Surface Paste Disposal of High-Sulfide Tailings – Monitoring and Prediction of Drainage Chemistry based on Bench-Scale Testing, Field Cells and Pilot Plant Testing

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Presentation Overview

- Site Background
- Geochemical Testing Program
  - Bench-scale
  - Field cells
    - Water quality prediction
  - Ongoing work (pilot plant)
- Conclusions

Objective

- Identification and evaluation of practical disposal options and related handling/ engineering practices for surface tailings disposal
  - minimize environmental impacts (sulfide oxidation, seepage)
  - maximize geochemical stability and operational flexibility
  - cost effective

Background Neves Corvo Mine

- Underground high-grade Cu-(Sn-Zn) mine in Iberian Pyrite Belt
- Eurozinc (Somincor)
- Volcanogenic Massive Sulfide (VMS)
- Five lenticular ore bodies (approx. 5% Cu)
- Production since 1989
- Dominant ore minerals
    - Pyrite, chalcopyrite, sphalerite, galena, cassiterite, stannite, tetrahedrite, arsenopyrite

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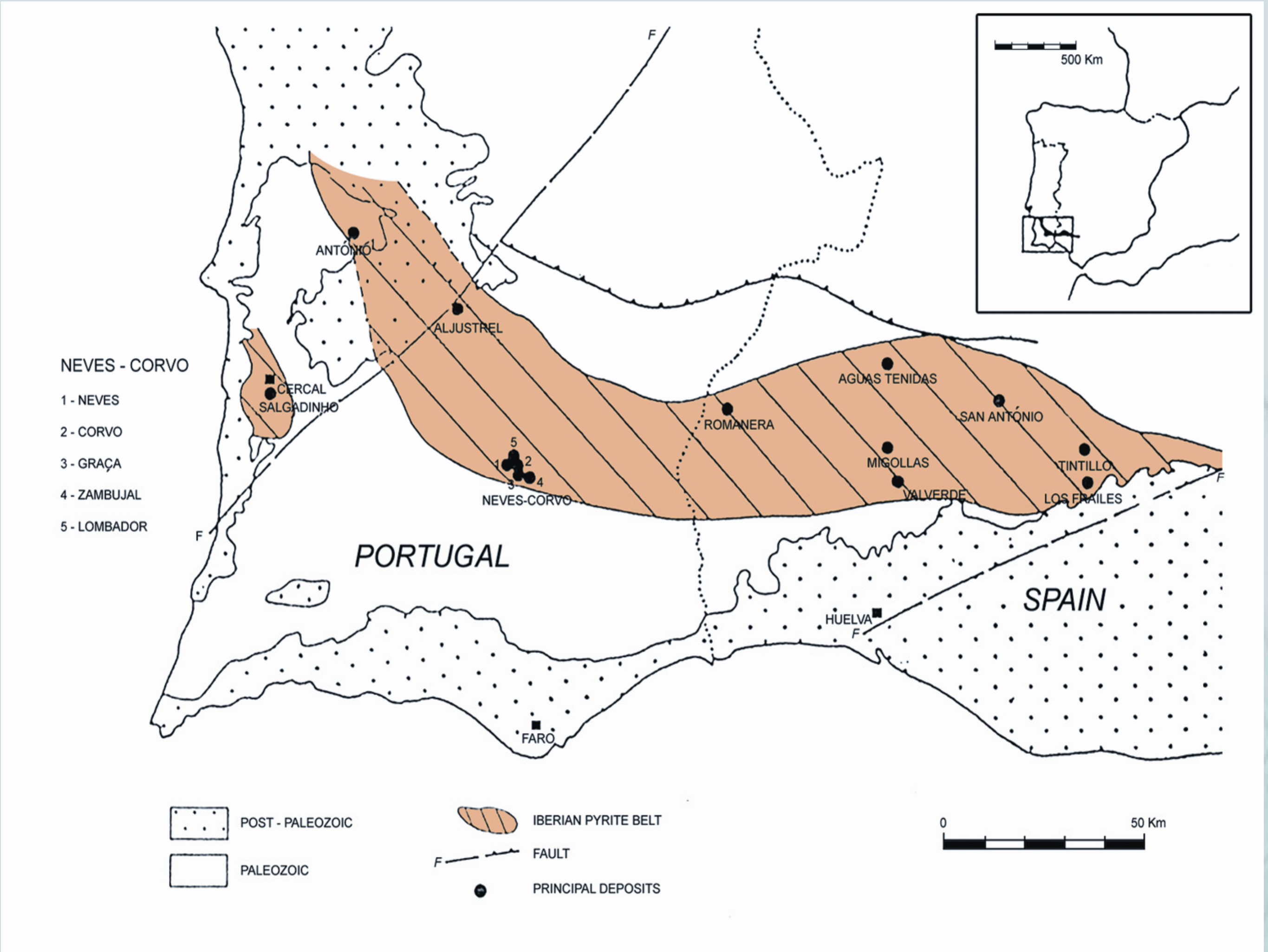
Location


NEVES - CORVO
1 - NEVES
2 - CORVO
3 - GRAÇA
4 - ZAMBUJAL
5 - LOMBADOR
ANTÓNIO
ALJUSTREL
CERCAL
SALGADINHO
NEVES-CORVO
ROMANERA
AGUAS TENIDAS
SAN ANTÓNIO
MIGOLLAS
VALVERDE
TINTILLO
LOS FRAILES
PORTUGAL
SPAIN
HUELVA
FARO
F
500 Km
0
50 Km
POST - PALEOZOIC
PALEOZOIC
IBERIAN PYRITE BELT
FAULT
PRINCIPAL DEPOSITS

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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Cerro do Lobo Impoundment

Tailings Characteristics

- ≈ 30 wt% total sulfur (≈ pyrite sulfur)
- pyrite + quartz + kaolinite > 90%
- AP: ≈ 910 kg $CaCO_3$/ton
- NP: ≈ 30 kg $CaCO_3$/ton
- Fine tailings: 60-70% < 20 micron

(Pre-)Feasibility Study

- Review of similar projects worldwide
- Conceptual design of placement options
- Evaluation of potential impacts to downgradient aquifer due to change in disposal method
- Geotechnical testing program
- Geochemical testing program
    - Bench-scale program
    - Field cells
    - Pilot plant

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Bench-Scale Testing Program

- Evaluate environmental stability of tailings mixtures
- Focus on sulfide oxidation and acid generation as function of
  - Moisture content
  - Amendment
- Cheap, rapid, easily-implementable
- Testing program not designed for rigorous quantitative evaluation

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Bench-Scale Testing

- Twenty-four tailings samples
- Moisture content
  - Filter cake
  - Agitated filter cake
  - 150-mm slump paste
  - 250-mm slump paste
- Amendment
  - None
  - Lime (0.5 and 1.0 percent)
  - Portland cement (0.5 and 1.0 percent)
  - Bactericide - Promac® (1.0 percent)
- Control sample (silica sand)

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Bench-Scale Testing

- Monitored conditions in Somincor laboratory
- 2-kg samples in plastic containers
- Measurement of temperature, paste pH, paste SC
- 30 weeks of testing
- Undisturbed (except agitated samples)
- Not intended to maintain constant ambient conditions and quantitatively control moisture content

Laboratory Set-Up

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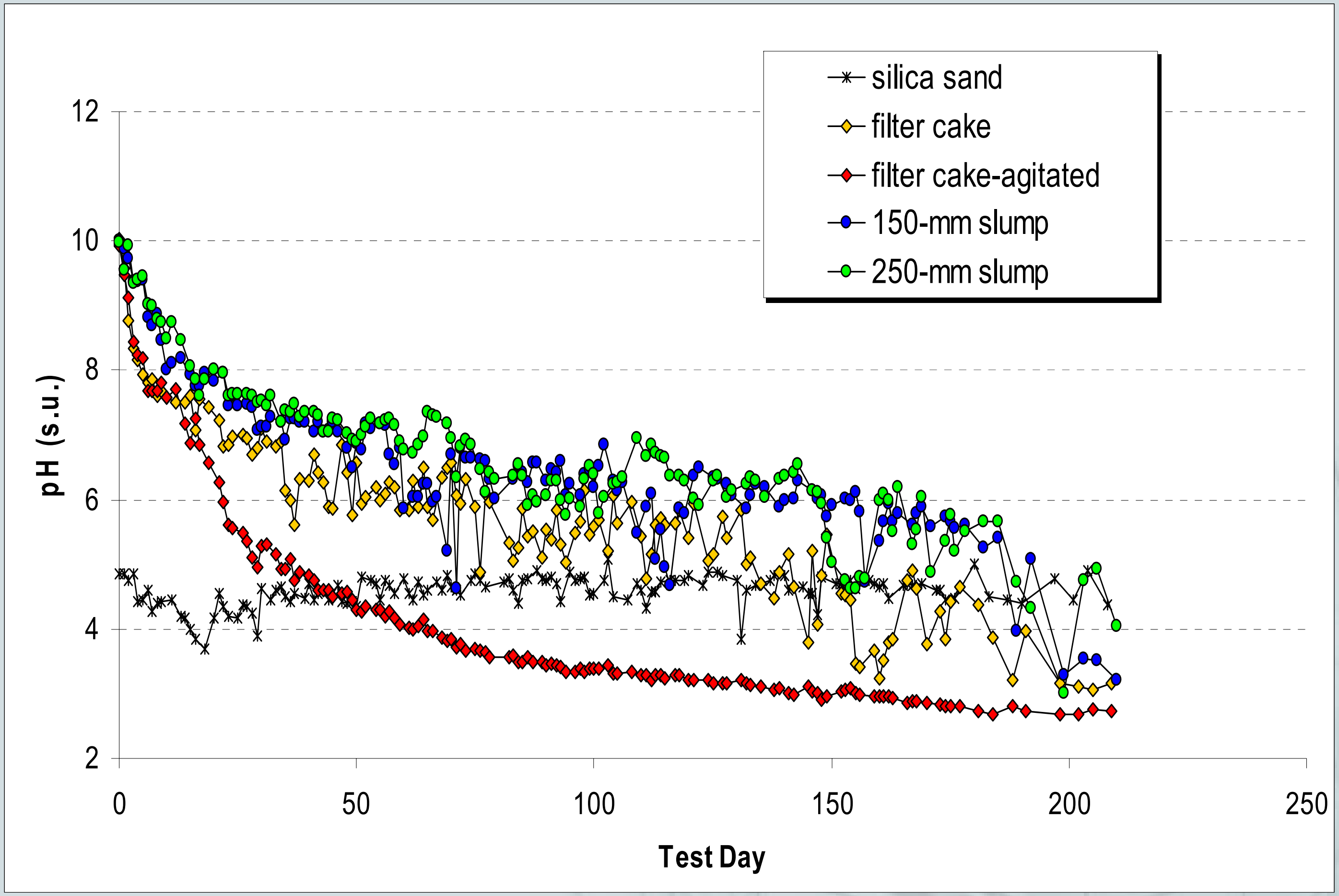
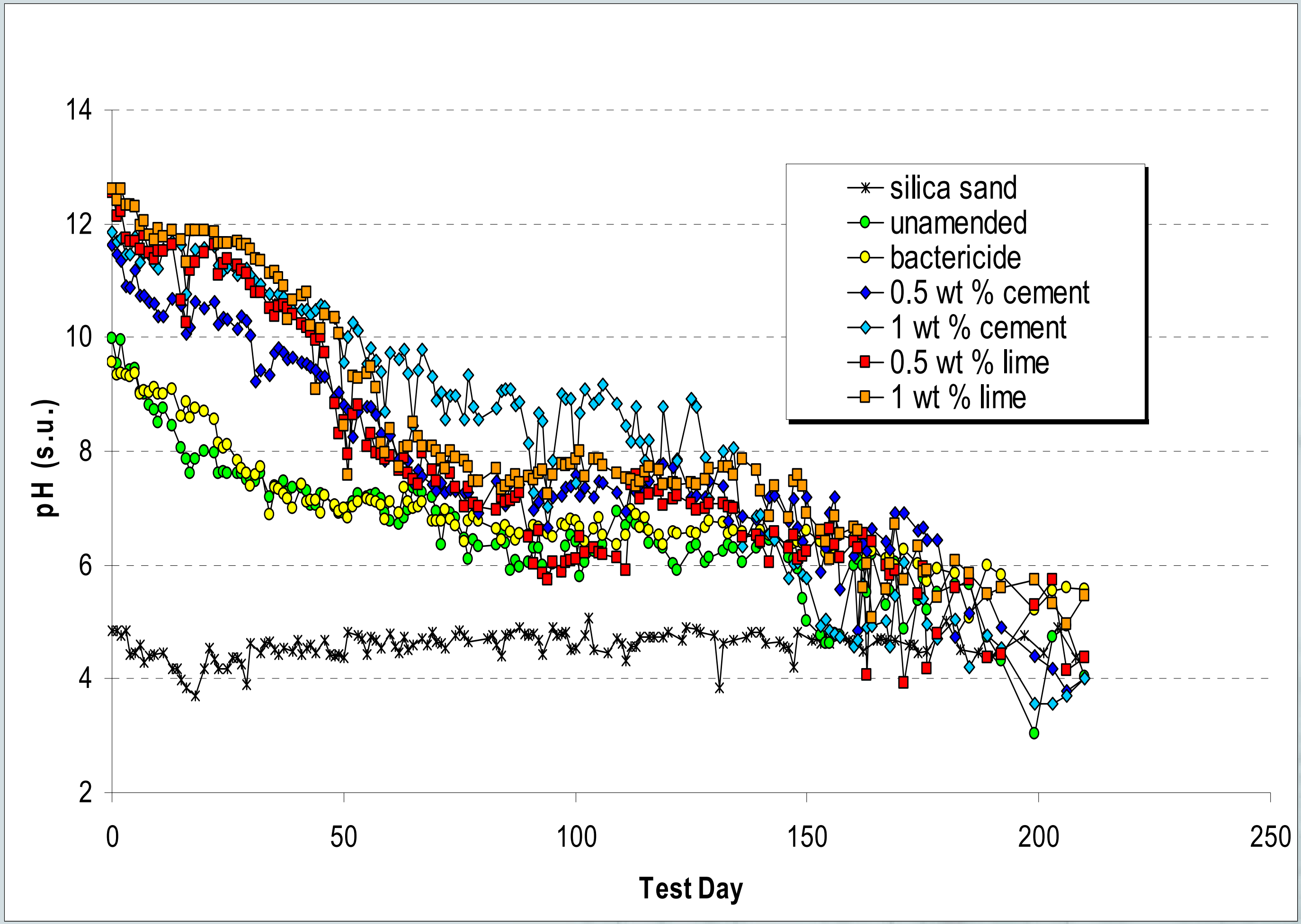
Unamended - pH



250-mm Slump - pH



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Summary of Bench-Scale Results

- Results generally consistent with expected relationships between moisture content, amendment, and sulfide oxidation
  - Best performance for highest moisture content
  - Lime/cement provide early buffering capacity but not for long term
  - Lime/cement do not affect oxidation rate
  - Differences between lime/cement minor
  - Bactericide shows short-term benefit

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Field Trials

- Field testing program
  - 250-mm slump (unamended)
  - 250-mm slump (bactericide)
  - 250-mm slump (0.5 percent cement)
- Two sets
  - Periodic irrigation
  - Ambient conditions
- Monitoring of overflow and underflow water quality

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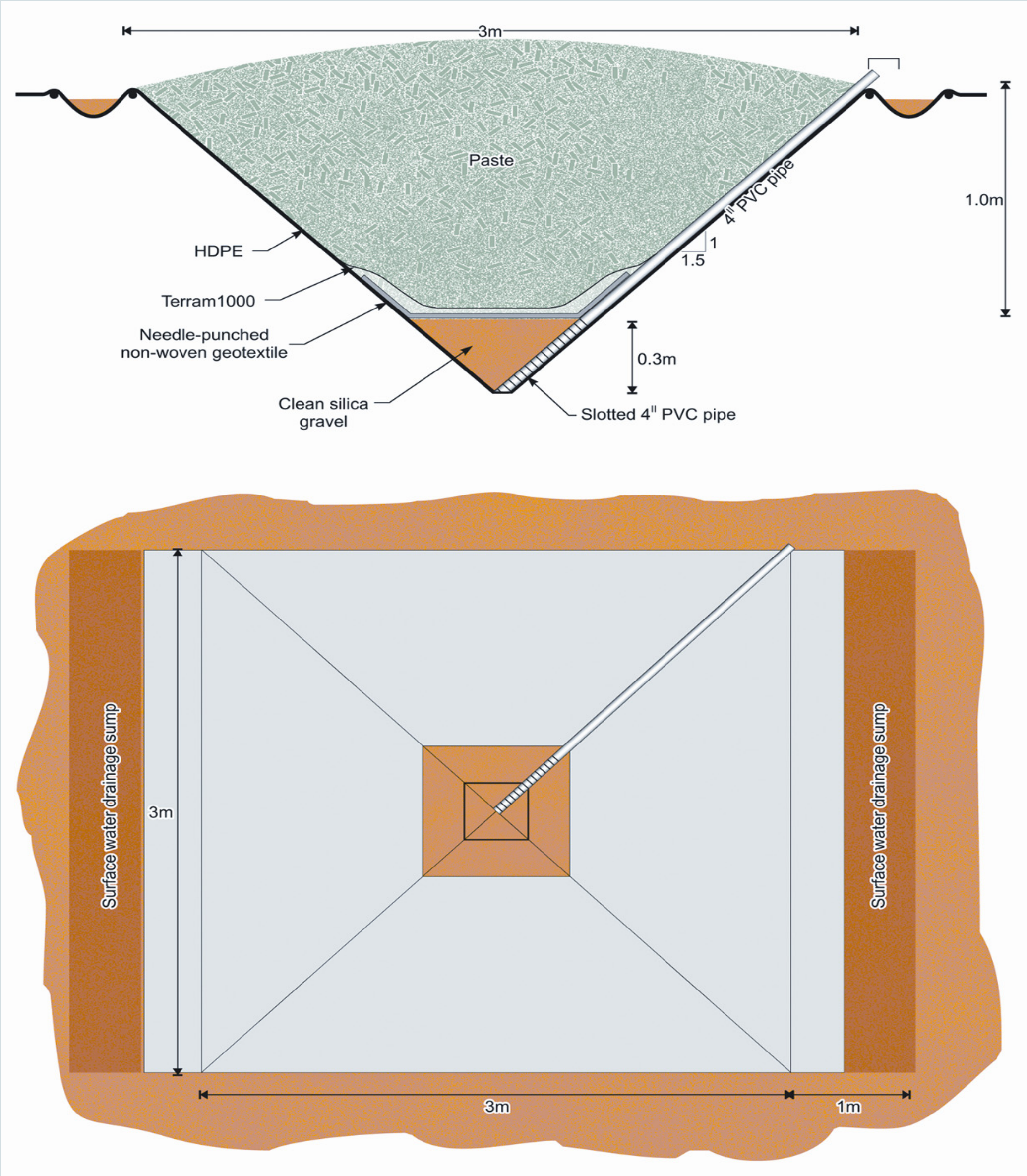
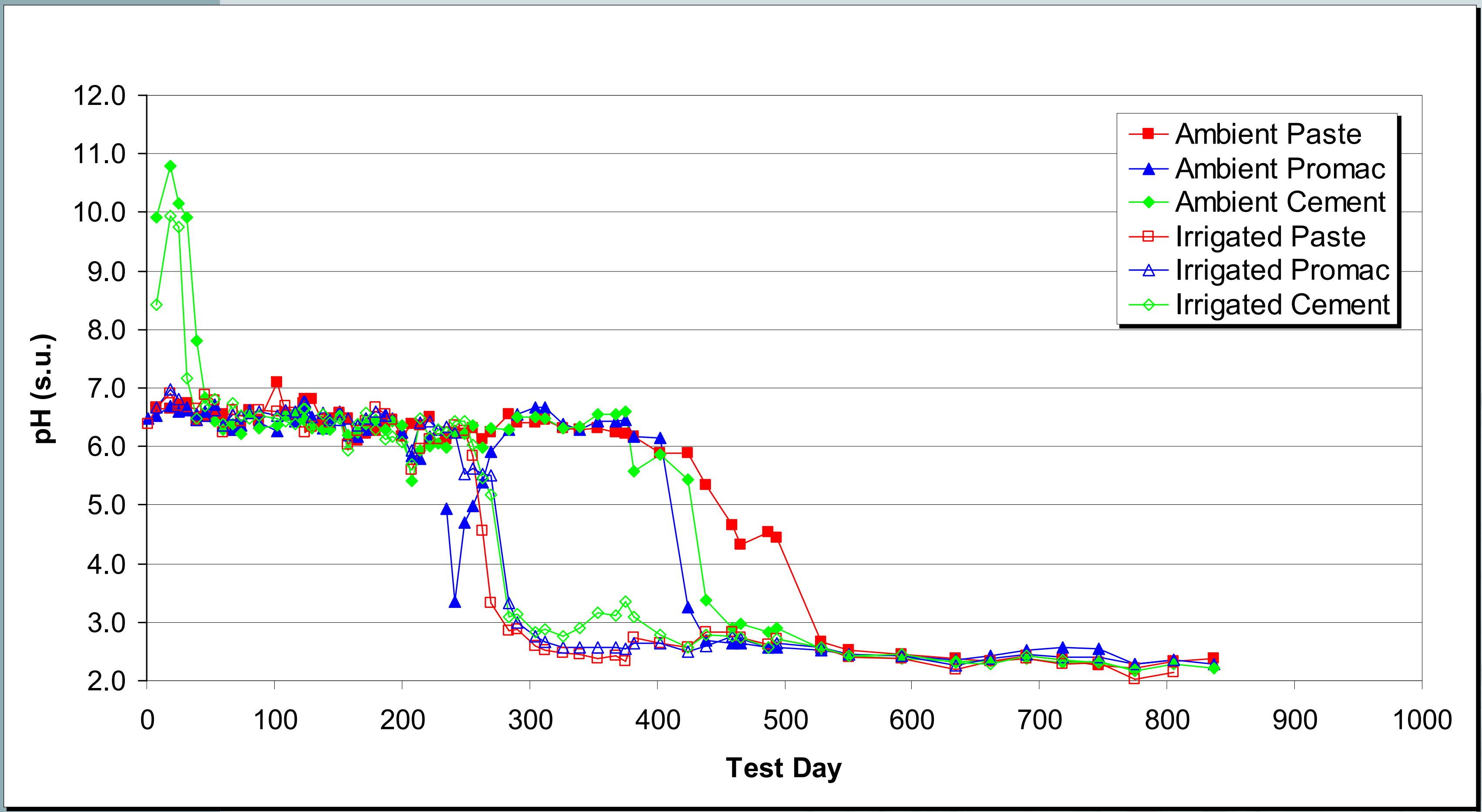
Cell Configuration



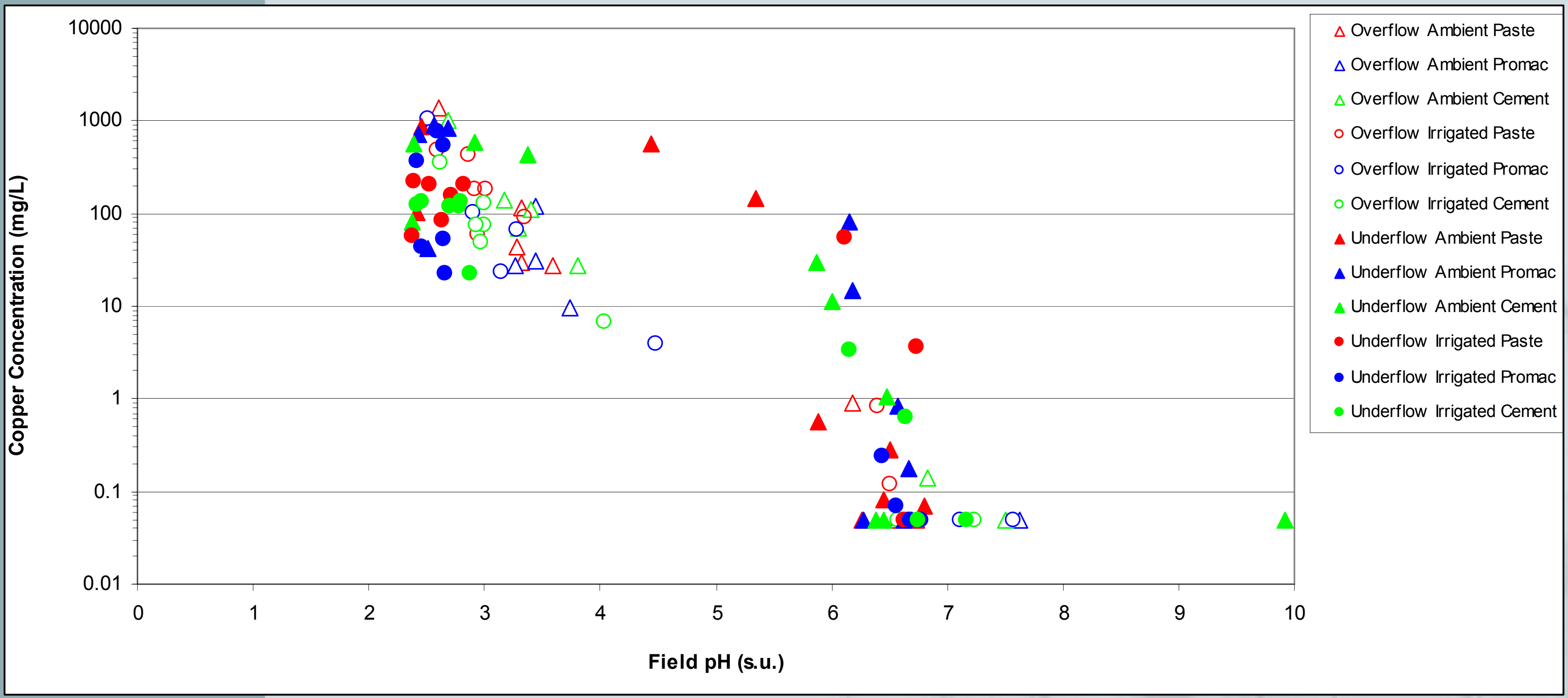
Cell Construction

Irrigation and Sampling

pH Trends Underflow



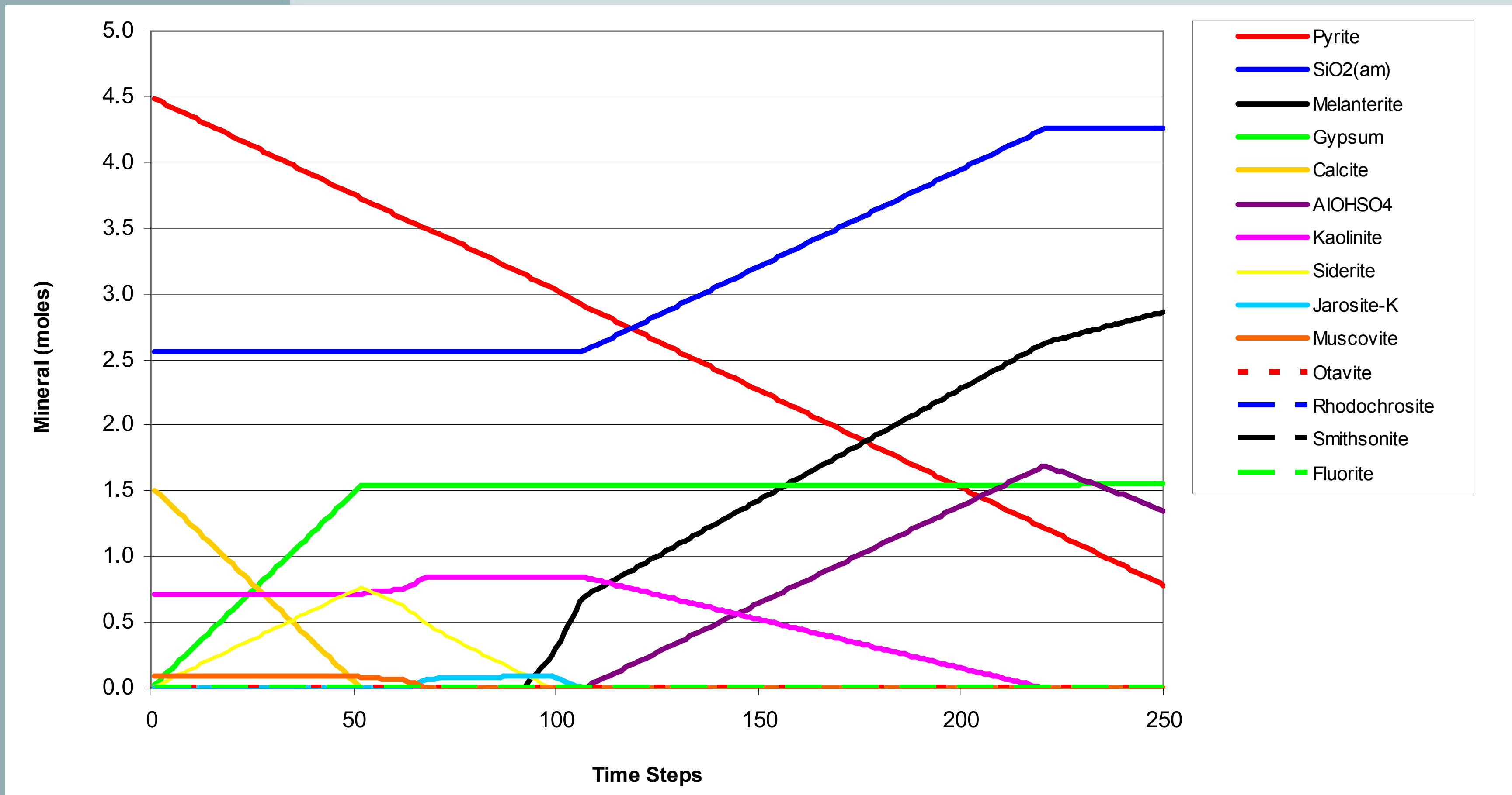
Cu-pH Relationship



Summary of Field Cell Results

- Majority of ambient and irrigation water report as runoff
- Seepage volumes reflect short-circuiting: chemical evolution governed by flow regime
- Differences in geochemical performance more pronounced between irrigated/ambient cells than between amended/unamended cells
- Lag time for acidic conditions in irrigated cells (7 months) provides benchmark for operational paste placement and closure
- What is long-term seepage quality?

Sequence of Mineral Reactions



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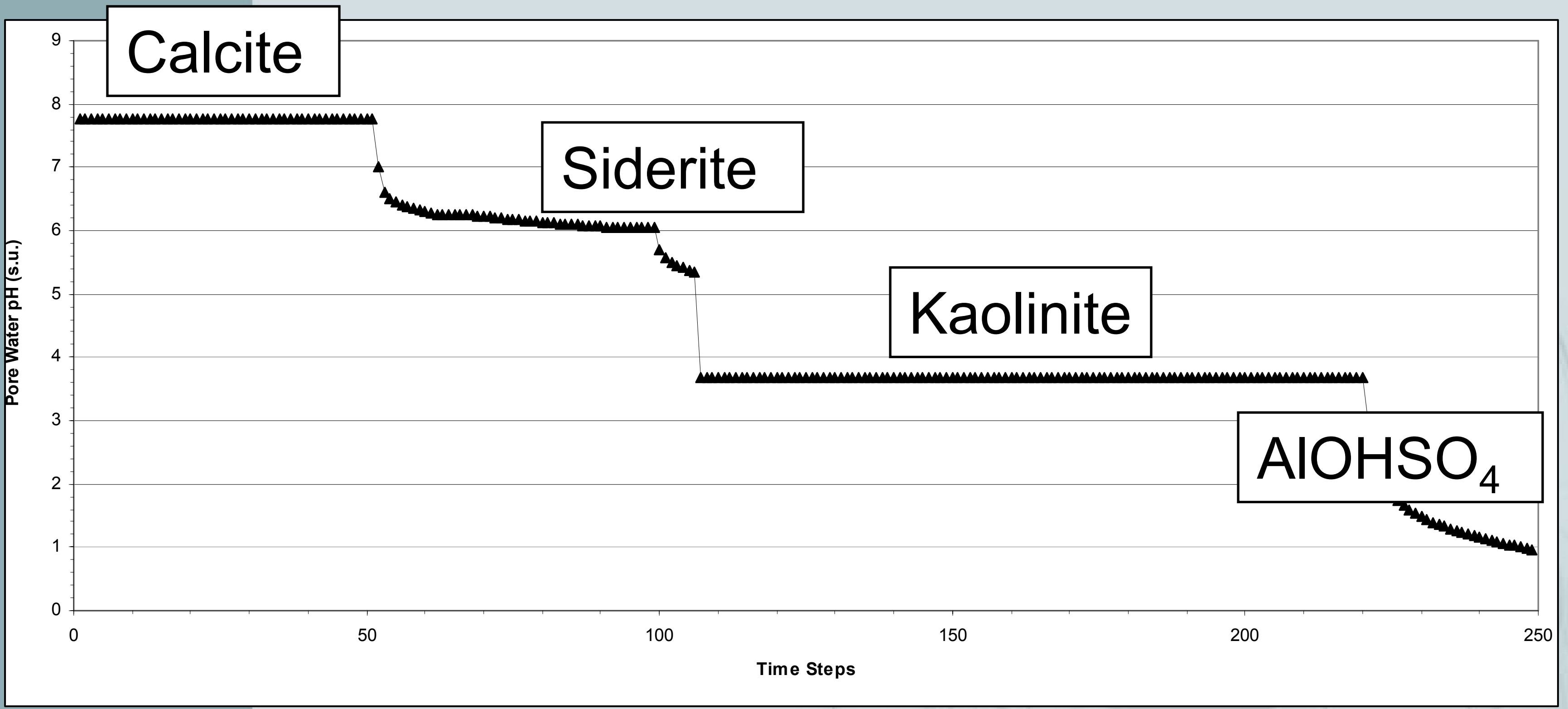
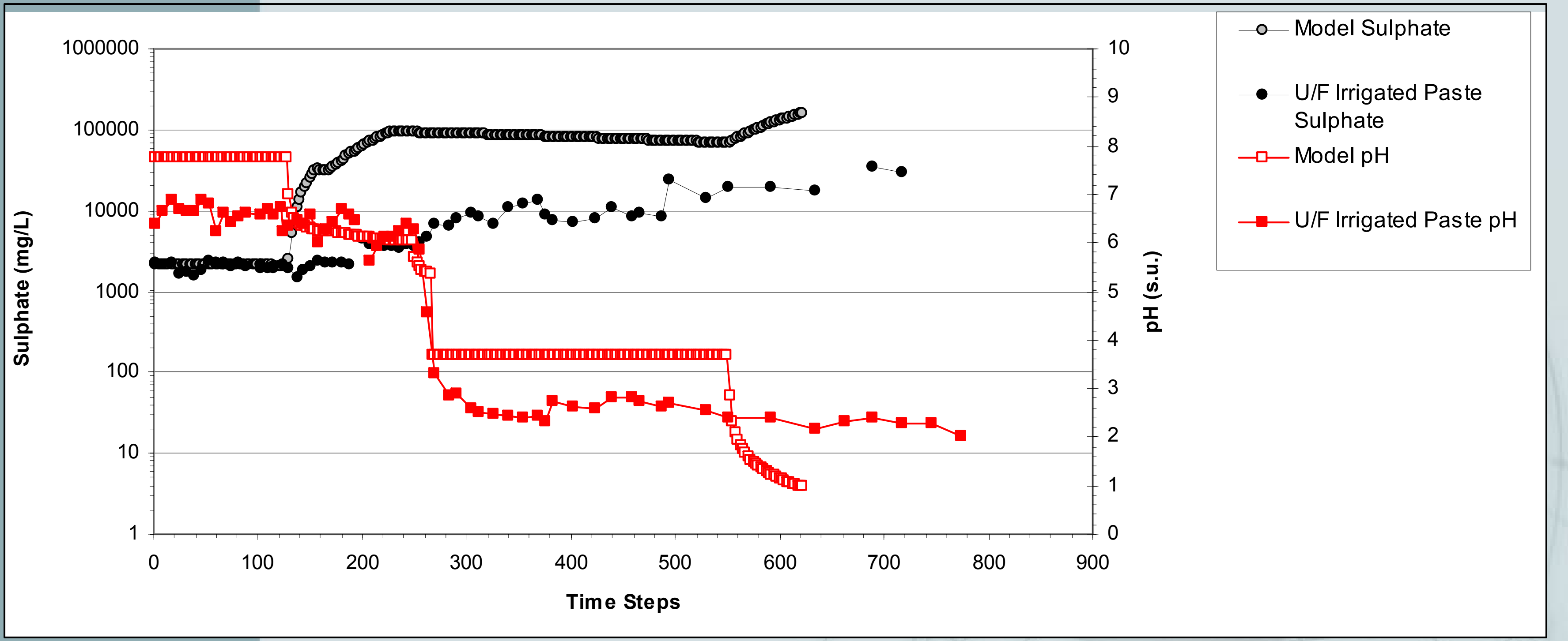
Buffering Sequence and pH Trend



Comparison Modeled and Observed Trends



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Discrepancies

- Equilibrium vs. kinetics: kaolinite dissolution not effective due to short-circuiting
- Incomplete mineralogy
  - Fe-carbonate instead of calcite
  - Unidentified secondary phase controlling sulfate

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What is Long-Term Seepage Quality?

- Evidence from bench-scale testing
- Buffering by kaolinite supported by supernatants of unamended samples (pH 3.5 to 3.8)
- Good agreement between predicted metal concentration from field cell (pH/metal relationships) and supernatants
- **If paste disposal and closure conducted in accordance with BMPs, supernatant reasonable representation of long-term seepage quality**

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Ongoing Work

- Pilot plant testing
  - 20m^3/hr production in Deep Cone Thickener (DCT)
  - 35,000 m^3 in 1-hectare area
  - Experience with plant operation/placement
  - Environmental monitoring
    - Suction lysimeters, piezometers, standpipes
    - Runoff collection
  - Geotechnical monitoring
    - Tensiometers
    - Berm design
  - Trials of cover designs
    - Store/release without capillary break
    - Store/release with capillary break
    - Infiltration barrier (sand/bentonite)

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Overview of Pilot Plant Area

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Preliminary Conclusions

- Investigation to date supports use of paste as viable disposal alternative
- Potential benefits
  - Flexibility in siting, disposal, reclamation strategy
  - Reduced leachate generation
  - Elimination of water cover
  - Co-mixing with waste rock
- Paste placement needs to maximize two key beneficial properties:
  - high degree of saturation
  - low permeability
- Water management (in particular runoff) will govern placement protocol

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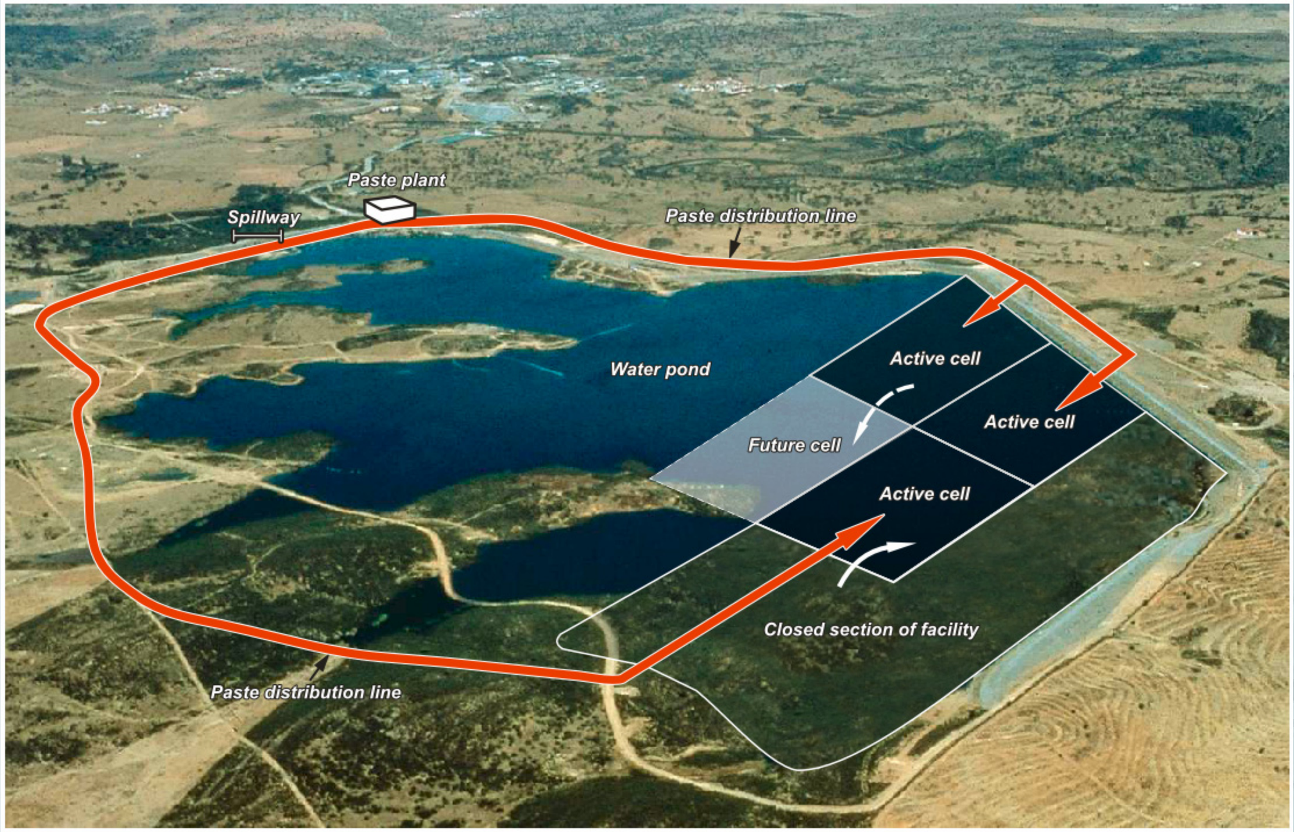
Conceptual Paste Placement

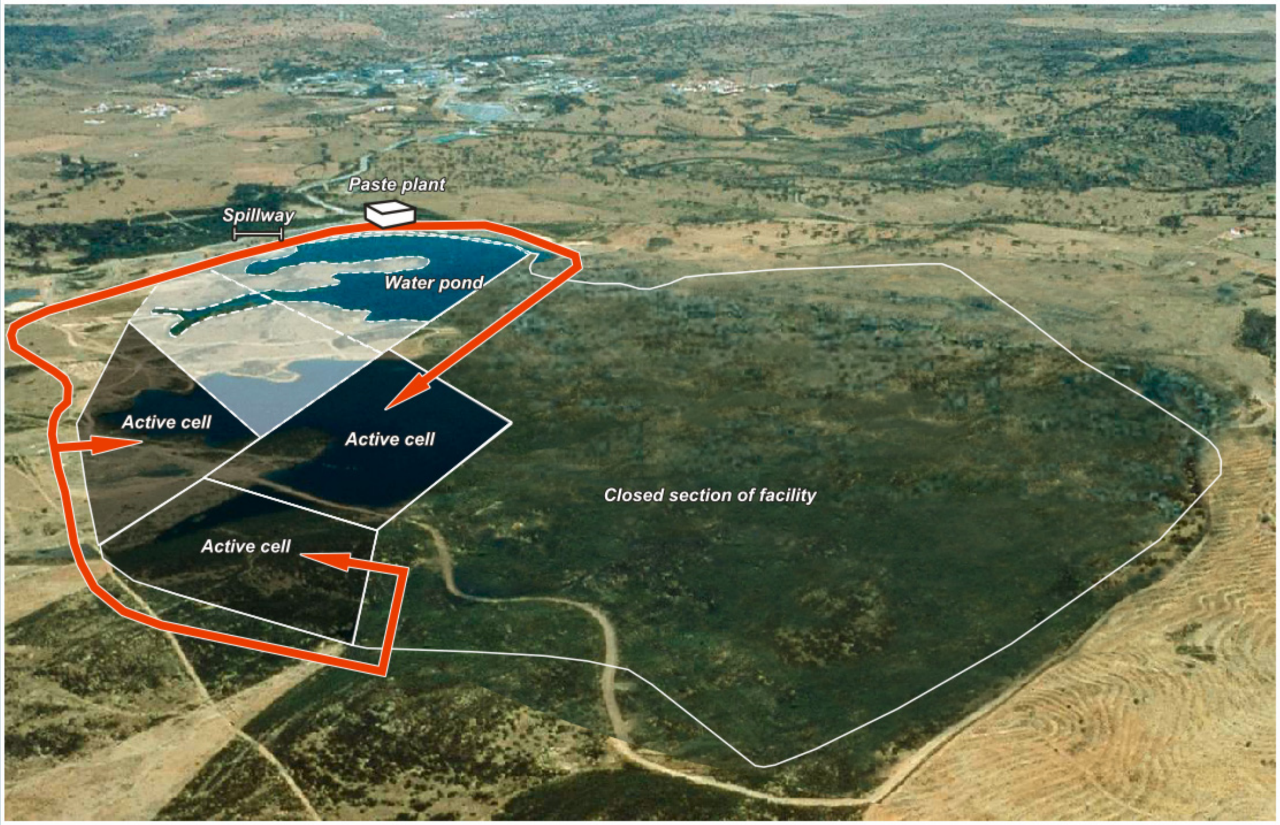
Early stage of filling

Conceptual Paste Placement (cont'd)



Progressive paste placement

Conceptual Paste Placement (cont'd)



Nearing final paste placement

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