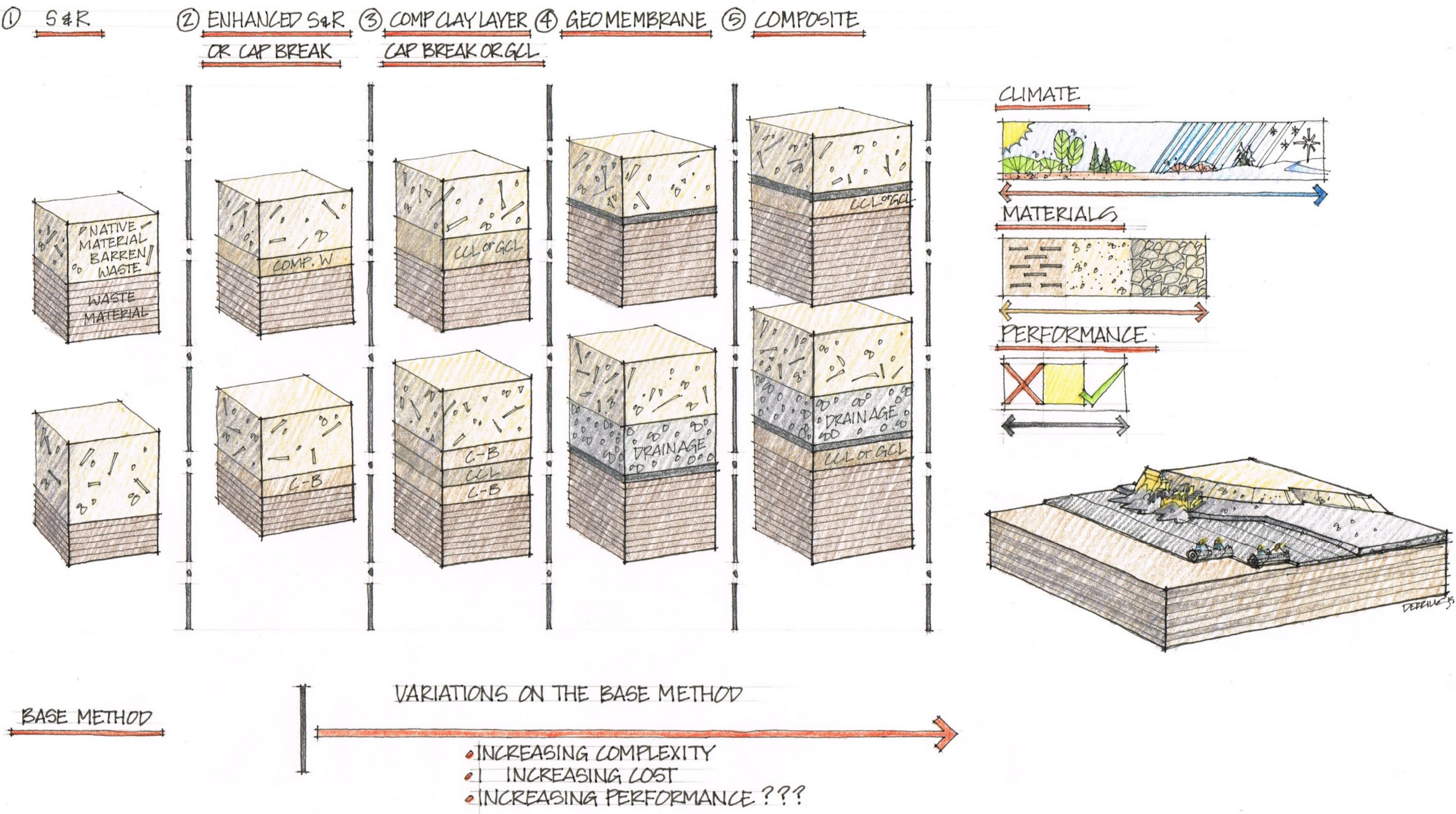
Closure Objectives – Summit

- Impact on ***closure objectives*** and ***site land use***
  - Vehicle restrictions
  - Ecosystem / habitat (example, raptors observed at VJ but not at Summit… rodents)
  - Vegetation development (example, reduction in the density of clover)

Treatment of Residual Seepage… ???

Fate of CBRM Dinking Water Supply …

Cost, Complexity and Performance



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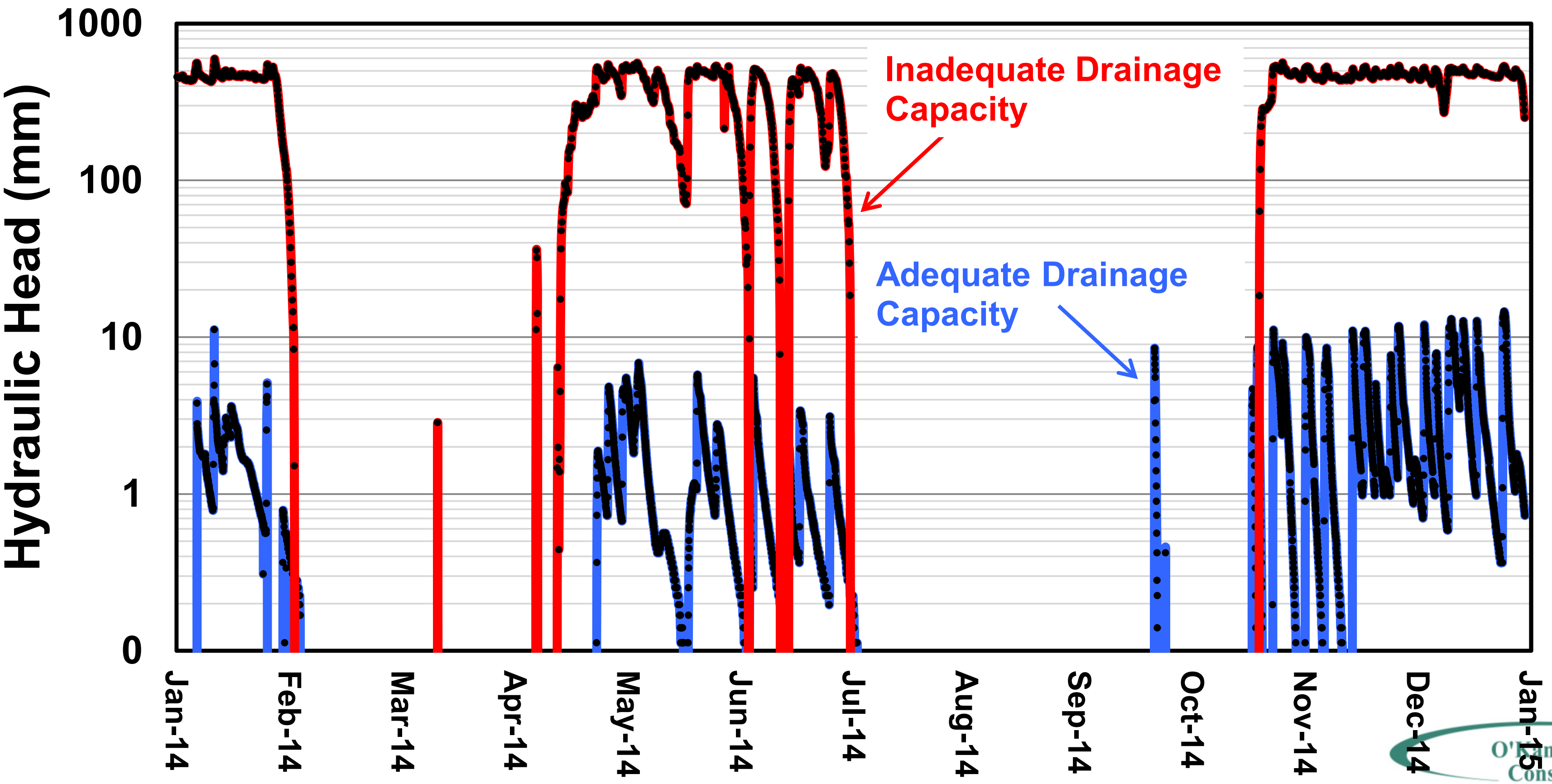
Cost, Complexity and Performance

- ***Climate, materials and landform*** will influence performance
  - ***Site specific pressure condition*** to inform on design



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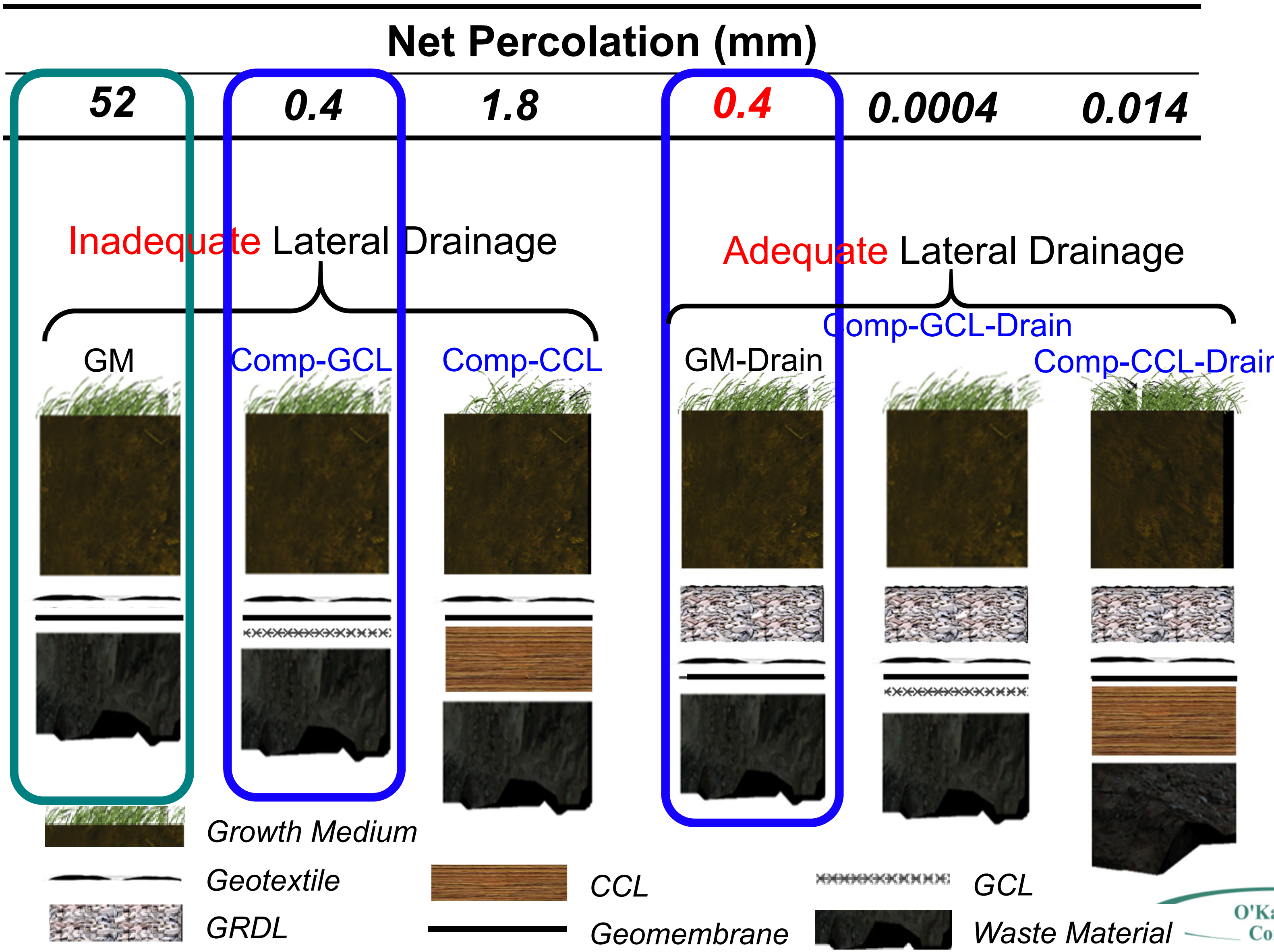
Cost, Complexity and Performance



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Cost, Complexity and Performance

Failure modes and effects analysis to inform on ***in-service*** and subsequent ***long-term*** performance

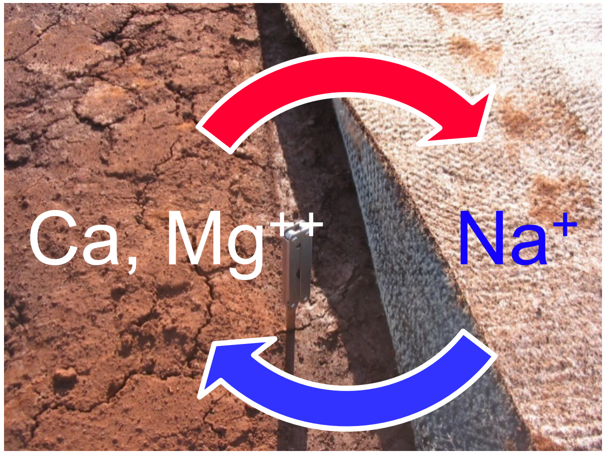
- CCL in Composite Cover System
  - ***Trampolining*** or ***folds*** may limit intimate contact with geomembrane
  - Borrow material not adequately defined, CCL does not meet design criteria



Cost, Complexity and Performance

Failure modes and effects analysis to inform on ***in-service*** and subsequent ***long-term*** performance

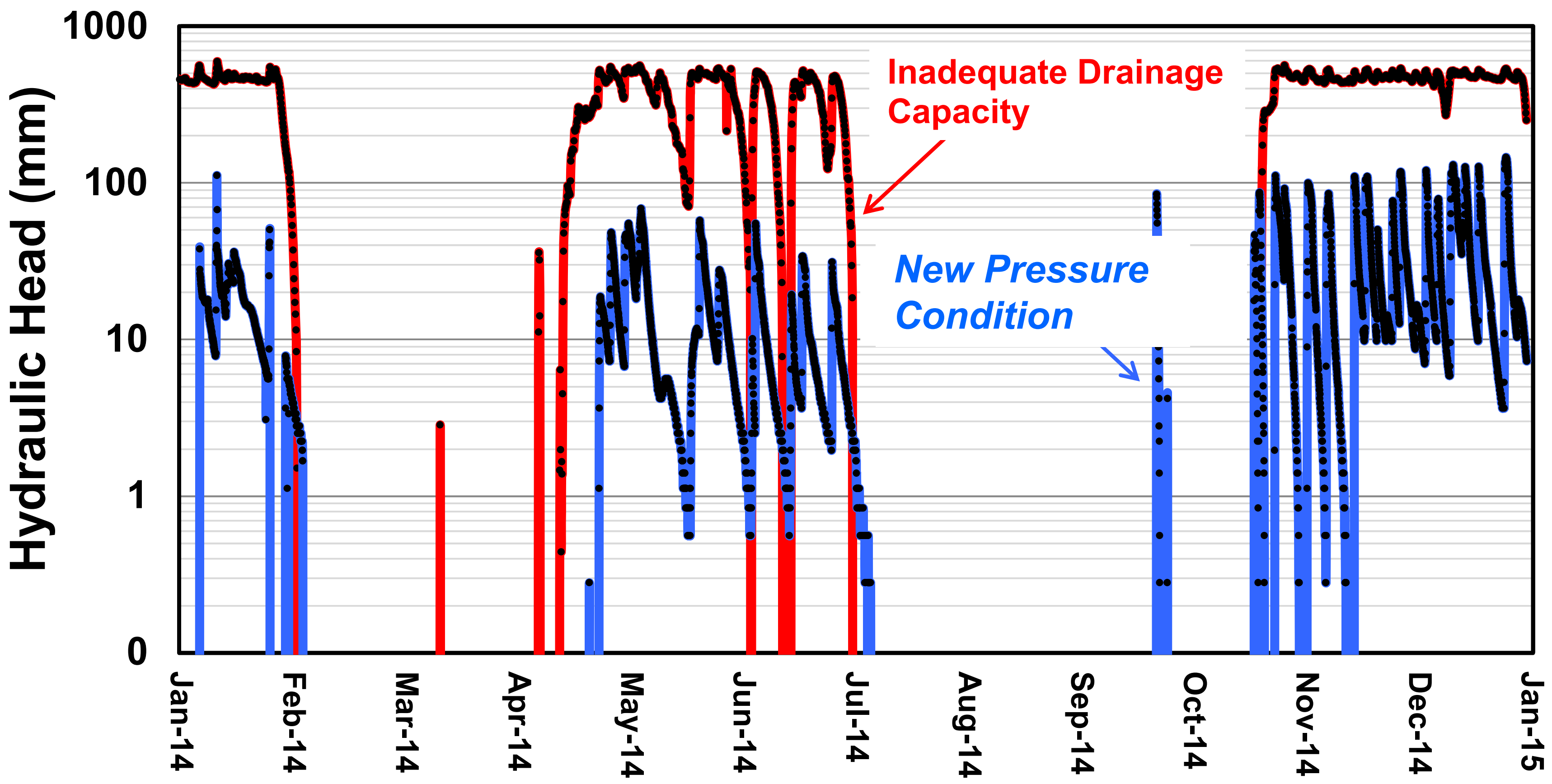
- GCL in Composite Cover System
  - ***Incompatible*** with in situ conditions (i.e. cation exchange), ***Ks increases***



- Drainage layer (granular or geonet)
  - ***Reduction factors*** decrease Ks (i.e. root matting, fines ingress, deformation…

Cost, Complexity and Performance

- Ks of drainage layer decreases from 1 cm/s to 0.1 cm/s
- Establish new pressure condition



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Cost, Complexity and Performance

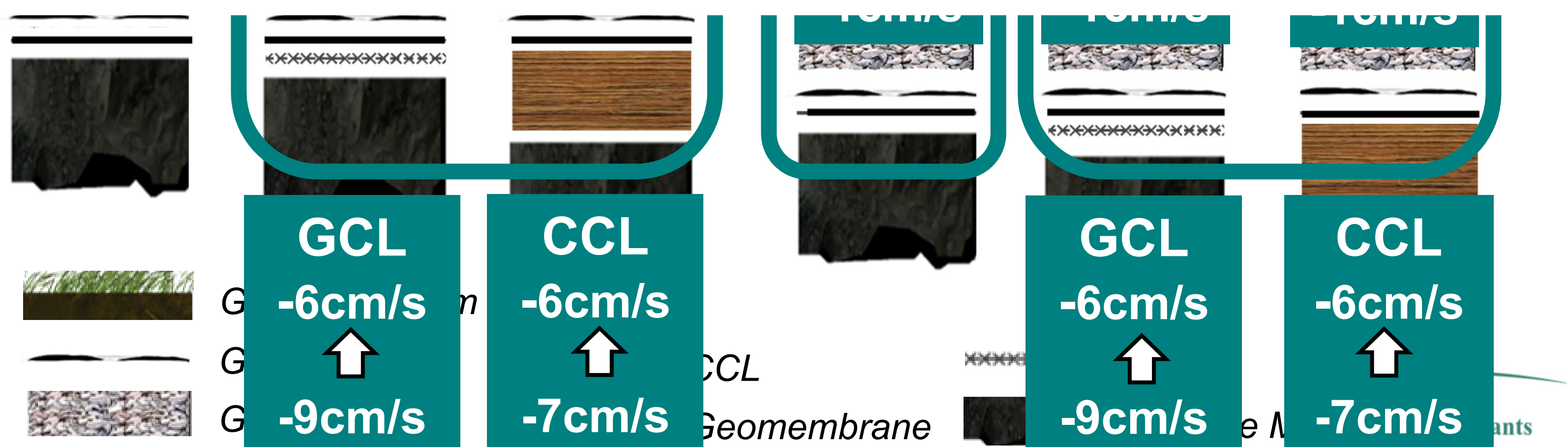
Net Percolation (mm)

	GM	Comp-GCL	Comp-CCL	GM-Drain	Comp-GCL-Drain	Comp-CCL-Drain
Predicted	*52*	*0.4*	*1.8*	*0.4*	*0.0004*	*0.014*
In-Service	*52*	*52*	*9.6*	*3.2*	*0.4*	*1.4*

Inadequate Lateral Drainage: GM, Comp-GCL, Comp-CCL

Adequate Lateral Drainage: GM-Drain, Comp-GCL-Drain, Comp-CCL-Drain

Which Failure Mode is More Likely to Occur



Summary and Discussion Points

- Direct performance monitoring provided ***understanding for net percolation and risk*** of it occurring
  - While design of ***monitoring systems for geosynthetics*** are in their infancy a ***water balance is the foundation*** of any system
- Design with geosynthetic layers has been ***historically approached from a civil engineering perspective*** (performance is purchased, slope failures concern, growth medium)
  - Is design with geosynthetics different than mineral cover systems?

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Summary and Discussion Points

- Cover system design with geosynthetics needs to consider site specific ***climate***, ***material properties*** *and* ***landform…*** ***Numerical simulations***
- Given uncertainty in what is reflective of post closure long-term defects, ***adequate lateral drainage capacity*** can ***reduce concerns and risk*** of leakage…
- Does the ***geomembrane in design carry the risk of failure, or a system***

Summary and Discussion Points

- ***Increase in cost and complexity*** may not provide ***increase in performance***
- ***FMEA*** is a useful tool to narrow down cover system alternatives

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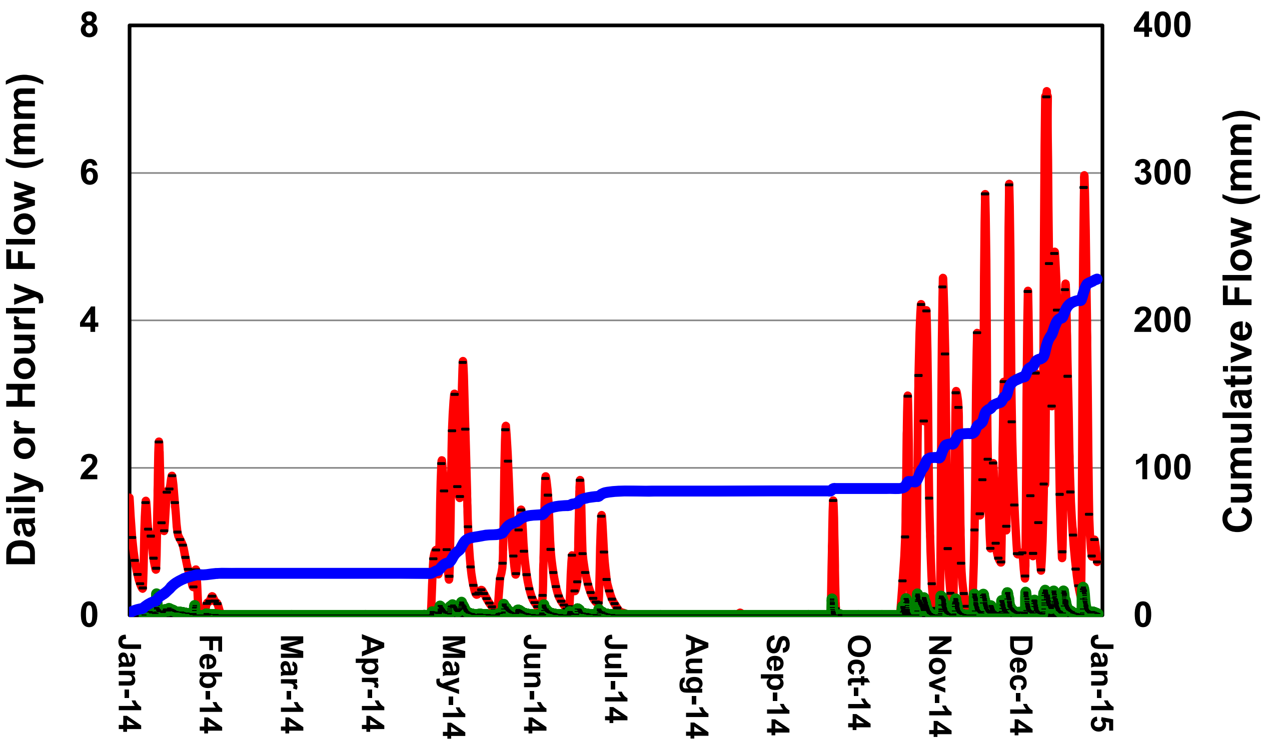
Rainbow of Hope for Children and,

Habitat for Humanity Initiative

Conceptual Understanding – VJ

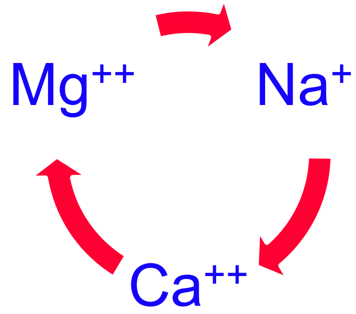
- Understanding for cover system performance is developed
- Adequate lateral drainage capacity
- Risk associated with leakage is low



Cost, Complexity and Performance

Failure modes and effects analysis to inform on ***in-service*** and ***long-term*** performance

- CCL
  - Requires intimate contact with geomembrane, ***trampolining*** over subsurface or ***folds*** in the geomembrane
- GCL
  - ***Compatibility*** with in situ conditions (i.e. cation valency, Na, Ca, Mg)
  - Potential increase in k_{sat} ($1x10^{-9}$ to $1x10^{-6}$ cm/s)



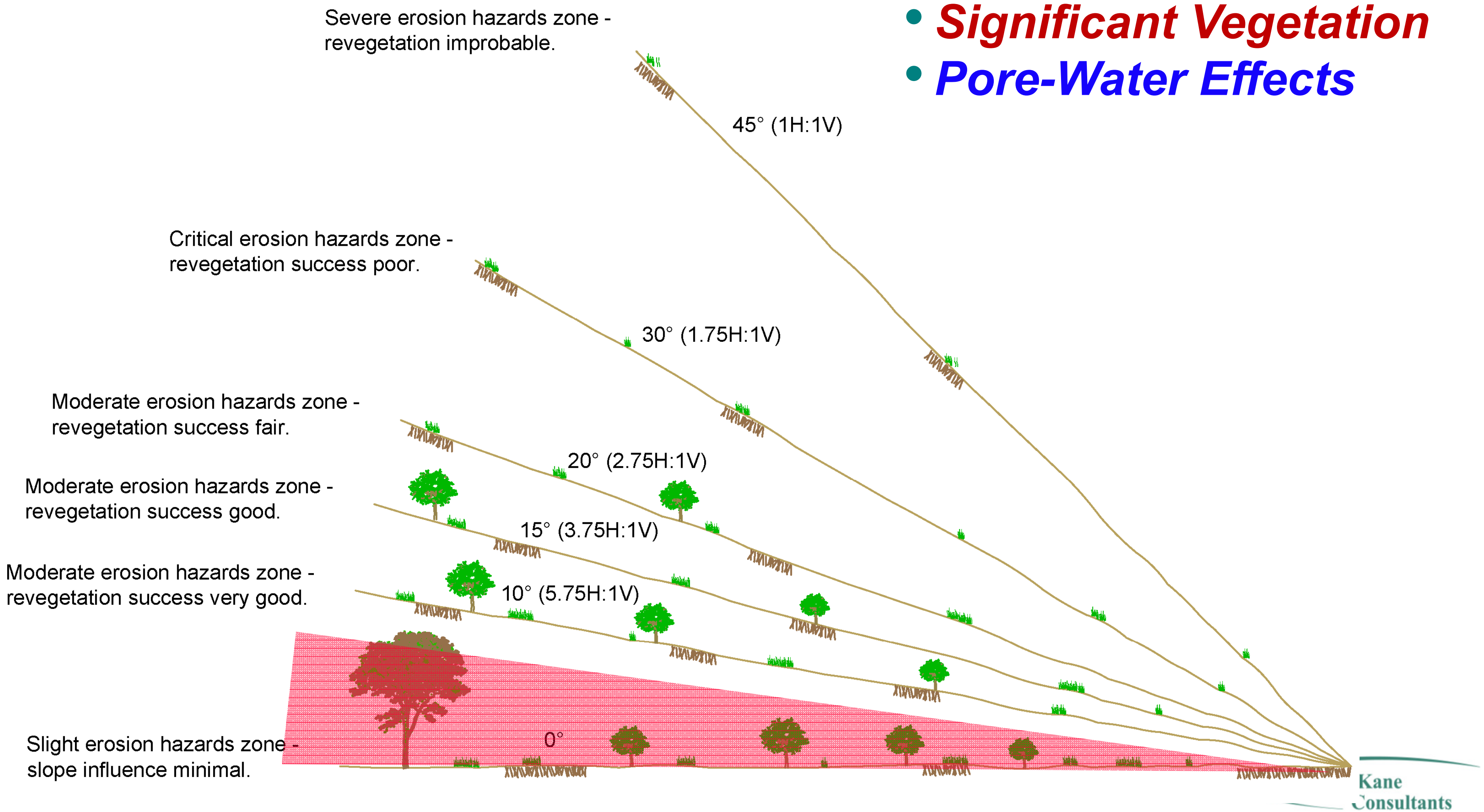
- Drainage layers (granular or geonet)
  - ***Reduction factors*** decrease k_{sat} (i.e. root matting, fines ingress, deformation…

Seepage Erosion – Summit

- Monitored performance provides understanding of ***mechanism causing erosion*** (i.e. seepage erosion >> runoff) and ***approach used to stabilize*** cover system

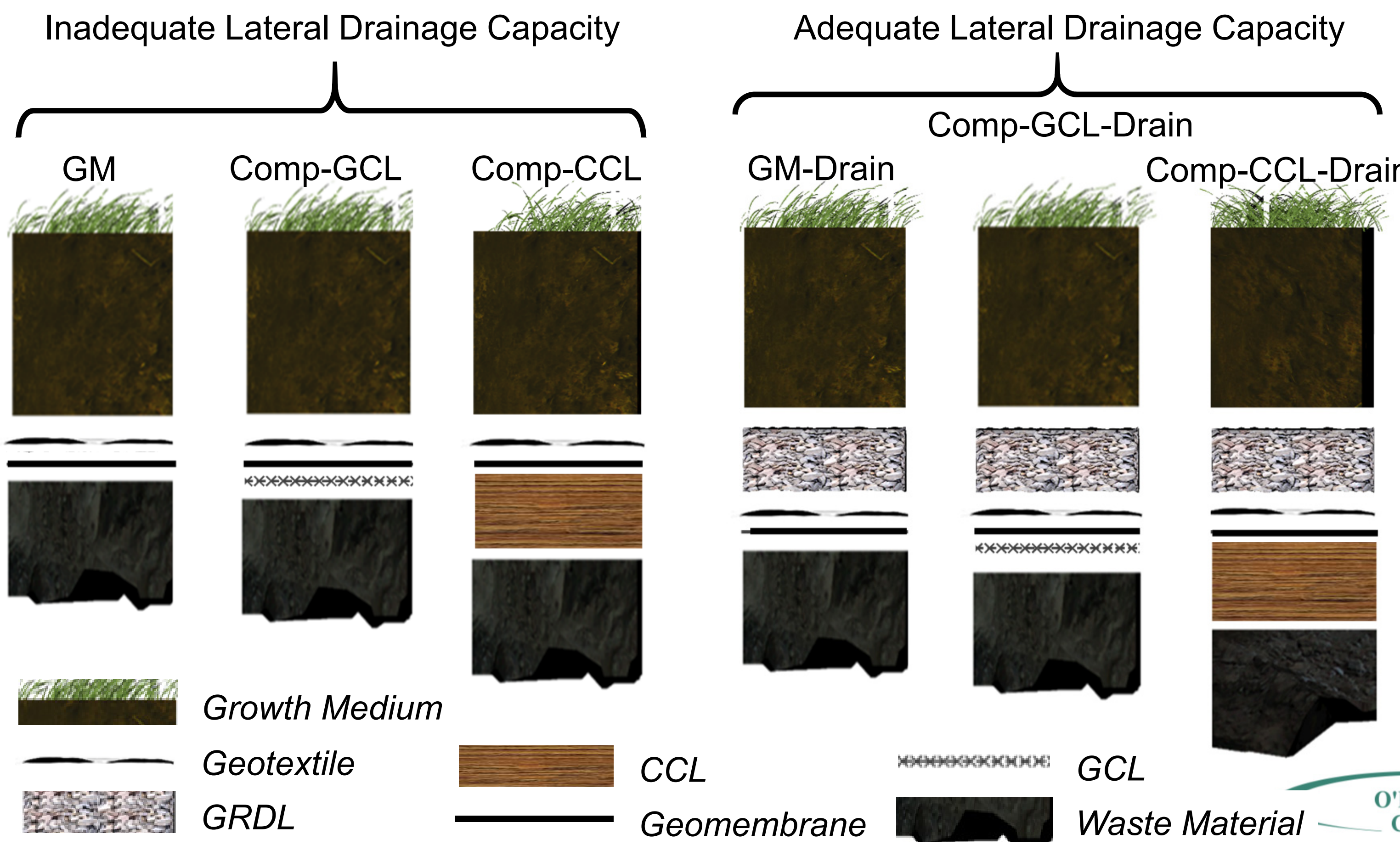
Erosion – Summit

- ***Chemically Stable***
- ***Low Slope Angles***
- ***Significant Vegetation***
- ***Pore-Water Effects***



Cost, Complexity and Performance

Net Percolation (mm)					
52	***0.4***	***1.8***	***0.4***	***0.0004***	***0.014***



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