Hydrogeochemical Considerations related to Disposal of Thickened Tailings, including Paste

Rens Verburg
Golder Associates, Redmond, USA

15th ANNUAL BC/MEND ML/ARD WORKSHOP
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Presentation Overview

- Introduction
- Thickened Tailings
  - Characteristics
  - Potential Benefits
- Environmental Benefits
  - Case Study A
  - Case Study B
- Conclusions

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Introduction

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Comparison of Characteristics

	Slurry	Thickened	Paste	Filter Cake
Segregation	High	Slight	None	None
Solids Content	30-50%	60-65%	70-75%	75-80%
Supernatant	Considerable	Some	None	None
Post-Placement Shrinkage	High	Some	Insignificant	None
Seepage	High	Some	Insignificant	None
Rehab Timing	Delayed, often considerable	Almost Immediately	Almost Immediately	Immediately
Angle of Repose	Up to 1^{o}	1^{o} to 3^{o}	3^{o} to 10^{o}	Up to Erosion Angle
Potential Water Recovery	Up to 53%	Up to 67%	Up to 82%	Generally above 82%

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Adopted from J. Johnson, Golder - Denver

Potential Benefits of Dry Disposal

- Siting flexibility
- Minimal liquid/solid segregation
- Minimal particle segregation
- Denser/lower permeability
- Smaller footprint
- Reduced need for dams
- Extend life of facility
- Reduced care and maintenance
- Less water to manage
- Less seepage/ contaminant migration
- Water conservation
- Engineered material
- Less reactive (sulfide oxidation)
- Concurrent/progressive closure
- Improved aesthetics
- Potential for co-disposal
- Enhanced sustainability

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Fact or Fiction?

- Assumed environmental benefit:
  - Sulfide oxidation/ARD generation retarded due to high degree of saturation
- However:
  - Lack of operational verification
  - Lack of systematic studies

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Case Study A

- Arid region
- 20-week HCT program

- Three thickened tailings samples
  - Filter cake
  - Paste
  - Thickened tailings

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Case Study A – Tailings Properties

- Moisture content:
  - Filter cake: 16%
  - Paste: 22%
  - Thickened tailings: 29%
- Sulfide Sulfur: 31%
- NNP: -957 kg $CaCO_3$/ton
- NPR: < 0.1

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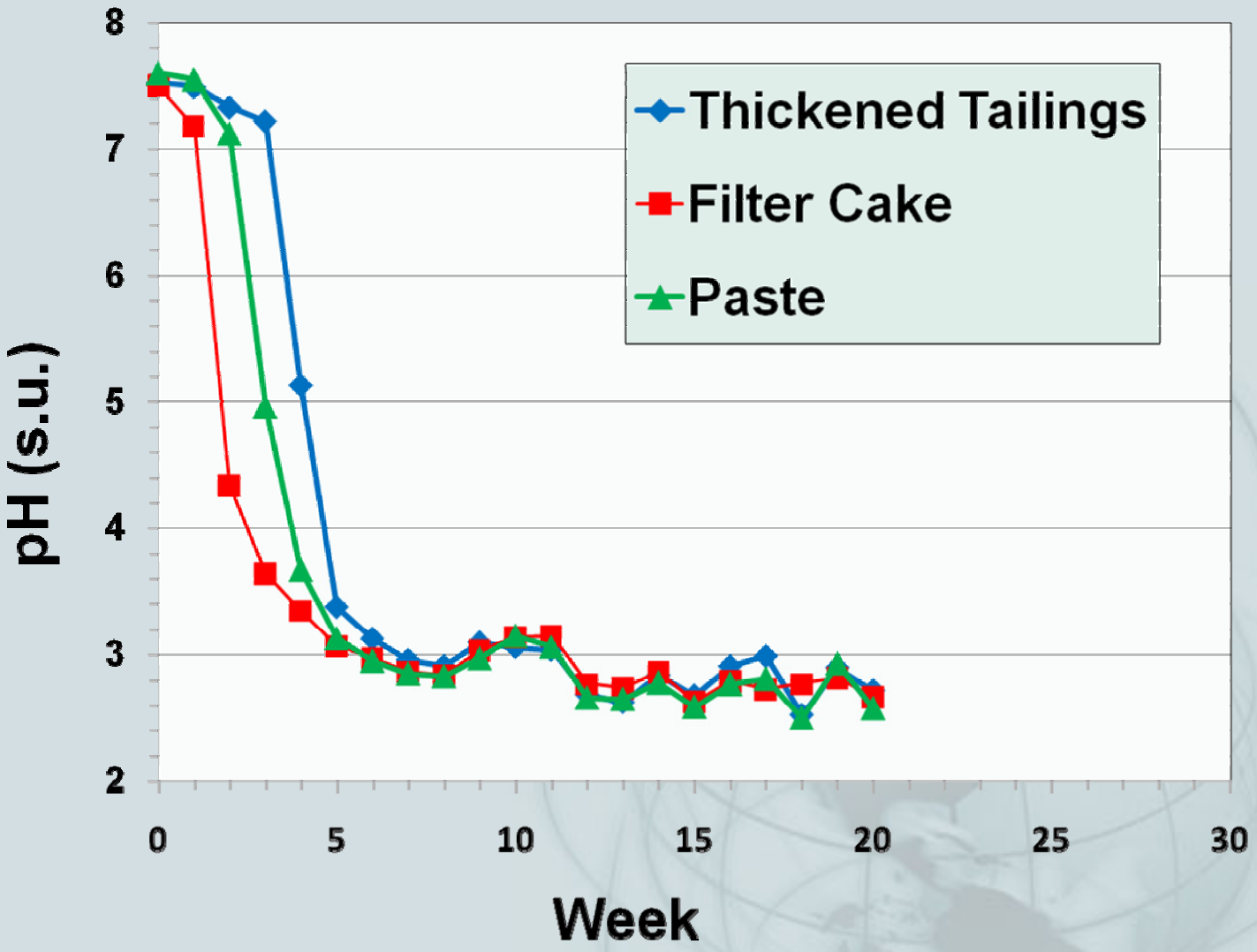
HCT Results - pH



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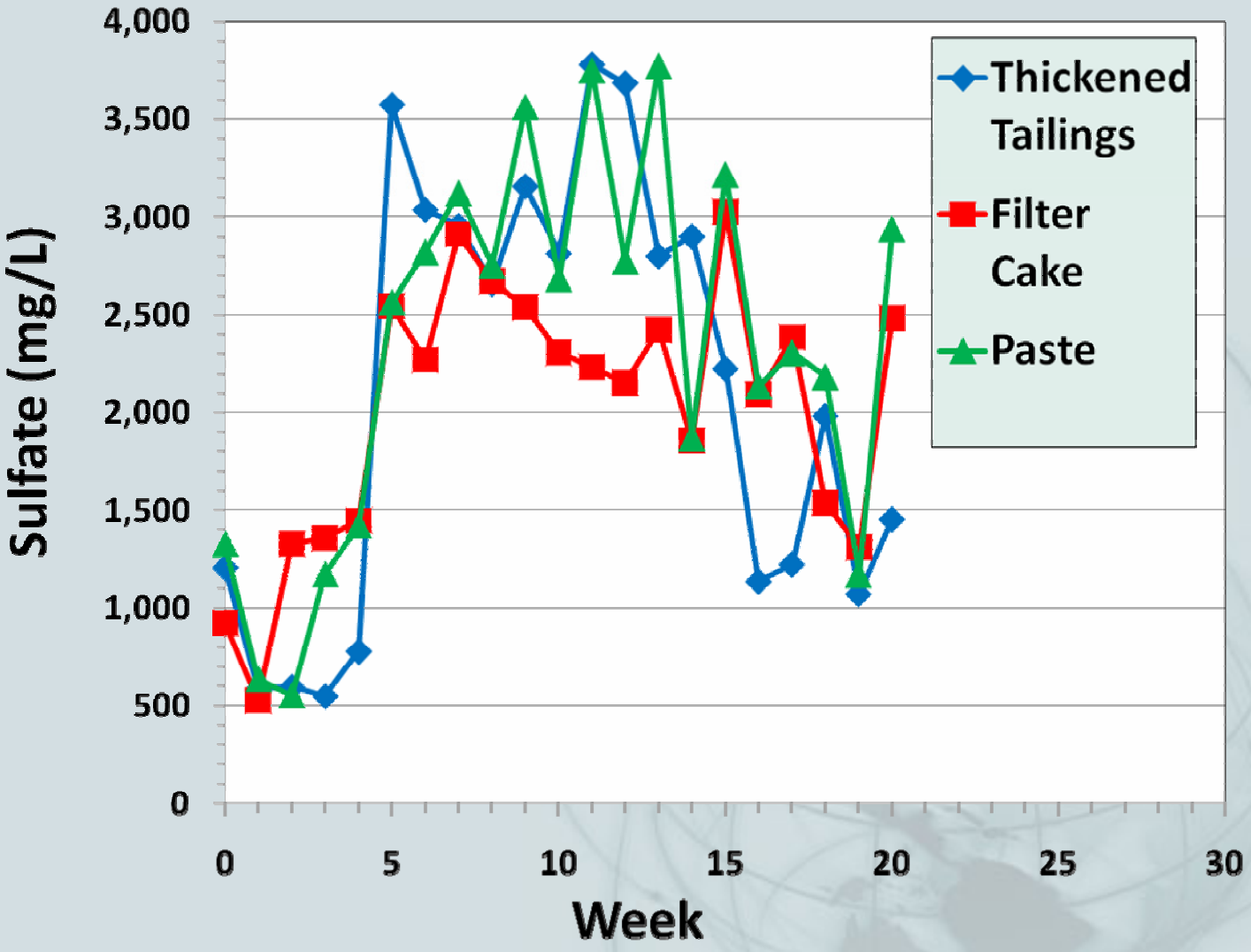
HCT Results - Sulfate



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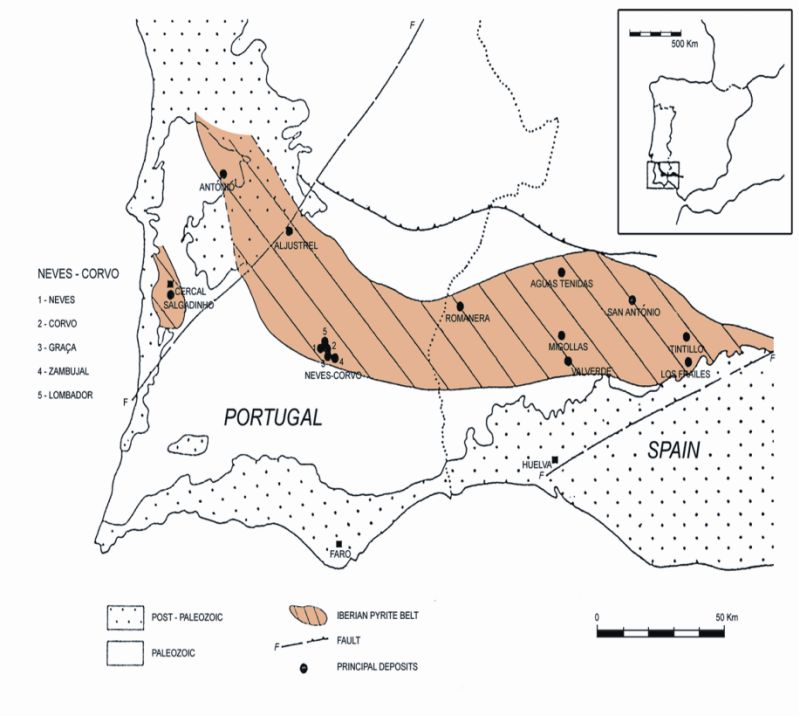
Case Study B - Neves Corvo Mine

- Underground high-grade Cu-(Sn)-Zn mine in Iberian Pyrite Belt since 1989
- Lundin Mining
- Volcanogenic Massive Sulfide (VMS)



Tailings Management

- Underground paste backfill and in unlined tailings impoundment (135 ha, 15 Mt)
- Production of 42 Mt anticipated (14 Mt underground)
- Sustainable operational and post-closure tailings management: dry disposal vs. subaqueous deposition
  - No requirement for new dam raises (cost, risk)
  - No increase in footprint
  - No requirement for maintaining pond in perpetuity (arid climate)
  - Co-mixing with PAG waste rock
  - Concurrent reclamation
  - Regulatory pressures

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Case Study B – Tailings Properties

- Moisture content:
  - Filter cake: 18%
  - Paste: 26%
  - Thickened tailings: 31%
- Sulfide Sulfur: 29%
- NNP: -880 kg $CaCO_3$/ton
- NPR: < 0.1

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Tailings Environmental Stability

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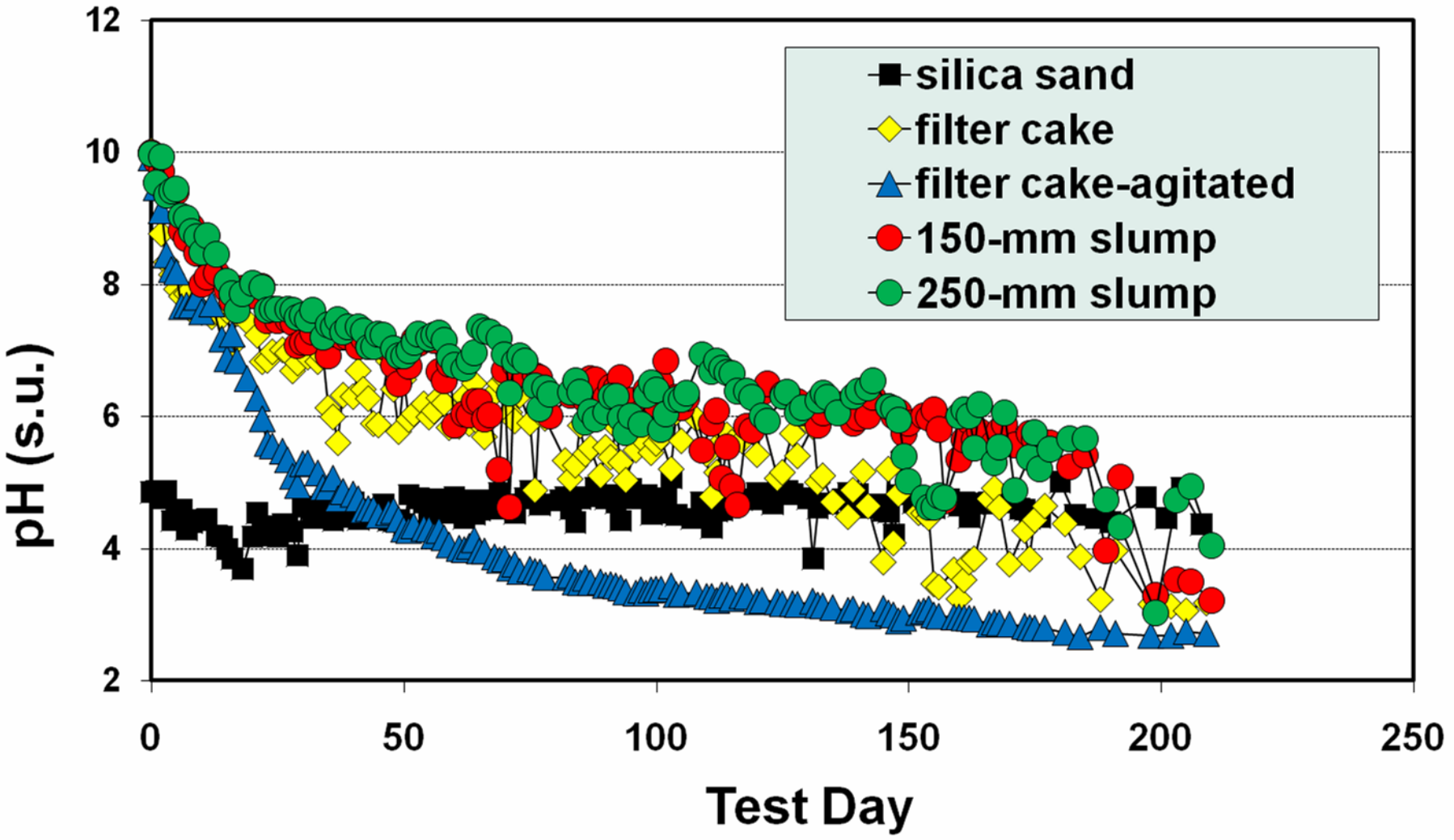
Bench-Scale Study - pH



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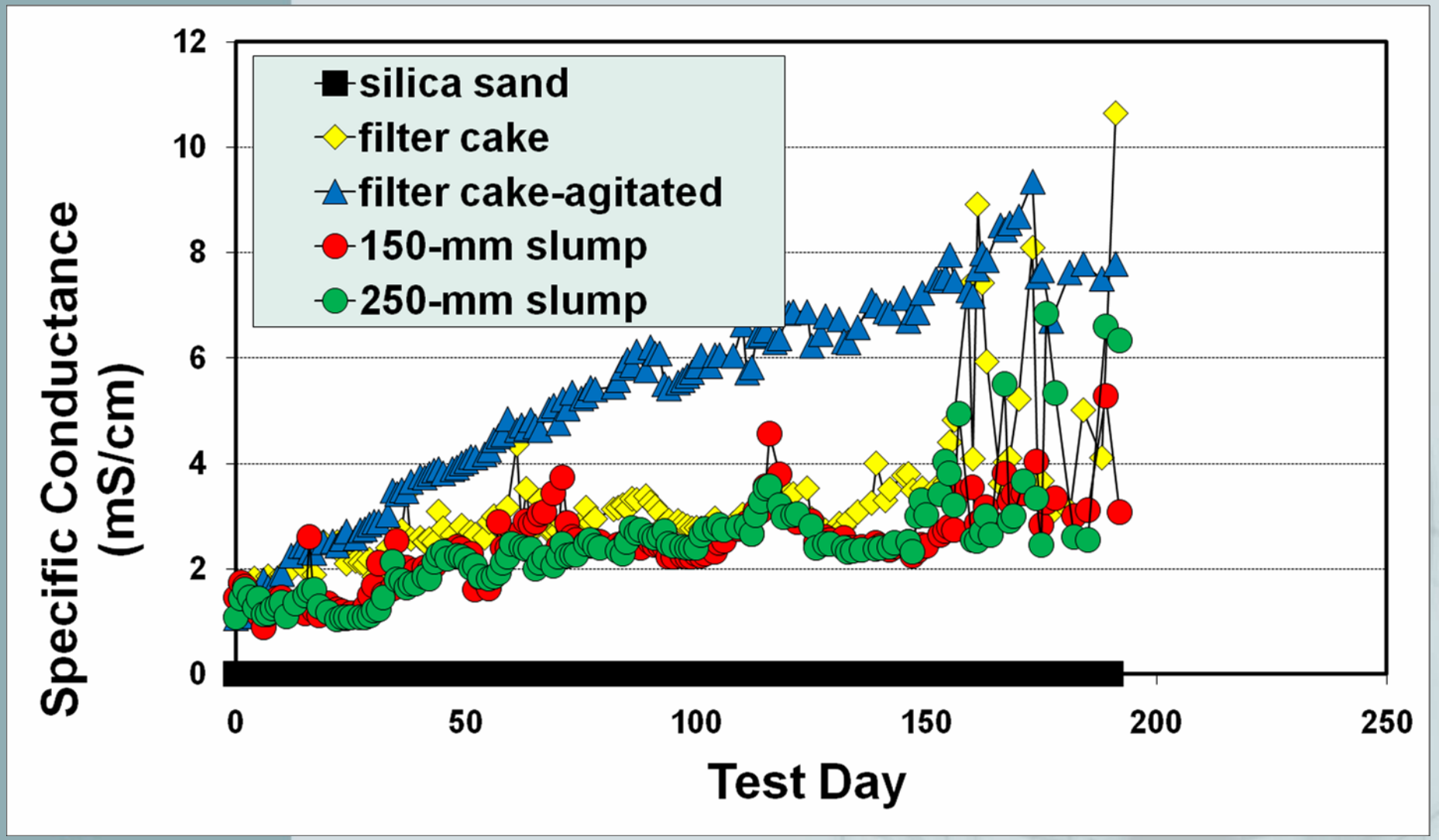
Bench-Scale Study - SC



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Paste Trial

- 35,000 m^3 in 1-hectare area
- Objectives:
  - Experience with plant operation/placement
  - Environmental monitoring
    - Suction lysimeters, piezometers, standpipes
    - Runoff collection
  - Geotechnical monitoring
    - Tensiometers
    - Berm design (PAG waste rock)
  - Trials of cover designs
    - Low-flux cover without capillary break
    - Low-flux cover with capillary break
    - Barrier cover (sand/bentonite)

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Pilot Cell Construction

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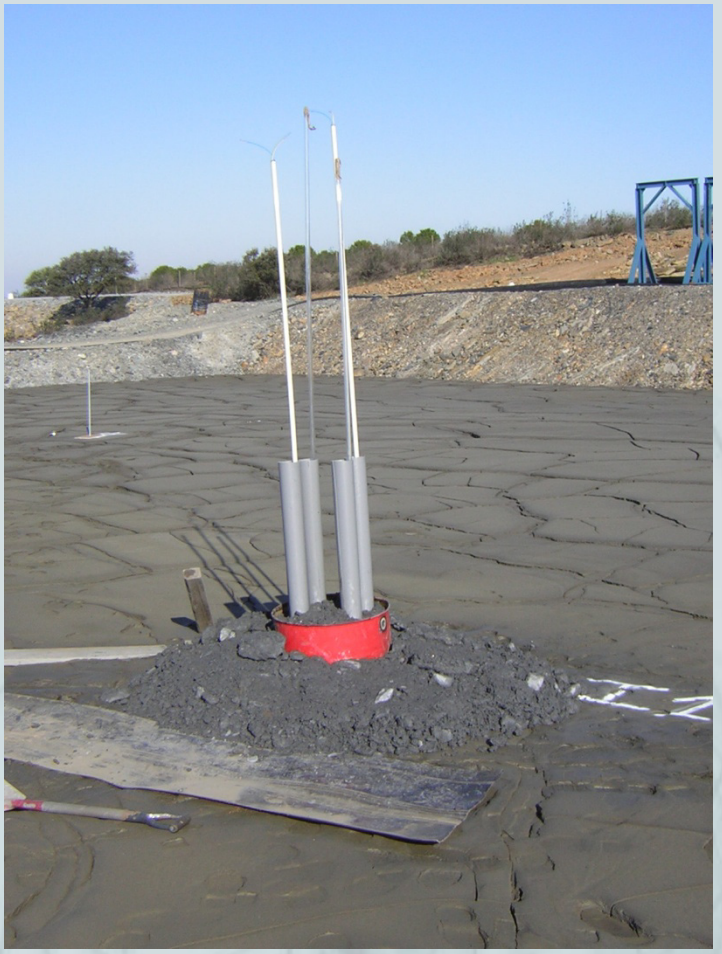
Cover Placement and Instrumentation



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Paste Trial

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Draindown Modeling

- Unsaturated flow modeling for estimation of seepage
  - Ward Wilson (UBC)
  - Fernando Junqueira (Golder-Burnaby)
- SVFlux™ - SoilVision
- 30-meter paste layer
  - No cover
  - Low-flux cover
  - Barrier cover

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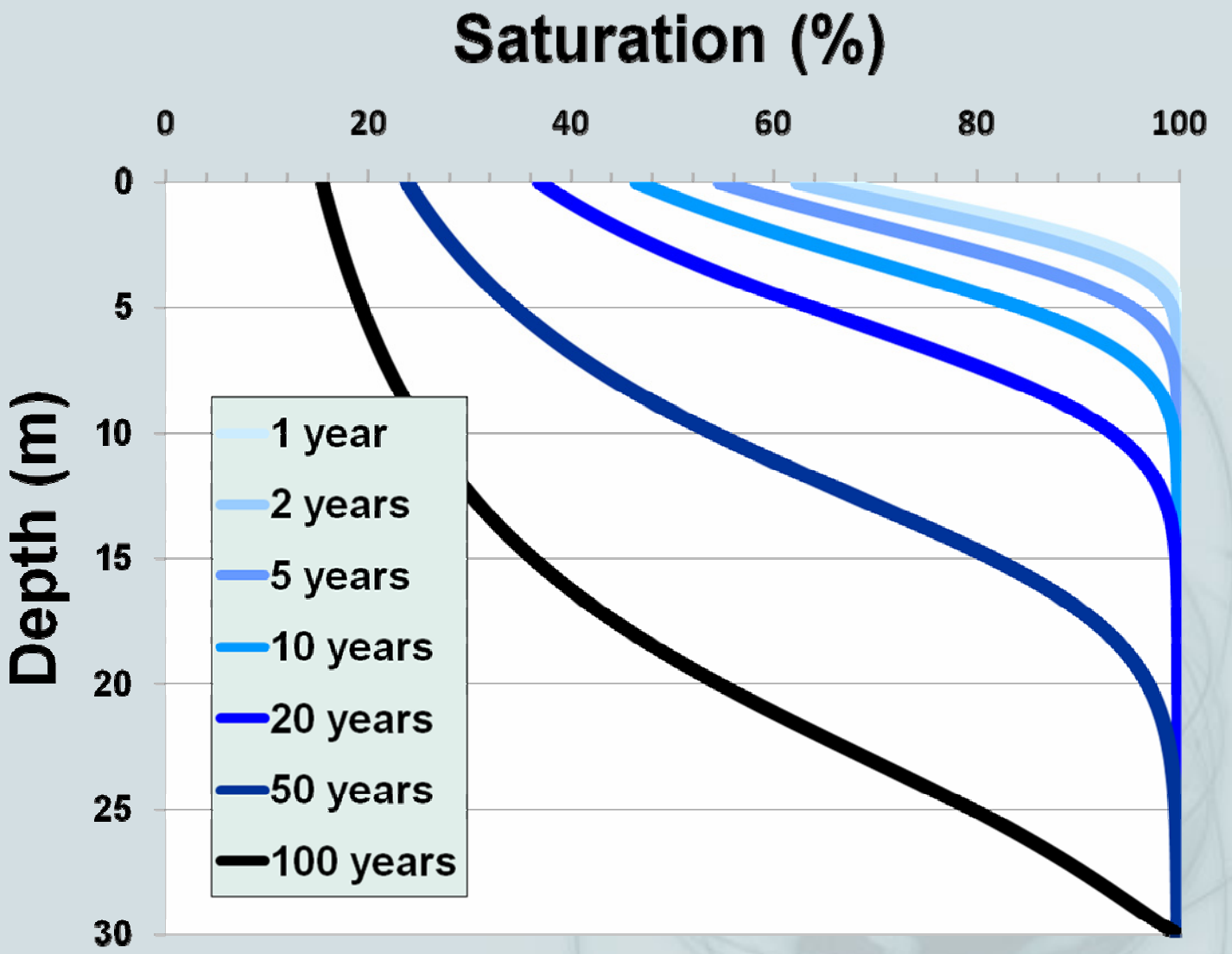
100-Year Saturation Profile – No Cover



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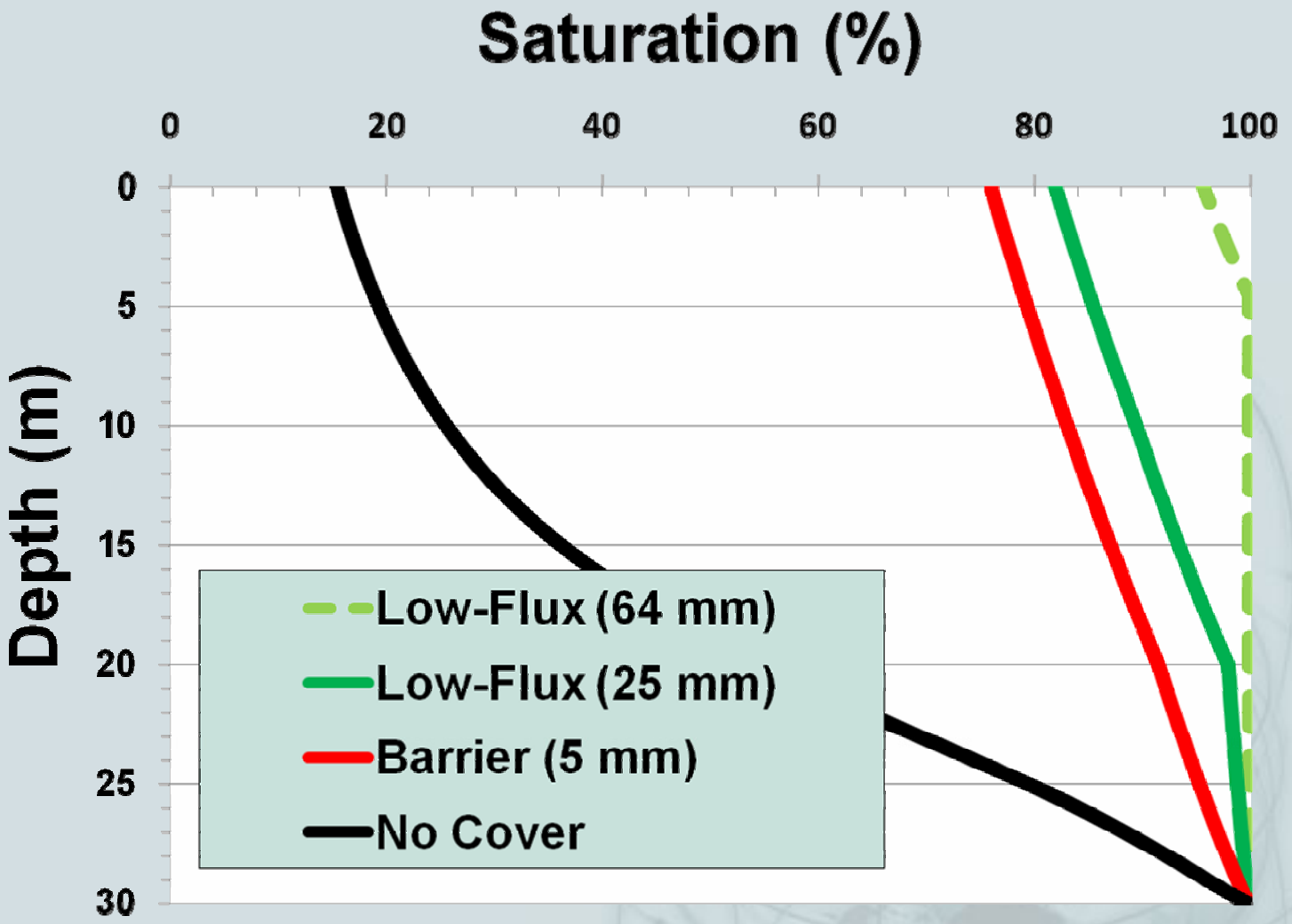
100-Year Saturation Profile – All Scenarios



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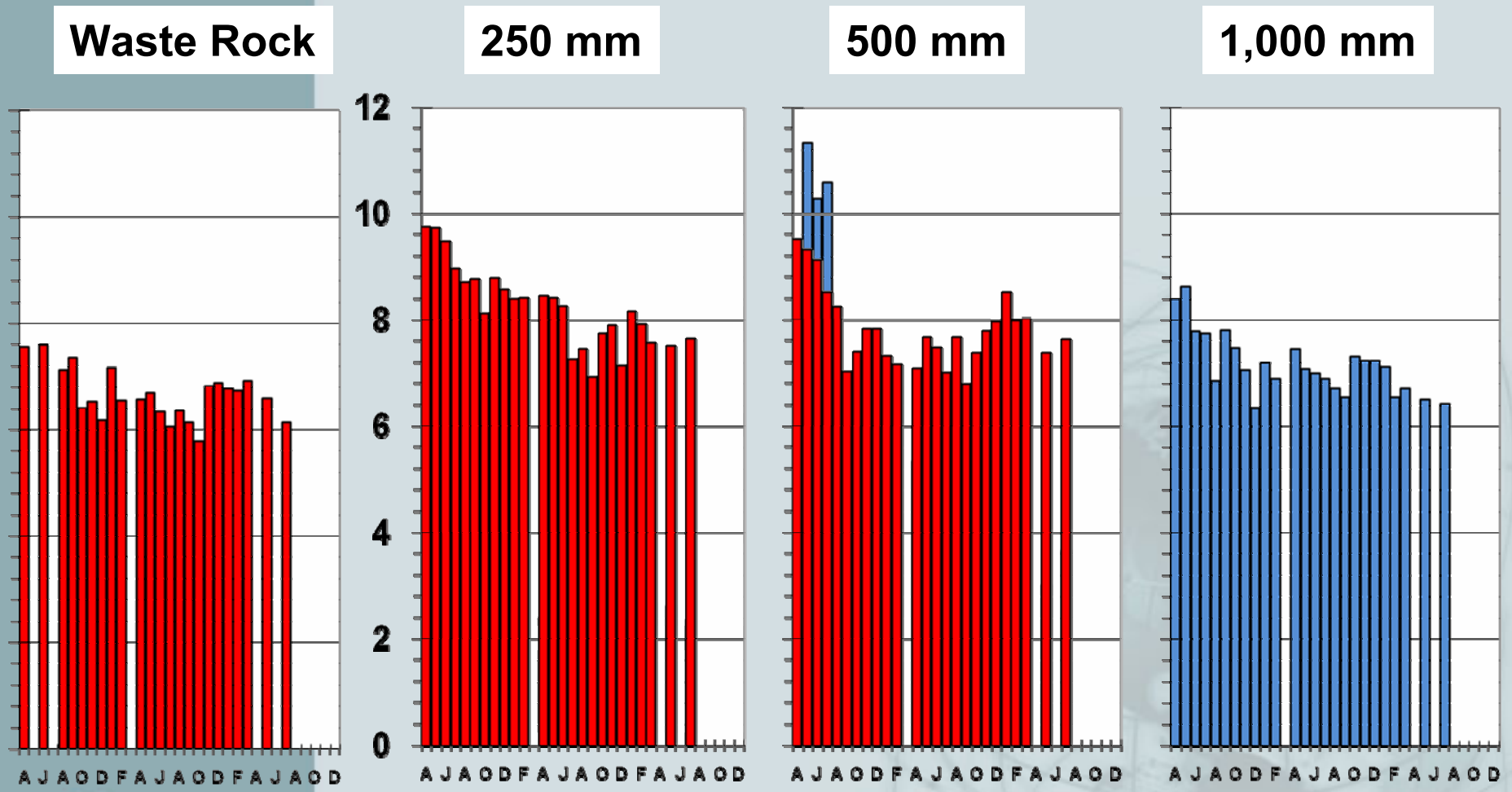
Paste Trial - Pore Water pH Trends

Control (no cover)

Barrier Cover (with bentonite)



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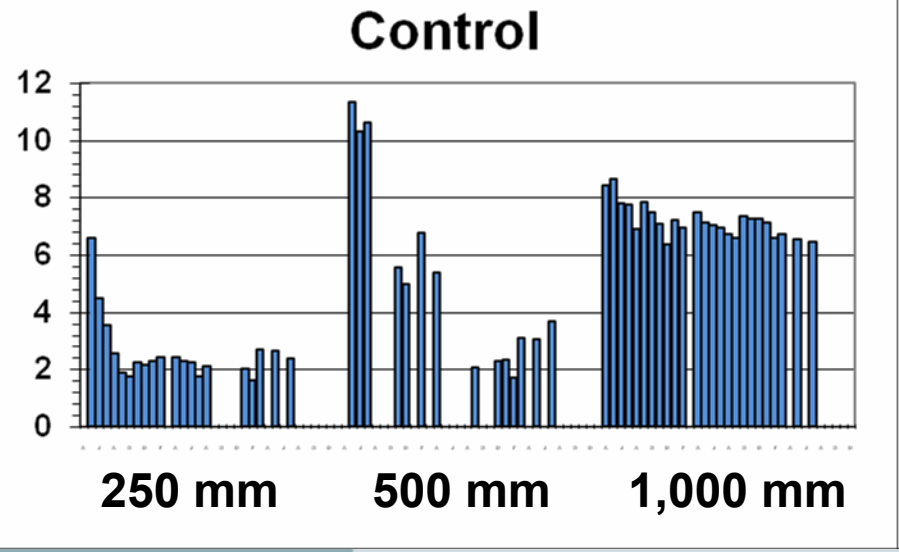
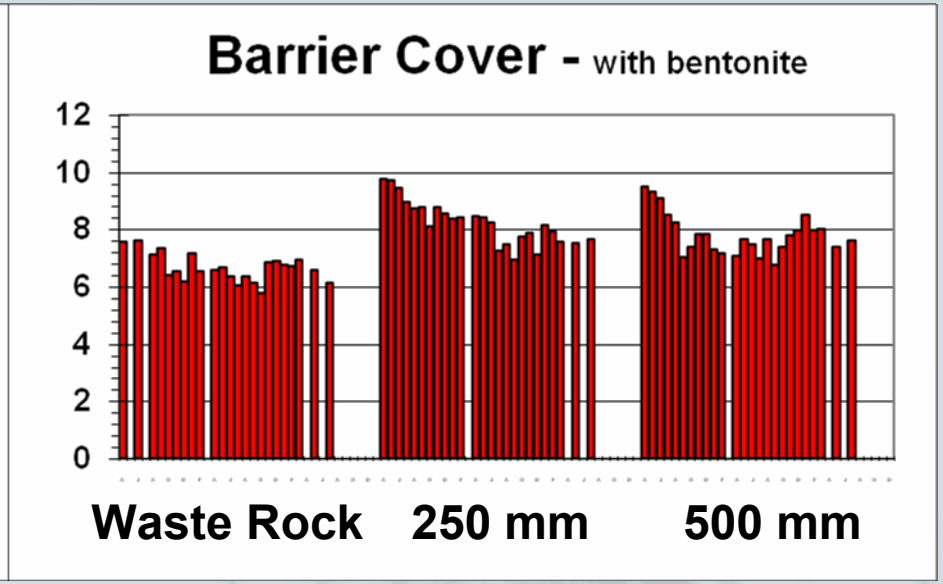
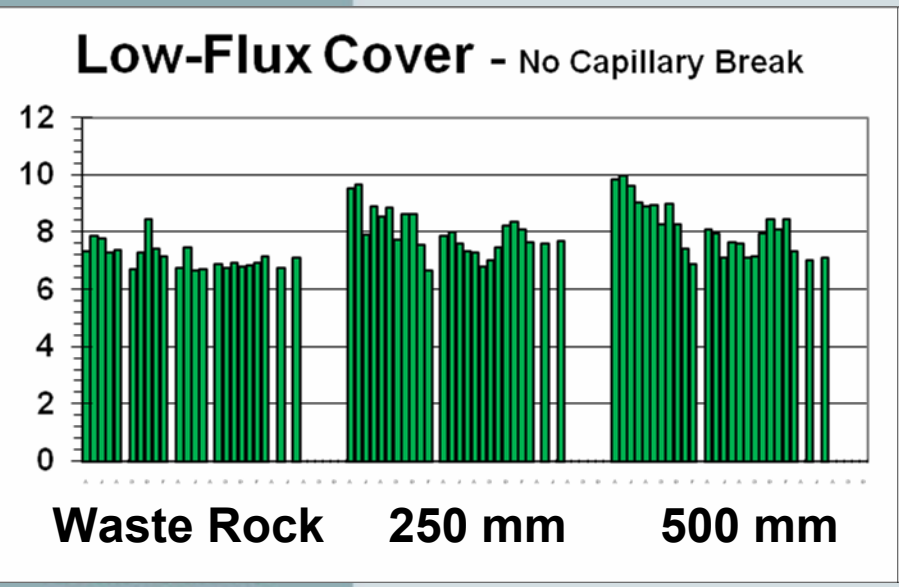
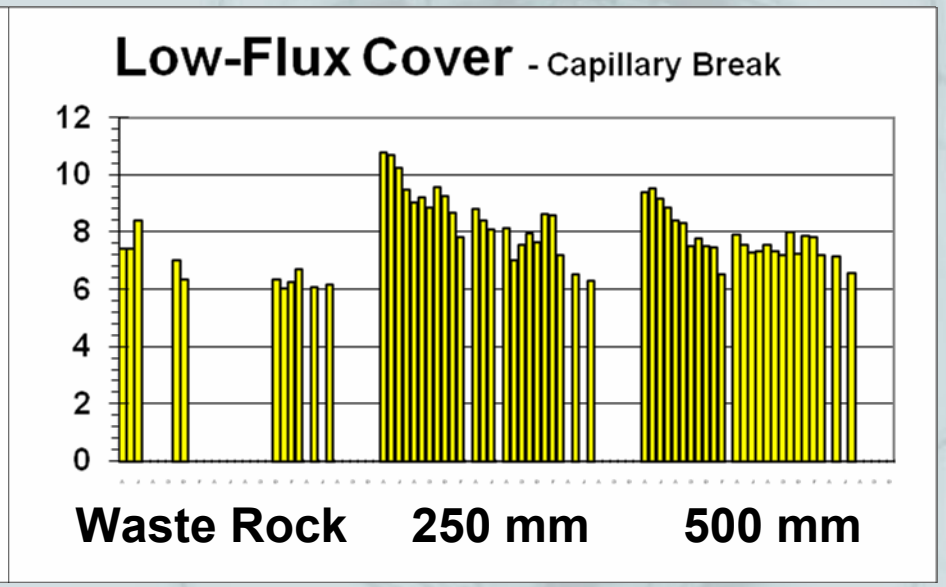
Paste Trial - Pore Water pH Trends









Fact or Fiction?

- Fiction:
  - ARD not a concern when using thickened tailings
  - Saturation can be maintained in arid climate without engineered controls
- Fact:
  - Lag time to ARD is proportional to moisture content – “operational window”
  - With engineered controls, saturation and prevention of ARD is feasible
  - Cover design is critical
    - in arid climate, low-flux cover better than barrier

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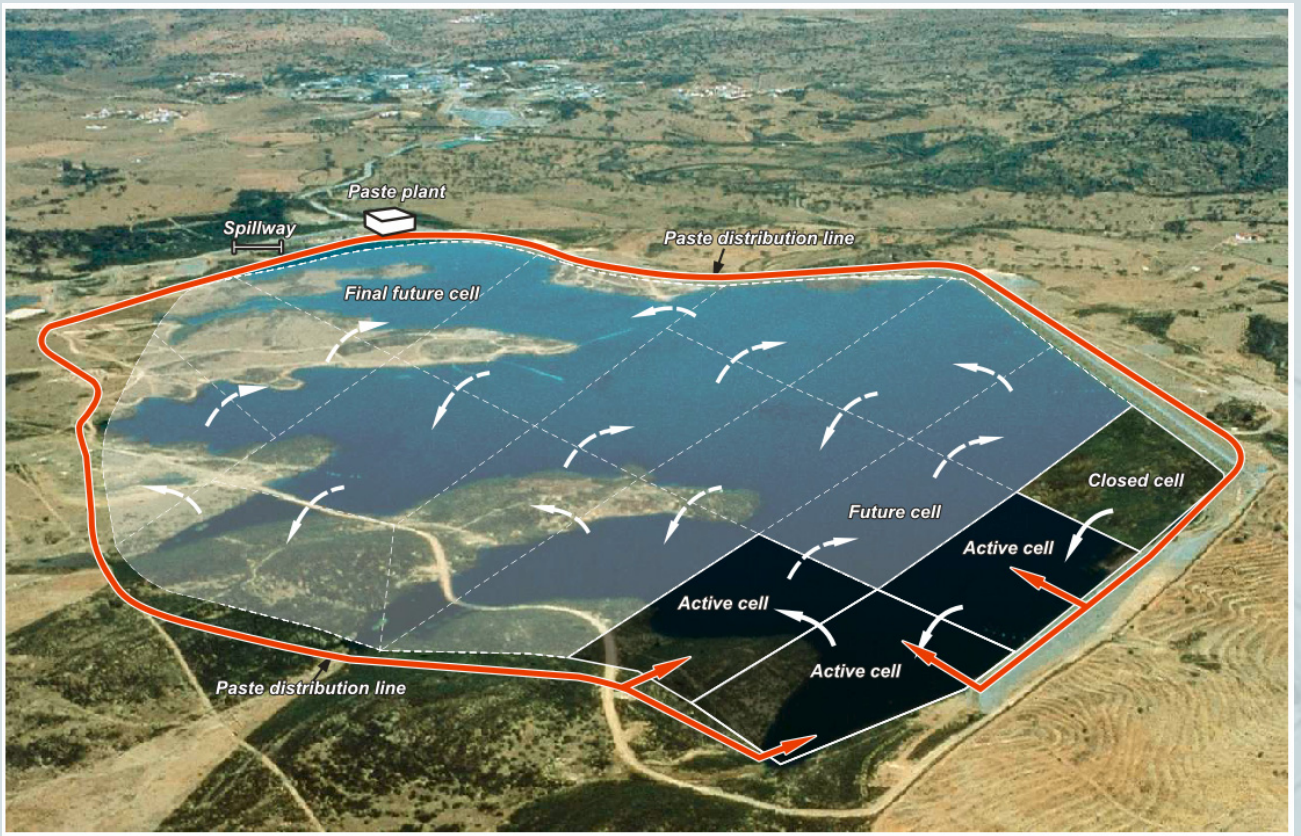
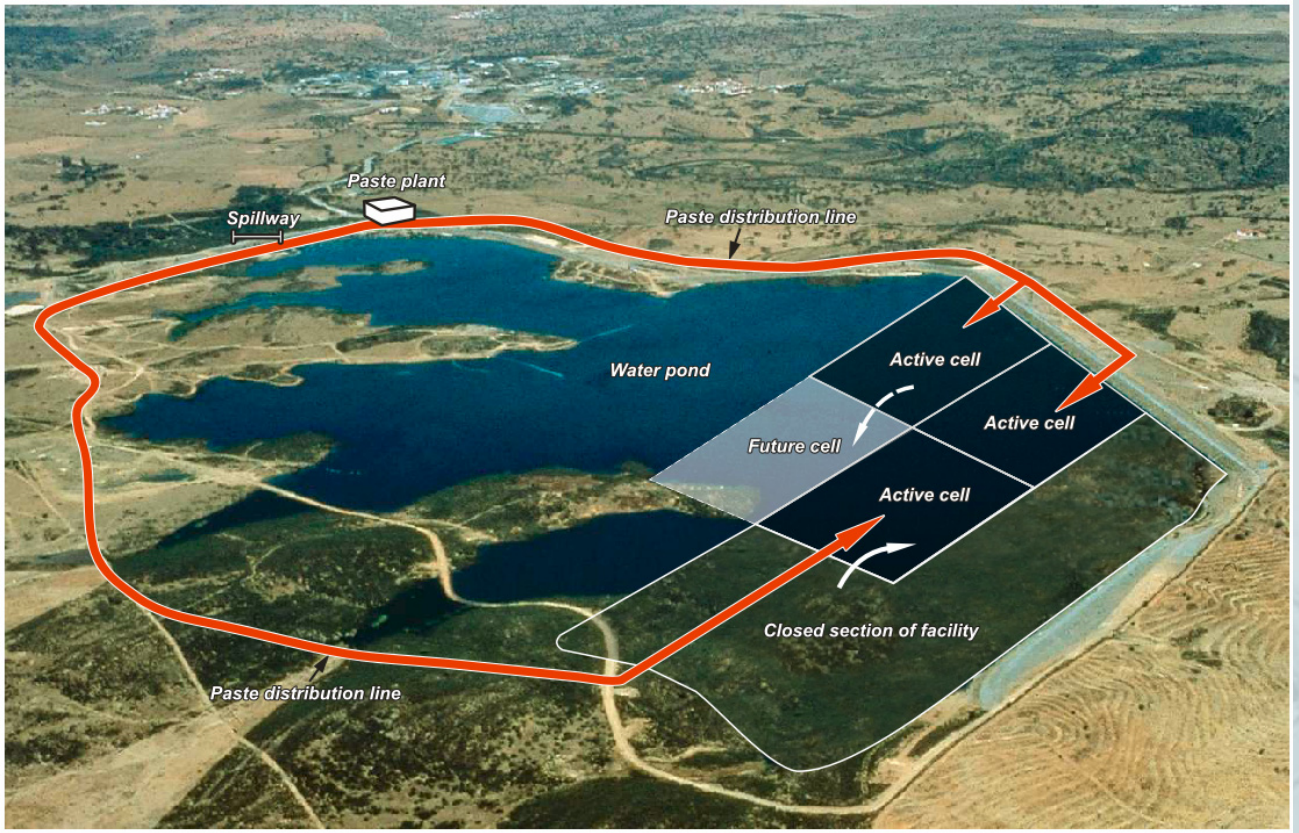
Conceptual Paste Placement



Early stage of filling

Conceptual Paste Placement (cont'd)



Progressive paste placement

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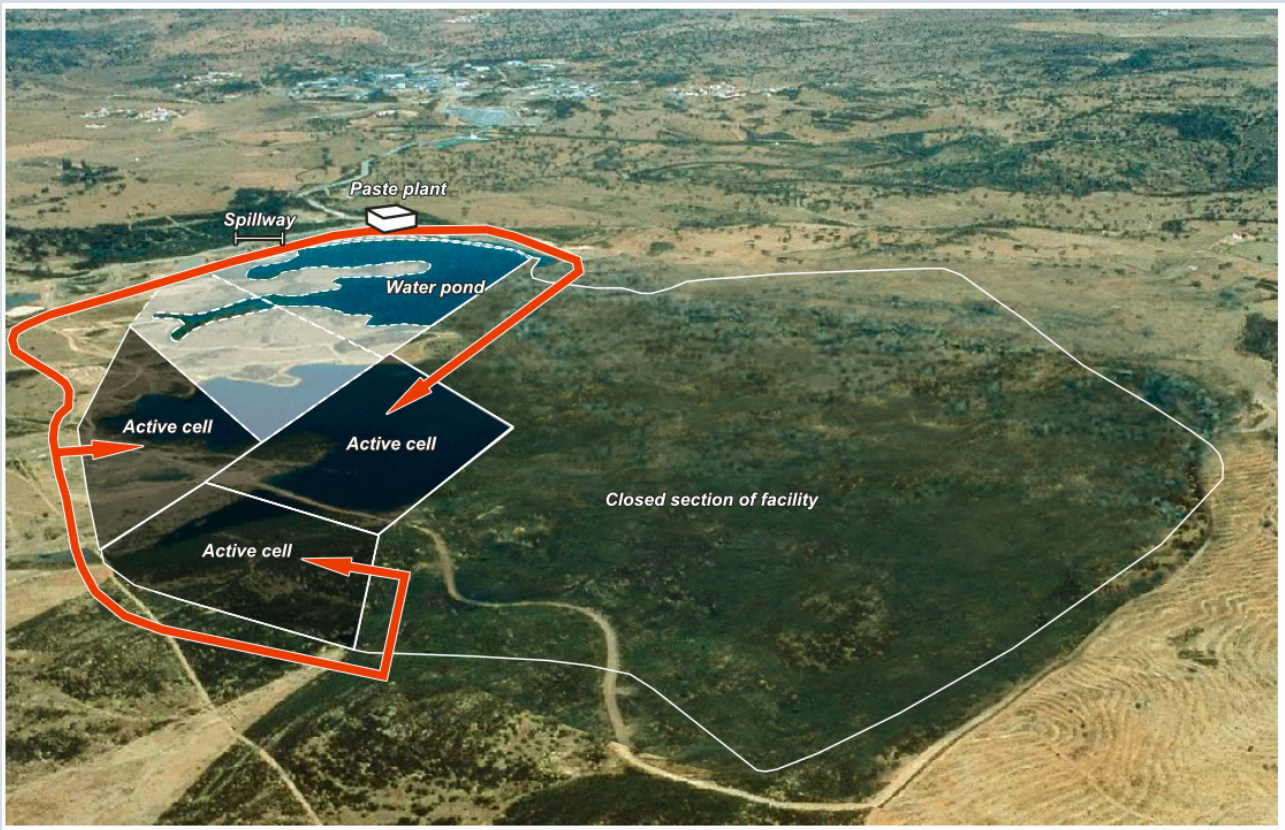
Conceptual Paste Placement (cont'd)



Nearing final paste placement

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Acknowledgments

- Mafalda Oliveira (Lundin Mining)
- Ward Wilson (UBC)
- Fernando Junqueira (Golder – Burnaby)
- Cheryl Ross (Golder – Redmond)

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Thank you for your attention

Any questions?

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