Field Performance Monitoring of ET Cover Systems

at

Mine Sites in Australia, Canada, and the U.S.

Designing, Building, & Regulating Evapotranspiration (ET) Landfill Covers

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RTDF

Presentation Overview

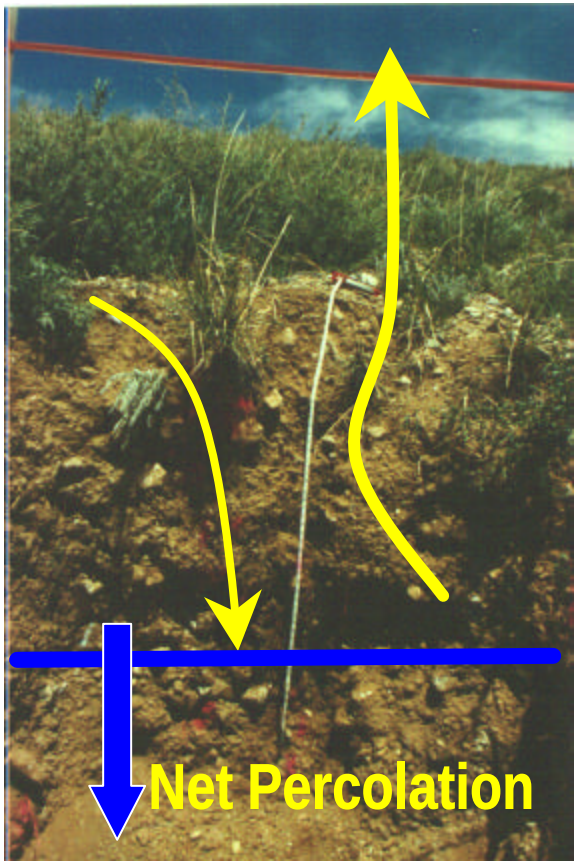
See References at end of Presentation for details on Sites

- ***Arid-Tropical Site in Australia***
  - *Ave: 300 mm Rainfall*
  - *Max (1996): 500 mm Rainfall*
- ***Seasonally Arid Site in Canada***
- ***Long-Term Performance***
- ***Lessons Learned***

Arid-Tropical Site - Australia

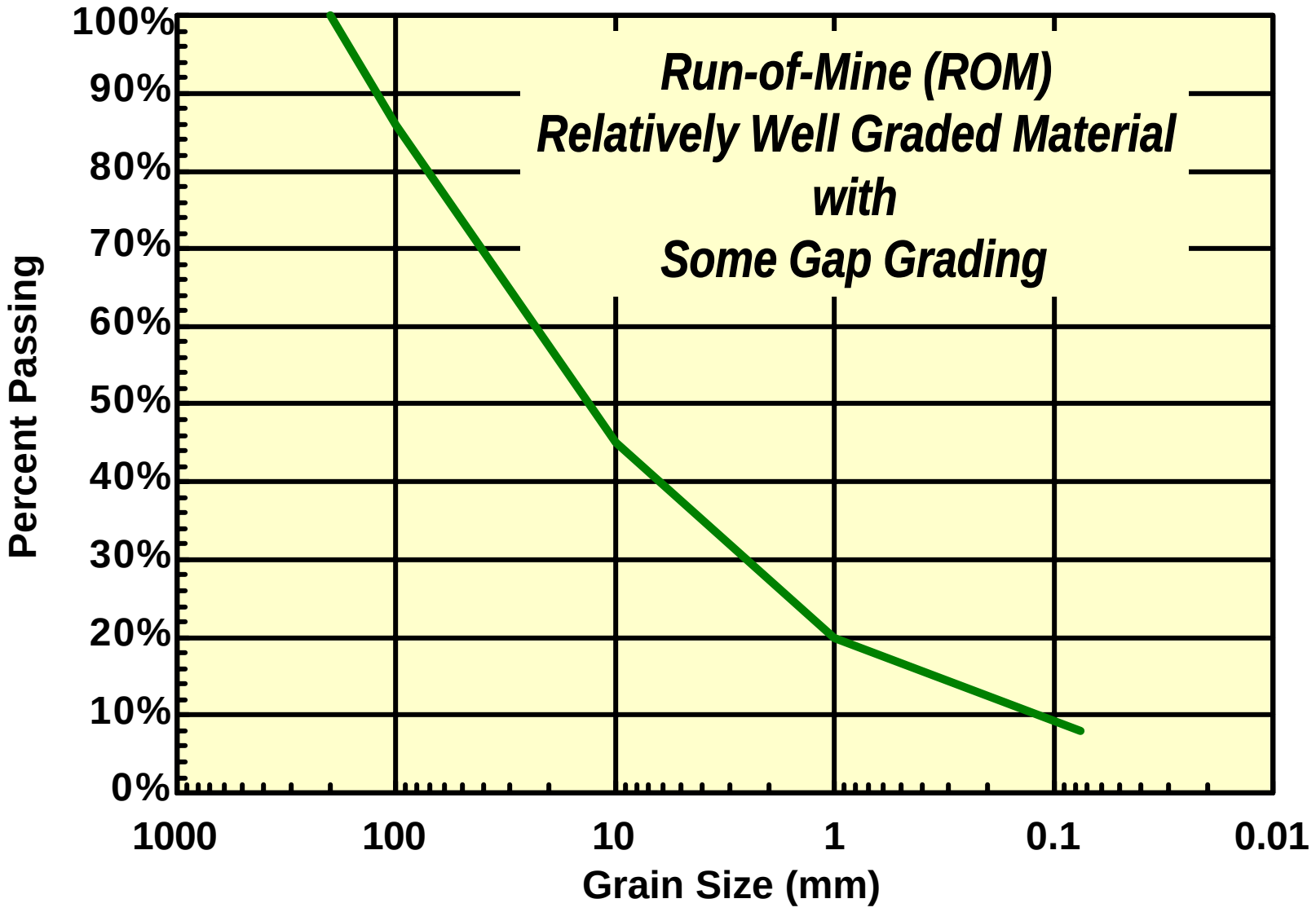
Cover System Design Philosophy

- **Issues**
  - *"Legacy" OSAs*
  - *"Building" a Better OSA*
- **Management of Pyritic Shale**
  - *Encapsulation*
  - *Use run-of-mine for cover material*
  - *Minimise Percolation to Underlying Waste*
  - *Store and Release Moisture in Capping Material*
- **Physical Integrity and Long Term Performance**

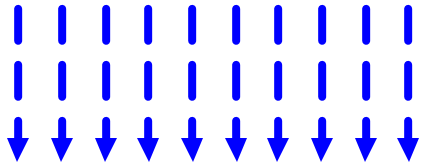


"Store and Release"

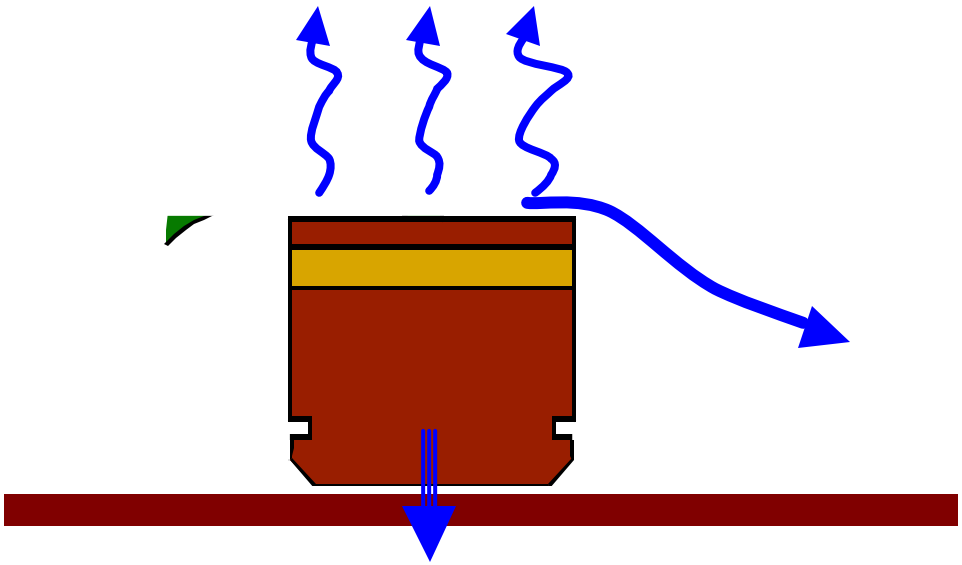
Capping Material



Preliminary Modelling Results



Rainfall



Evaporation

Runoff / Interflow

Moisture Storage

1996 Modelling
1 m ROM Material
~0% Net Percolation

See References for Conceptual Modelling Presentation Idea

Large-Scale Field Trials

- *Uniform Sloping Surfaces*
  - *Vegetation*
- *Horizontal Surfaces – Larger Catchment Areas*
  - *Variable Catchment Sizes*
  - *Variable Native and Crop Species*

- *Horizontal Undulating Surfaces*
  - *No Vegetation*
  - *Varying Thicknesses*

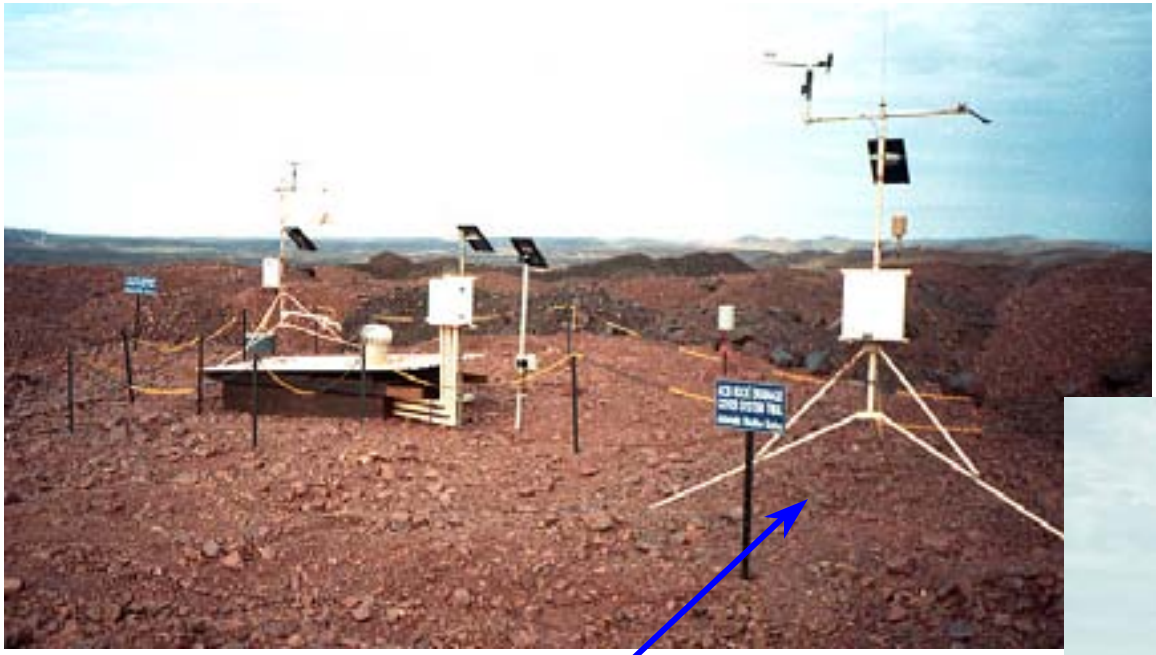
Transpiration Rates?

Vegetation

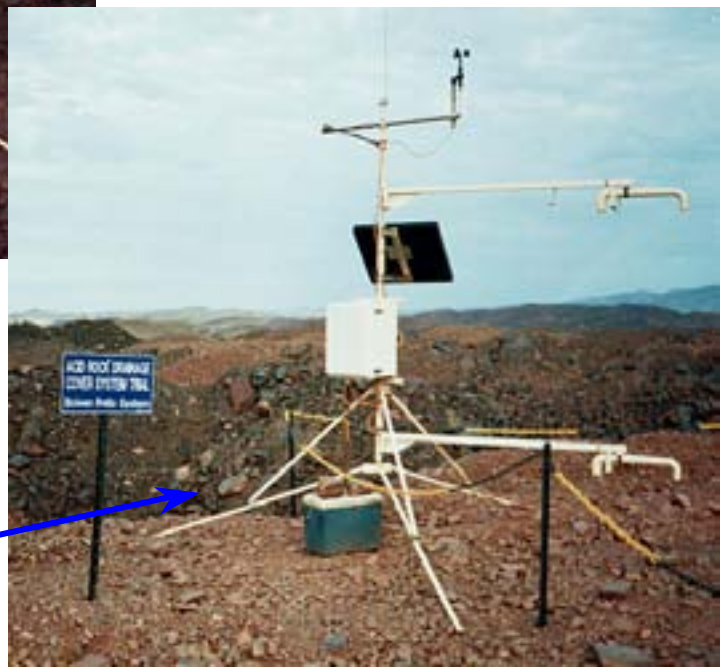
Transpiration Rates of Native Species

Bare Surface

Climate

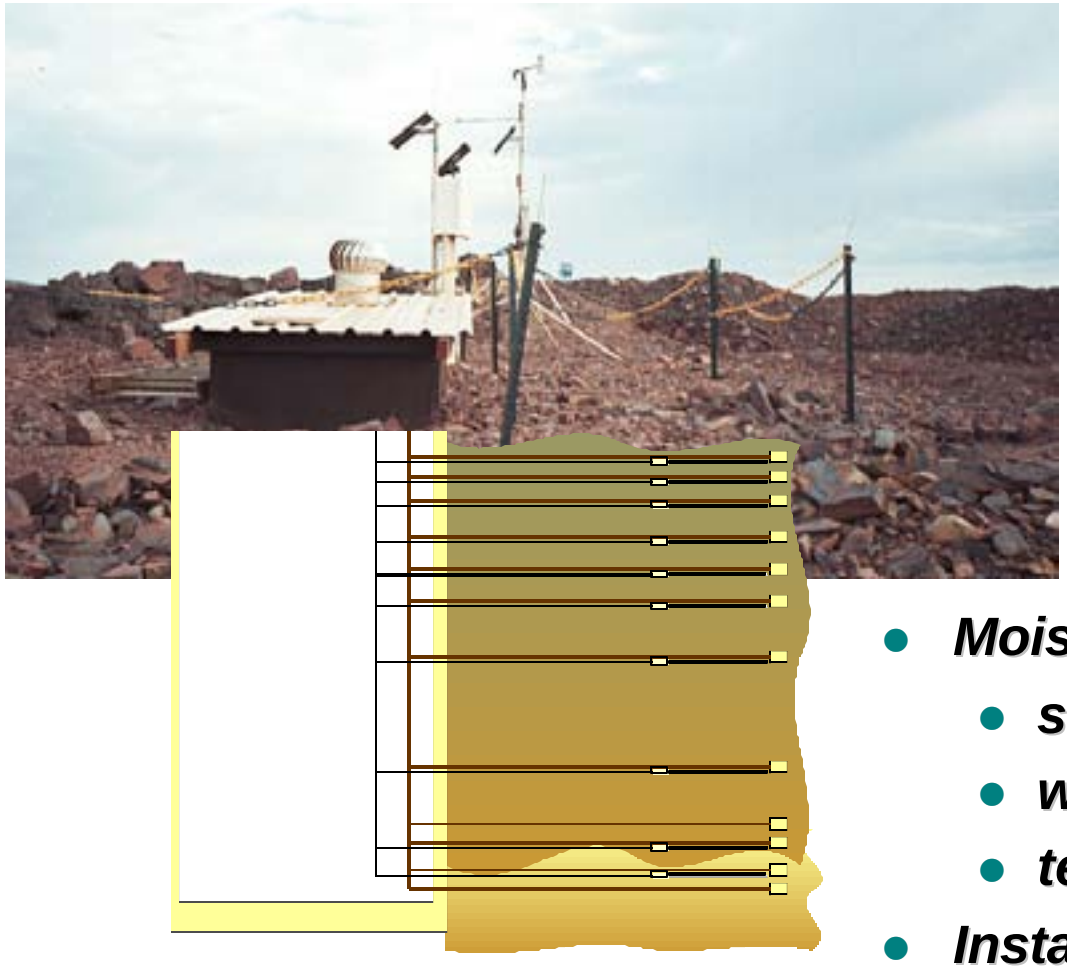


Fully Automated Meteorological Station



Actual Evapotranspiration (Bowen Ratio System)

Moisture Storage



- *Moisture changes*
  - *soil suction*
  - *water content*
  - *temperature*
- *Installed in capping material and underlying waste*

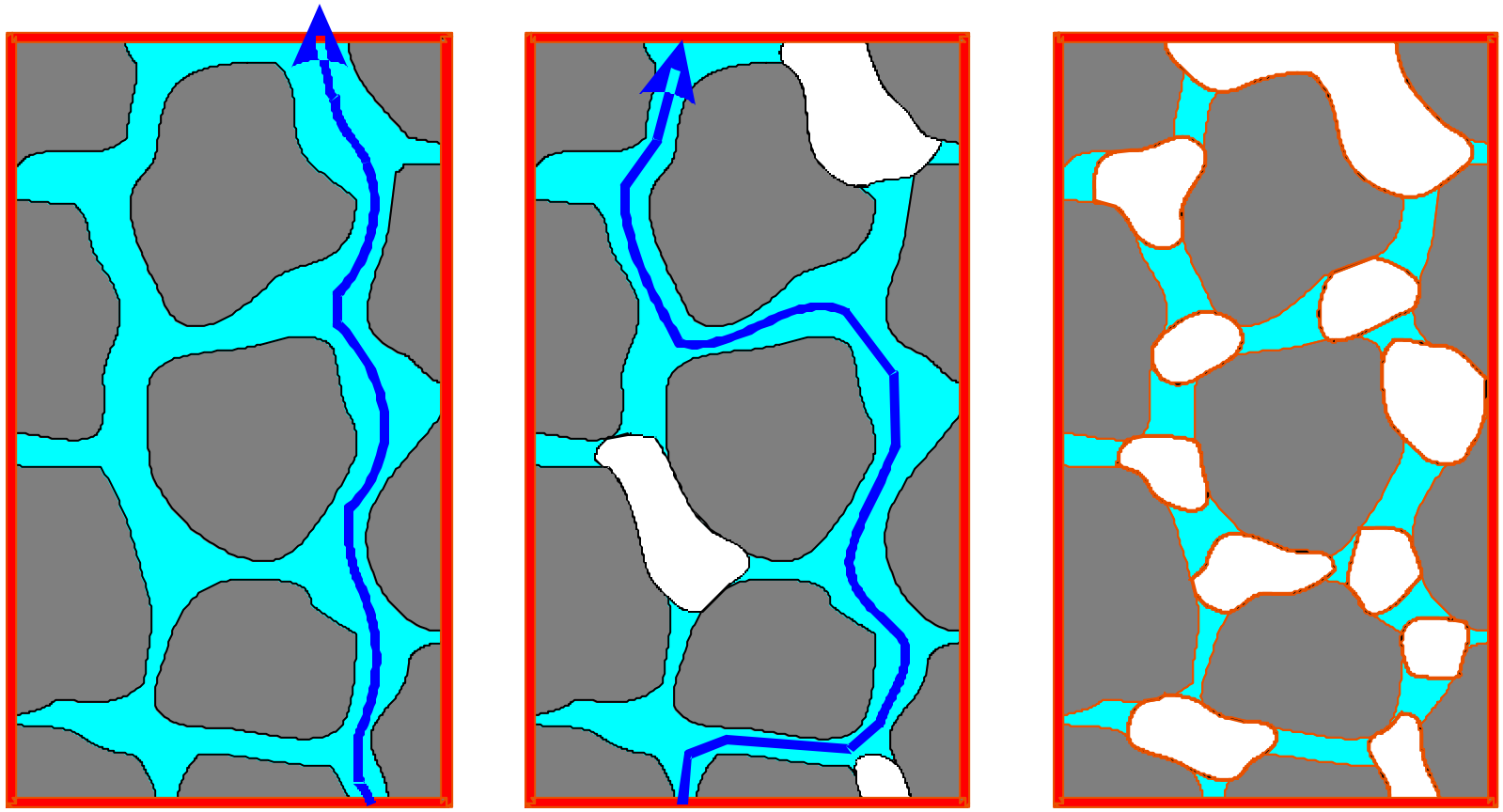
Net Percolation

- *Large HDPE tank*
  - *function of percolation rate and material properties*
  - *internal moisture monitoring*

- *Installed into original waste rock surface prior to placement of capping material*

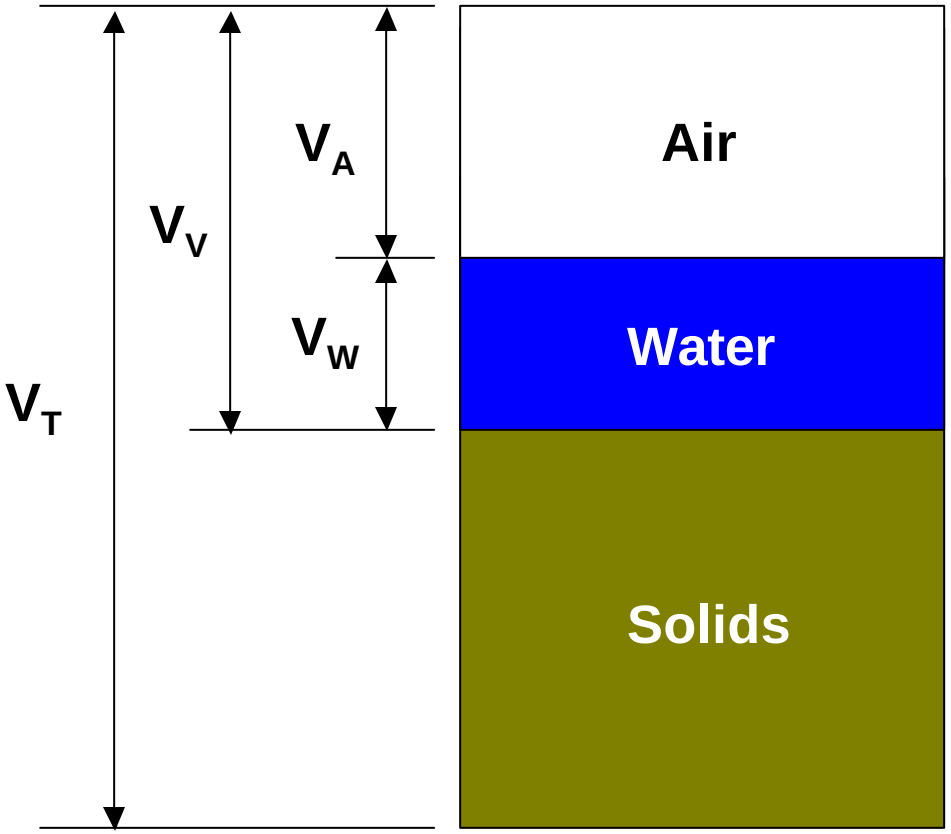
See References for Lysimeter Design Methodology

Degree of Saturation



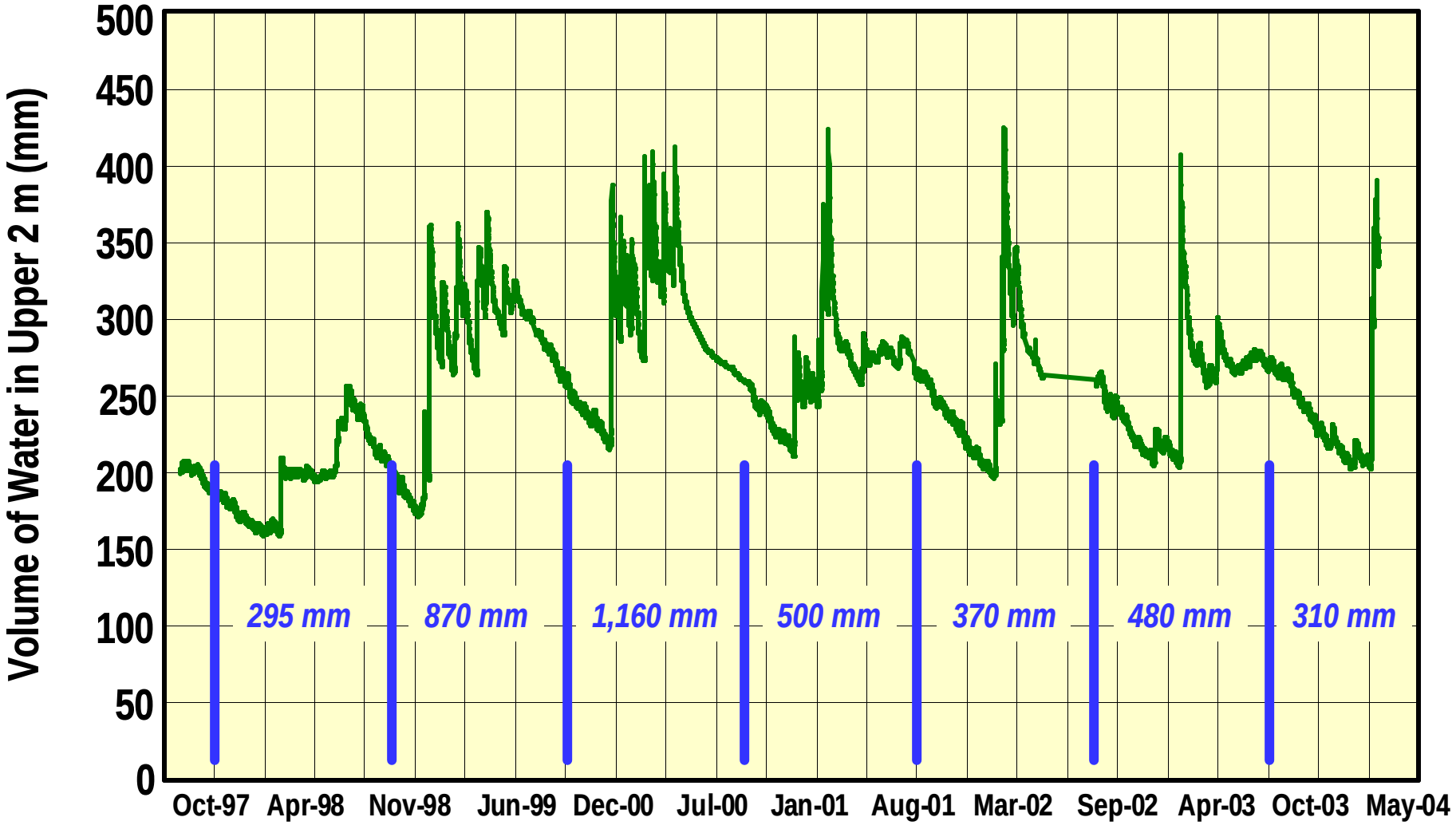
$S = 1$ $1 > S > S_r$ $S = S_r$

Degree of Saturation

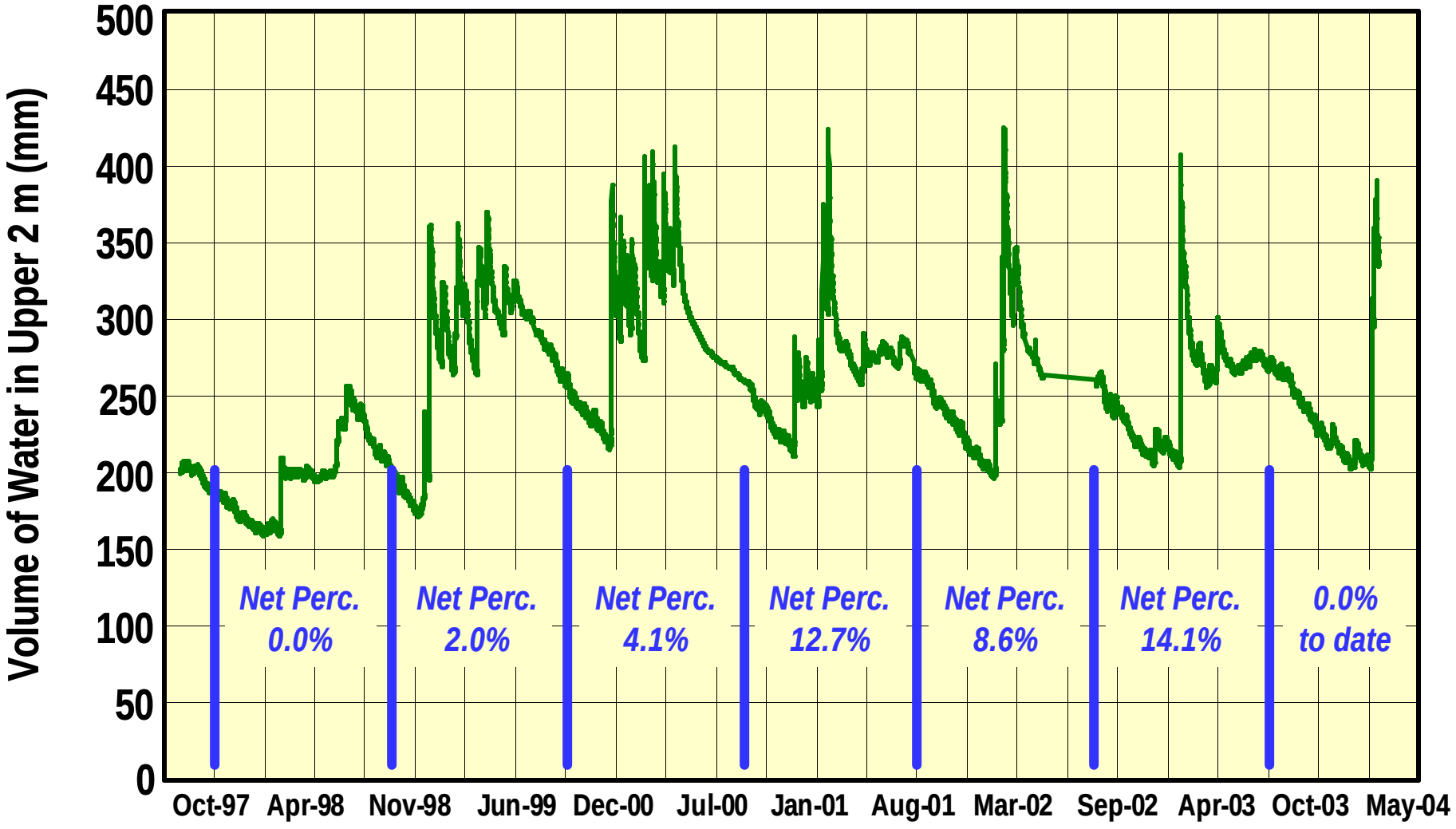


$$S = \frac{V_W}{V_V}$$

Volume of Water in Cover Profile



Volume of Water in Cover Profile



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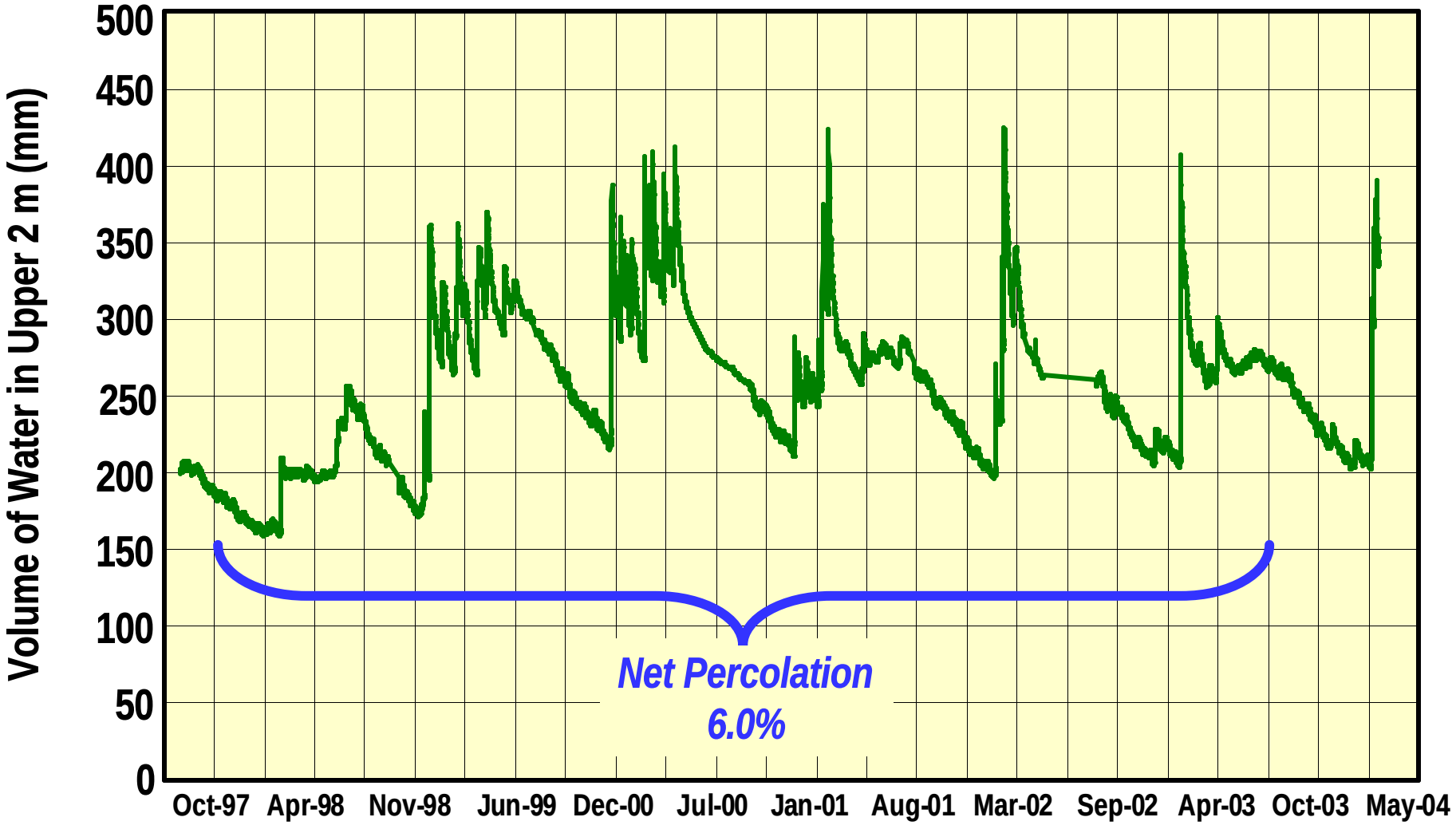
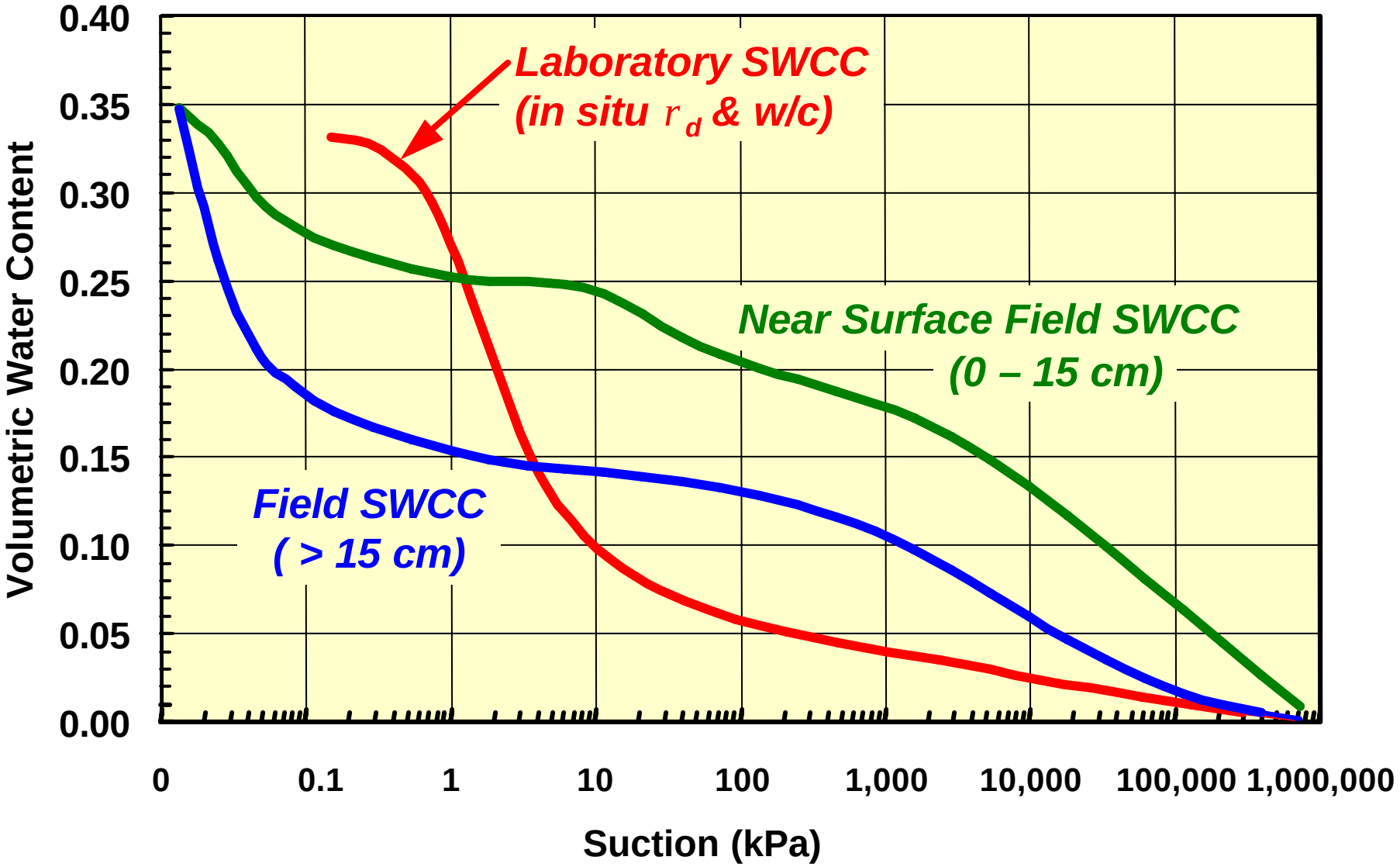


ROM Cover Mat'l – Field SWCCs



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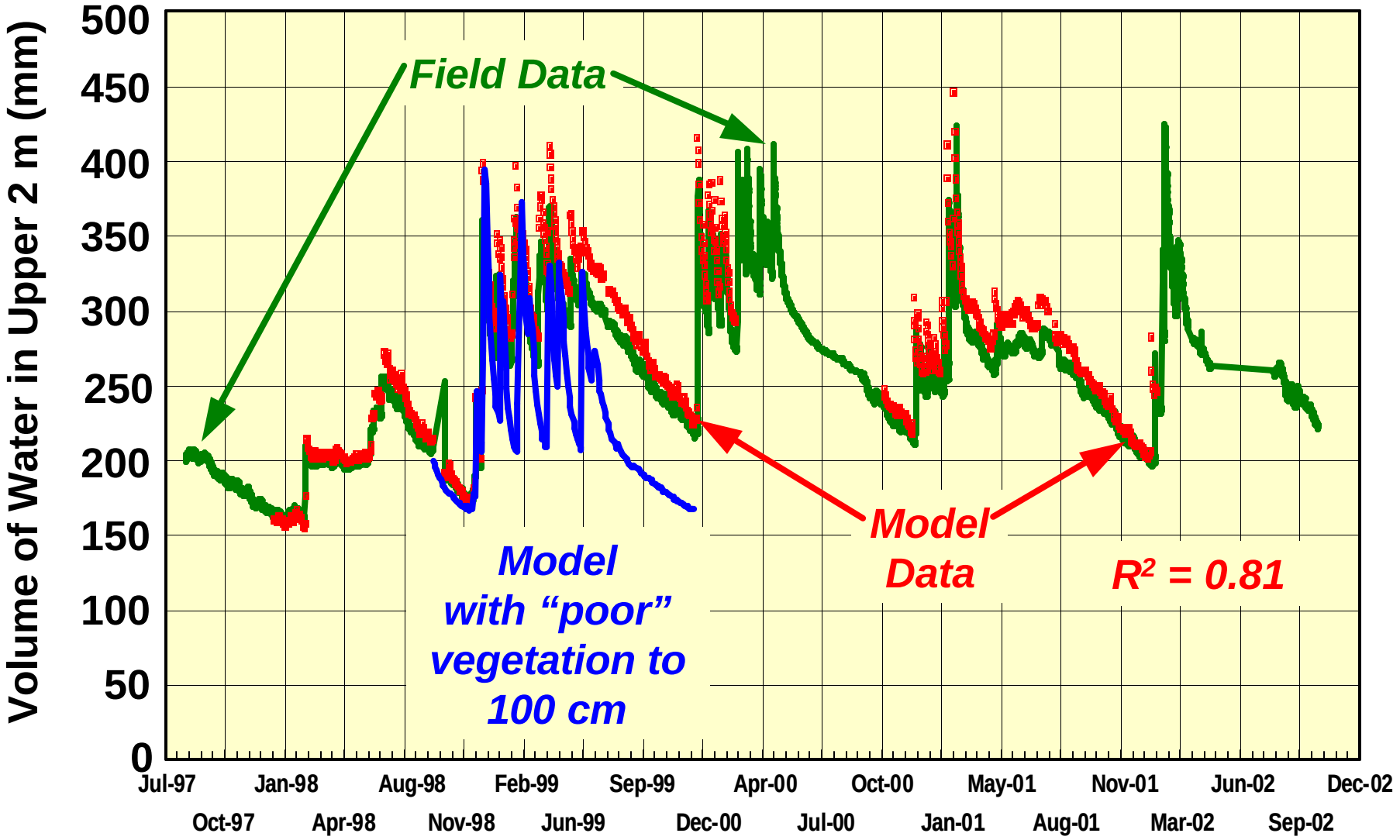
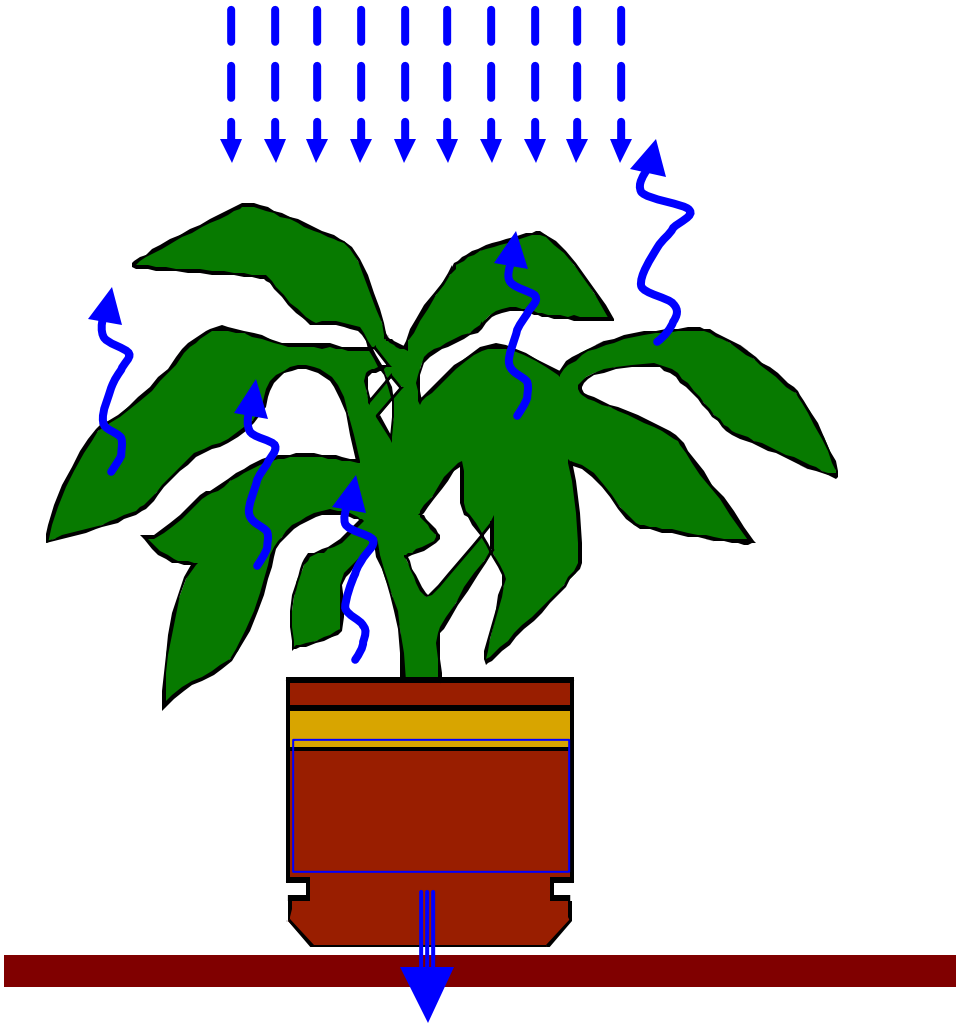


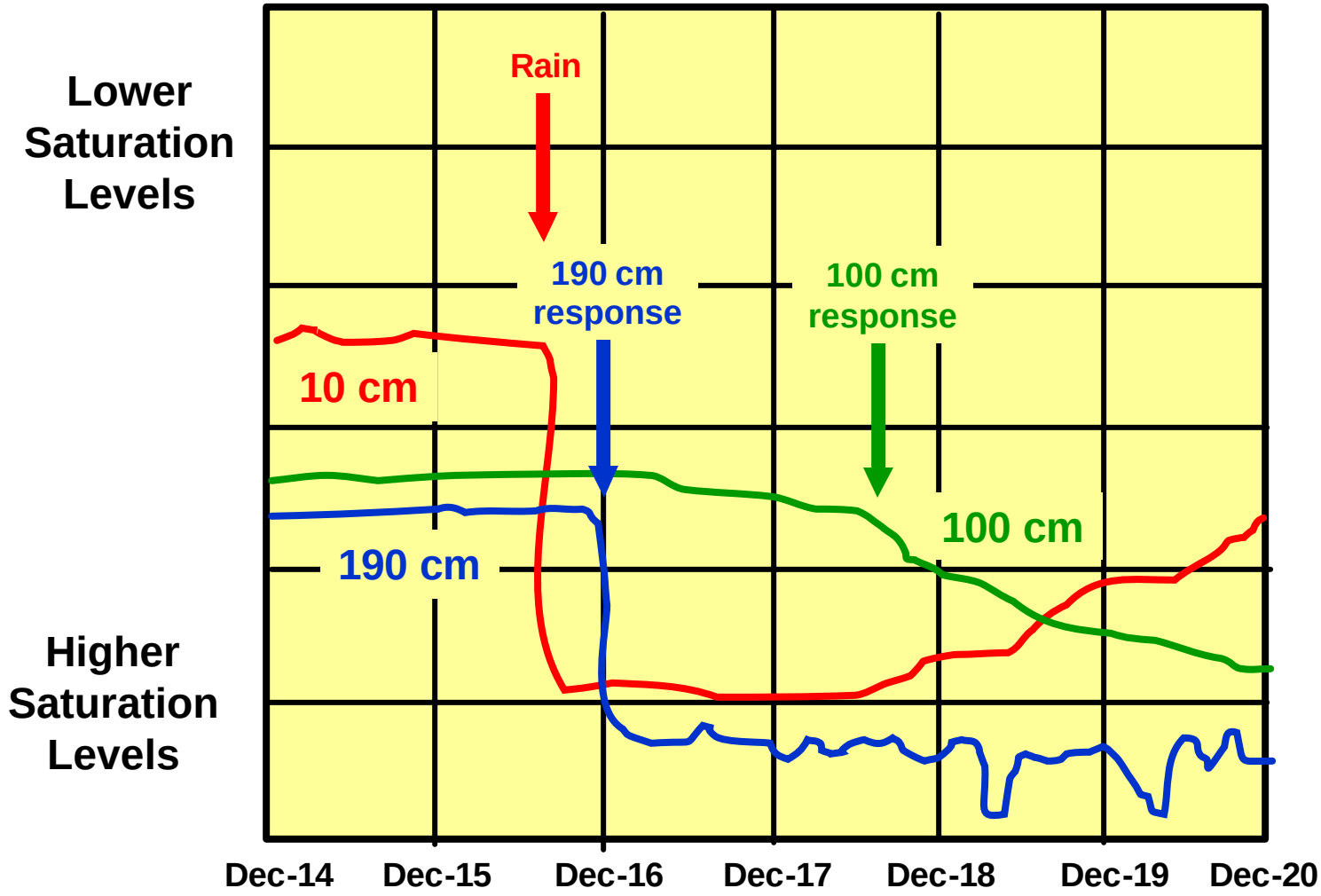
"Designing the Right Size Flower Pots"



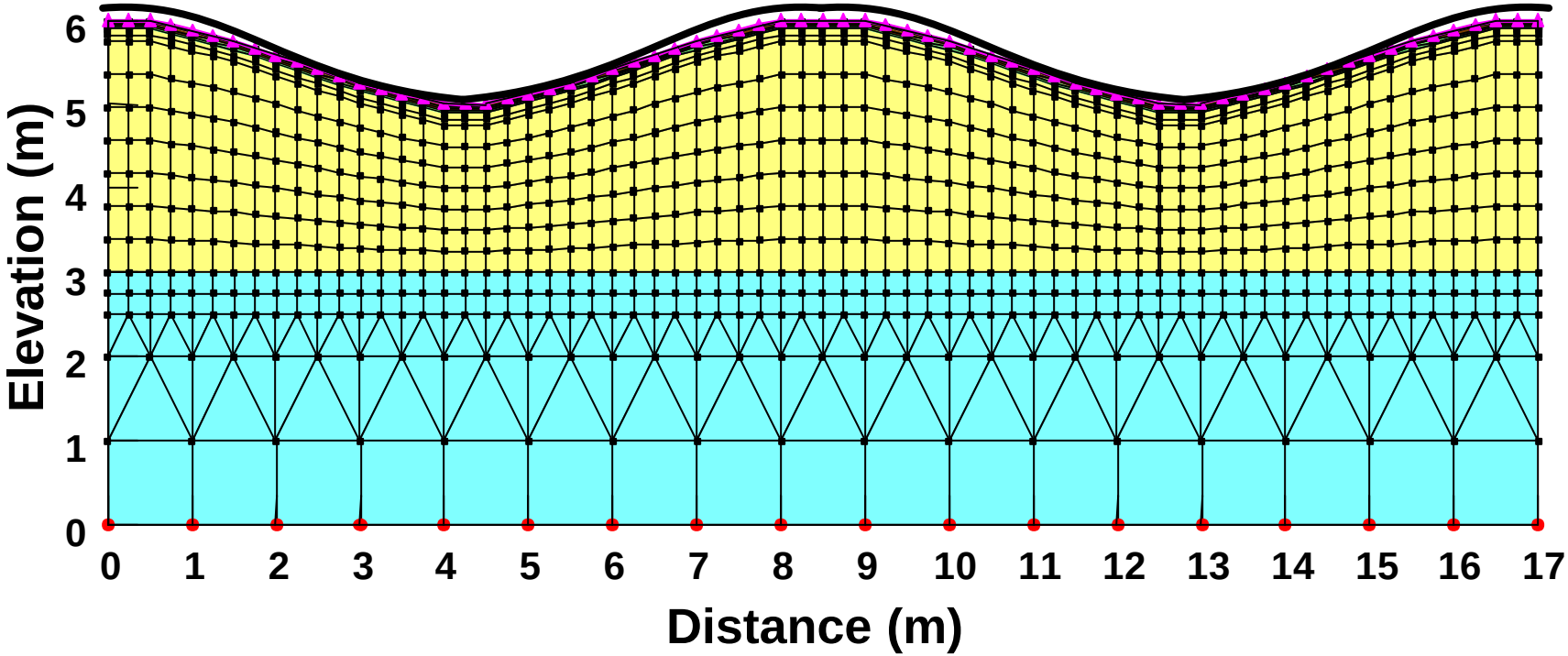
Calibrated Model
With Vegetation
("poor" to 1m)
2 m BIF = 0%

See References for Conceptual Modelling Presentation Idea

Evidence of "Macro-Pore" Flow due to Segregation of Material



Evaluation of Hypothesis Using Numerical Modelling



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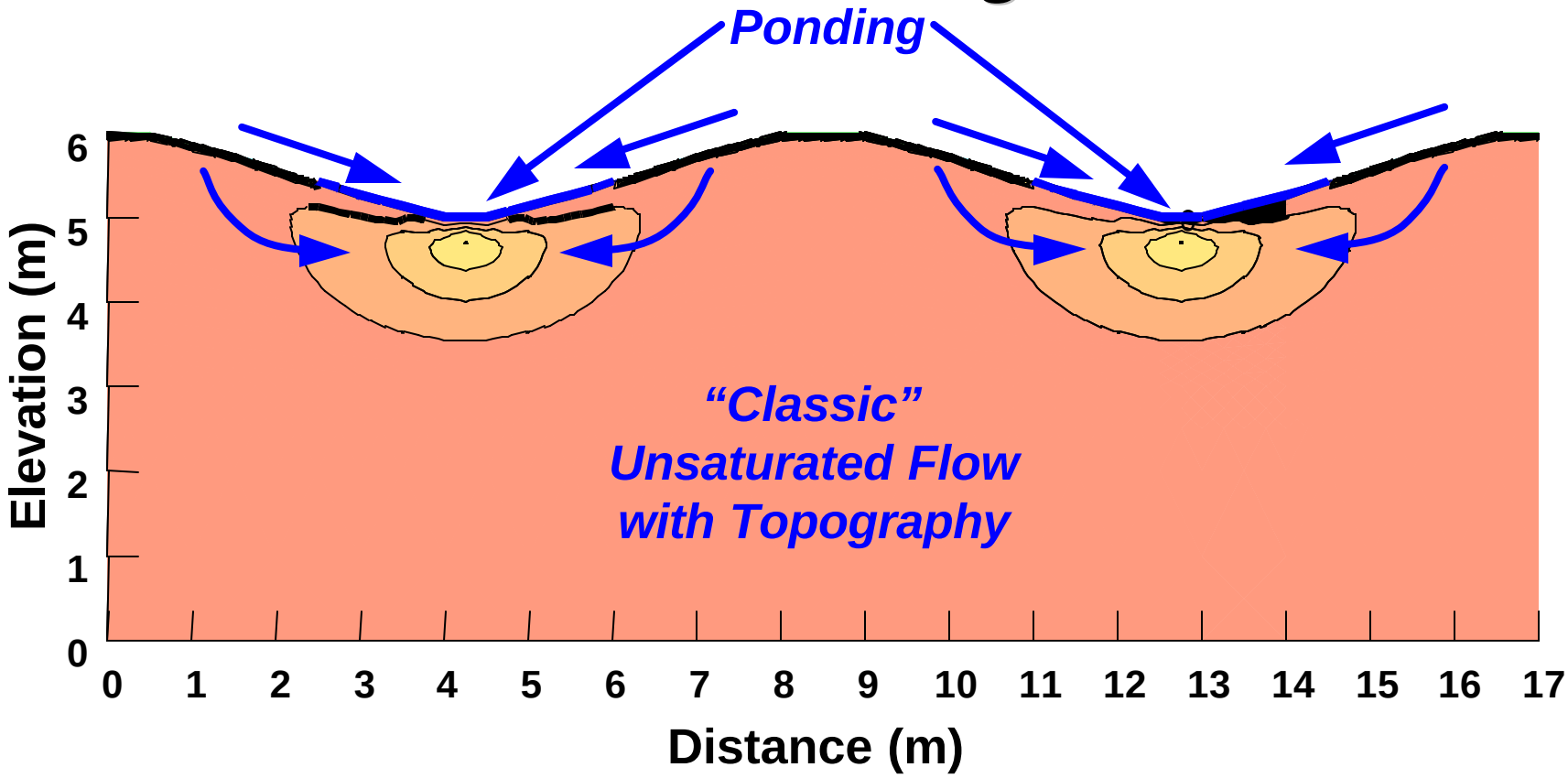

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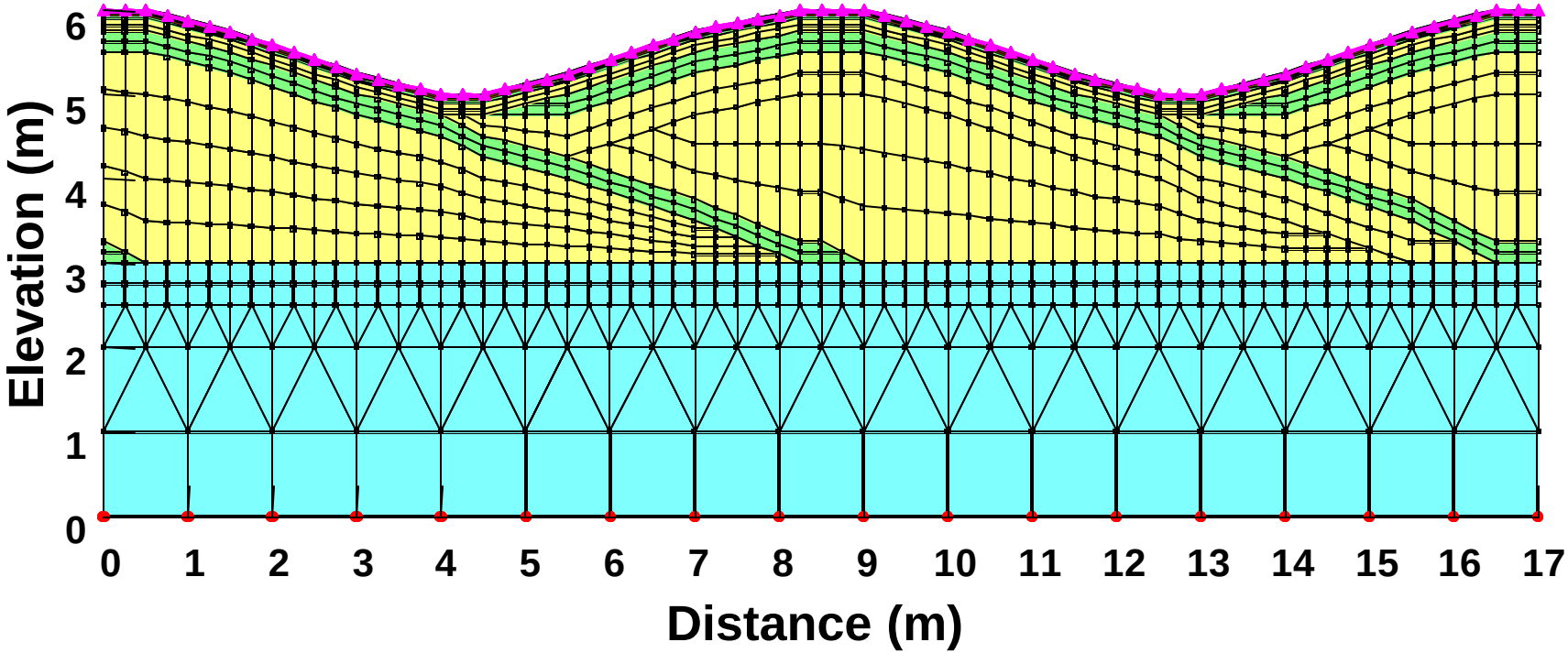

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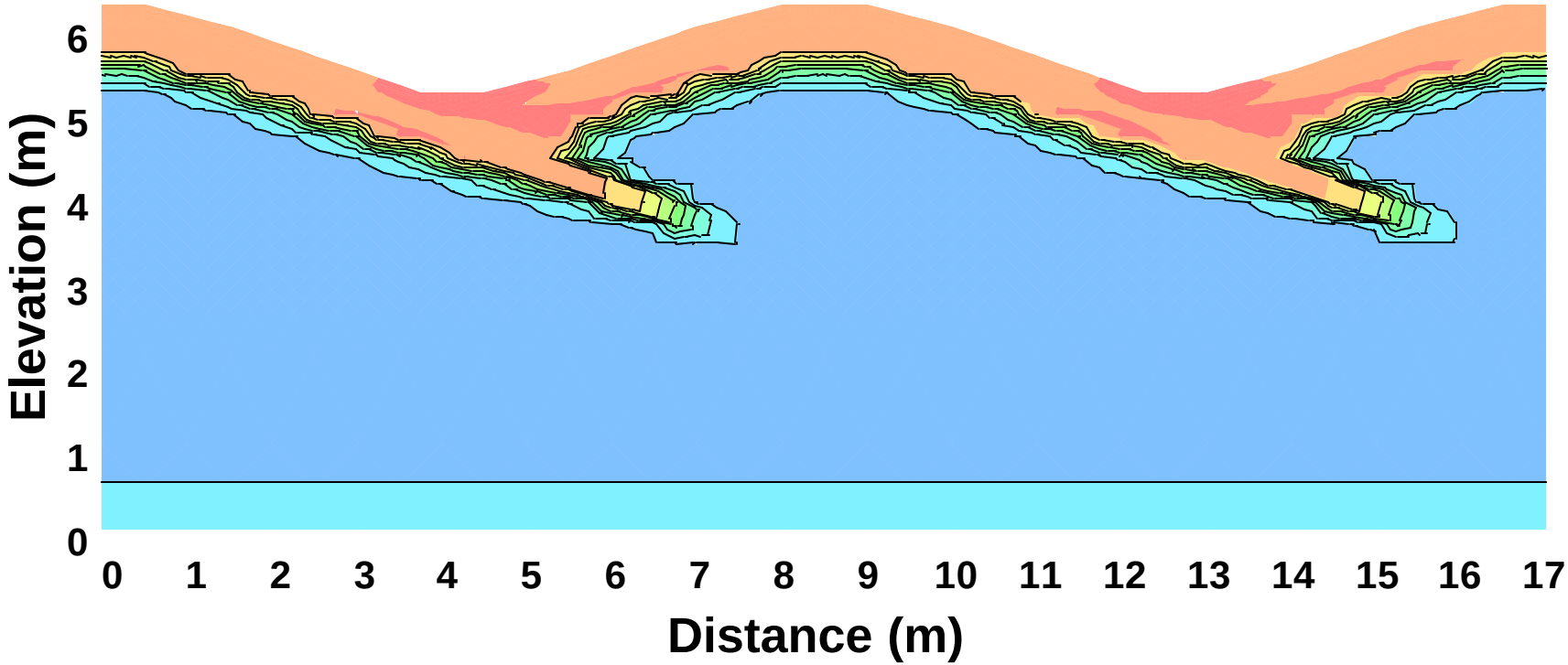

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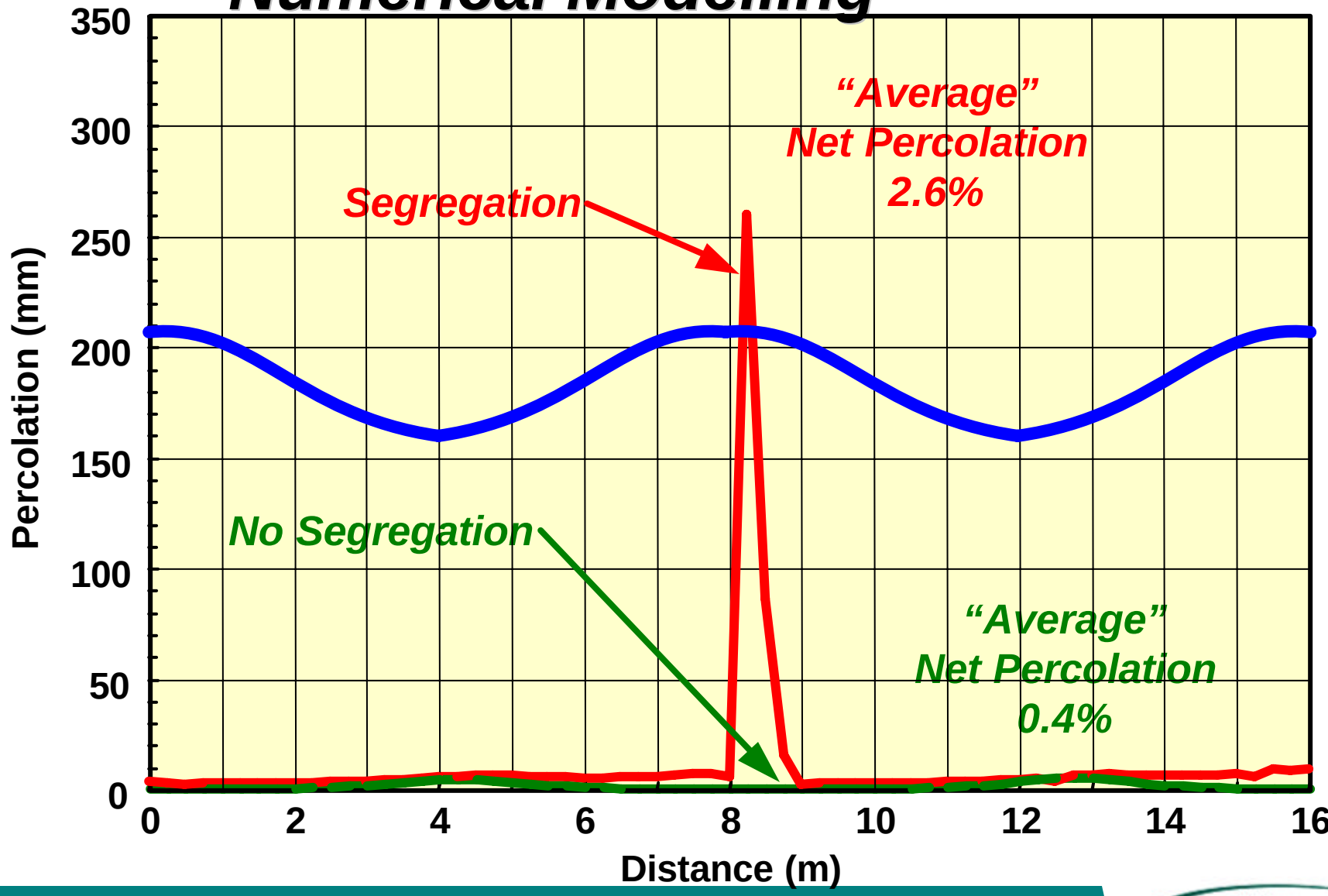


Lessons Learned

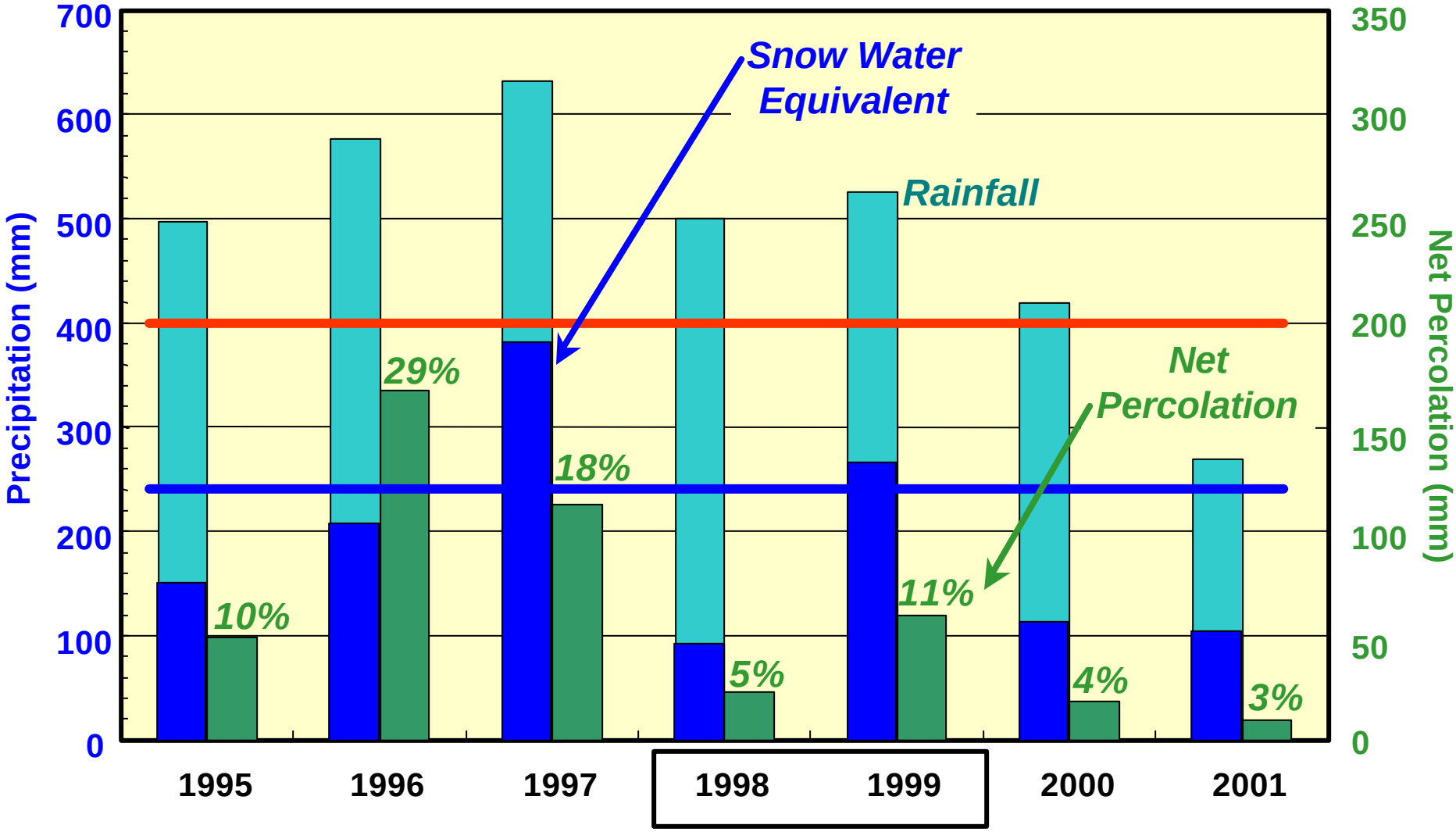
- *2 m* Run-of-Mine: *6%* Net Percolation Over Last Six Years
  - *Segregation:* Material Placement is Critical (Homogeneous)
  - *Sloping* Surface Reduces Net Percolation to *< 1%*
- Return *to Antecedent Moisture* Conditions Requires *Transpiration* to Remove Deeper Infiltration
- *Native Species* Transpiration Rates?

Seasonally Arid Site - Canada

- Site can be characterized on an annual basis as arid to semi-arid
- Site experiences hot dry summers

- Humid fall and winter
- Spring freshet contributes significantly to flow in surface drainage courses

Case Study One – Climate

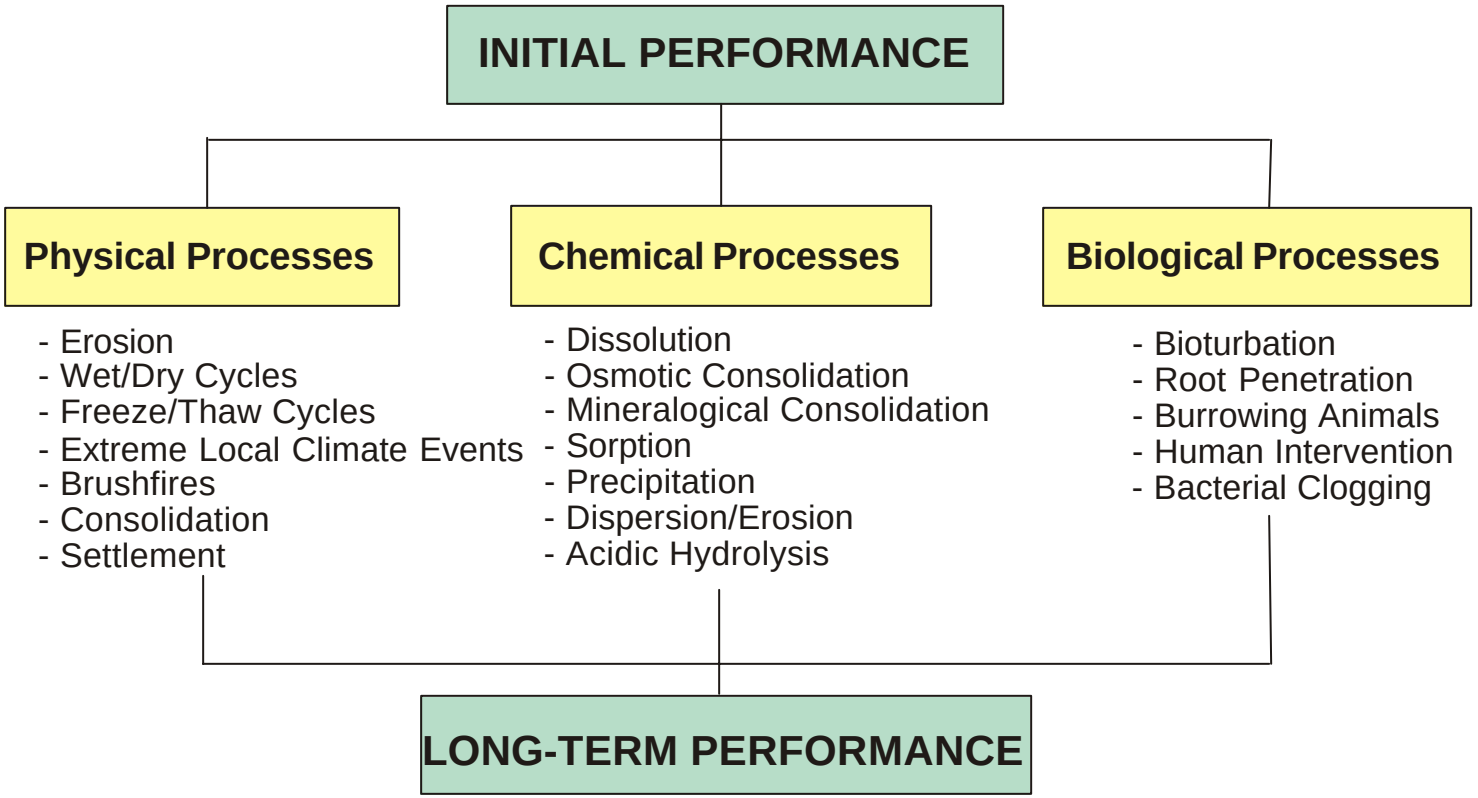


Lessons Learned

- **For Sites that Typically Experience Seasonal Snowfall**
  - **There is no "Average" Annual Performance**
  - **Clearly Obvious, but is often "Lost" in the Detail of Predicting Performance with a Model**

- **Characterization of Snow Water Equivalent**
  - *Critical to Understanding Field Performance*
- **Time of PPT. Strongly Influences Performance**
  - *precipitation contributing to snowpack…..increase in net percolation*
  - *summer precipitation…..buffered by presence of till (store and release)*

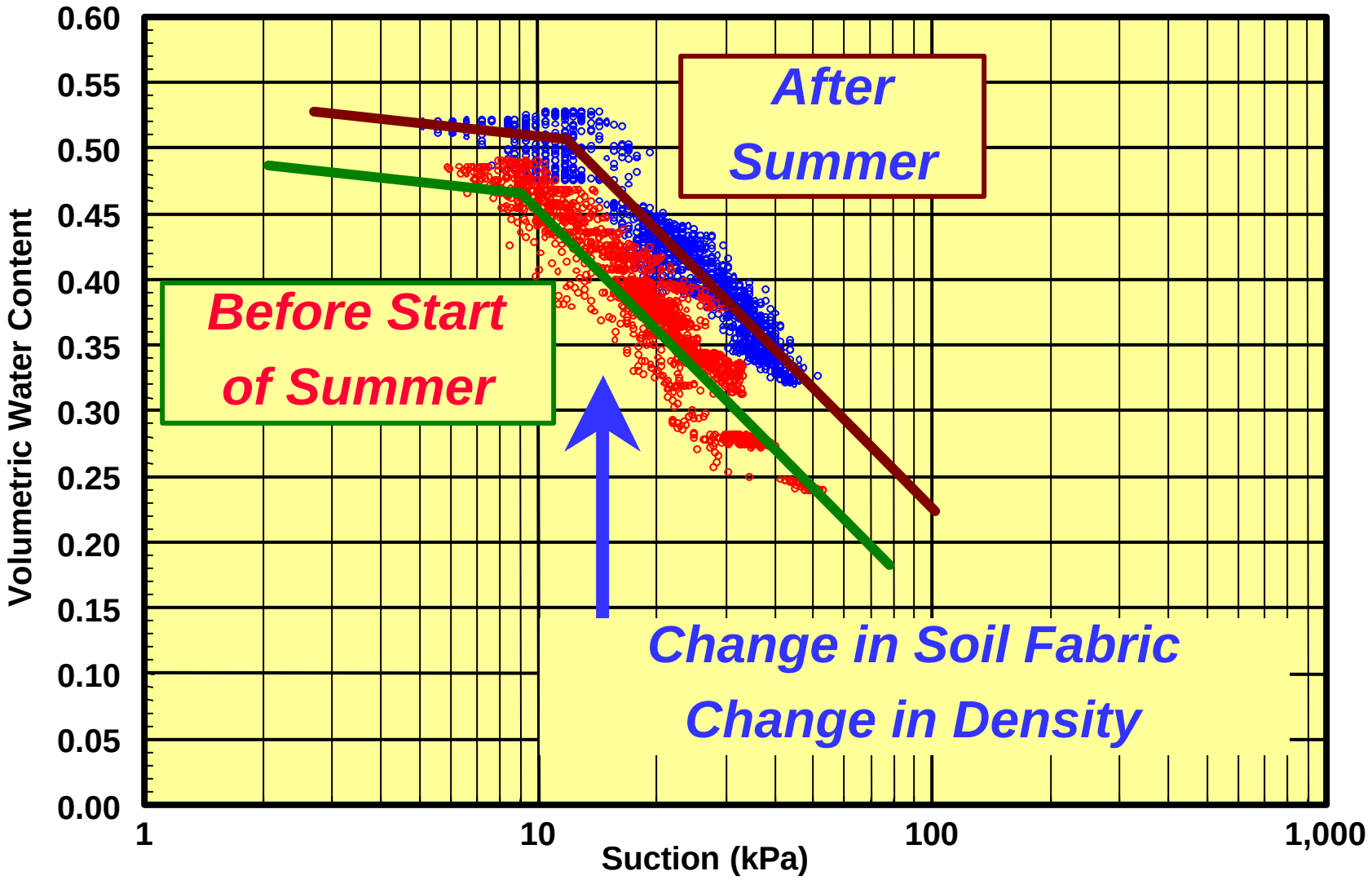
Long-Term Performance



Resulting In:

- ***Change in Field Hydraulic Conductivity***
- ***Change in Moisture Retention Characteristics***
- ***Change in Oxygen Diffusion Characteristics***
- ***Change in Physical Integrity of Cover System***

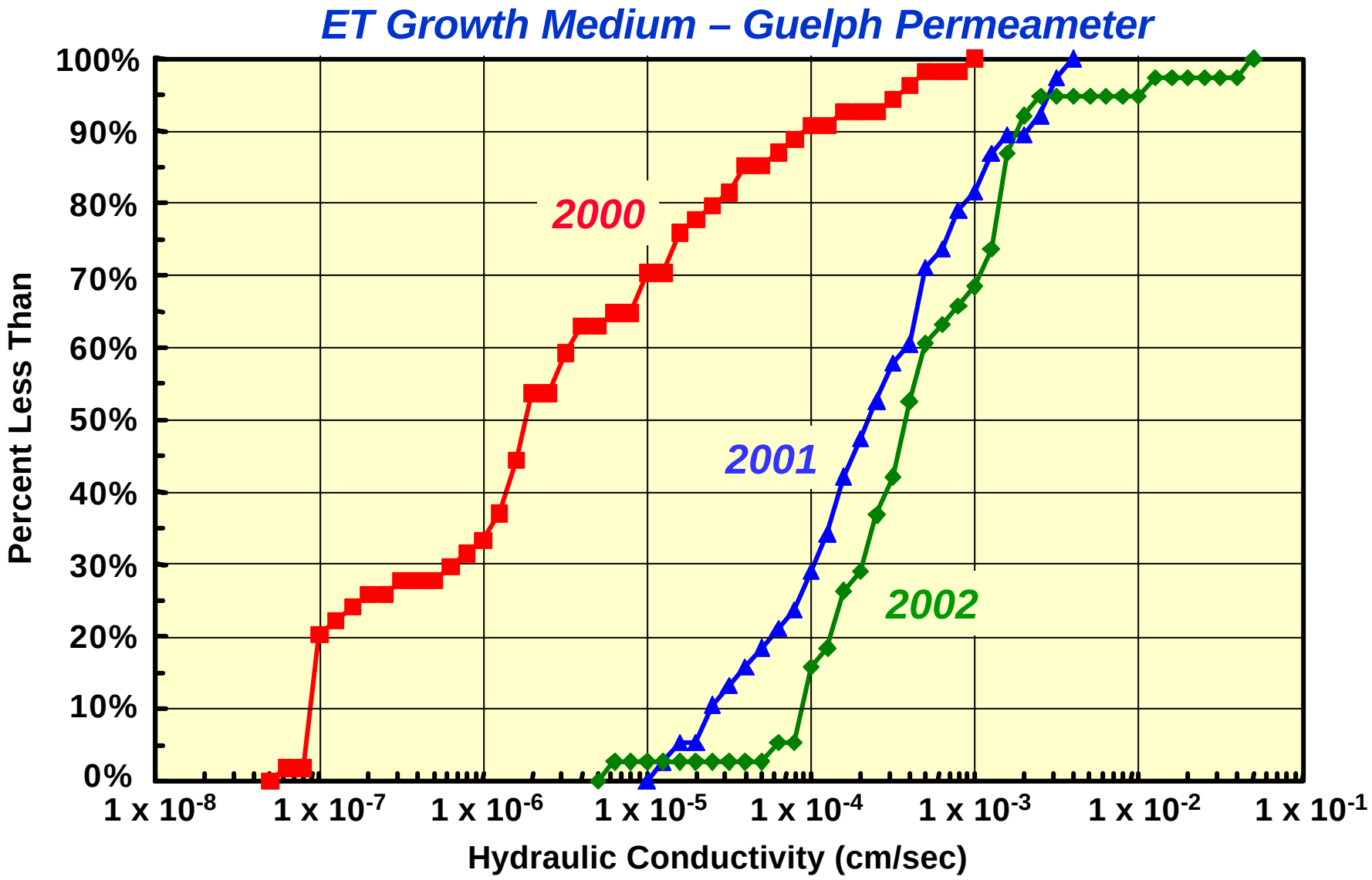
Evolution of Key Mat'l Properties



In Situ Hydraulic Conductivity

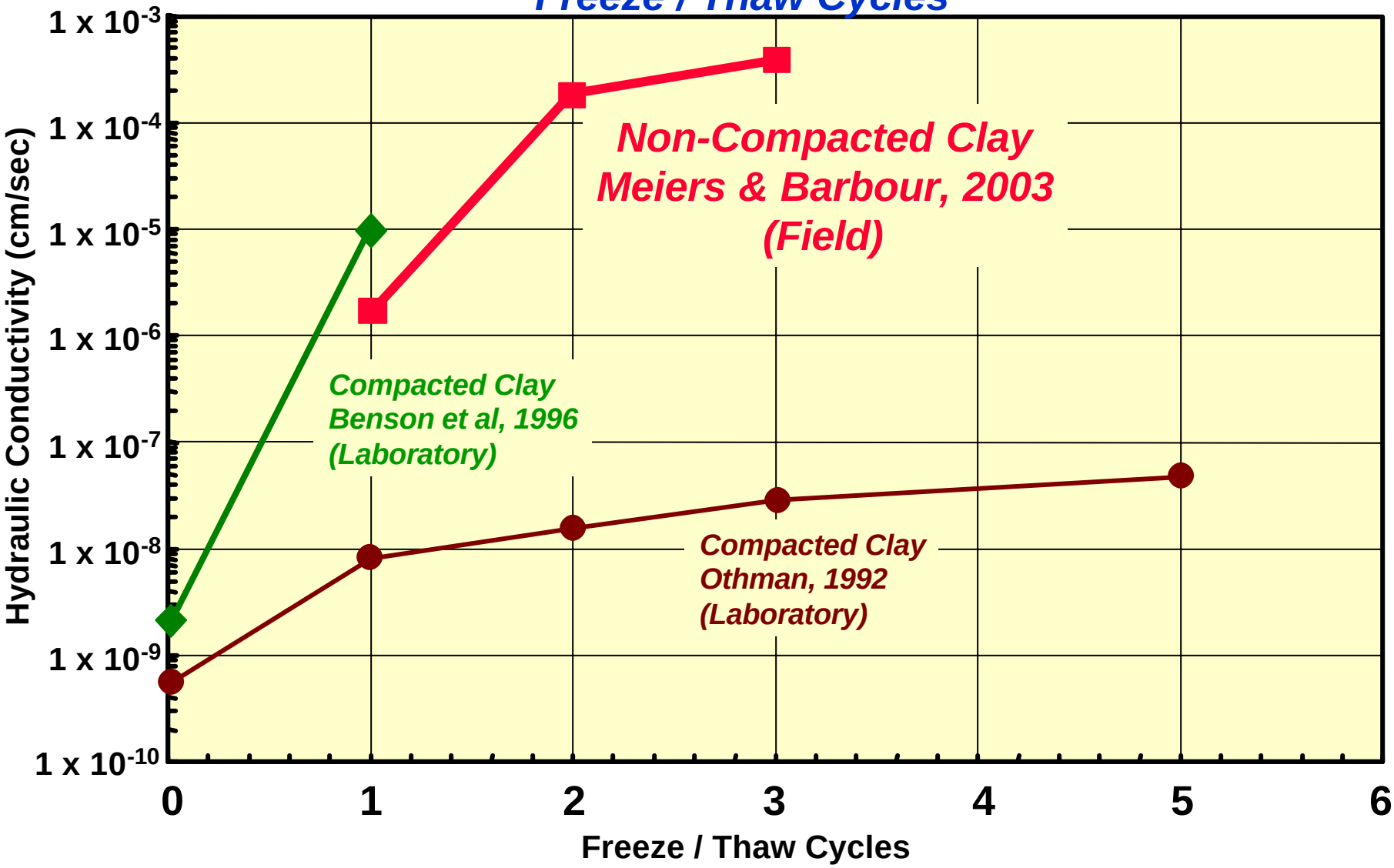
Direct Measurement Guelph Permeameter and Tension Infiltrometer

Field K_{fs} – Growth Medium



Field K_{fs} – Growth Medium

Freeze / Thaw Cycles



Longevity of Cover Systems - Lessons Learned

- ***Physical / Chemical / Biological Processes***
- ***In Situ* Performance Monitoring**
  - ***SWCC / K_{sat} / O_2 diff. / Physical Integrity***
  - ***Paramount for Understanding the Processes Controlling Long-Term Performance***
  - ***In Situ K-tests as a Surrogate for Evaluating Impact of Processes***

References

- ***For Arid-Tropical Site in Australia***
  - *O'Kane, M. and Waters, P., 2003. Dry Cover Trials at Mt Whaleback – A Summary of Overburden Storage Area Cover System Performance. Paper presented at the 6th International Conference for Acid Rock Drainage, Cairns, Qld., Australia, July 2003.(available at www.okane-consultants.com)*
  - *International Network for Acid Prevention (INAP), 2003. Evaluation of the Long-Term Performance of Dry Cover Systems. Report # 684-02 prepared by O'Kane Consultants Inc., March 2003. (available at www.inap.com.au)*
- ***For Seasonally Arid Site in Canada***
  - *O'Kane, M., Gardiner, R.T., and Ryland, L., 1999. Field Performance Monitoring of the Kimberley Operations Siliceous Tailings Test Plots. In Proceedings of the Tailings and Mine Waste Conference, Fort Collins, Colorado, January 24 – 27, 1999, pp. 23-33. (available at www.okane-consultants.com)*
  - *International Network for Acid Prevention (INAP), 2003. Evaluation of the Long-Term Performance of Dry Cover Systems. Report # 684-02 prepared by O'Kane Consultants Inc., March 2003. (available at www.inap.com.au)*
- ***For Lysimeter Design***
  - *Bews, B.E., O'Kane, M., Wilson, G.W., Barbour, S.L., and Currey, N., 1997. The Design of a Low Flux Cover System, Including Lysimeters, for Acid Generating Waste Rock in Semi-Arid Environments. Fourth International Conference on Acid Rock Drainage, Vancouver, B.C., May 31-June 6, 1997, pp. 747-762.*
  - *O'Kane, M. and Barbour, S.L., 2003. Field Performance of Lysimeters used to Evaluate Cover Systems for Mine Waste. Paper presented at the 6th International Conference for Acid Rock Drainage, Cairns, Qld., Australia, July 2003 . (available at www.okane-consultants.com)*

References (continued)

- **For Long-Term Performance Discussion**
  - *International Network for Acid Prevention (INAP), 2003. Evaluation of the Long-Term Performance of Dry Cover Systems. Report # 684-02 prepared by O'Kane Consultants Inc., March 2003. (available at www.inap.com.au)*
  - *Meiers, G.P., Barbour, S.L., and Meiers, M.K., 2003. The use of Field Measurements of Hydraulic Conductivity to Characterize the Performance of Reclamation Soil Covers with Time. In Proceedings of the International Conference on Acid Rock Drainage, July 2003, Cairns, Qld., Australia. (contact Dr. Lee Barbour at lee.barbour@usask.ca or Greg Meiers at gmeiers@okc-sk.com)*
  - *Meiers, G.P. 2002. The use of Field Measurements of Hydraulic Conductivity to Characterize the Performance of Reclamation Soil Covers with Time. M.Eng. Thesis, Division of Environmental Engineering, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.*
- **For Conceptual Cover System Data Presentation Methodology (Flower Pot)**
  - *Barbour, S.L., 2003. Characterization and Prediction of the Performance of Reclaimed Watersheds on Sodic Waste from Oil Sands Mining, Syncrude Canada Ltd. Watershed Monitoring Group Meeting, Canmore, AB., Canada, October 2003.*