Design, Construction, and Performance Monitoring of Cover Systems for Waste Rock and Tailings

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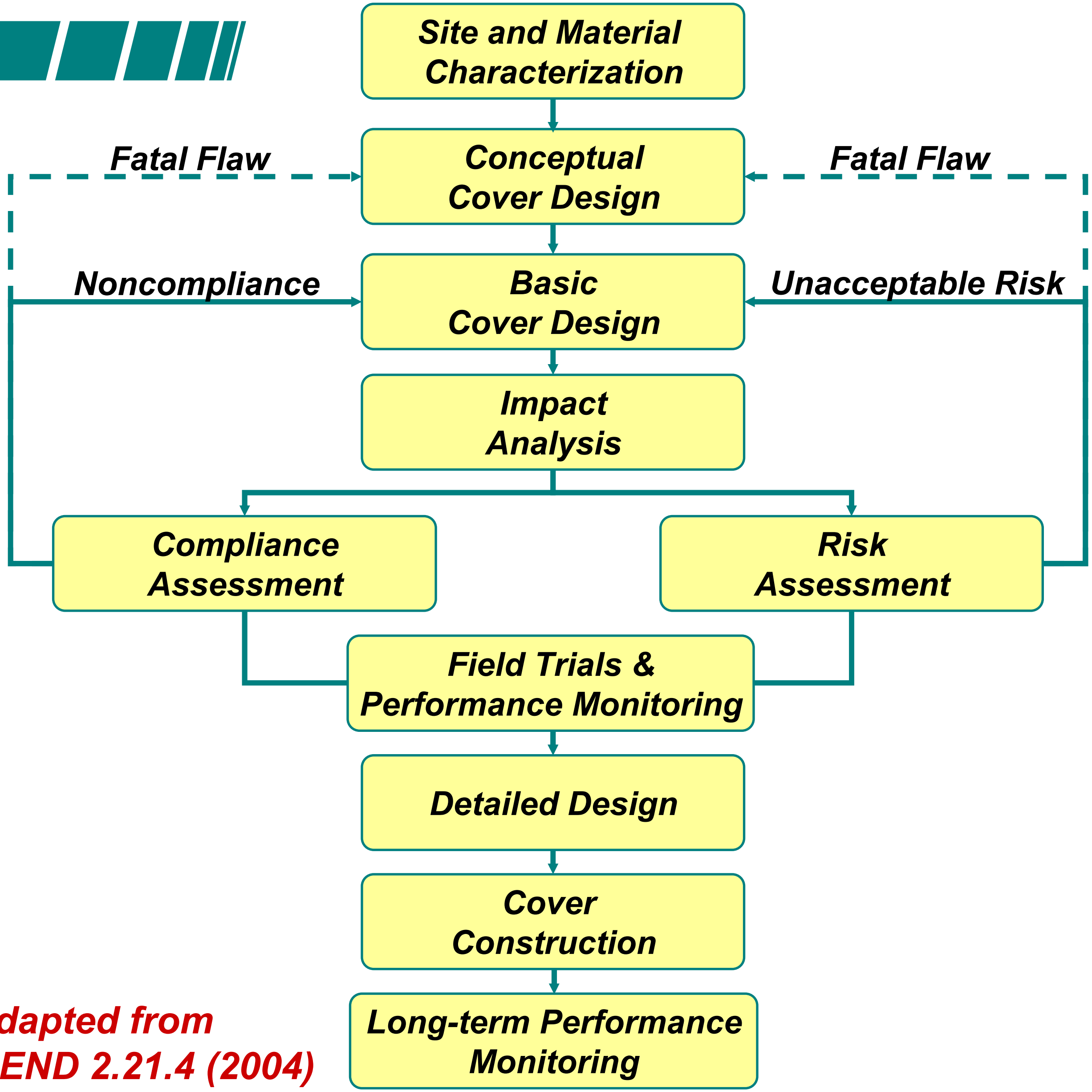
MEND MARITIMES WORKSHOP
Challenges in Acidic Drainage: Case Studies on Mitigation Technologies and Current Research
Halifax, NS – May 23-24, 2006

O'Kane Consultants
Integrated Geotechnical Engineering Services
Specialists in Unsaturated Zone Hydrology

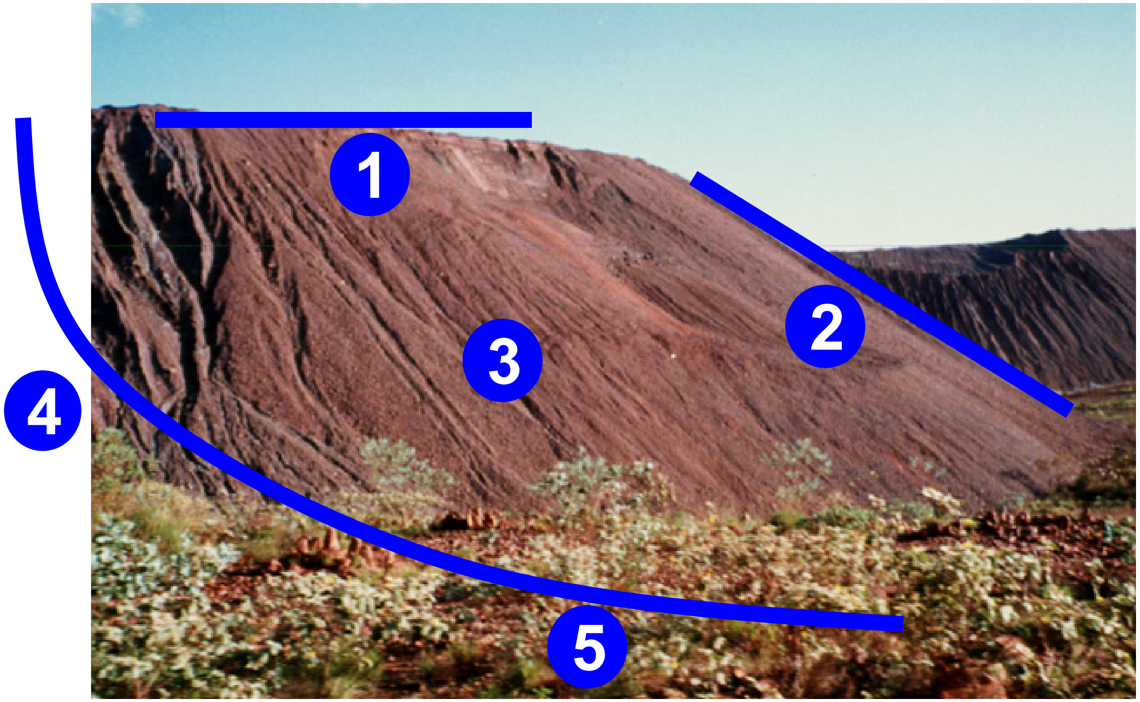


Adapted from MEND 2.21.4 (2004)

Key Aspects of Presentation:

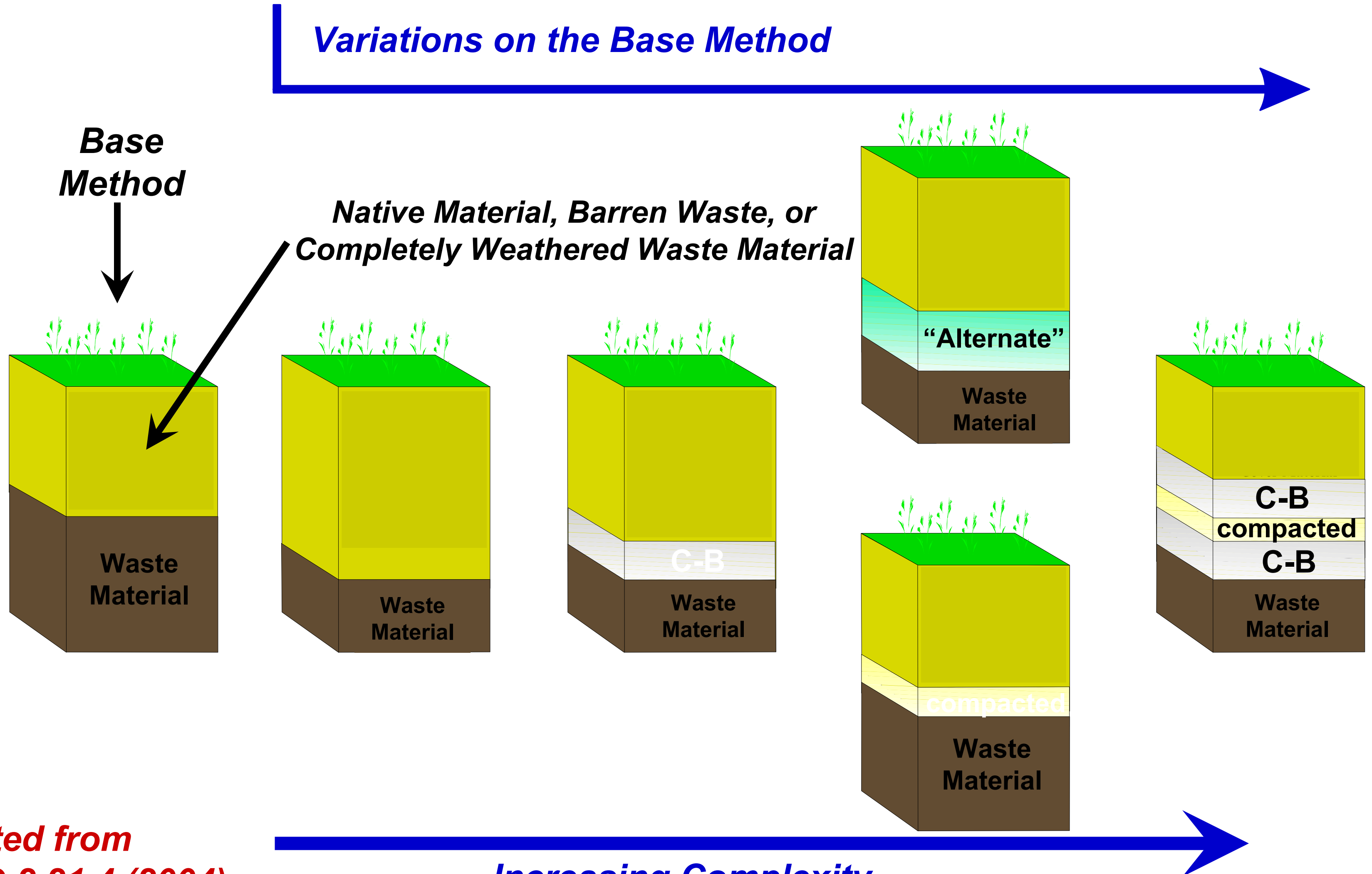
- ***Cover Design … Micro-Scale***
- ***Landform Design … Macro-Scale***
- ***Focus on "Subtleties"***
- ***Cover Longevity***
- ***Case Studies***

Scope of Cover System Design



1. Performance on a horizontal surface
2. Performance on a sloping surface
3. Internal gas, moisture, contaminant transport/storage
4. Contribution of flow from valley wall and historic surface water paths
5. Prediction of leachate entering groundwater and surface water systems and/or collection system

Cover System Alternatives



Adapted from MEND 2.21.4 (2004)

Increasing Complexity
Increasing Performance???
Increasing Cost

Influence of Climate Conditions

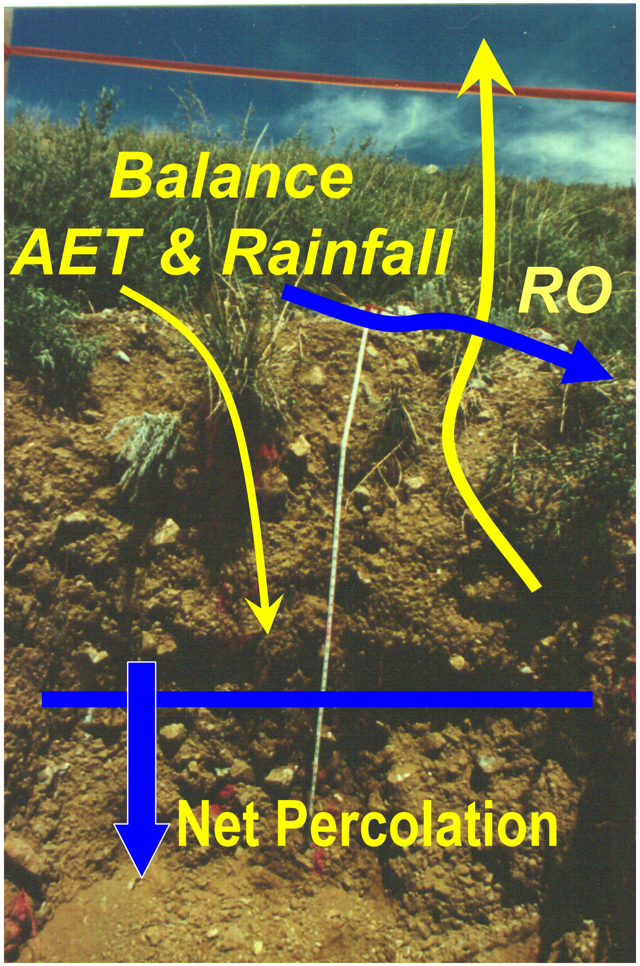
"Humid" Site

"Blanket of Water"

& Low Permeability

Canadian Climate Conditions?
Can be Difficult for Cover Design

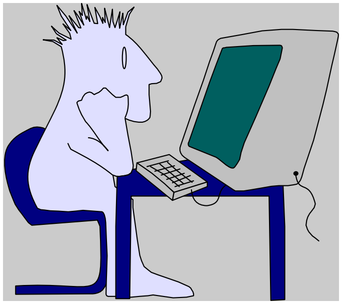
"Arid" Site



"Store and Release"

Cover Design … Micro-Scale

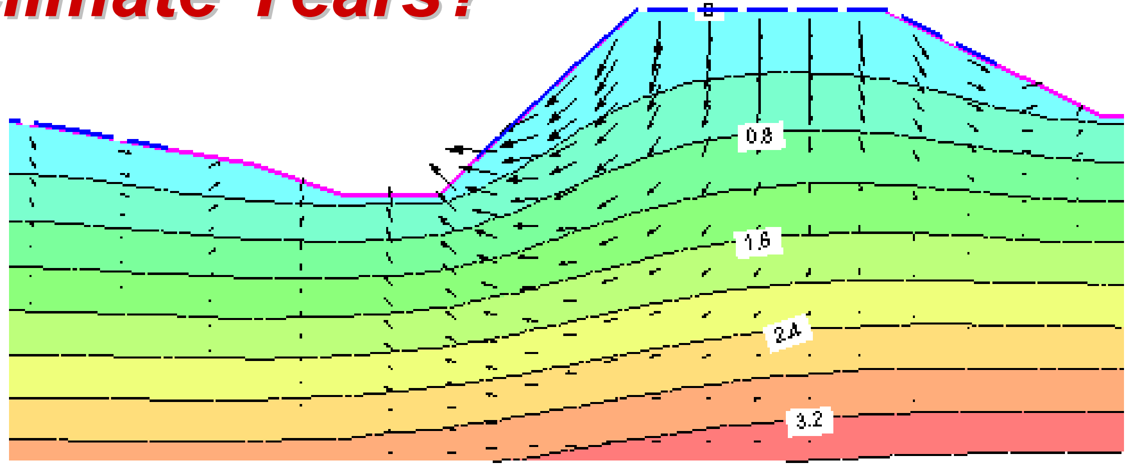
Numerical Modelling – Purposes:



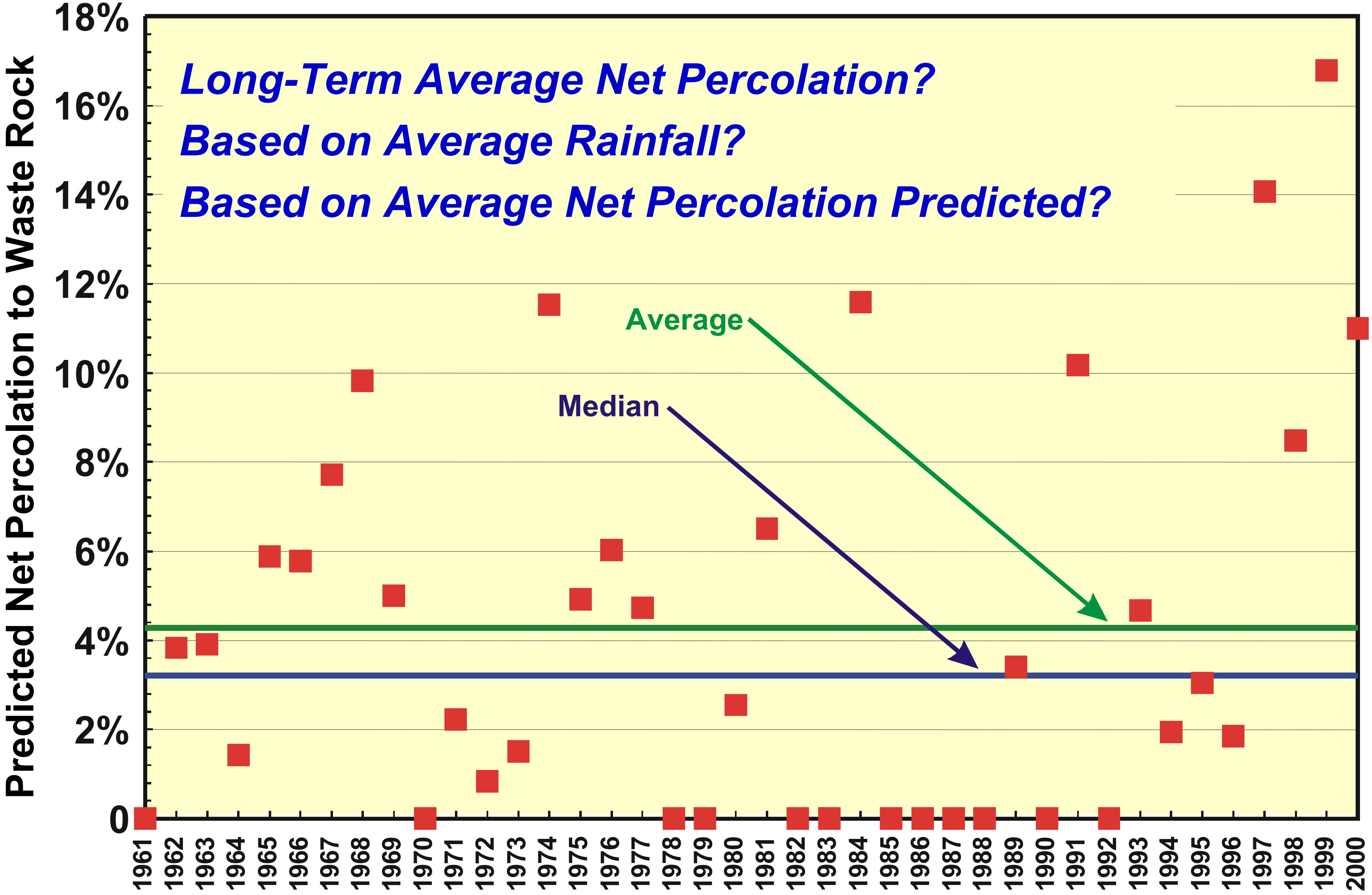
- Interpretation
  - Understand a mechanism or process
    - To prove a hypothesis…..To train our thinking
  - To make sense of monitoring data
- Design
  - Evaluation of relative performance of alternatives
- Prediction
  - To make a final prediction of future behaviour or impact

Cover Design Modelling Input?

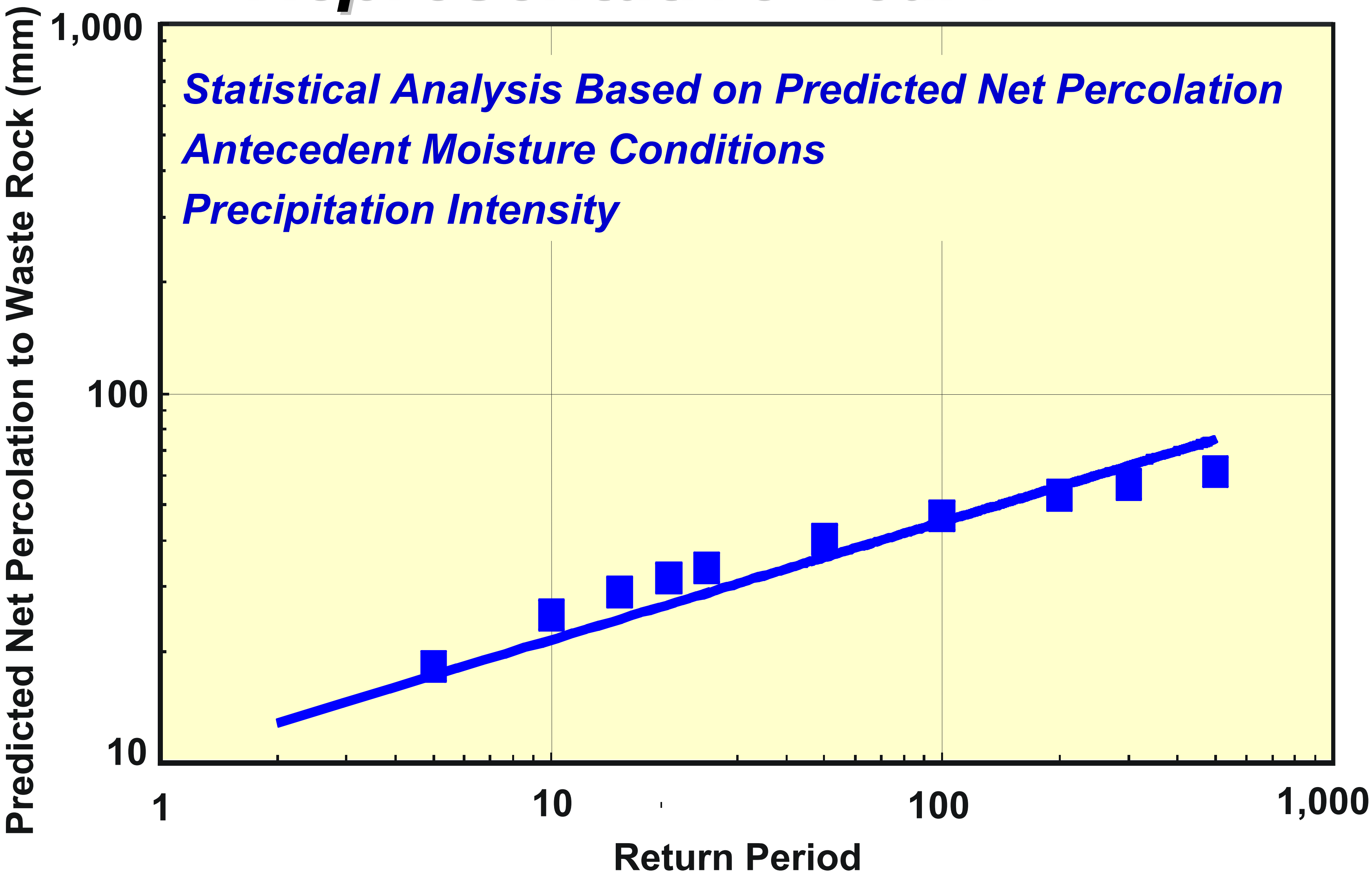
- ***Initial Conditions***
- ***Material Properties***
- ***Boundary Conditions***
  - ***Lower Boundary Conditions***
  - ***Upper Boundary Conditions…Focus on Precipitation***
- ***Representative Climate Years?***
  - ***Wet?***
  - ***Dry?***
  - ***Average?***



Representative Year?



Representative Year?

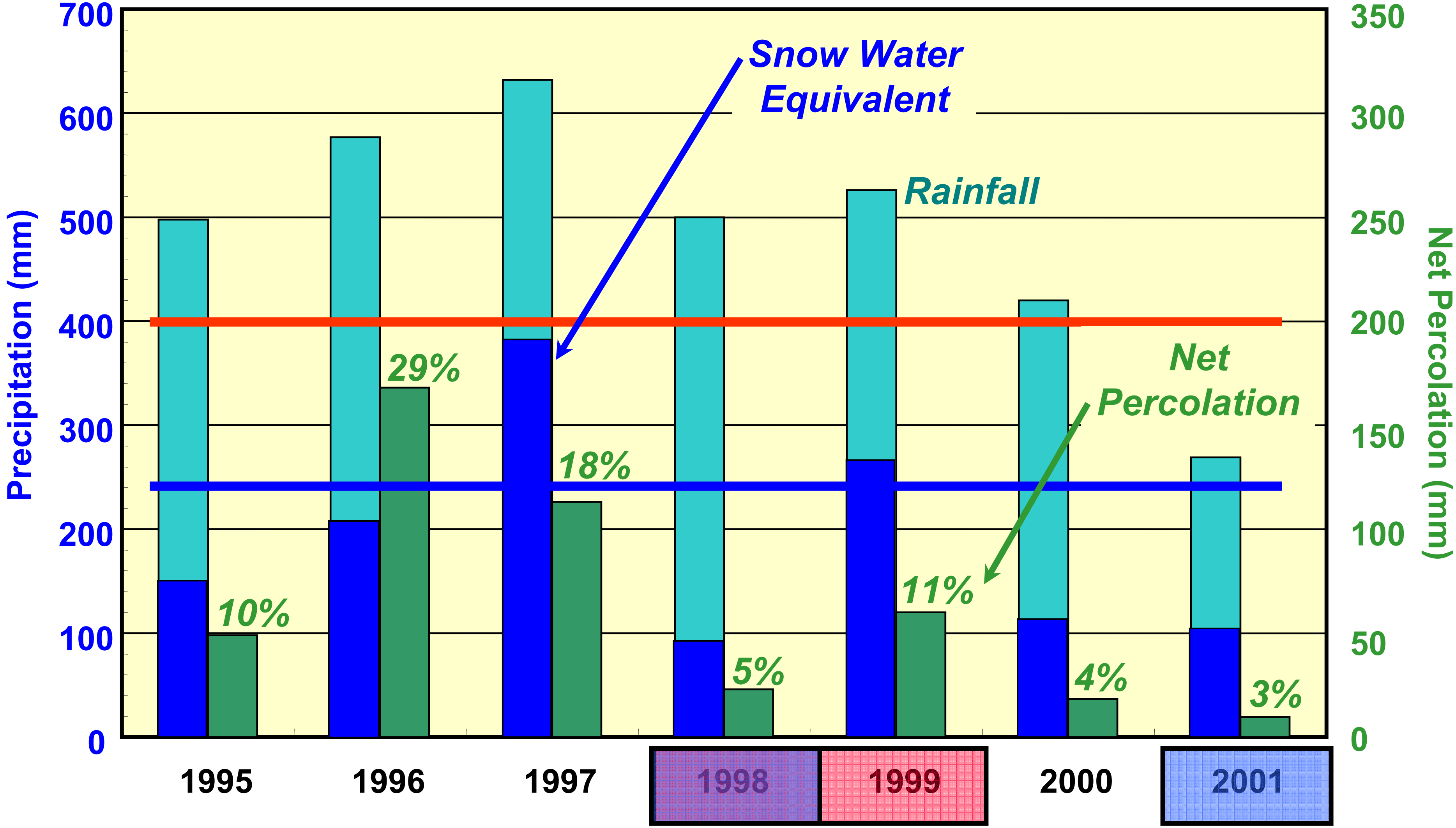


Kimberley Operations

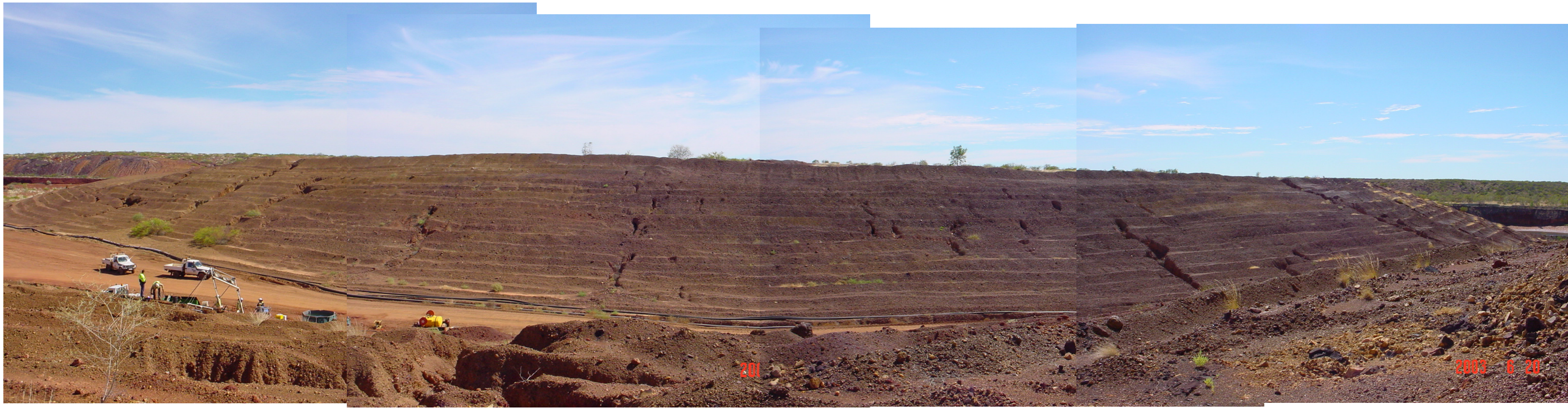
- Site has annual moisture deficit
- Site experiences hot dry summers

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

Kimberley Operations



Landform Design … Macro-Scale



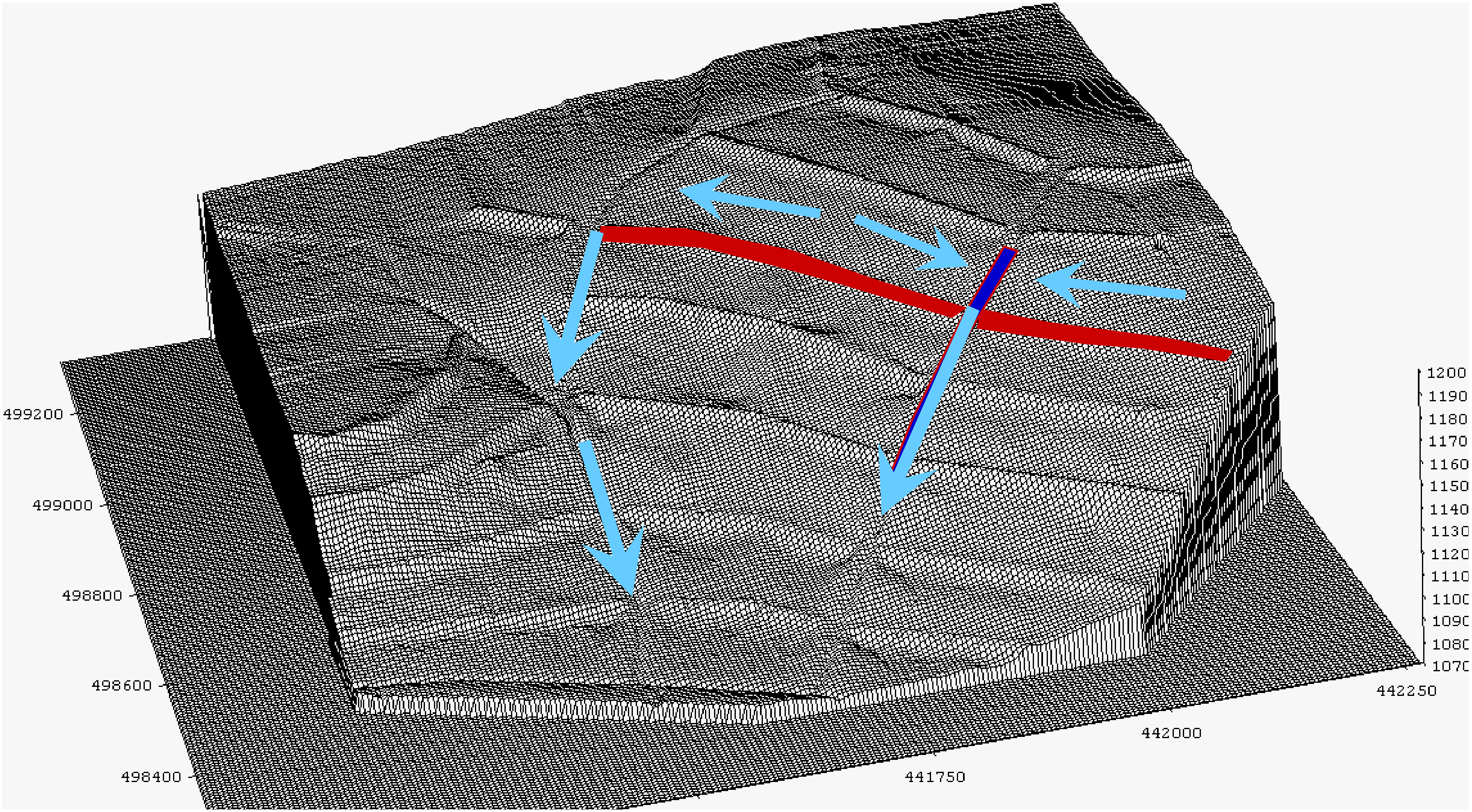
- ***Steep unarmored slopes will flatten, planar slopes will gully, straight drainage courses will meander, and linear or convex slopes will become concave***
- ***Greatest physical risk to reclaimed mine landforms is associated with gully erosion and re-established surface water drainage courses (McKenna & Dawson, 1997)***

Designing Sustainable Final Landforms

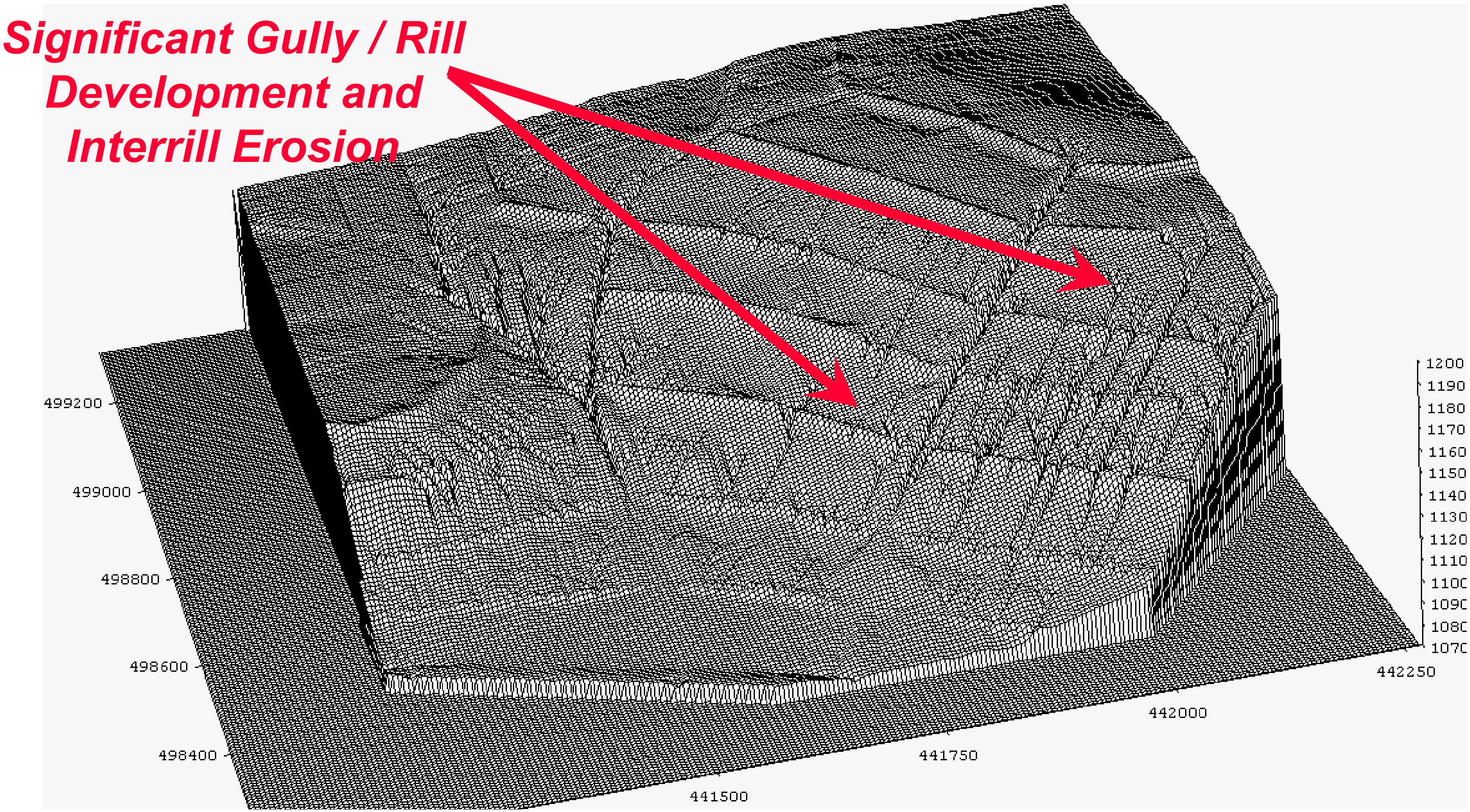
- *Incorporation of natural slope features not only improves aesthetics, but emulates slopes that are in equilibrium with local conditions of rainfall, soil type, and vegetation*

- *Time and resources are NOW available!!*
- *Two key components to design a sustainable F / L:*
  1) *Follow geomorphic principles*
  2) *Holistic view of mining operations*

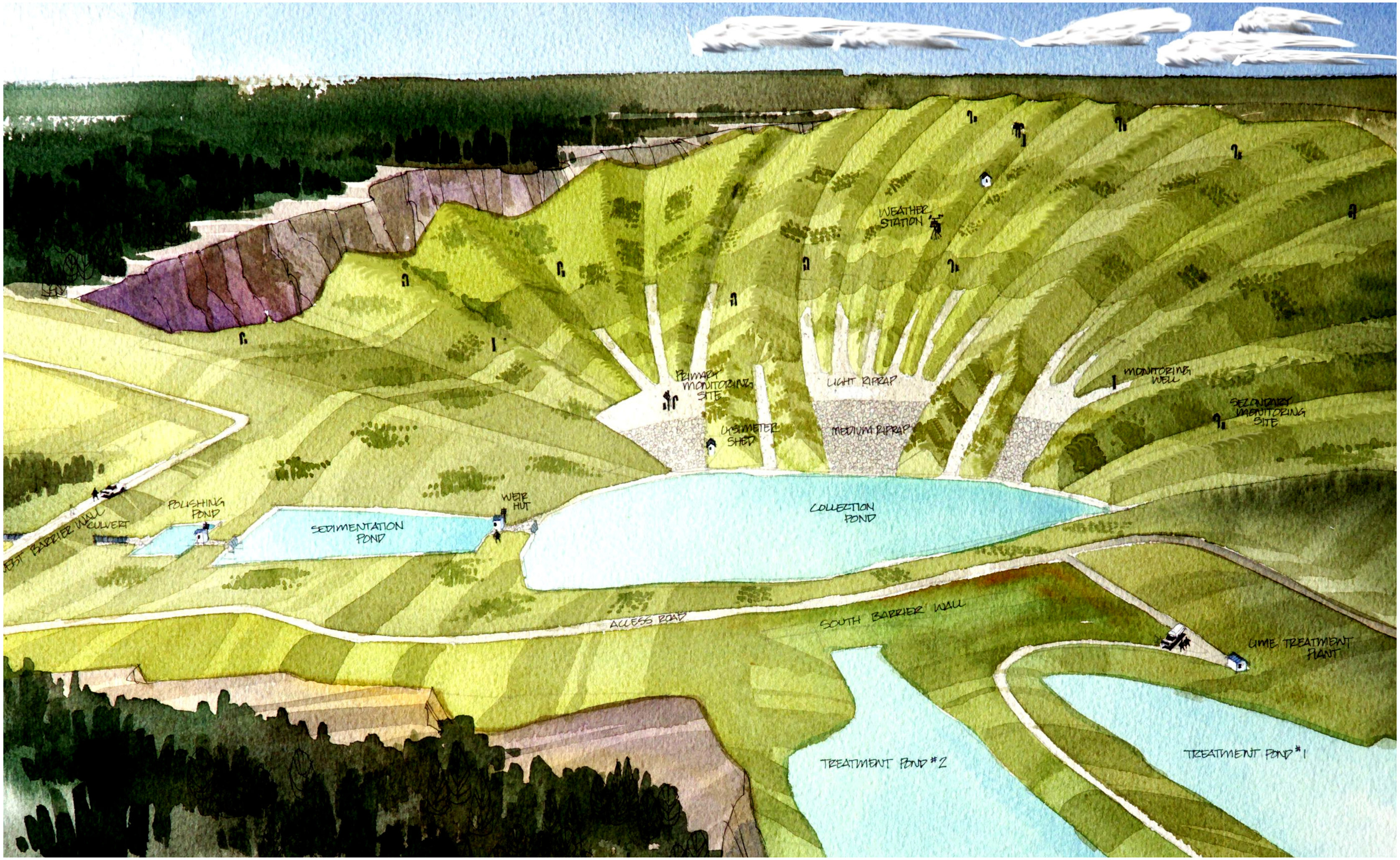
Evaluation of Original Landform Design for Whistle Mine Pit



Original Landform Design – Output from SIBERIA Model (after 100 yrs)



Ultimate Final Landform for the Whistle Mine Pit Cover



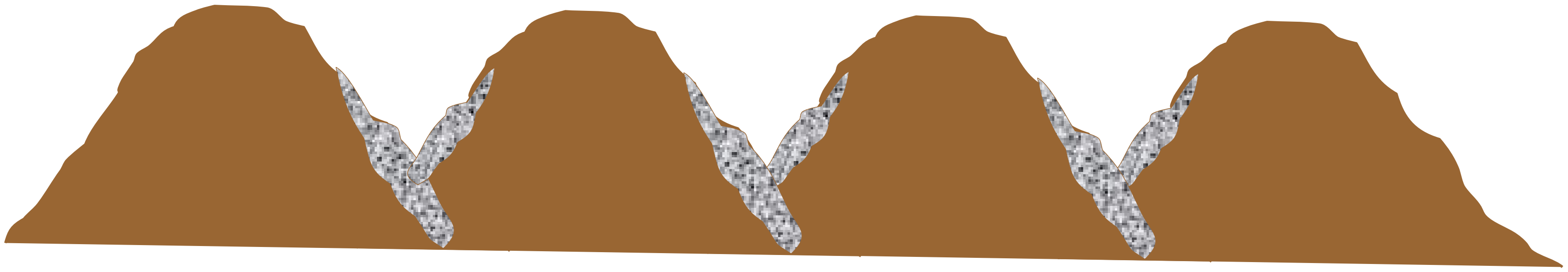
Cover Construction

- ***Engineering supervision***
  - ***Expertise in both cover design and earthworks aspects***
- ***Compacted clay layers***
  - ***Use test pads to iron out specs and methods***
  - ***Permeability testing!!***
- ***Growth medium / store-and-release layers***
  - ***Avoid over-compaction … restricts root growth***
  - ***Extent of material segregation … can be a problem!***
  - ***Topsoil stockpiles … can be a source of noxious weeds***
  - ***Consider cross-slope ripping topsoil into granular surface***

Material Segregation

- ***An ideal growth moisture store-and-release cover is a homogenous layer of well-graded material***
- ***Barren run-of-mine waste is often a natural choice for cover material … typically gap-graded***

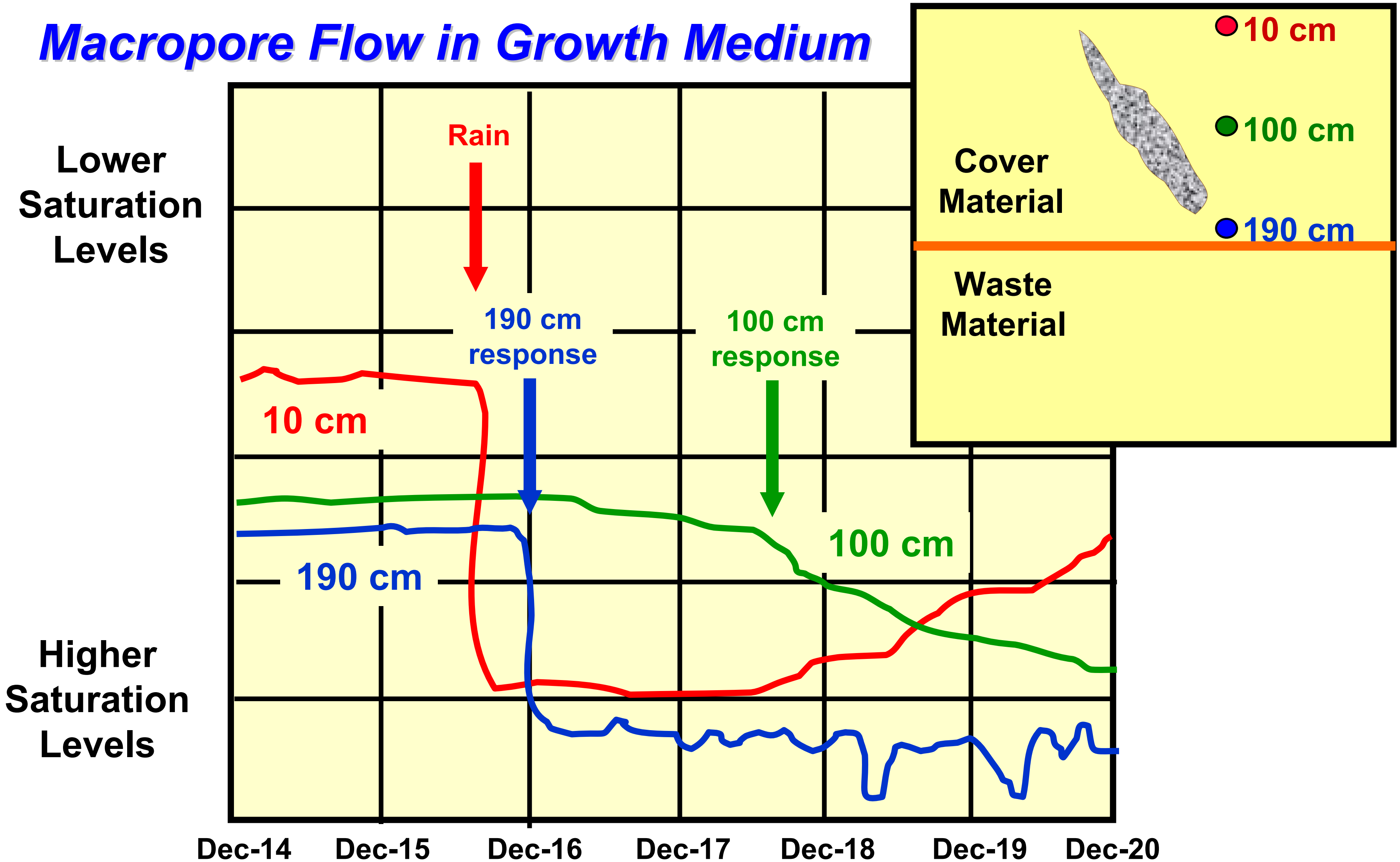
Paddock dumping of ROM waste … potential coarse "rubble" zone



Near Surface Preferential Flow

Material Segregation *(cont')*

Macropore Flow in Growth Medium



Cross-Slope Ripping

Why cross-slope rip?

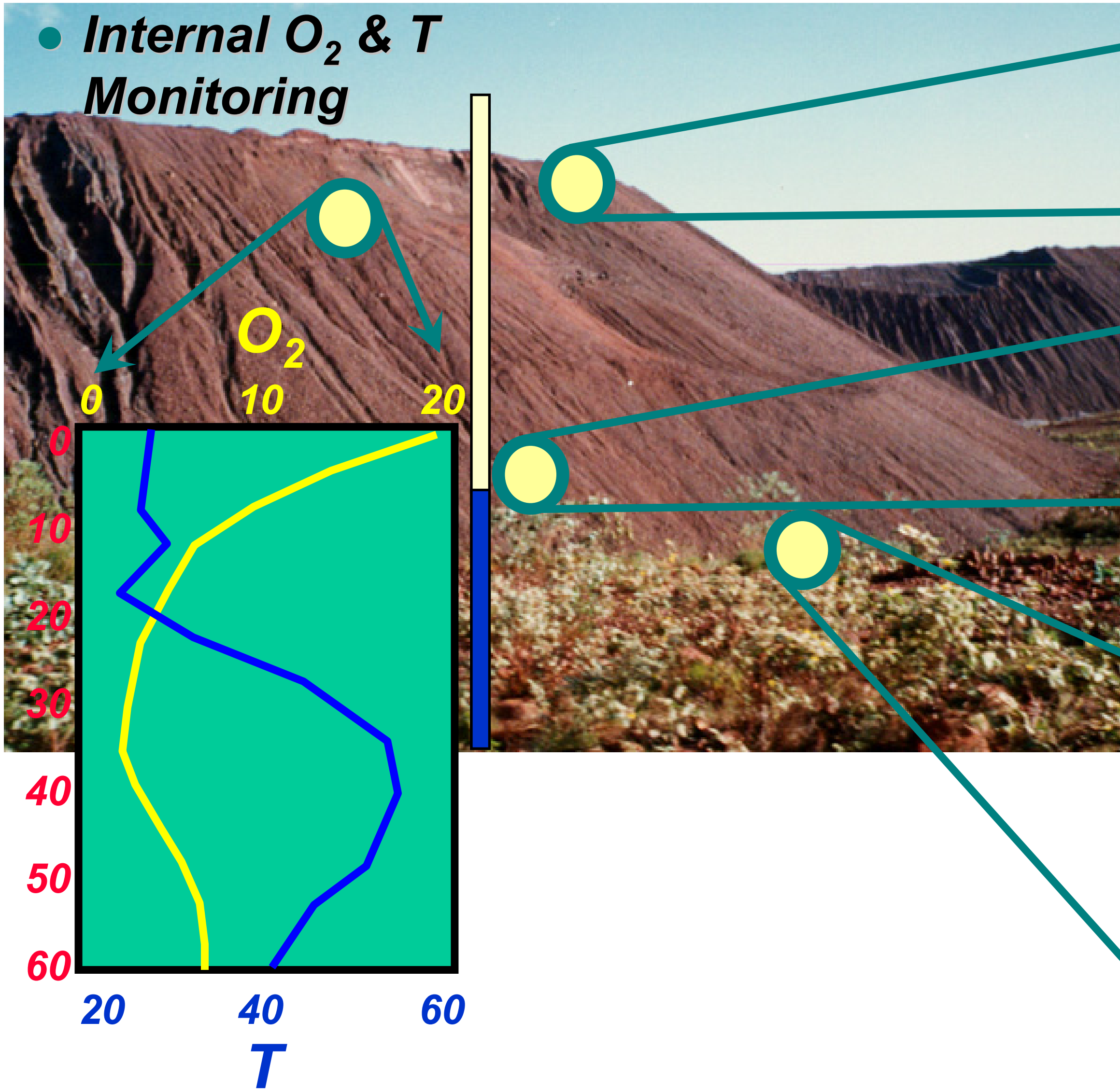
- Till topsoil into granular material
- Wind break for seeds
- Trap moisture
- Channel water to drainage channels (S-T)

Potential Problems:

- Ripping too deep in some areas … leads to ponding & eventual overtopping
- Vehicular traffic on freshly ripped surface … leads to accelerated gully erosion

Cover Performance Monitoring

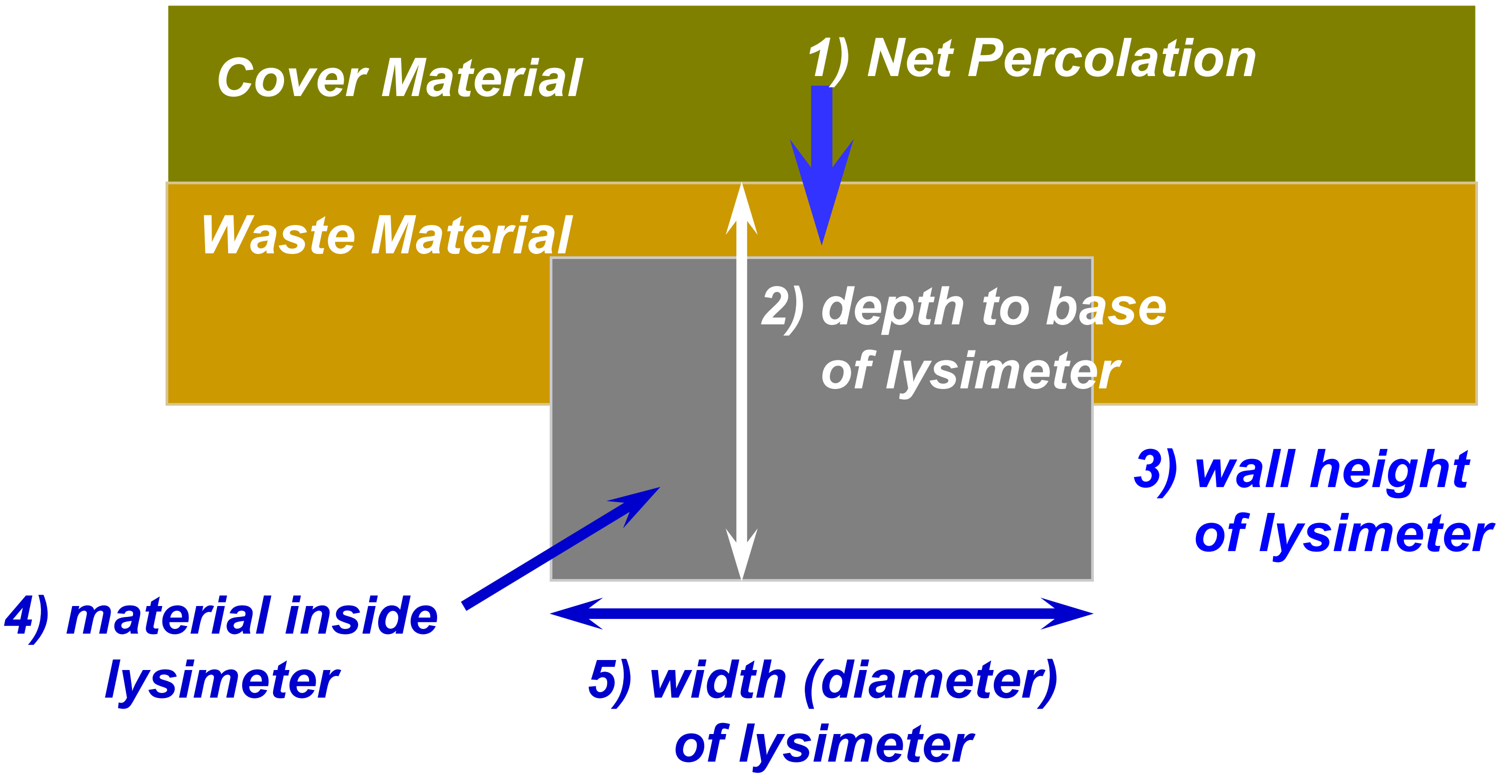
- *Internal O_2 & T Monitoring*



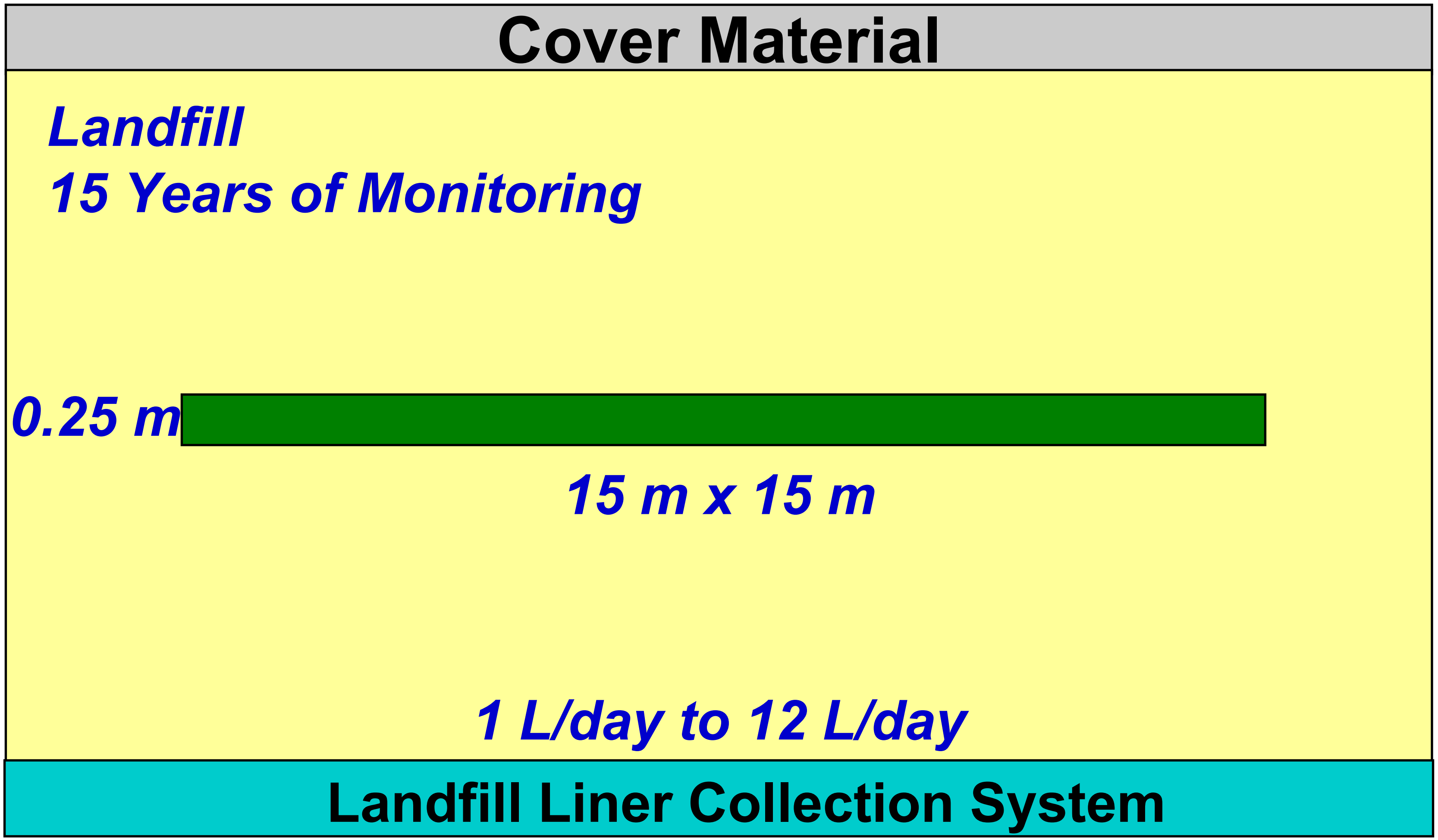
- *Direct In Situ Monitoring*
- *Basal Flow?*
- *Water Quality Monitoring*

Lysimeter Design

- NOT intuitive … dealing w/ an unsaturated system
- Problems arise due to artificial water table in tank
- 5 aspects to consider when designing a lysimeter:



Increase Lateral Surface Area?



(Barone et al., 1999)

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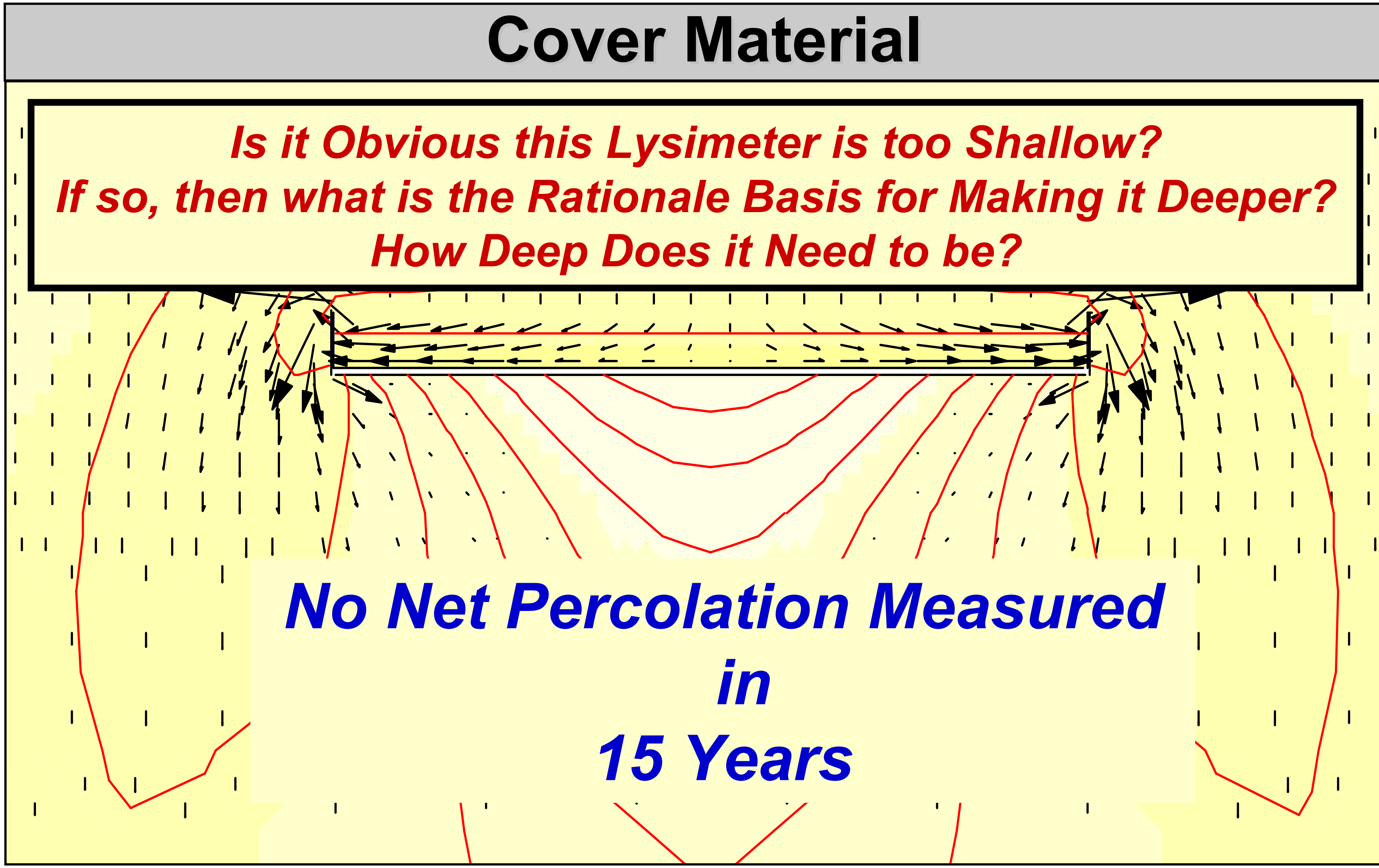


(Barone et al., 1999)

Landform or Macro-Scale Performance Monitoring

- *Watershed is ideal unit size to evaluate behavior … major building block of landscapes*
- *Key elements to track or monitor are revegetation and erosion developments, defining the water balance, and evolution of cover soils*

MEND 2.21.6. Macro-scale cover design and performance monitoring manual. (fall 2006)

Longevity of Cover Systems

INITIAL PERFORMANCE

Physical Processes

- Erosion
- Wet/Dry Cycles
- Freeze/Thaw Cycles
- Extreme Local Climate Events
- Brushfires
- Consolidation
- Settlement

Chemical Processes

- Dissolution
- Osmotic Consolidation
- Mineralogical Consolidation
- Sorption
- Precipitation
- Dispersion/Erosion
- Acidic Hydrolysis

Biological Processes

- Bioturbation
- Root Penetration
- Burrowing Animals
- Human Intervention
- Bacterial Clogging

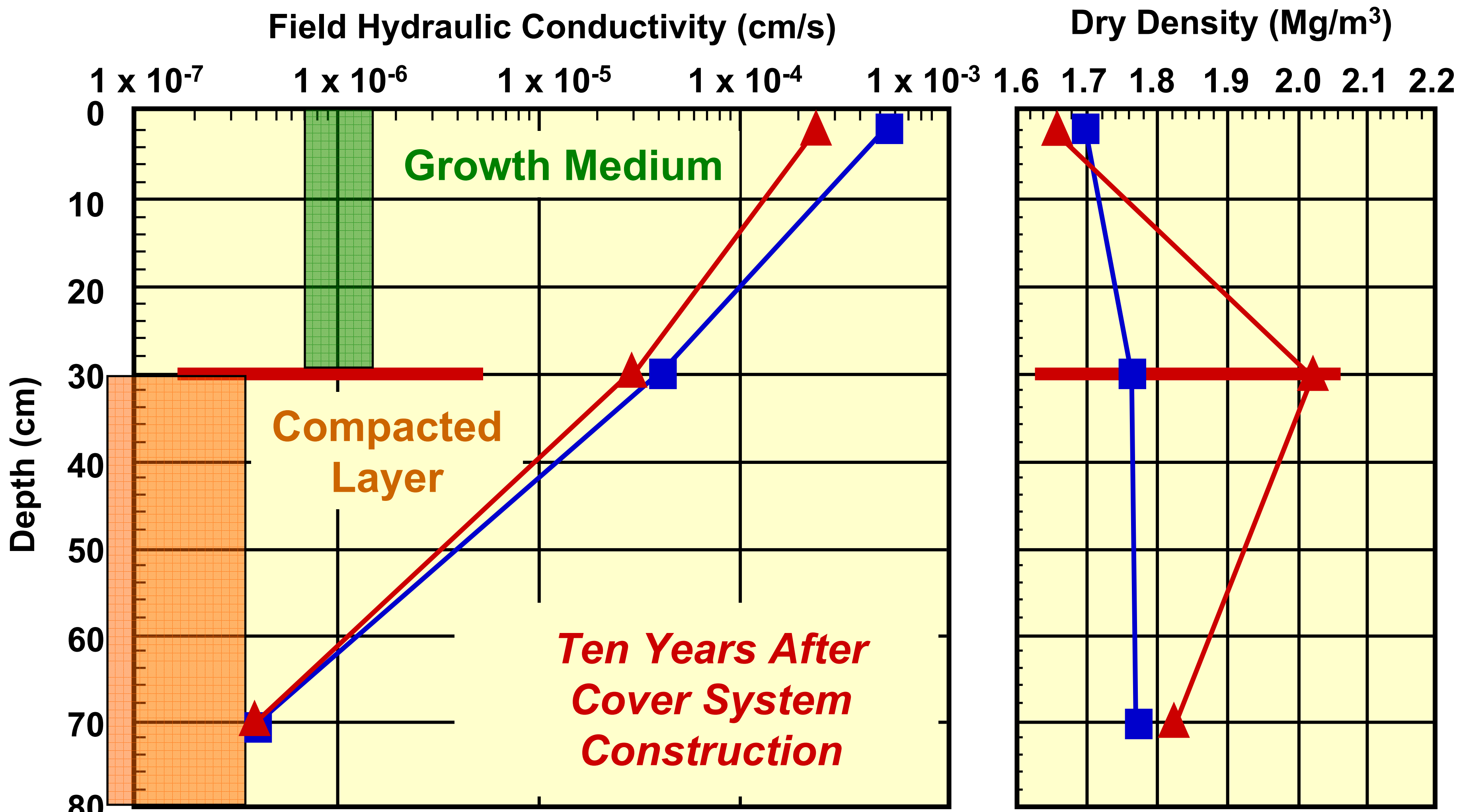
LONG-TERM PERFORMANCE

Resulting In:

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

Equity Silver Mine – WRD Cover

INAP (2003) Study – Guelph Permeameter Testing



Equity Cover – Measured In Situ Moisture Conditions