



The GARD Guide: Status Report to BC MEND ARD/ML Workshop

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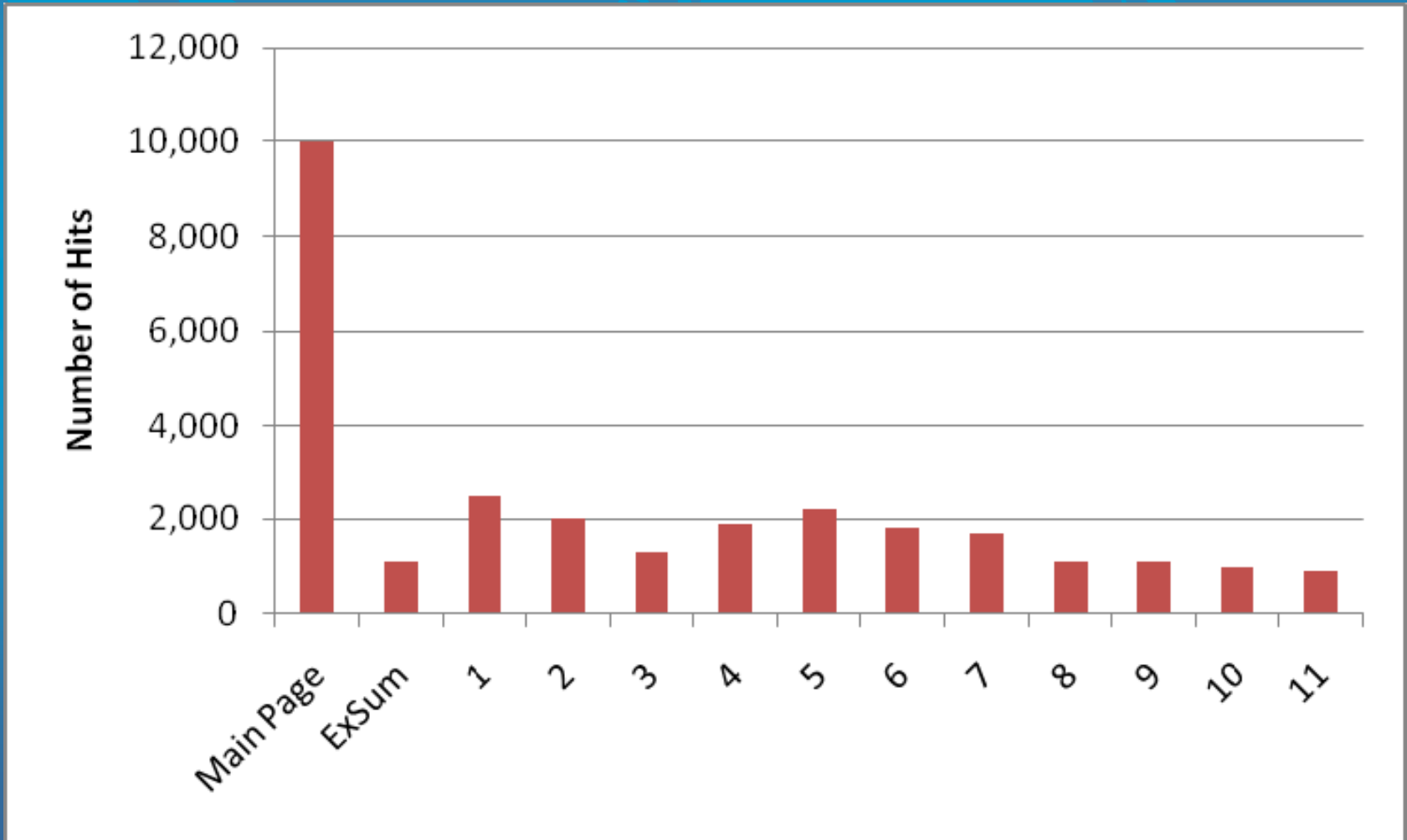
Vancouver, British Columbia

Summary of Effort



- Two year project:
 - >120 hours - conference calls
 - >3,000 emails
 - > 2,500 man hours
 - 30 key contributors across multiple time zones
 - engaged >200 stakeholders across 5 continents
 - 3 versions of the GARD Guide
 - on schedule and
 - on budget!

GARD Guide Usage





Frequently-Asked Questions

- Where can I find the GARD Guide?
- How do I contribute?
- Hard copy?
- Spanish translation?
- Plans for periodic updates?
- Request for presentations

6.0 Prevention and Mitigation



6.1 Introduction

6.2 Goals and Objectives of Prevention and Mitigation

6.3 Approach to Acid Rock Drainage Prevention and Mitigation

6.4 Drivers of Acid Rock Drainage

6.4.1 Physical Factors

6.4.2 Geochemical Weathering Processes

6.4.3 Climate and Physical Environment

6.5 Phased Approach

6.6 Overview of Best Practice Methods

6.6.1 Avoidance

6.6.2 Re-mining

6.6.3 Special Handling Methods

6.6.4 Additions and Amendment Methods

6.6.5 Water Management Methods

Reduction of Surface Infiltration

6.6.6 Liners

6.6.7 Dry Cover Methods

6.6.8 Water Cover Methods

6.7 Secondary Impacts

6.8 Selection and Evaluation of Alternatives

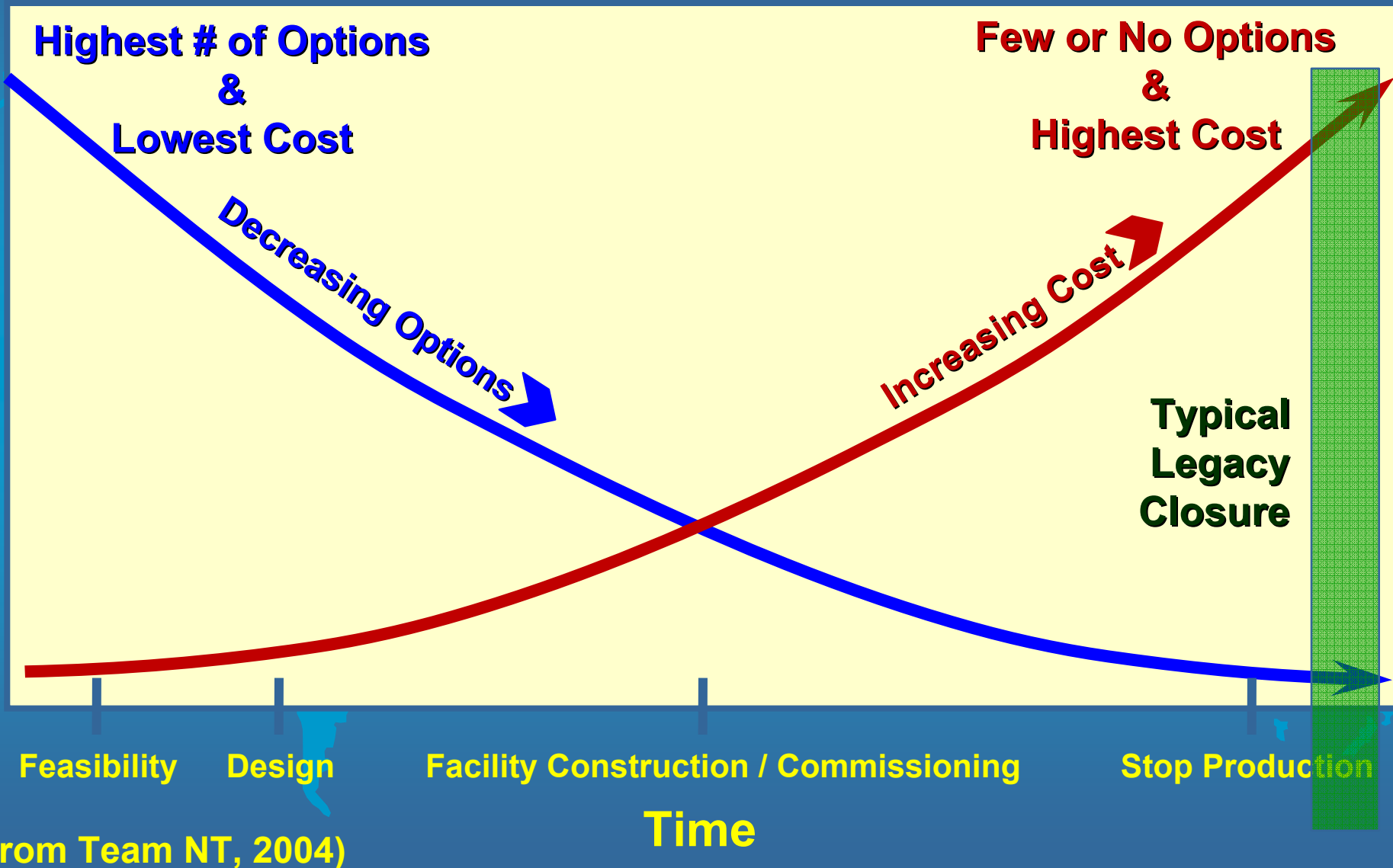
6.9 Design and Construction Considerations

6.10 Maintenance and Monitoring Considerations

6.11 References



Options and Cost with Time



Closure Technologies



● Cover Systems:

- One of Numerous Remediation Technologies

- Avoidance
- Re-Mining
- Special Handling
- Additions and Amendment
- Water Management
- Covers (wet and soil covers)
- Collection and Treatment (in situ, passive, active)

No Universal Solution

- Site Specific
- Will typically require a Combination of Technologies

What is a Cover System?



- **Placement of a Layer, or Layers, of Material on the Waste Surface**

- Native Materials (clay, silt, sand, etc.)
 - Engineering Materials (plastics, geotextiles, etc.)
 - Mining Materials (suitable (benign) run-of-mine waste)
- **Simple**
 - One to Two Layers
 - **Complex**
 - Multi-layer



What is a Cover System?



Purpose:

● Short Term:

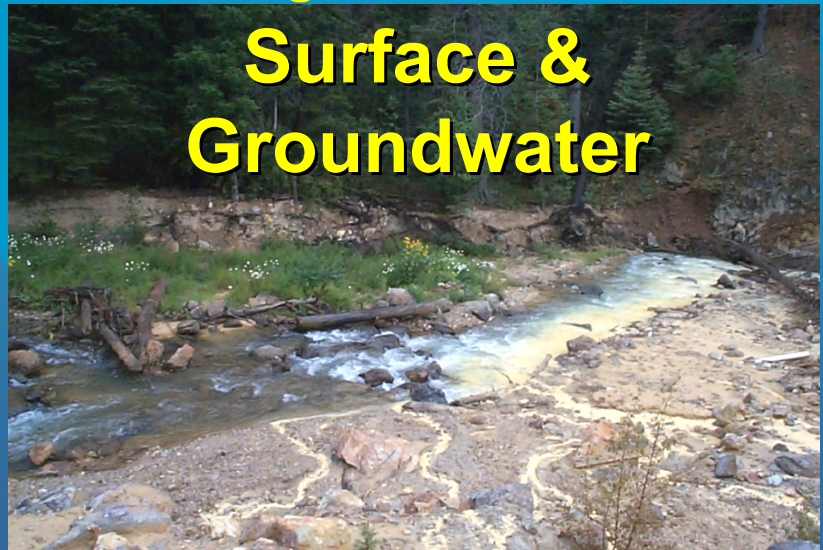
- Minimize Further Degradation of the Receiving Environment

● Long Term:

- Facilitate Recovery of the Receiving Environment

- Medium for Establishing Sustainable Vegetation
- Redevelop Landscape to Equivalent Capability

Surface & Groundwater



Purpose and Design Objectives



Objectives

- Control the ingress of oxygen
 - High saturation layer
- Control water infiltration
 - Low permeability layer
 - Store and release of moisture

Additional Objectives

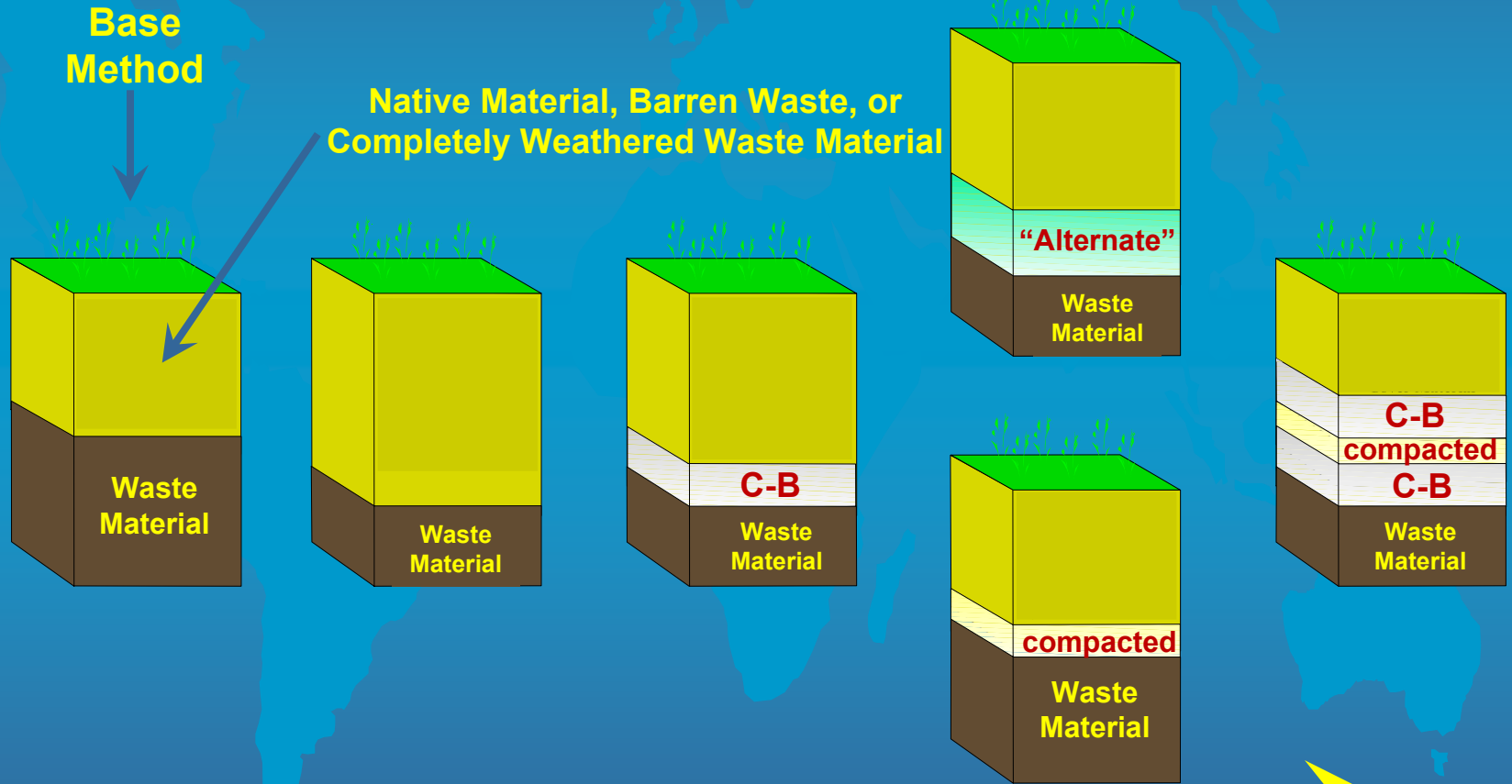
- Control of consolidation and differential settlement
- Reduce dust emissions
- Prevent physical weathering
- O₂ consumption
- Upward capillary movement



Cover System Alternatives

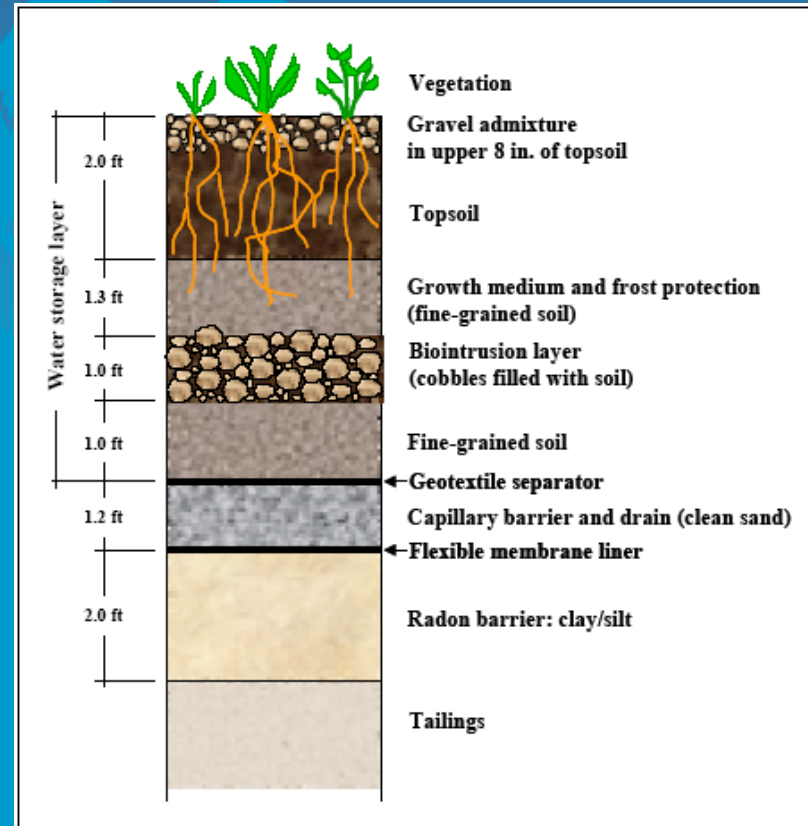
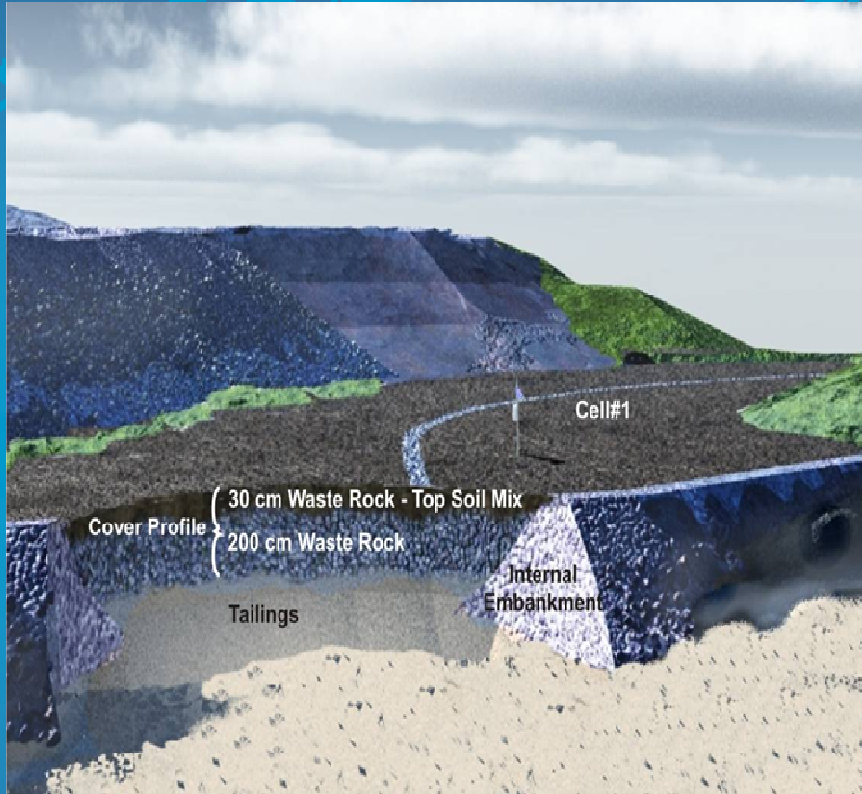
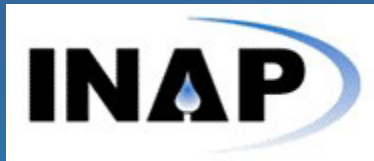


Variations on the Base Method



Increasing Complexity
Increasing Performance???
Increasing Cost

Cover System Alternatives



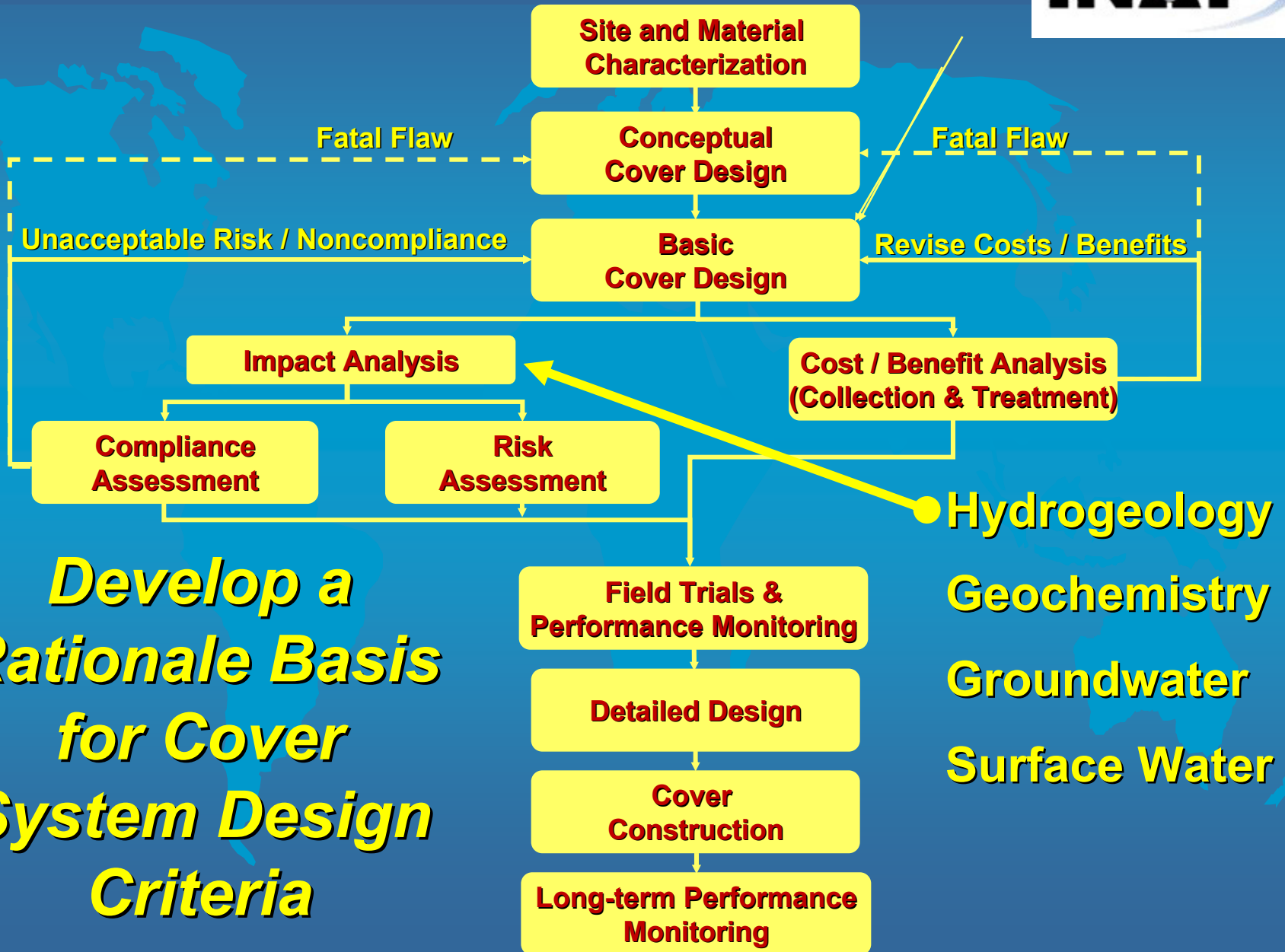
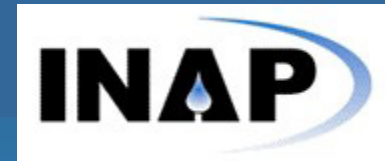
Simple

- Two Layers (~2.3m)
- Thick Growth Medium

Very Complex

- Nine Layers (~2.3m)
- Thinner Growth Medium

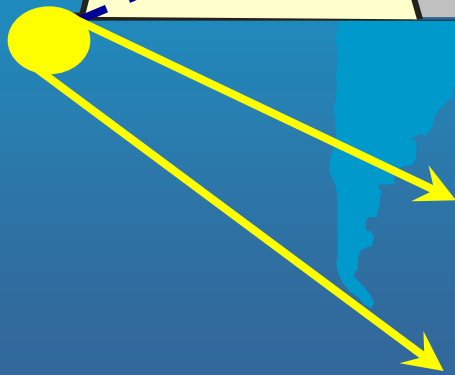
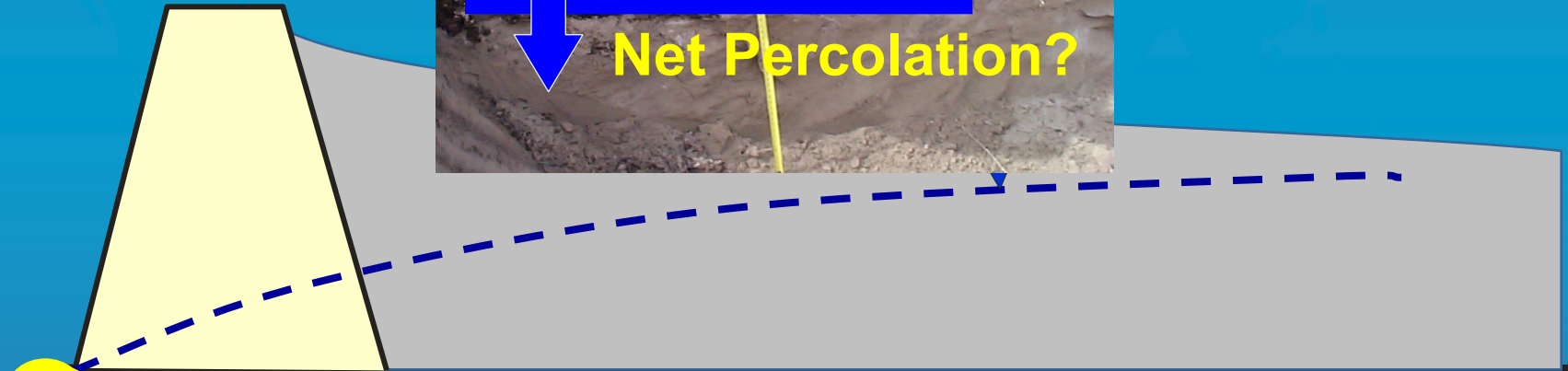
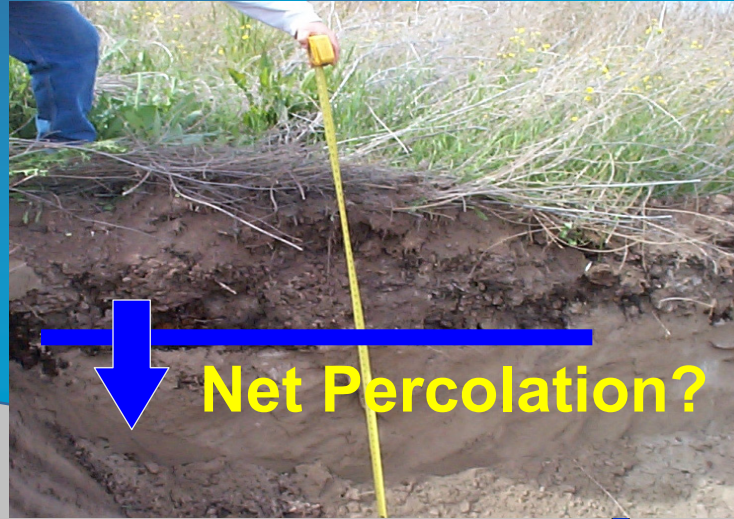
Closure Criteria



Develop a Rationale Basis for Cover System Design Criteria

- Hydrogeology
- Geochemistry
- Groundwater
- Surface Water

Cover System Design Criteria?



- Seepage Water Quality
 - Compliance
 - Risk
 - Collection / Treatment

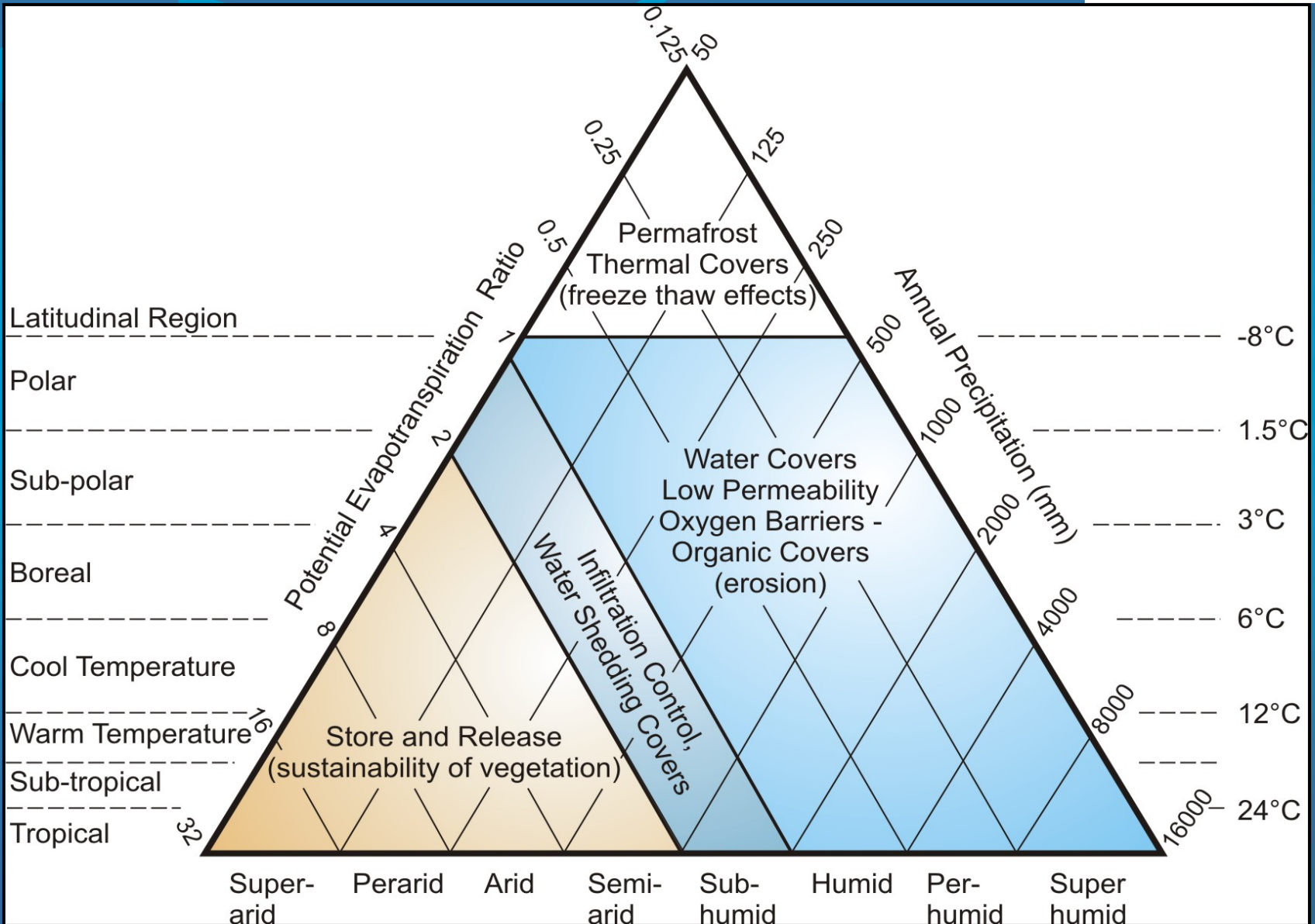
Design Factors



- Factors that control the economic and technical feasibility of a cover system for a particular site include, but are certainly not limited to:
 - Site climate conditions
 - Availability of cover material(s) and distance to borrow source(s)
 - Cover and waste material properties and conditions
 - Surface topography
 - Soil and waste material evolution
 - Vegetation conditions
 - Geomorphological considerations



Climate



Influence of Climate Conditions



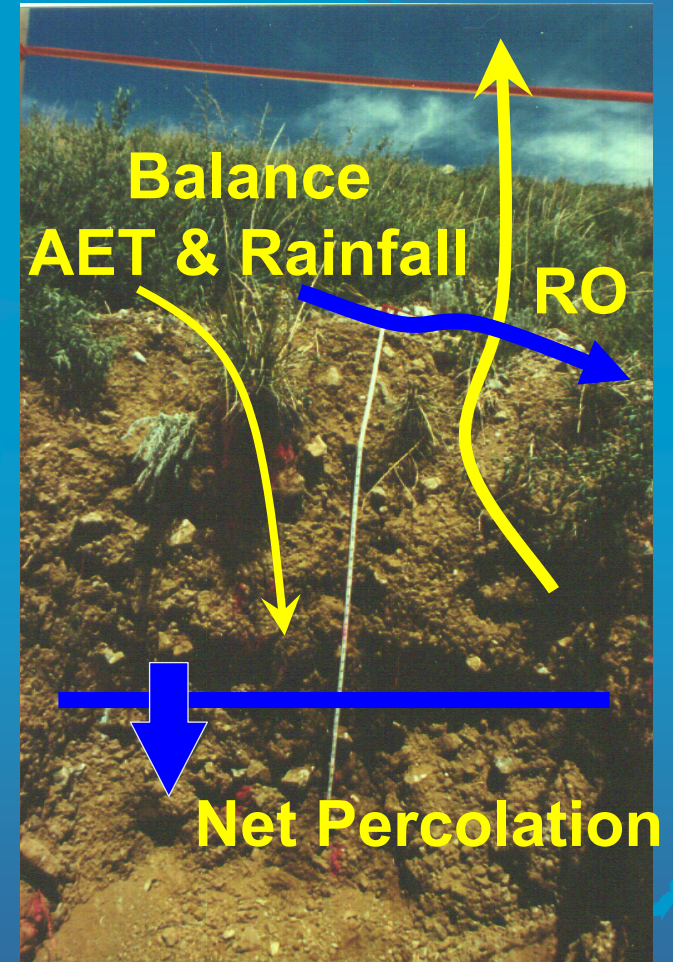
“Humid” Site



“Blanket of Water”
& Low Permeability

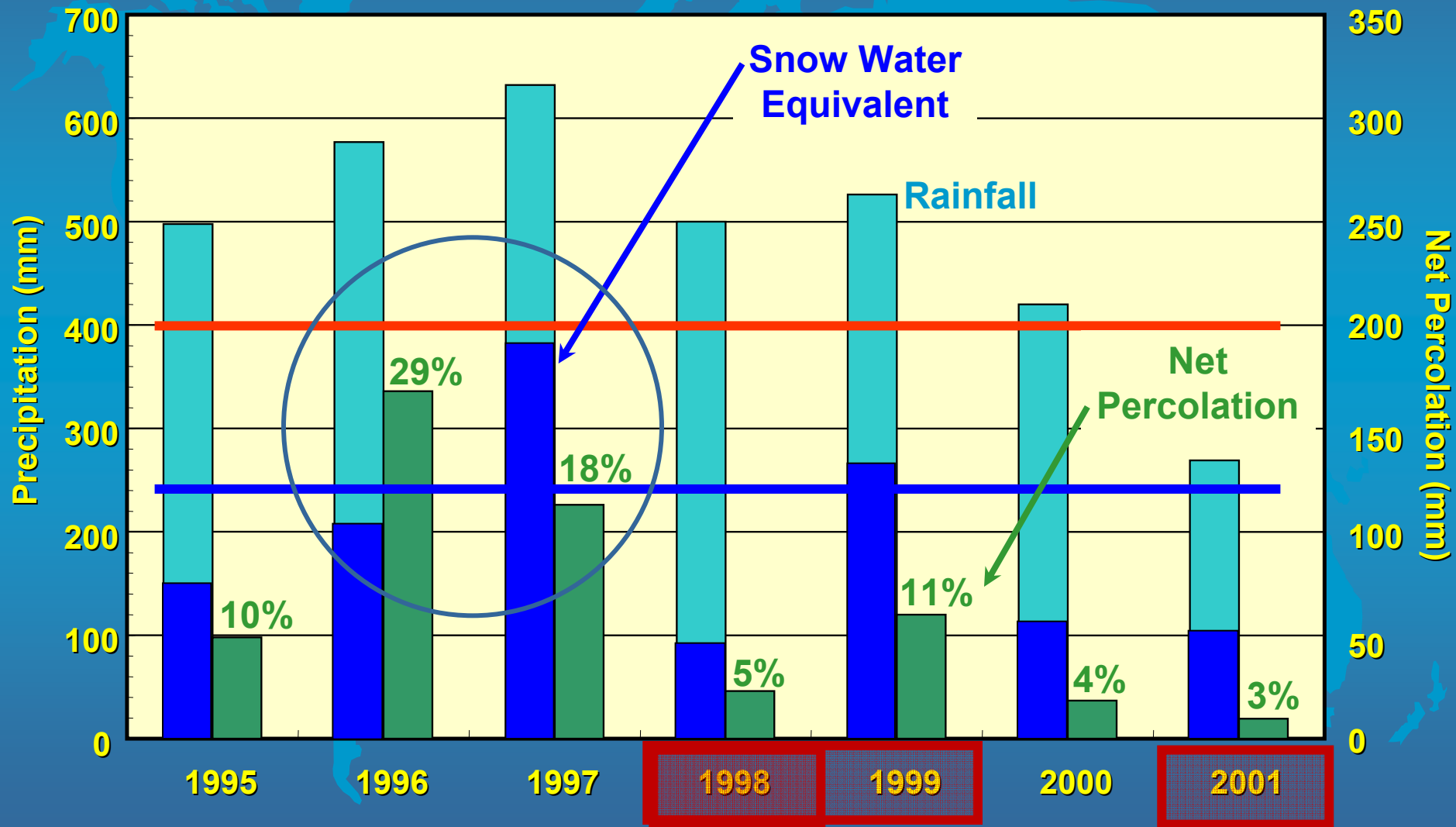
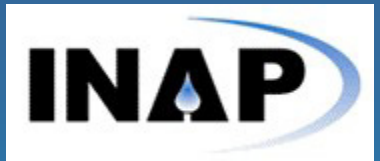
**Typical Climate Conditions?
Here Lies our Challenge**

“Arid” Site

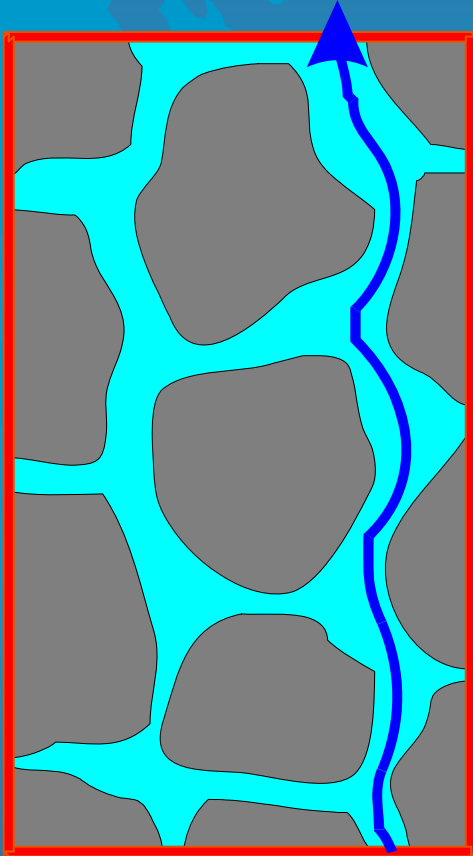


“Store and
Release”

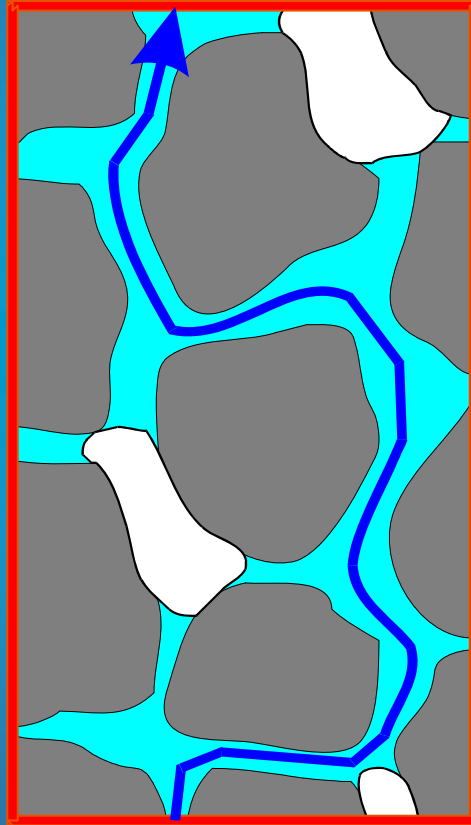
Representative Climate Year?



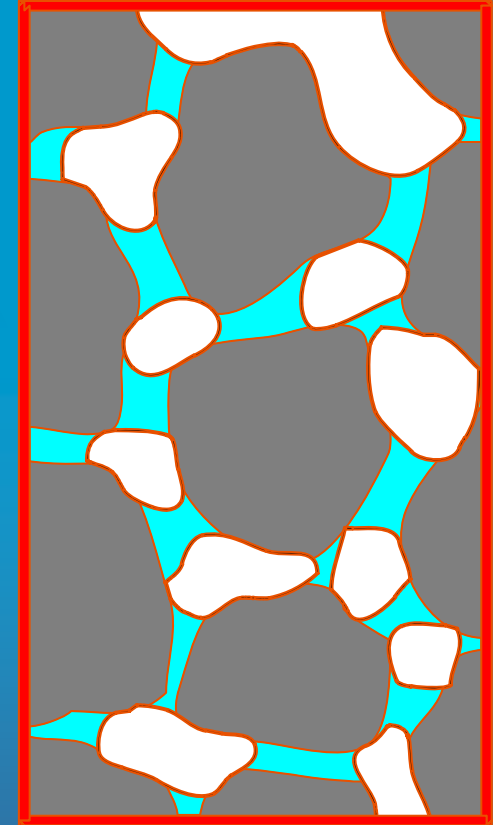
Degree of Saturation



$$S = 1$$

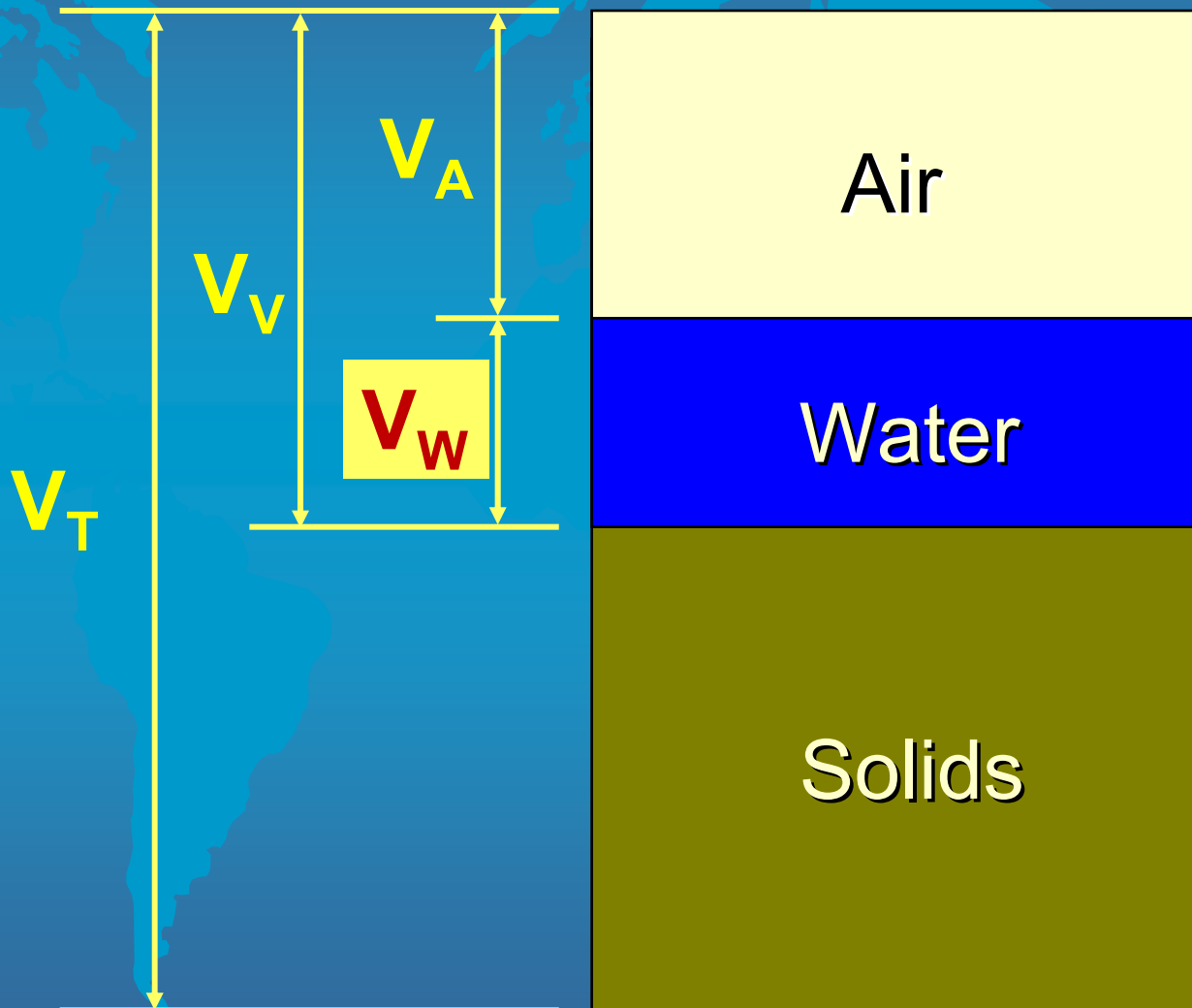


$$1 > S > S_r$$



$$S = S_r$$

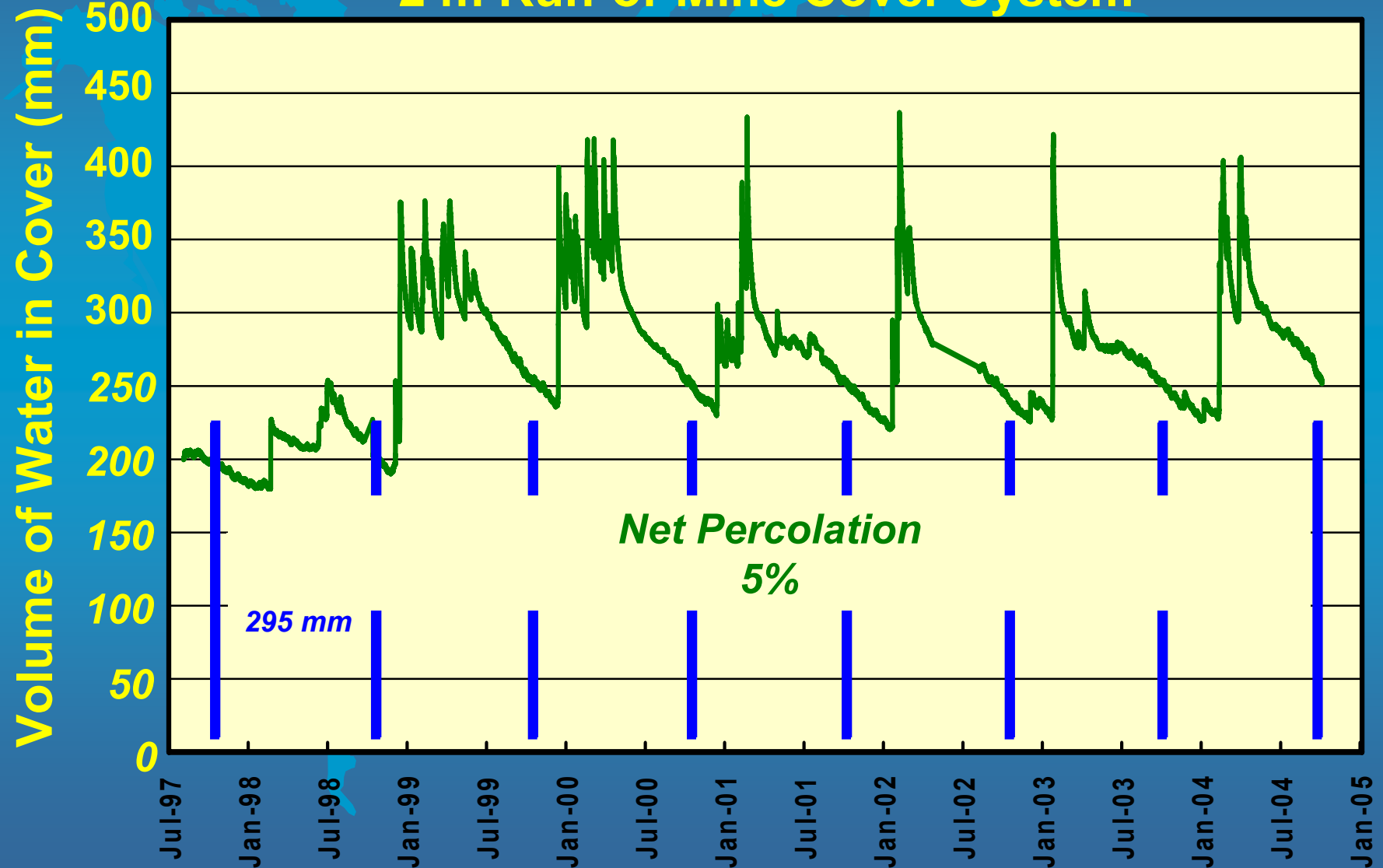
Volume of Water



Volume of Water in Profile



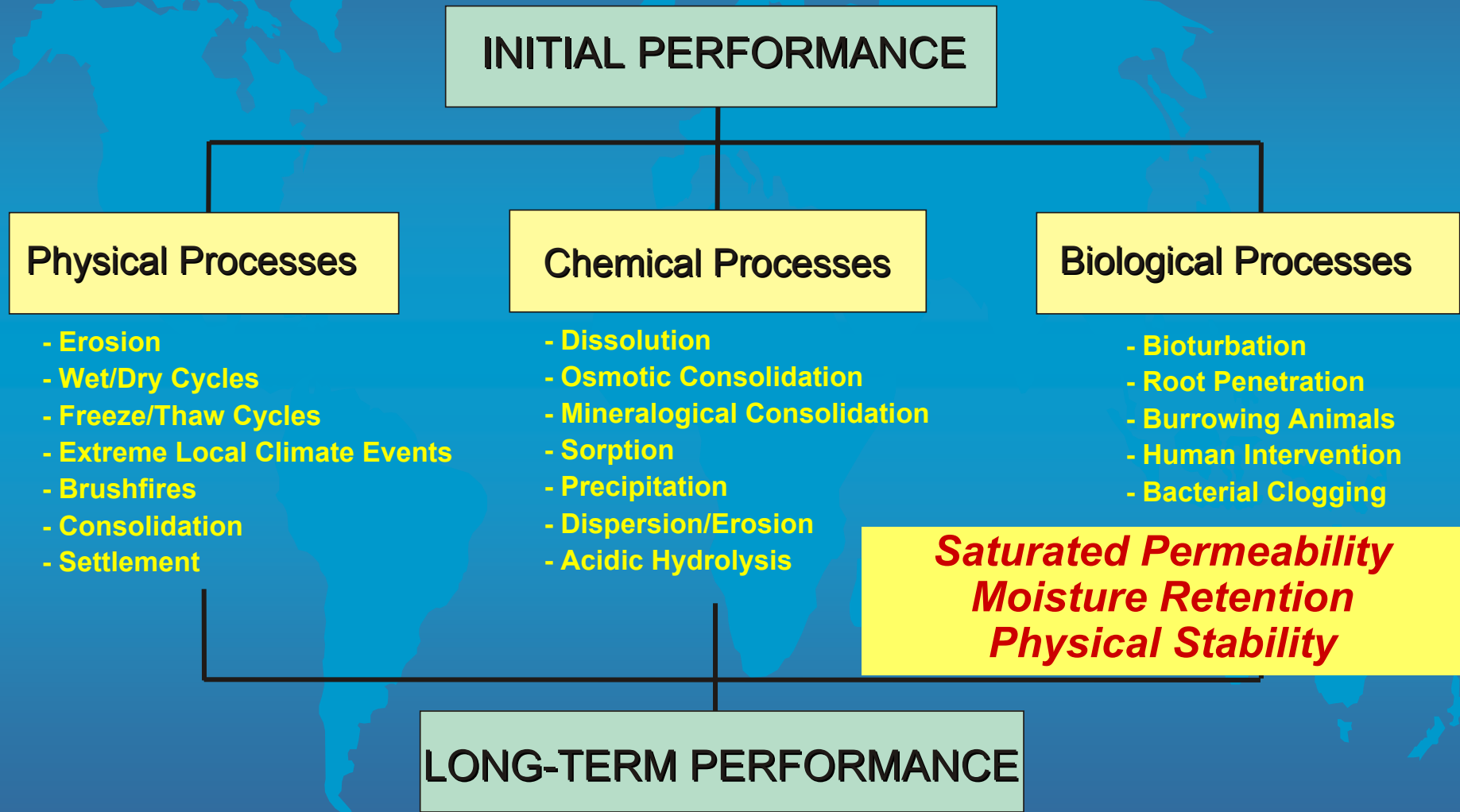
2 m Run-of-Mine Cover System



Vegetation



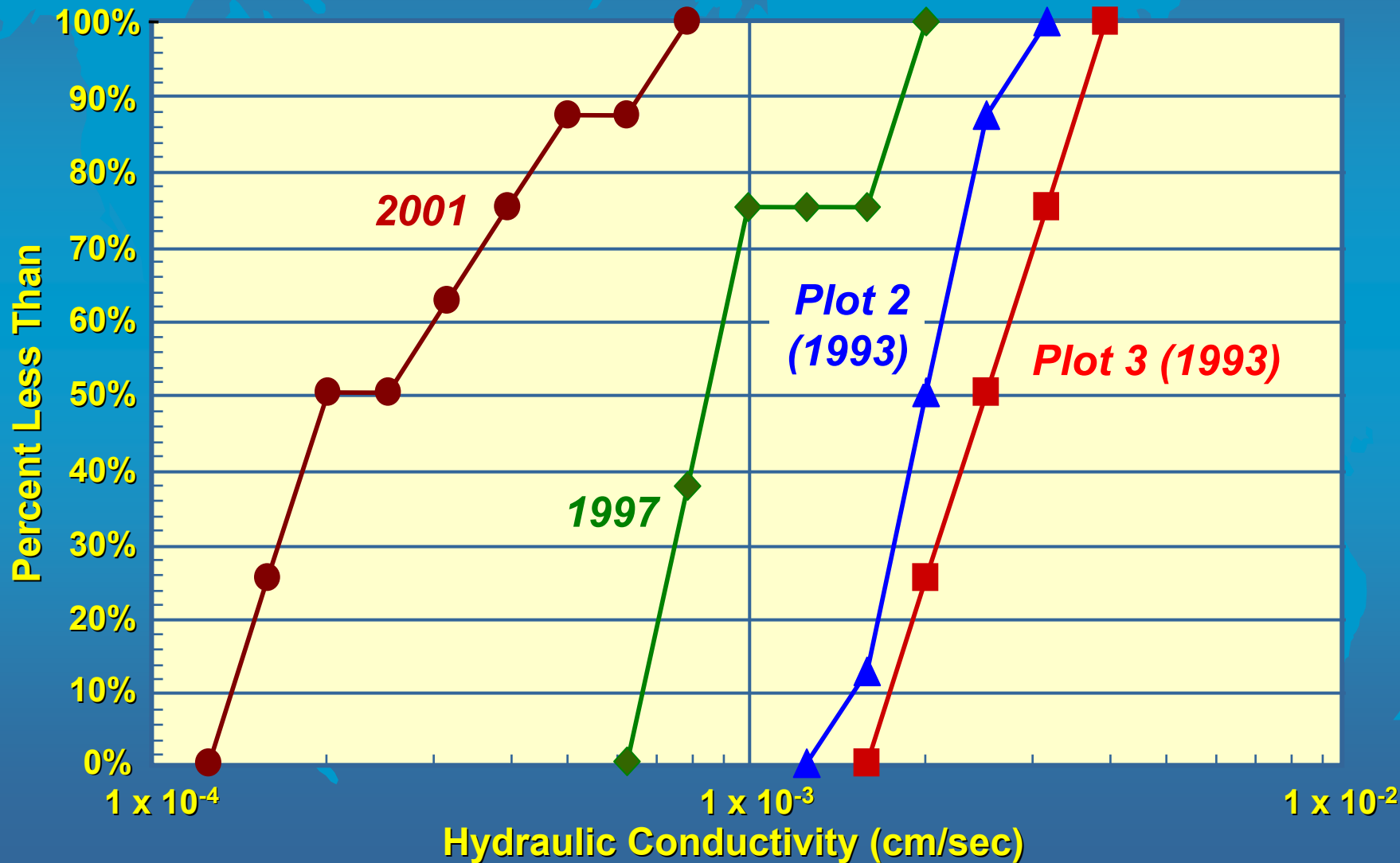
Long Term Performance



Change in Field k_{fs}



Overlying Growth Medium – Guelph Permeameter

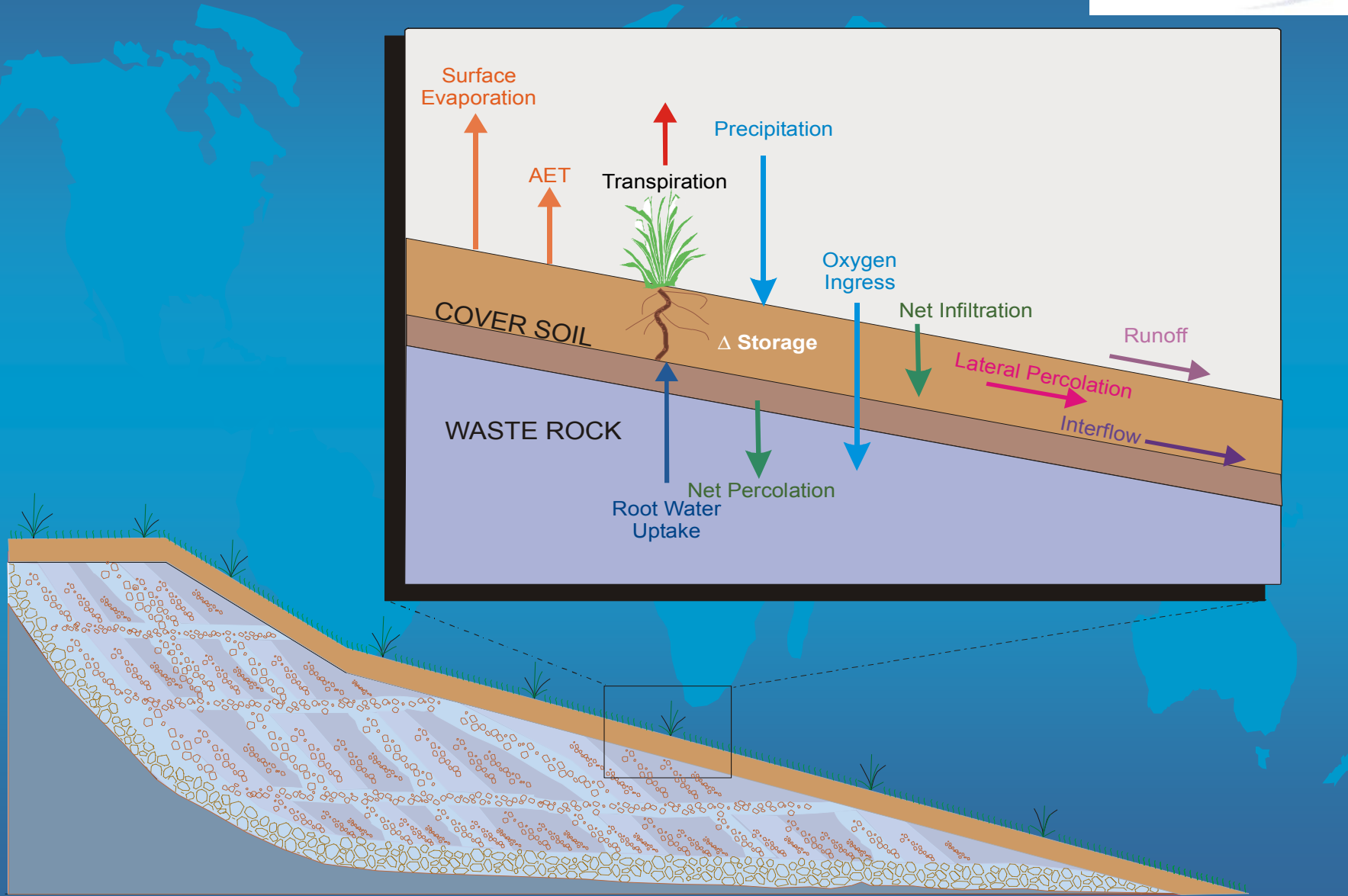


Landform Design



- **High Performance Expectations for Reclaimed Mine Landscapes**
- **Traditional Reclamation Methods:**
 - Sufficient to provide reasonable assurance of meeting stated goals and objectives?
- **Landscape Design is:**
 - A more holistic approach to mine reclamation and closure that encompasses many disciplines in a more structured approach
 - Surface water hydrology, soft tailings reclamation, design and monitoring of cover systems

Performance Monitoring (Direct)

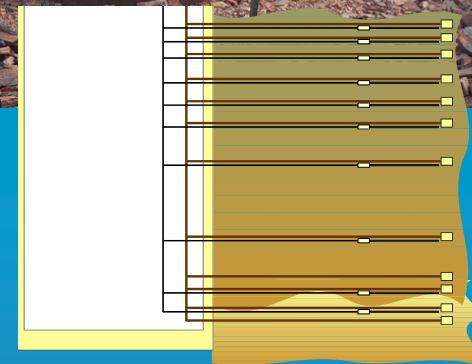
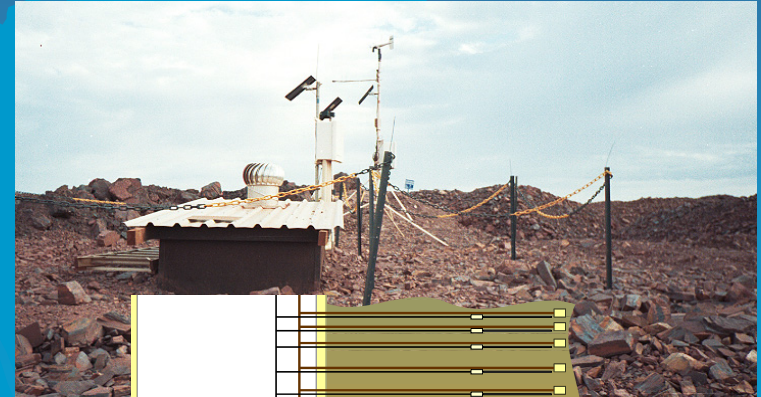


Rationale for Field Monitoring (and Trials)



- Objectives:

- Develop understanding for key processes and characteristics that control performance
- Identify practical construction and implementation issues
- Develop database to calibrate numerical model
- Develop credibility with respect to closure performance



- Should not be viewed as indicative of long-term performance
- “Snapshot” in time

Surface Runoff Monitoring?

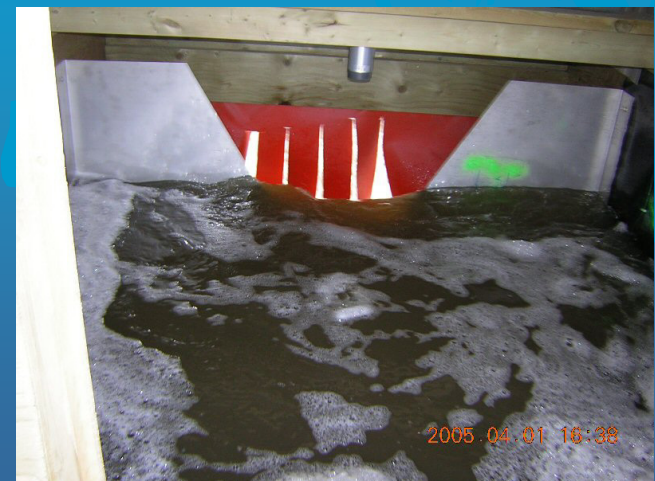


- Conceptually simple ...
 - Very challenging to implement properly
 - Requires manual intervention

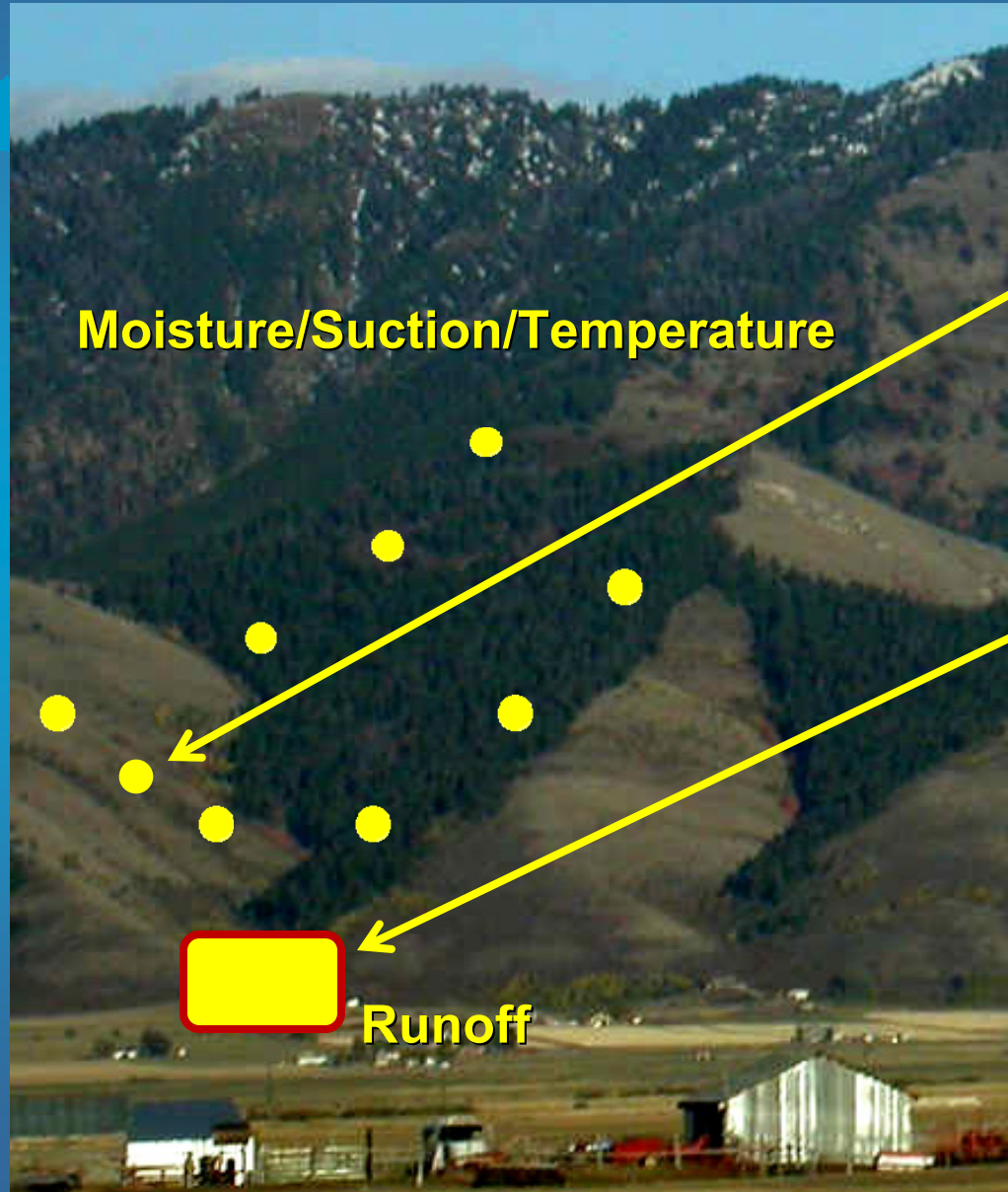
Measuring Net Percolation?



- Direct Measurement
 - Lysimeters
- Hydraulic Gradient
 - Suction sensors
- Change in moisture storage
 - Water balance
- Pore-water Conditions
 - Isotopic analysis
 - Salts
- Numerical modelling
 - Calibrate to changes in
 - Water table
 - Near surface conditions



Scale?



Moisture/Suction/Temperature

Micro-Scale

Macro-Scale

Runoff



Thank You!