Challenges

with

Measuring Cover System Performance

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and
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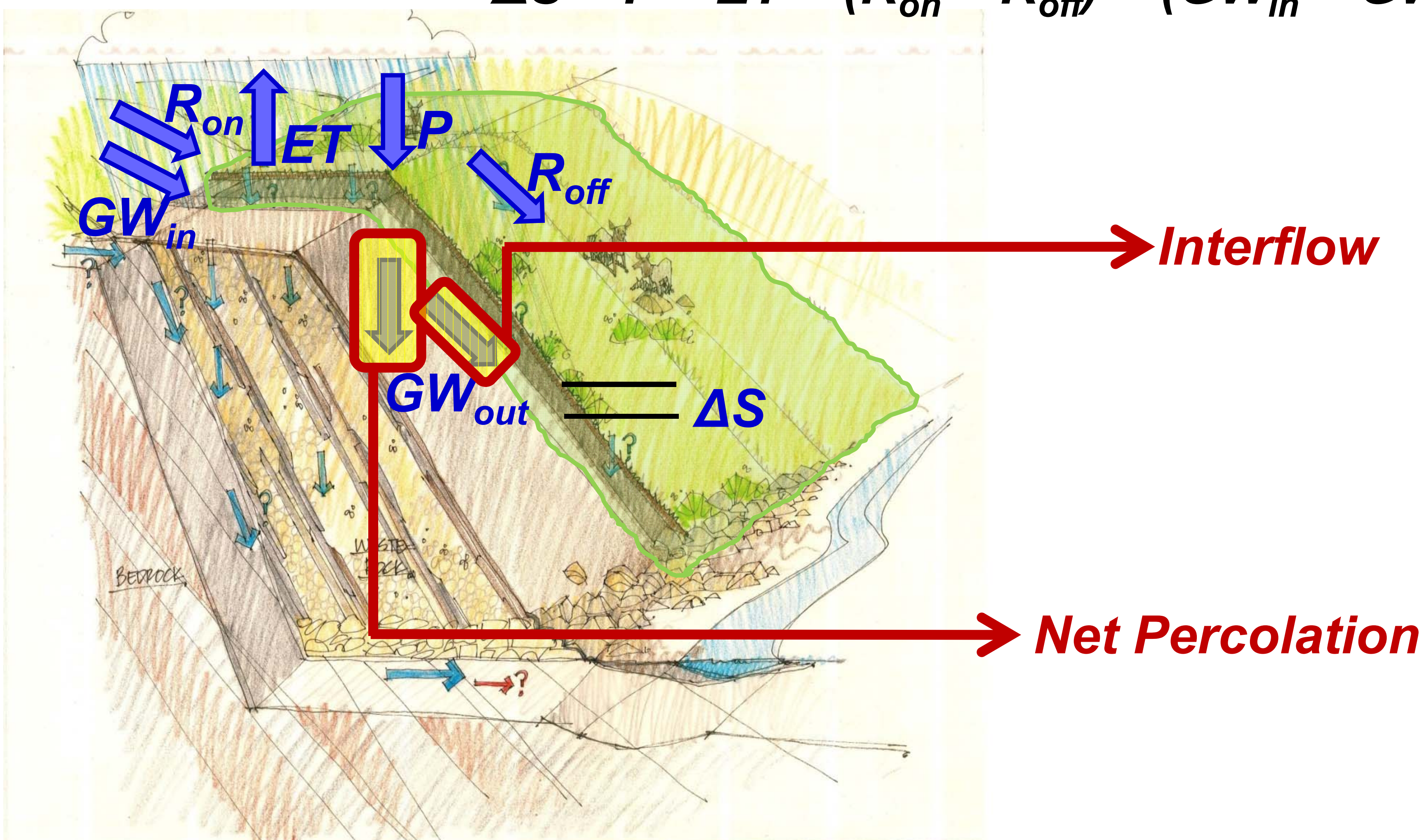
Specialists in Geochemistry and Unsaturated Zone Hydrology

Presentation Discussion Points

- ***Setting Context for Cover System Monitoring***
  - ***What is a cover water balance?***
  - ***Examples***
- ***The Design Process w/ Timelines***
- ***Challenges and Limitations with "Conventional" Cover System Monitoring***
  - ***Soil water storage, precipitation, AET, Runoff***
- ***Opportunities for "Non-Conventional" Cover System Monitoring***

Cover System Performance

$$\Delta S = P - ET + (R_{on} - R_{off}) + (GW_{in} - GW_{out})$$

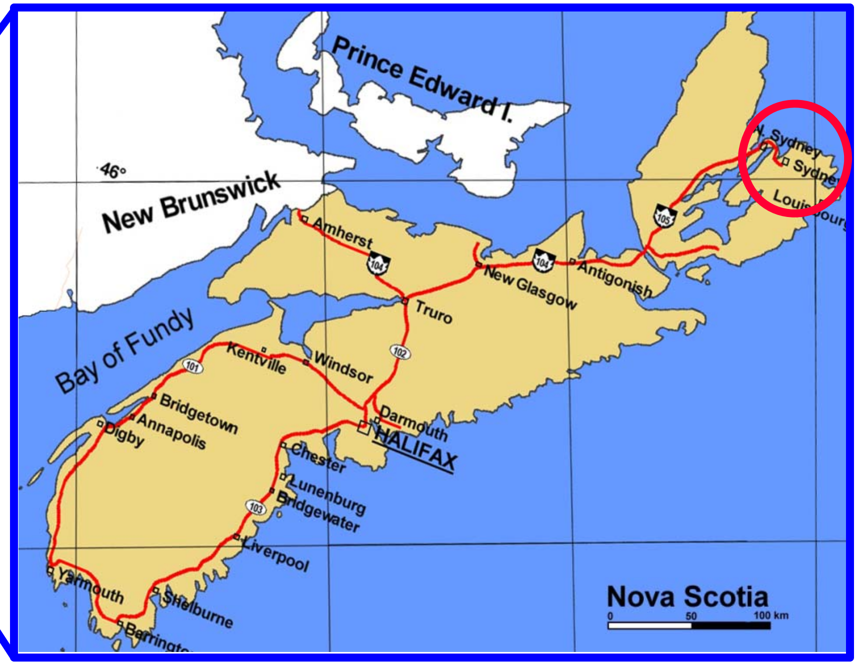


Courtesy of Justin Straker, Integral Ecology Group

Case Study: ECBC Sites

Site: Near Sydney, NS
Cape Breton Island

Atlantic Canada



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Background…. ECBC

- ECBC is a Federal Crown Corporation responsible for environmental remediation associated with coal mining activities in Cape Breton
  - Mining operations began in 1685 to the 1980s
  - 50 underground mines produced 500 million tonnes of coal

- Responsibility for sites now under Public Works and Government Services Canada
  - O'Kane Consultants installed cover system monitoring system over past 2-3 years
  - Collaboration program with Cape Breton University to interpret and evaluate performance

CAPE BRETON UNIVERSITY

Meiers et al (2014)

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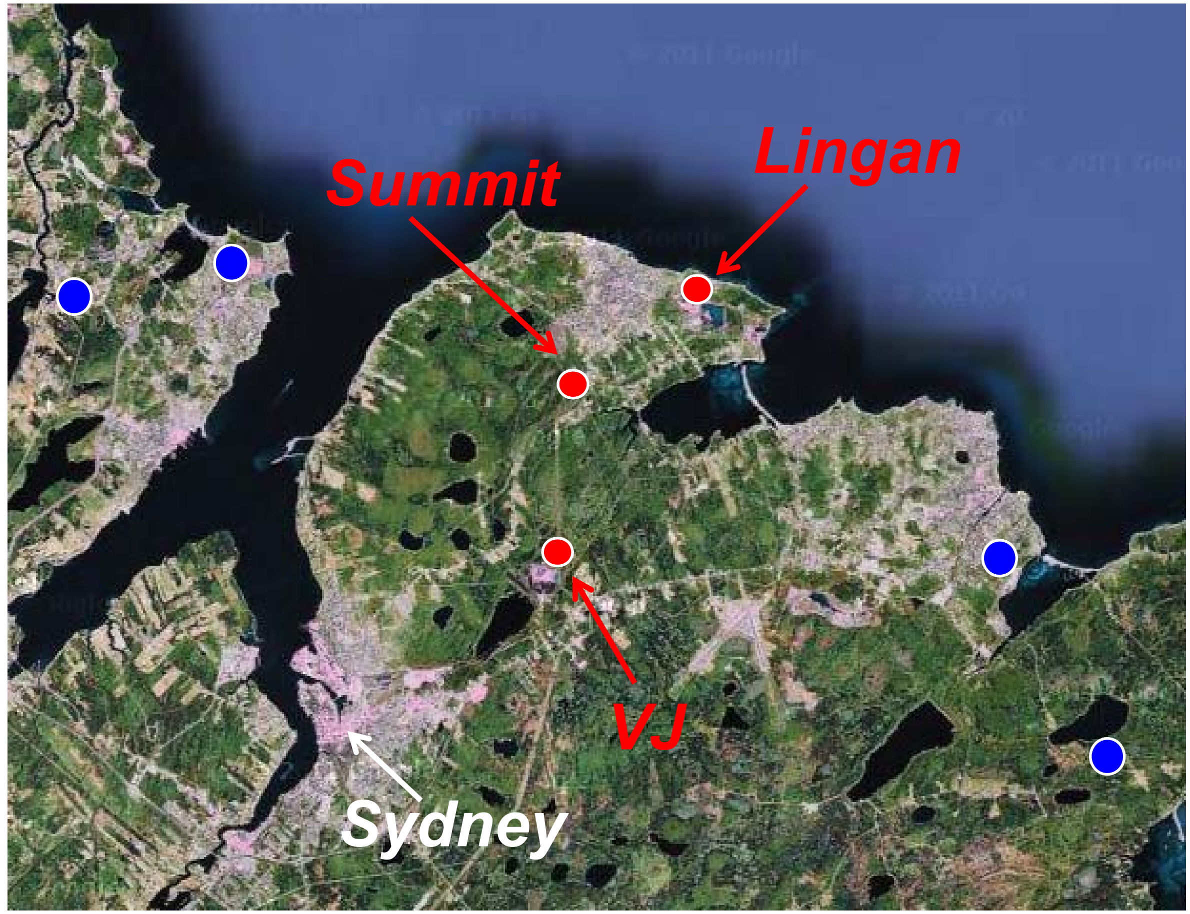
ECBC Site Location

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

Other Reclaimed WRPS

- Dominion No.4
- Gowrie
- Princess
- Franklin

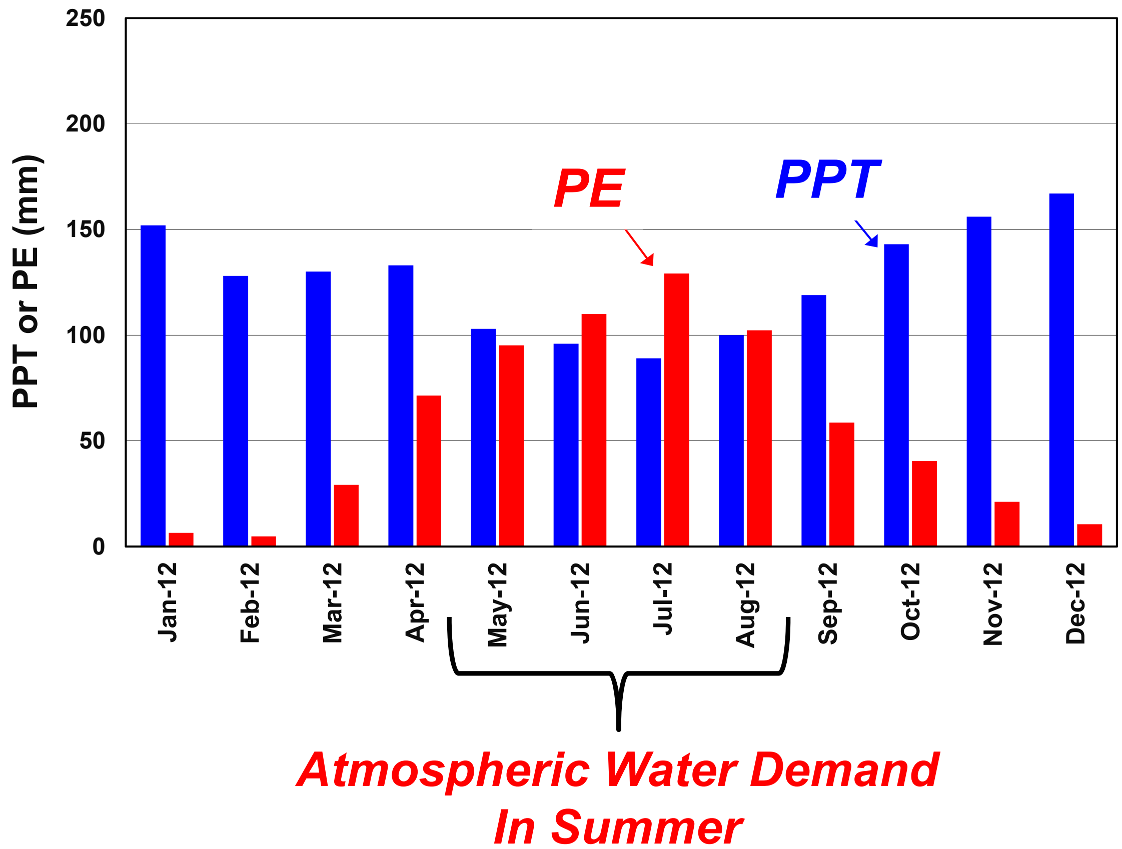


Meiers et al (2014)

Typical Site Climate Conditions

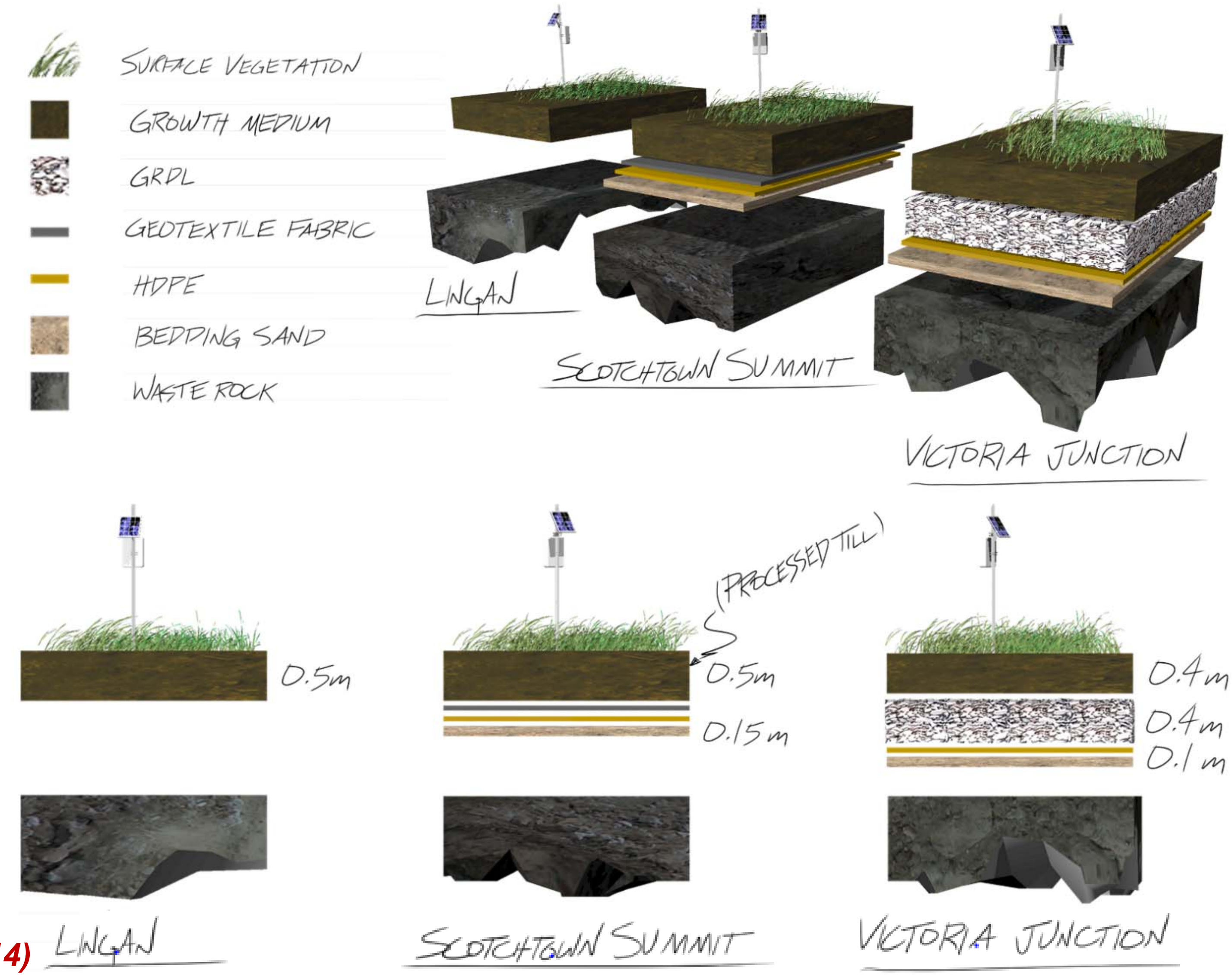
Climate:

- ***Mean annual PPT is ~ 1,517 mm***
  - ***60% occurs in Winter (from October to March)***
  - ***~50% of winter TTP is snowfall***
- ***Mean annual PE ~700 mm***
- ***Energy deficit in most months***



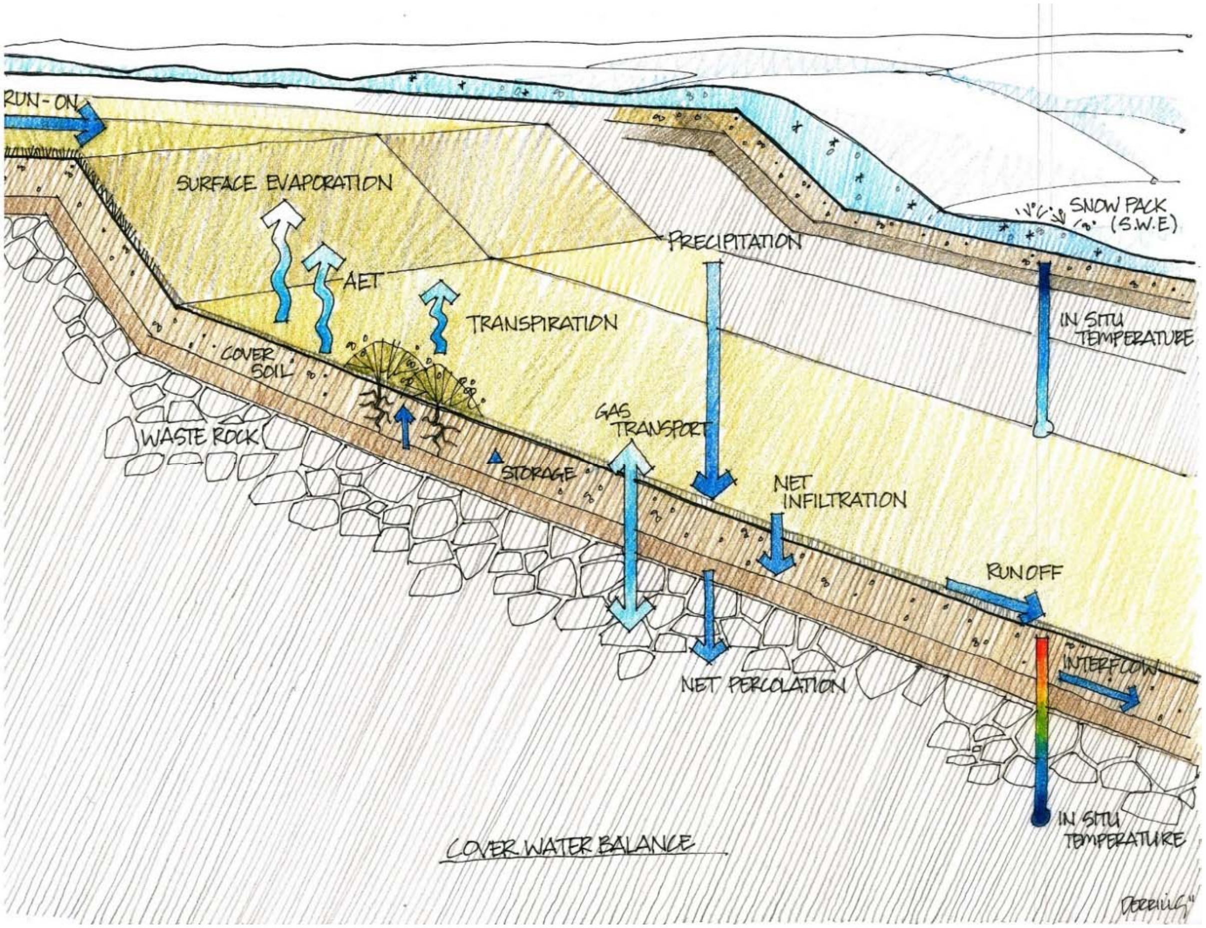
Meiers et al (2014)

Site Cover System Profiles



Meiers et al (2014)

In Situ Direct Cover Monitoring



- ***Monitored water balance component:***
  - ***AET***
  - ***PPT***
  - ***Runoff***
  - ***Interflow***
  - ***Water Storage***
  - ***Net percolation (NP)***
- ***NP Estimated through:***
  - ***Water balance***
  - ***Conservative tracer***
- ***Internal WRP Monitoring System:***
  - ***Temperature***
  - ***Pressure***
  - ***GW elevations***
  - ***Pore-gas concentrations***
  - ***Pore-water quality***

Meiers et al (2014)

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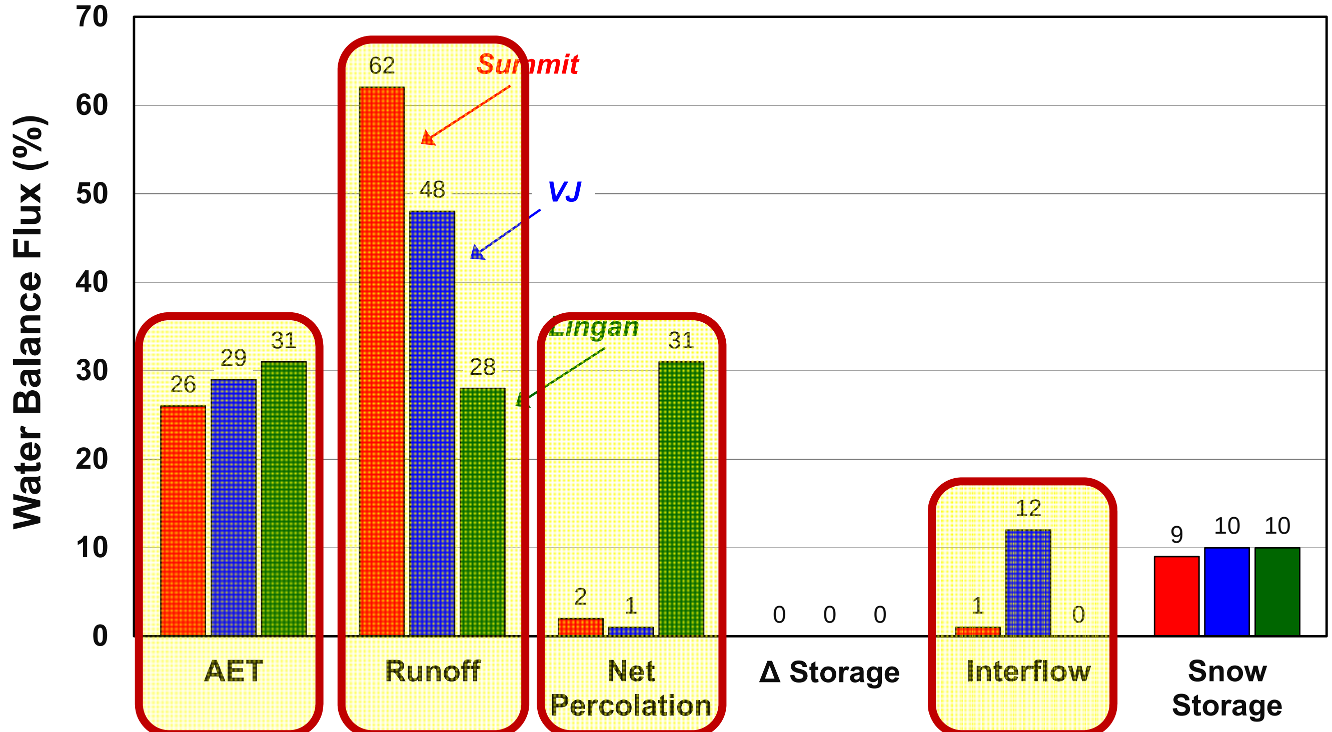
Monitoring: VJ, Summit, Lingan

Cover System Water Balance:

- ***Runoff at Scotchtown Summit ~60%***
- ***Interflow at Victoria Junction ~15%***
  - ***Interflow offsets proportional runoff volume***
  - ***Minimum 20% interflow volumes to minimize buildup of positive pore-water pressures***
- ***AET Similar***
- ***Net Percolation at Lingan ~30%***
  - ***Net percolation offsets a proportional volume of runoff and/or Interflow***



Meiers et al (2014)

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And then there is…..

- The Challenge of Actually Obtaining these Measurements
- Meaning…
  - Well developed tools for
    - Rainfall, PE, AET, Soil Water Storage
  - But… Measuring
    - SWE, Runoff, Net Percolation
    - While Simple in Concept
    - Can in Practice be very Challenging

Surface Runoff Monitoring

- *Dealing with sediment is challenging*
- *"Young" cover systems often require sediment removal before wet climate periods*
- *Cold regions require removal of ice (glaciation)*
- *Peak flow requires most attention*
- *Often require manual intervention*
- *Data QC can be intensive*

Surface Runoff Monitoring

Surface Runoff Monitoring

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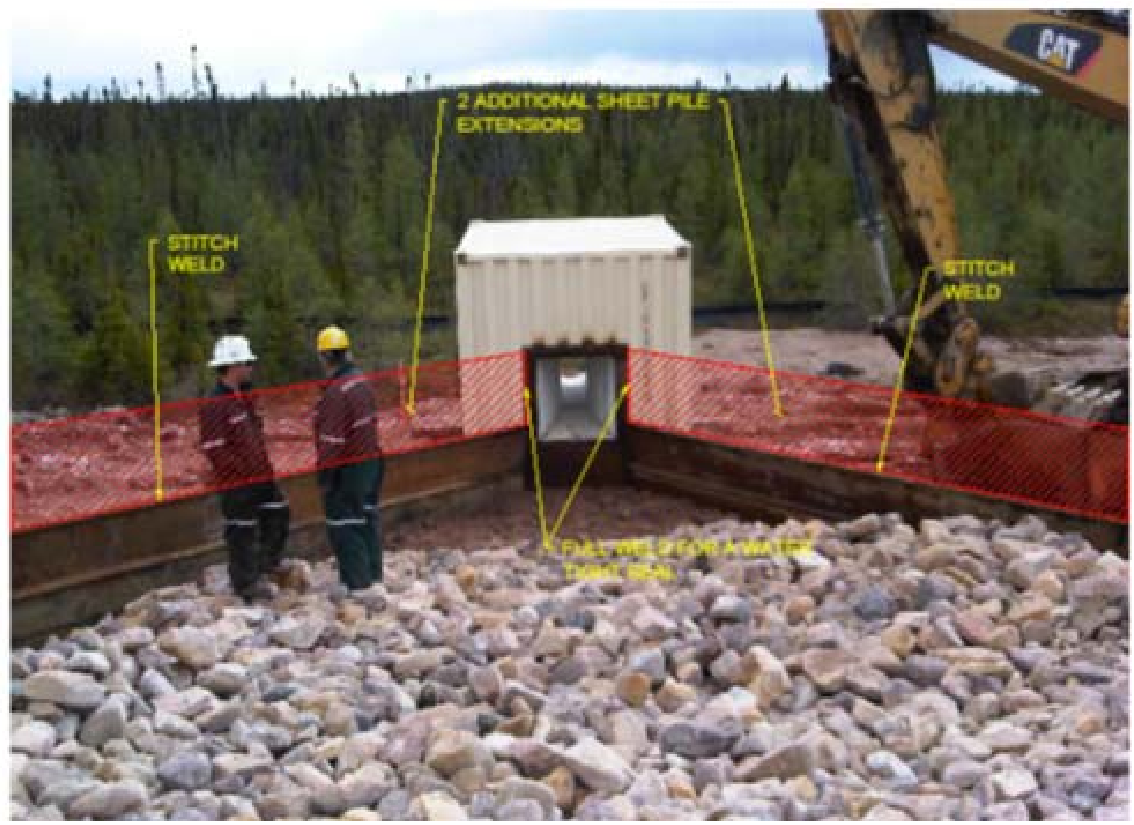
Surface Runoff Monitoring

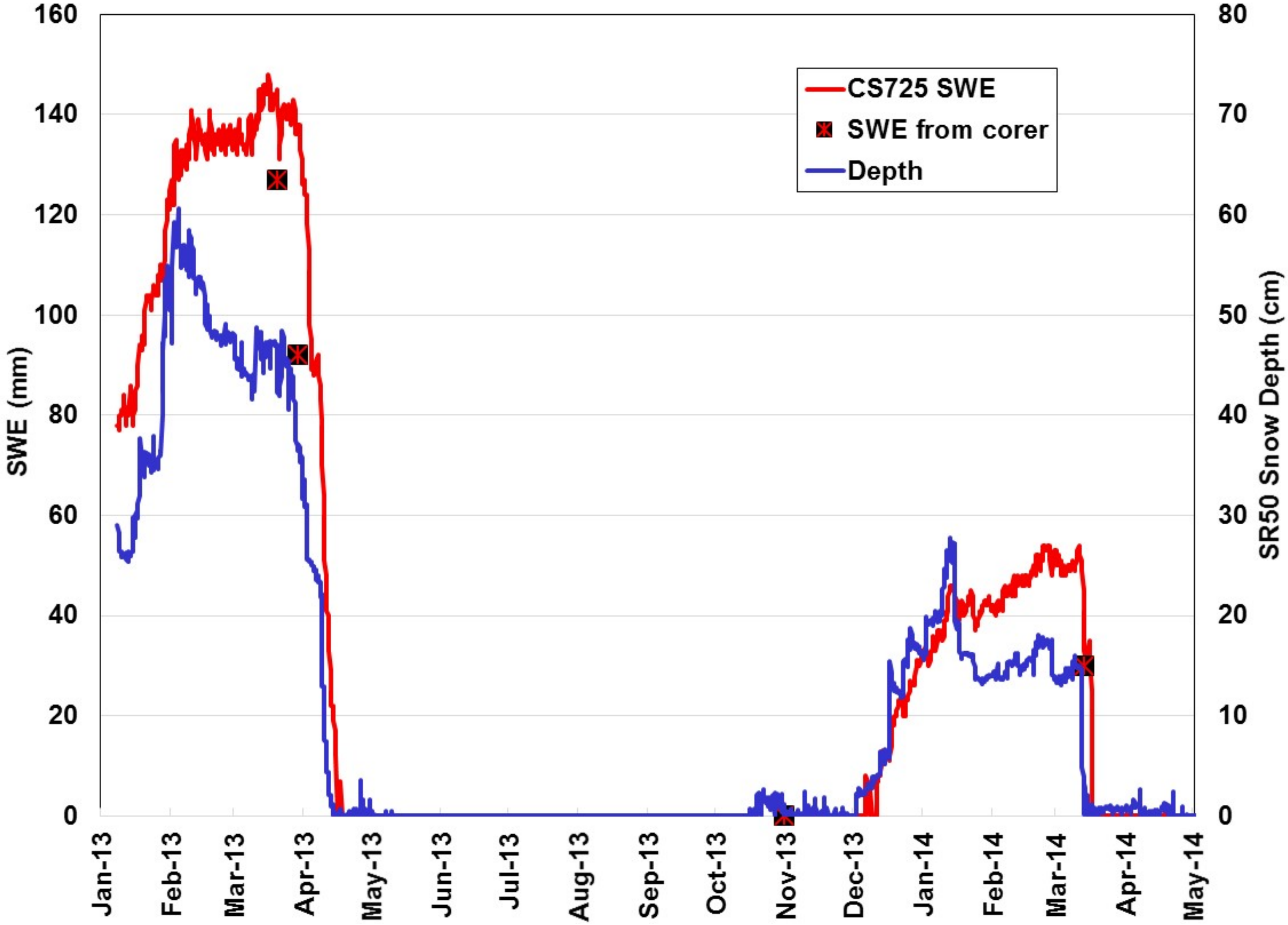


Surface Runoff Monitoring

Snow Water Equivalent

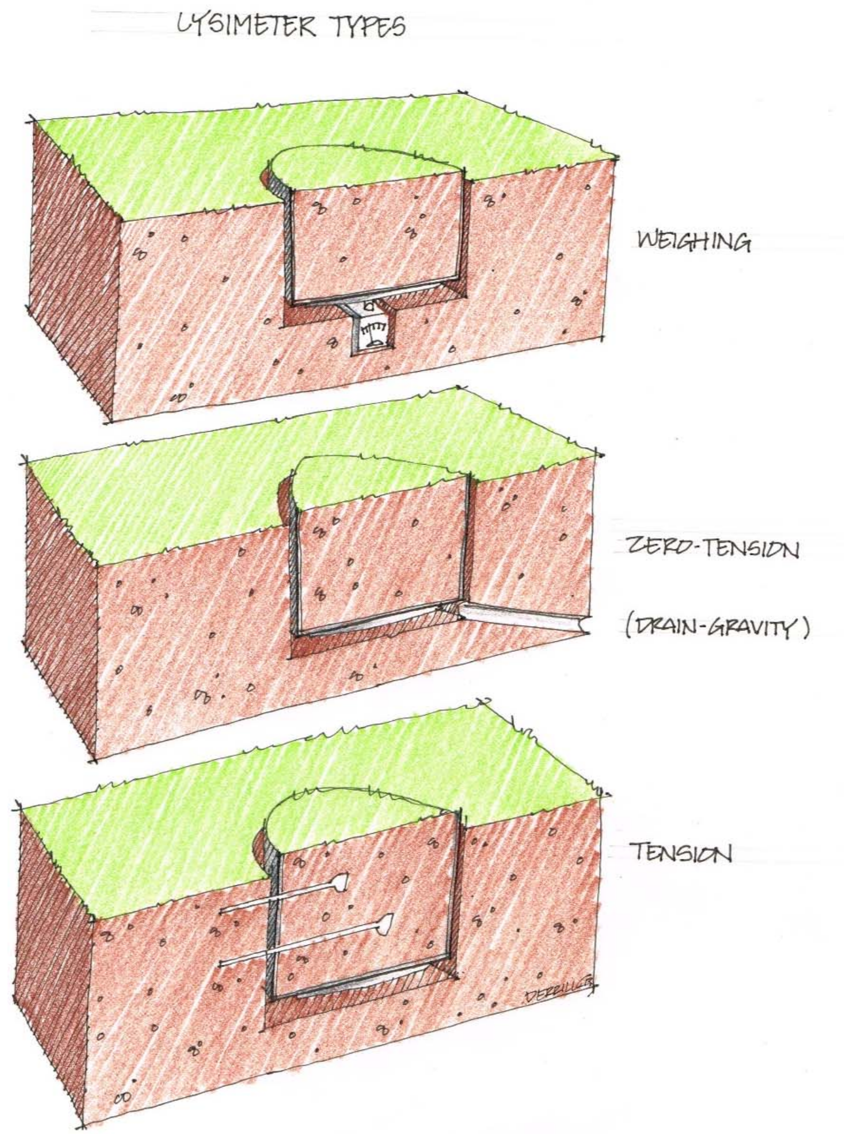
Snow Water Equivalent

Snow Water Equivalent



Net Percolation

- *Direct measurement*
  - *Lysimeters*
- *Indirect methods*
  - *Hydraulic gradient*
    - *Suction sensors*
  - *Changes in moisture storage*
    - *Water balance*
  - *Numerical modeling*
    - *Calibrate to changes in:*
      - *Water table*
      - *Near surface conditions (soil-plant-atmosphere modeling)*
  - *Pore-water conditions*
    - *Isotope analysis*
    - *Salts*
    - *Tracers*



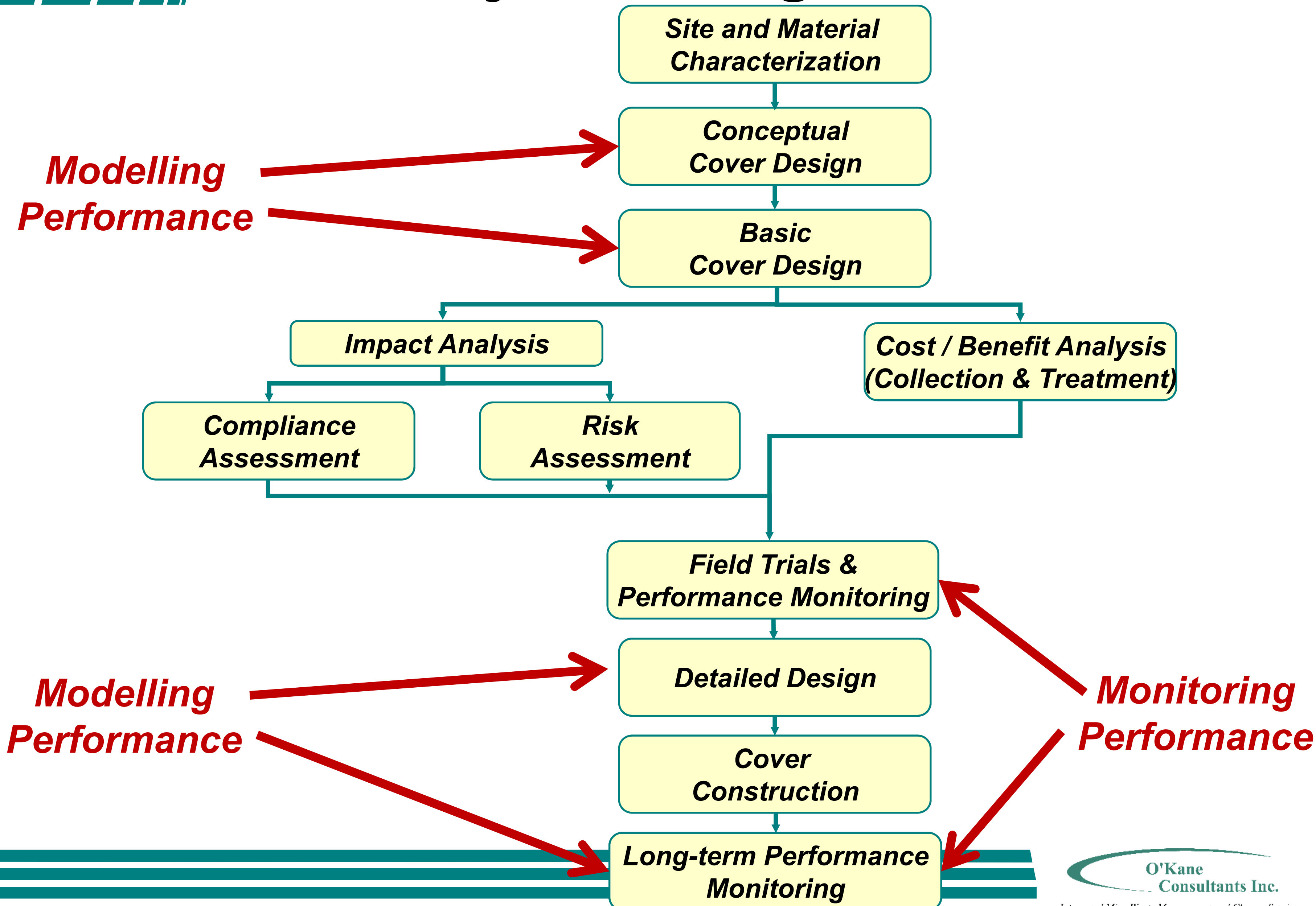
Net Percolation

- Common design issues
  - Too shallow and insufficient areal extent
- Field challenges
  - Safety
  - Replicating conditions
  - Plateau locations

Net Percolation

- *Delays timing of recording spring melt associated net percolation events*
- *Again….*
  - *Heated enclosures*
  - *Metal enclosures*
  - *Insulated*
  - *etc.*

Summary of Design Process



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Summary of Design Process

Process	Time Frame
Establish Design Objectives	Months
Characterize Available Materials	Months
Develop Design Alternatives • Modelling – Analytic, Spreadsheet, Numerical	Months to year

Field Prototype
• Full Scale Construction
• Monitoring
  – All elements of water balance
• Data Interpretation and Analyses
  – Complete water balance
  – Identify controlling mechanisms/process
	3-5 years

Final Cover Construction	1 year
Long-term Monitoring • Verification of Design Properties/Processes • Tracking Evolution of Landscape with Time	10-20 years (Cover Performance) 20-100+ years (Closure Assurance)

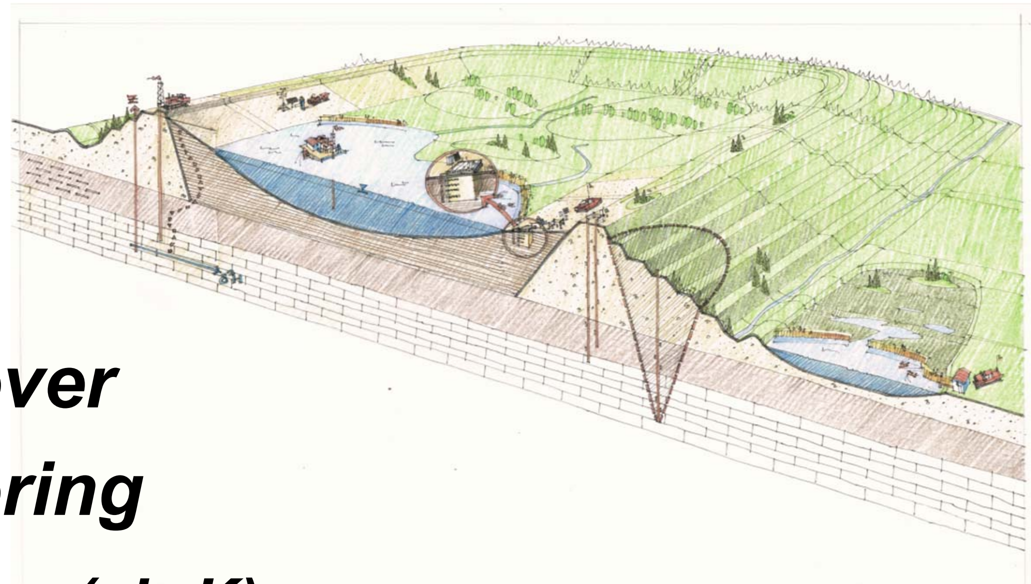
(Barbour 2014)

Limitations of Current Approach

- Small Time Scales
  - 5-10 years of monitoring
    - Evolution of soil properties
    - Calibrate/parameterize models
  - Project driven climate window
    - May not experience climate variability
  - Closure monitoring
    - 100+ years?
- Small Spatial Scales
  - Monitored soil volume ~ 1 m^3
    - 1/100 of 1% of the cover in 1 ha
- Small Numbers
  - Small # of significant figures – e.g. estimate NP
    - Major input
      - Precipitation
        - ~ 500 of mm/year
    - Major output
      - Evapotranspiration
        - ~ 400-450 mm/year
    - Minor outputs
      - Net percolation & runoff
        - ~ 0-50 mm/year
- Large Cost
  - 1 instrumented watershed
    - ~100k capital – 10 year life
    - ~ 20k/year maintenance

(Barbour 2014)

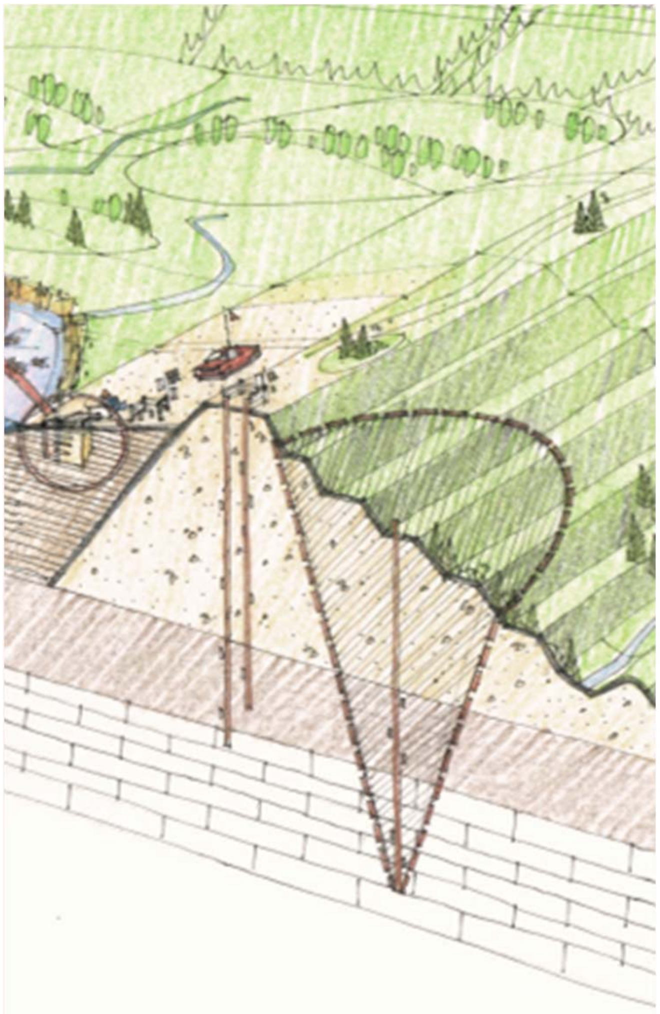
Non-Conventional Monitoring

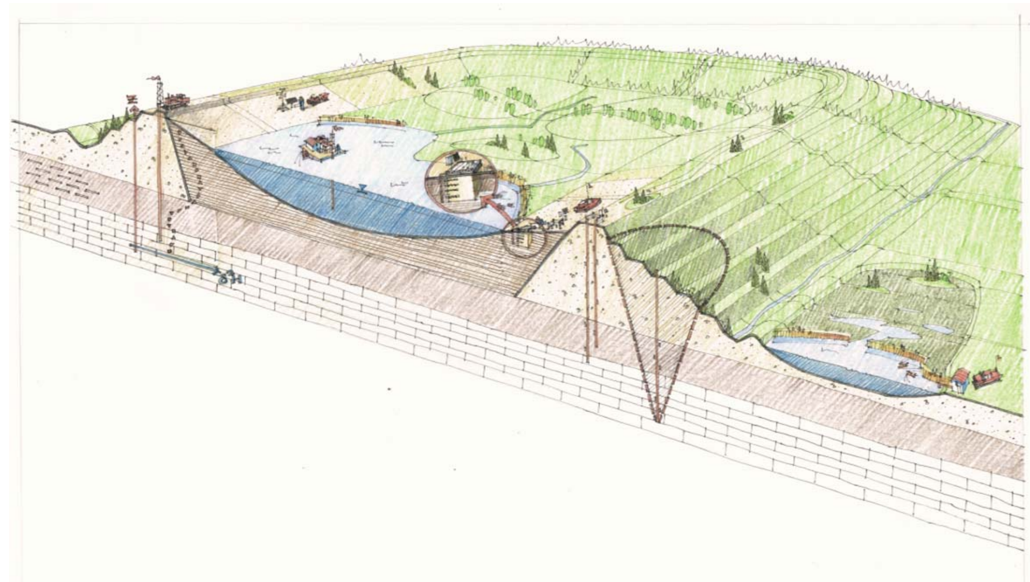


- **_Non-Conventional Cover and Landform Monitoring_**
  - **_Air-permeability Testing (air-K)_**
  - **_Distributed Temperature Sensing (DTS)_**
  - **_Geological Weighing Lysimeters (GWL)_**
  - **_Stable Isotopes of Water_**

(Barbour 2014)

Non-Conventional Monitoring





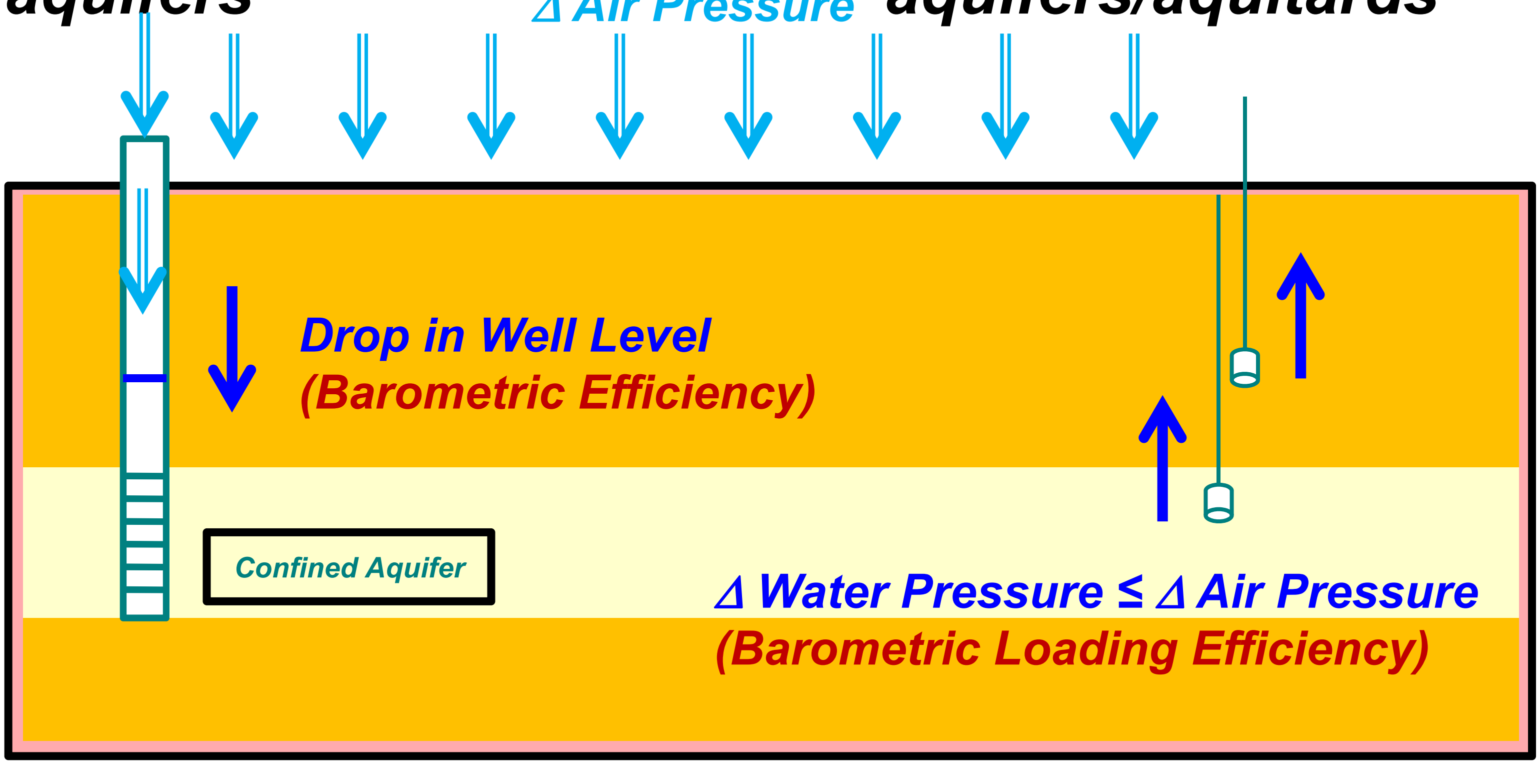
Geo-Lysimeters

(Barbour 2014)

Geo-Lysimeters

Hydrogeology Example – Barometric Loading

- **Wells in confined aquifers**
- **Piezometers in aquifers/aquitards**



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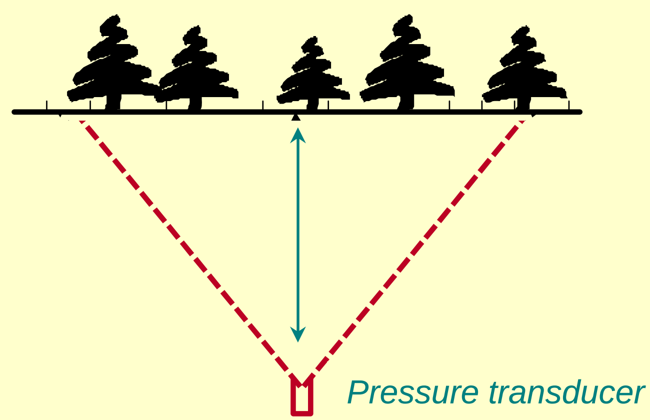
Geo-Lysimeters:
Self Calibrating Soil Water Weighing Scales

- ***Assumption***
  - ***Any surface loading transmitted to depth results in change of pore water pressure***
- ***Potential Application***
  - ***Pore pressures used to track key hydrological processes such as***
    - ***Snow melt runoff***
    - ***Rainfall***
    - ***Evapotranspiration***

Conceptual Sketch of Piezometric Weighing



[after Van der Kamp et al, 2003]

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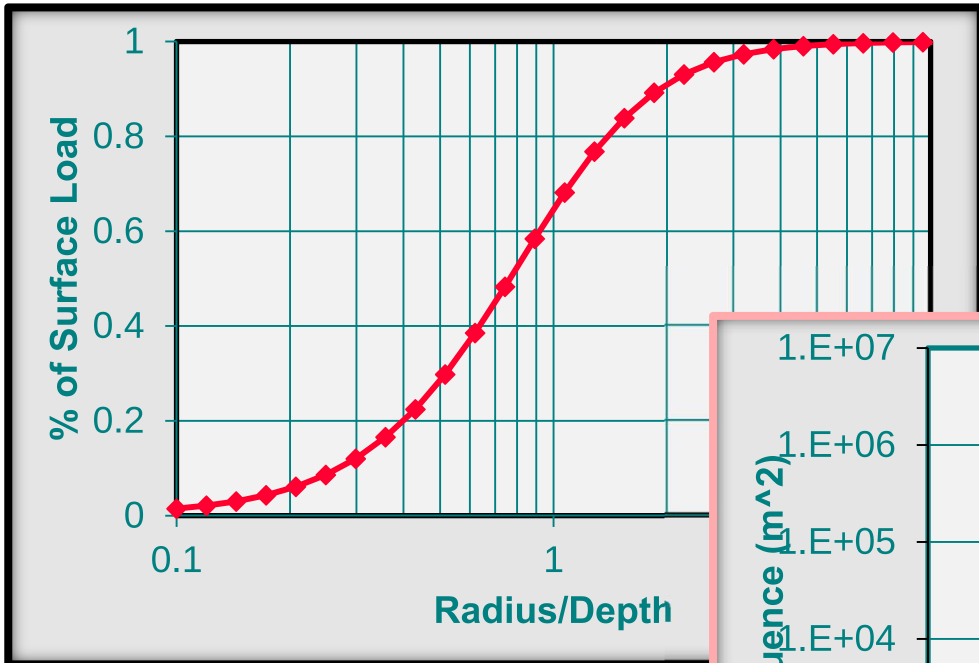
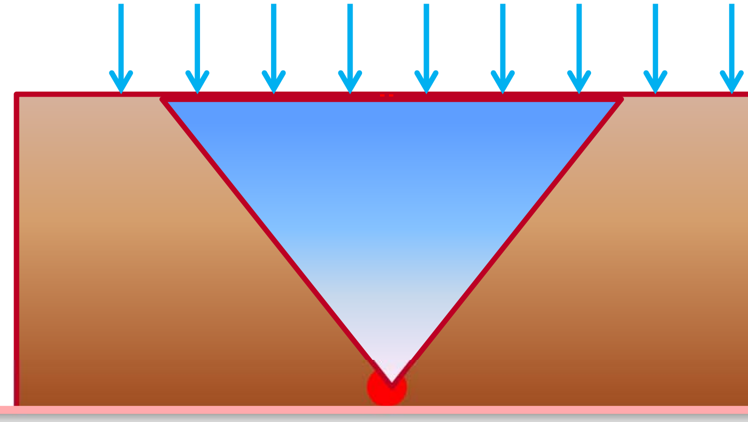
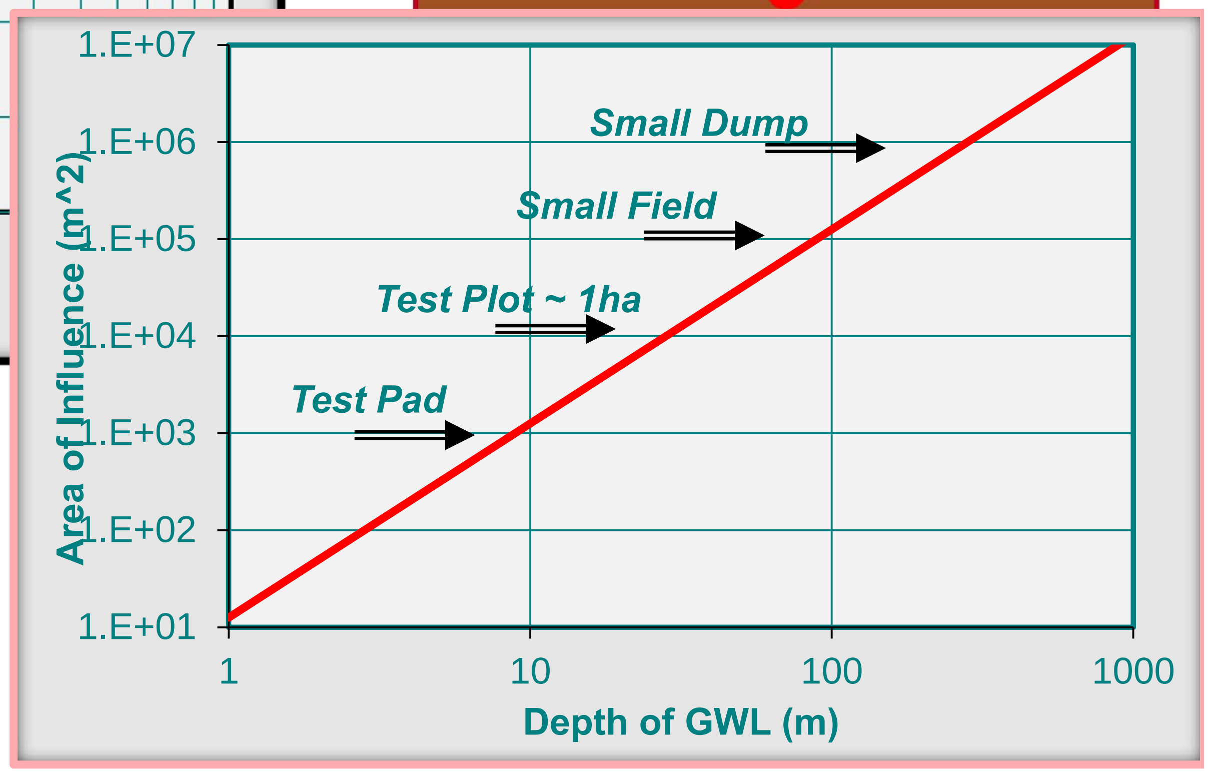
Geo-Lysimeter :
Area of Influence







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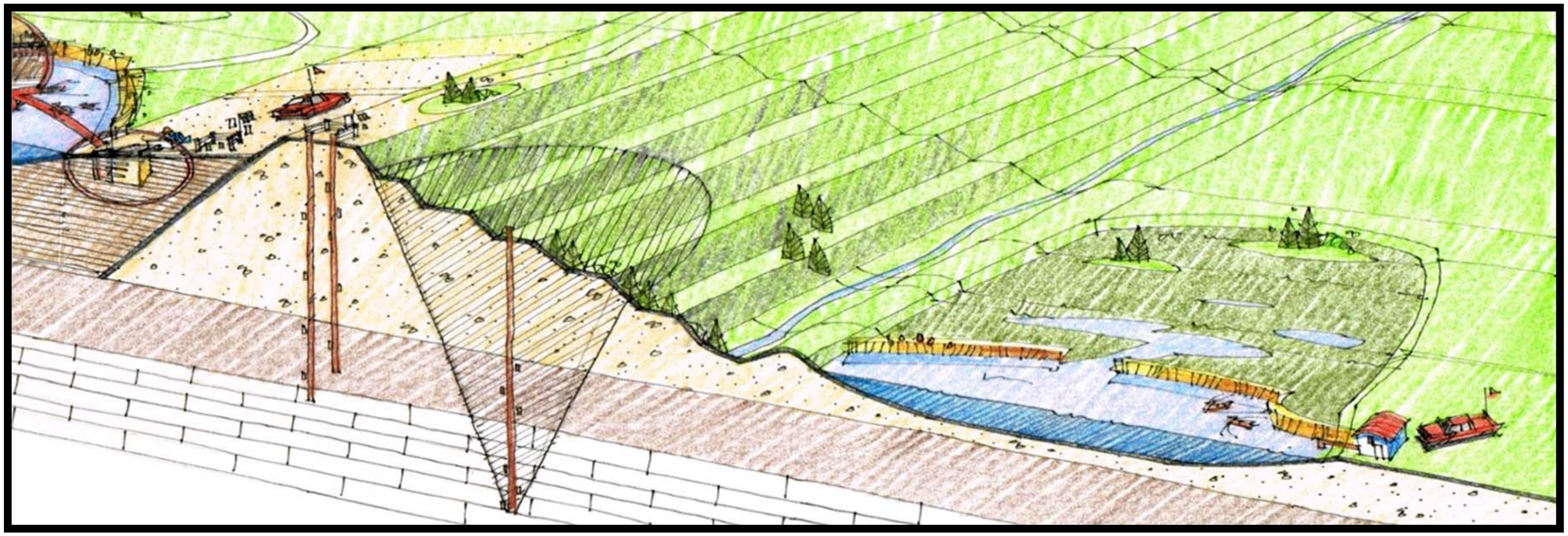
Geo-Lysimeter Example:
Syncrude Sand Tailings Dyke

- ***Existing geotechnical monitoring piezometers***
- ***Additional geo-lysimeters***
  - ***Adjacent soil cover monitoring & Eddy covariance***



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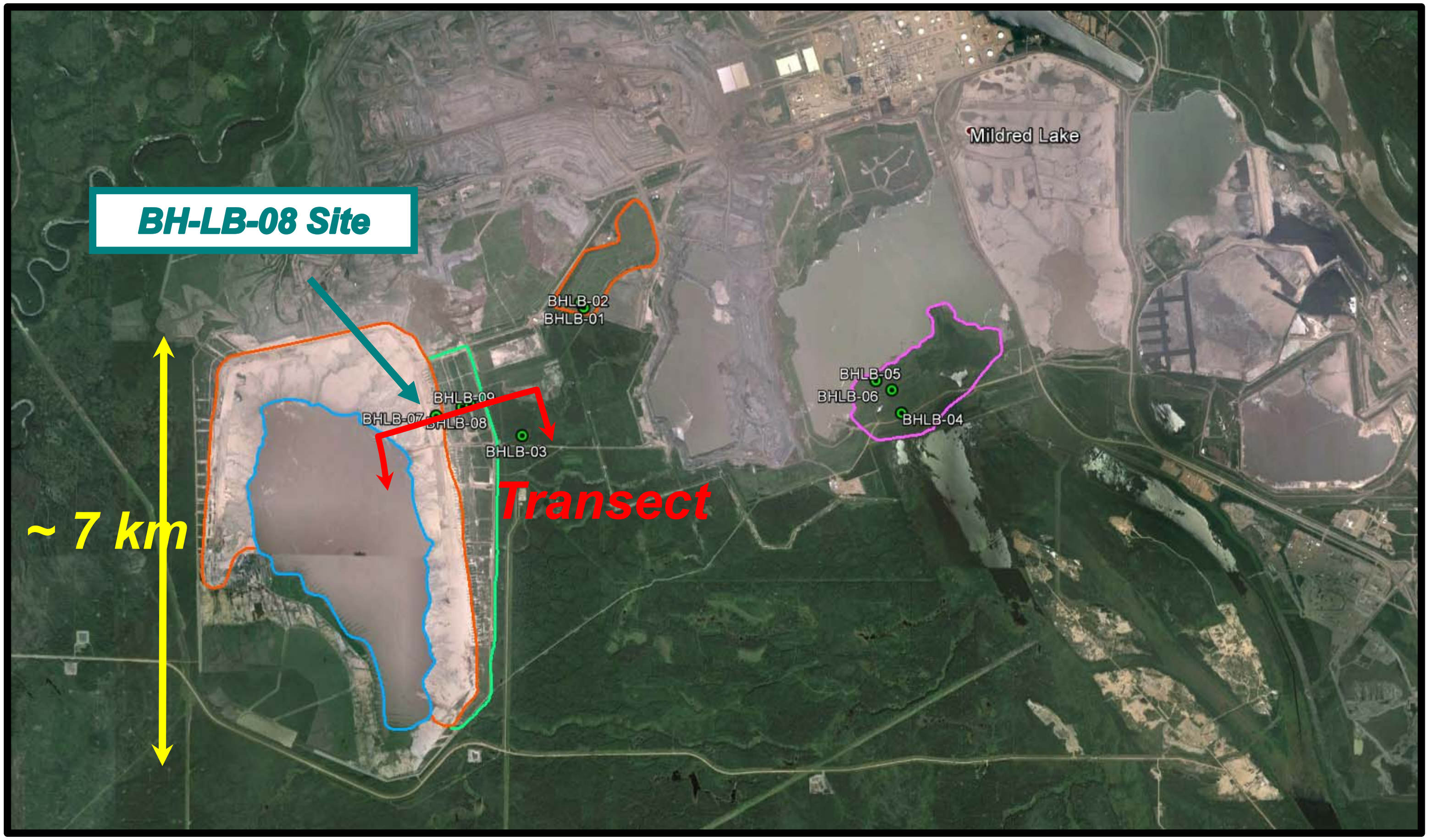
Geo-Lysimeter Location

Syncrude South West Sand Storage (SWSS)



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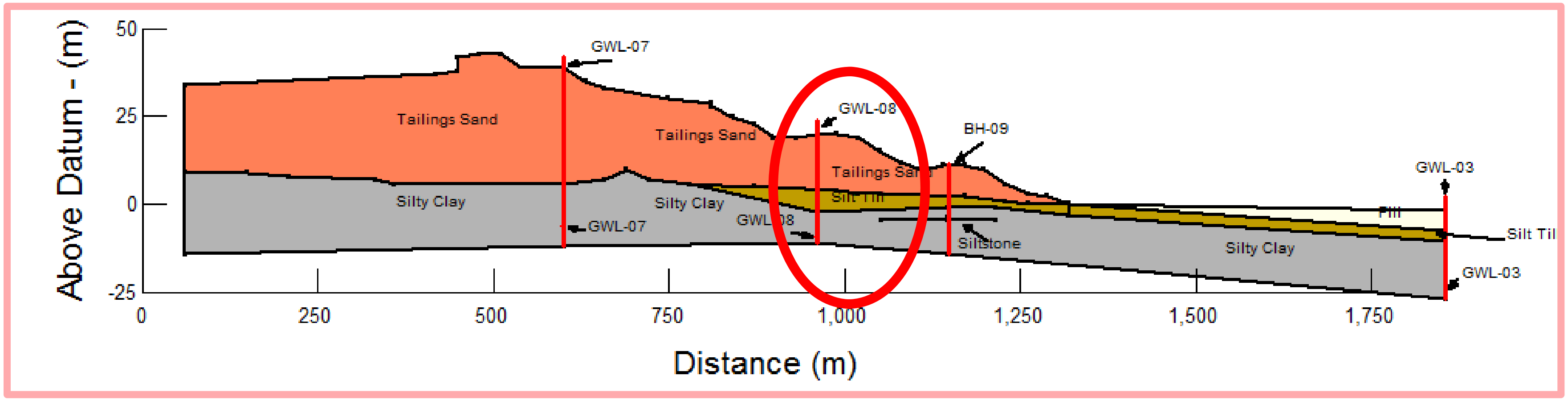
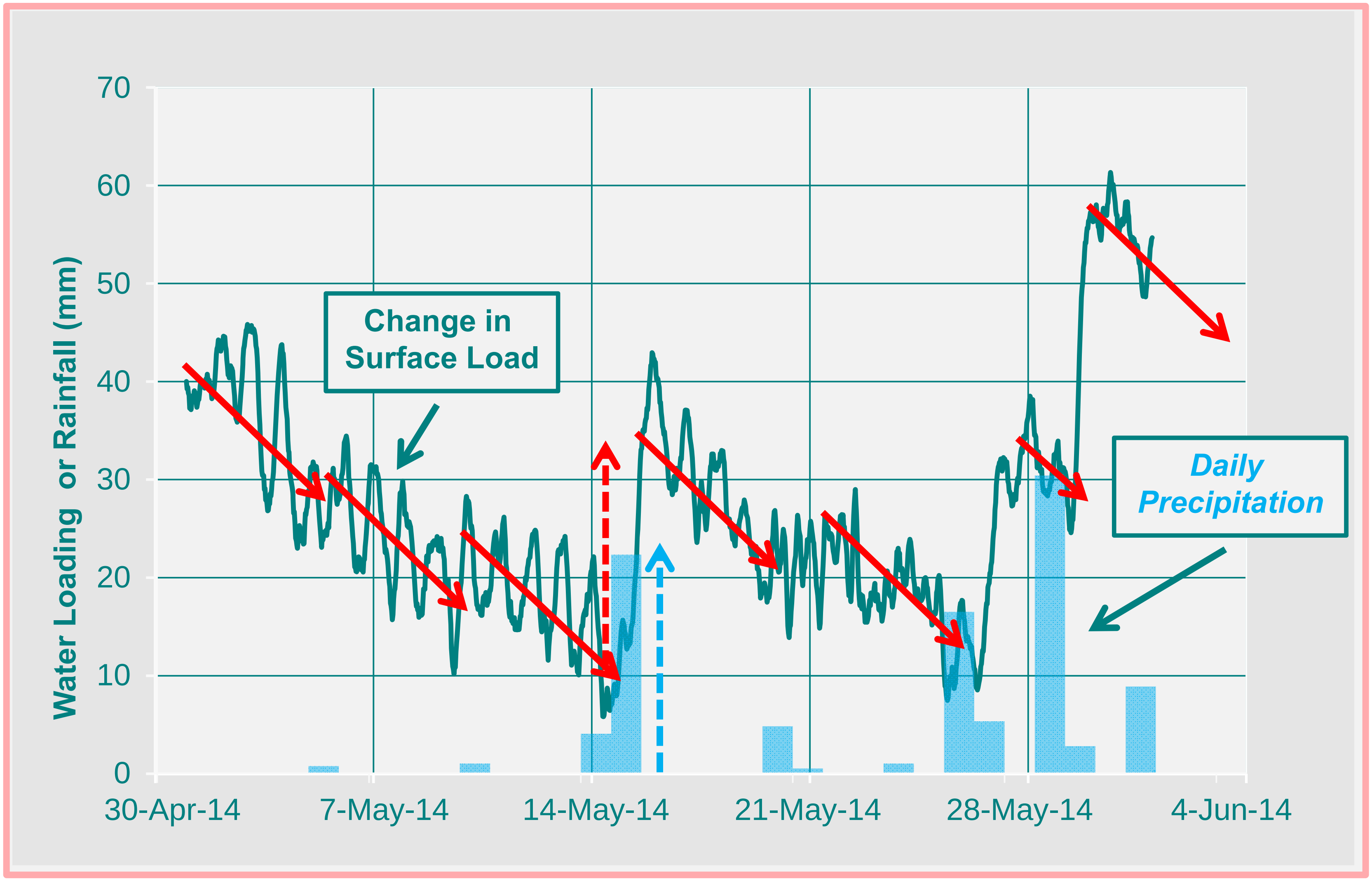
Geo-Lysimeter Response

- ***Southwest Sand Tailings – Syncrude***
  - ***Cross Section and Flow Model***



[after Adrianne Price, M.Sc./ Mendoza, UofA Earth Science and Keely Kulpa, Research Assistant]

Geo-Lysimeter Response to Rainfall:



[James Tipman, MSc / Garth van der Kamp, Env Canada]

Biological Monitoring Example

Millions of spiderwebs cover Scotchtown field

Sharon Montgomery-Dupe
Published on November 19, 2014

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."

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© 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

Thank You!

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