The Affect of Tailings Characteristics on Cover System Design

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Presentation Overview

- General observations on cover systems in semi-arid climate:
  - Hydraulic behavior
  - Vegetation behavior
  - Salinity and pH migration
- Observation drawn from five tailings reclamation case studies performed in the southwest United States

Physical, Geochemical and Spatial Characteristics

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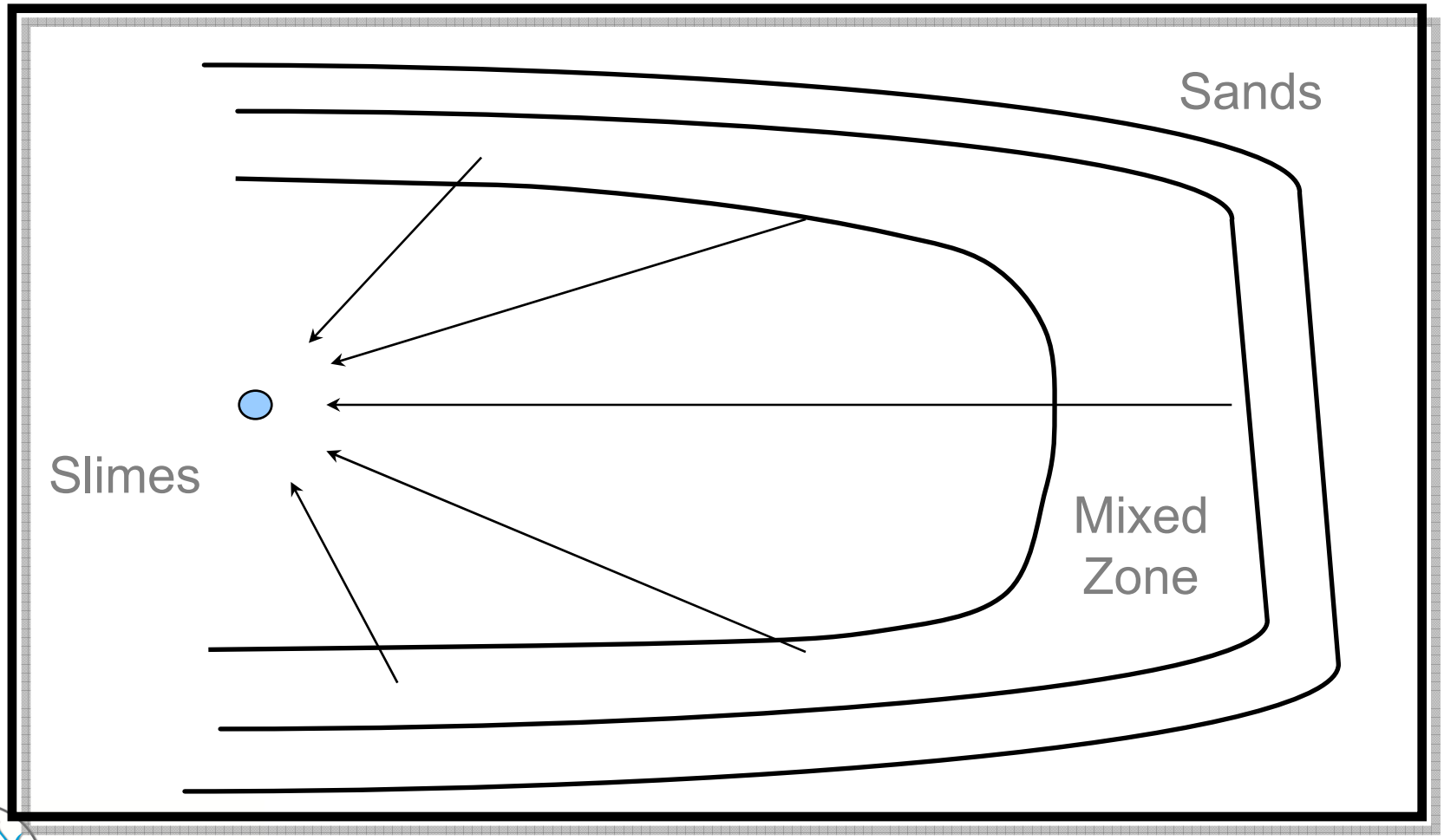
Physical Characteristics

- Tailings are poorly graded
  - Mostly silt size
  - Highly erosive (high intensity precipitation/wind)
  - No soil structure
- Impoundment construction results in additional sorting and layering
  - beach sands
  - slimes
  - mixed areas
- Moisture retention and permeability varies by material types
- Variable saturation and drainage
- Drainage can take decades to centuries (size, height….)

Tailings Segregation and Structure



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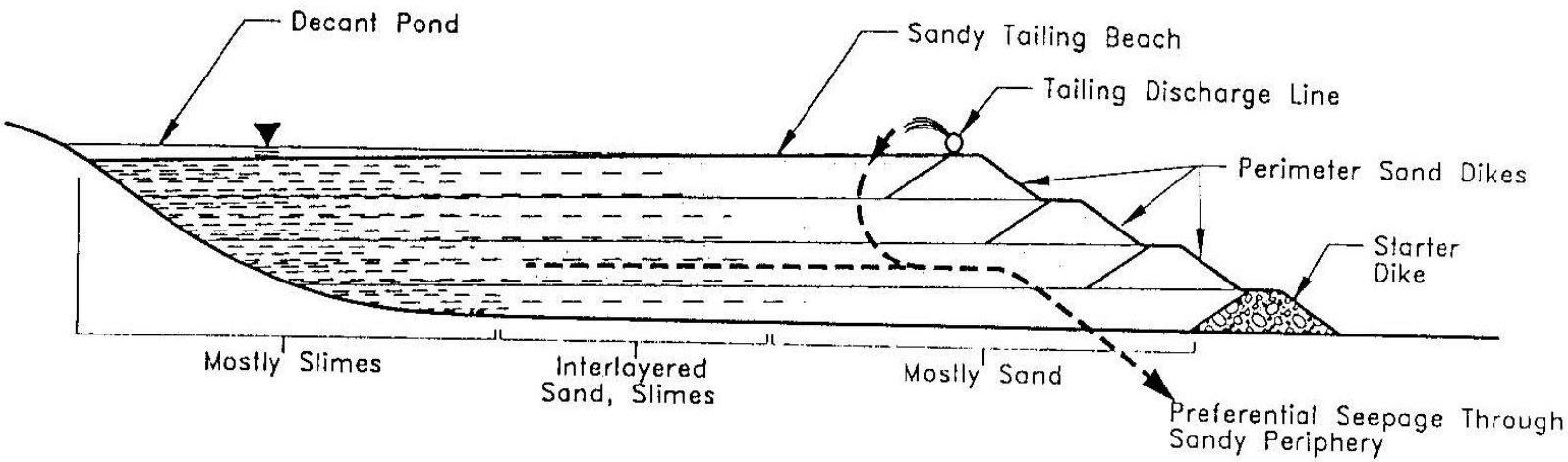
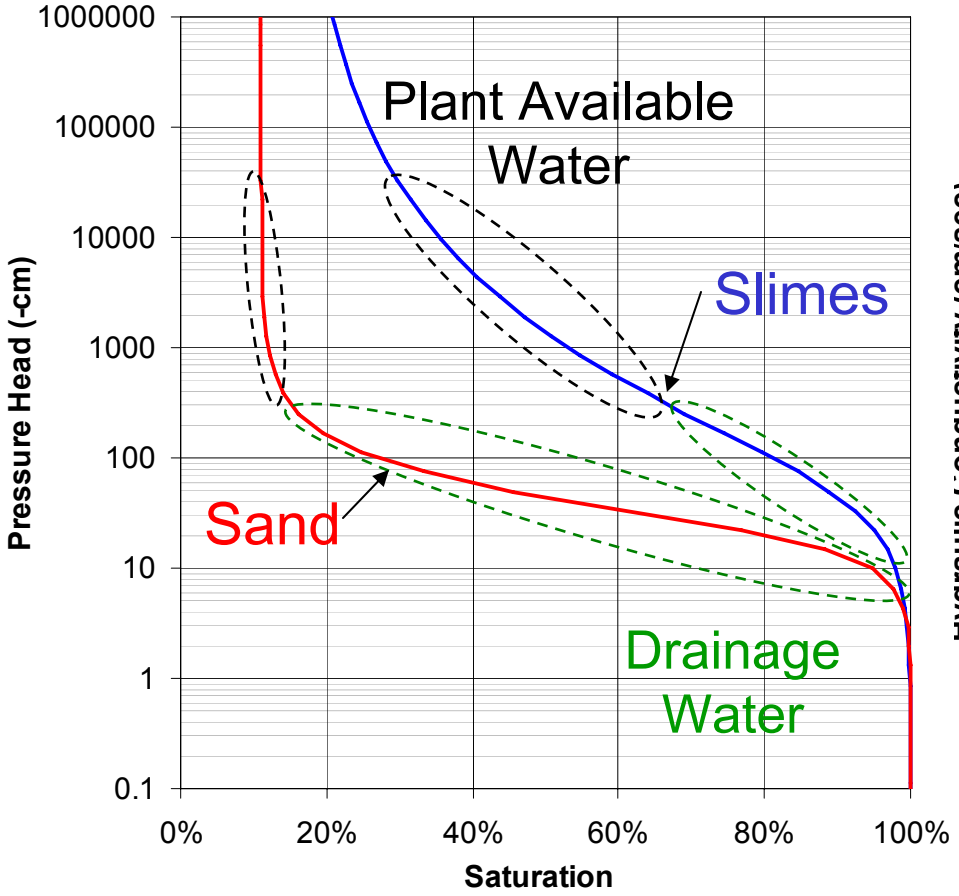
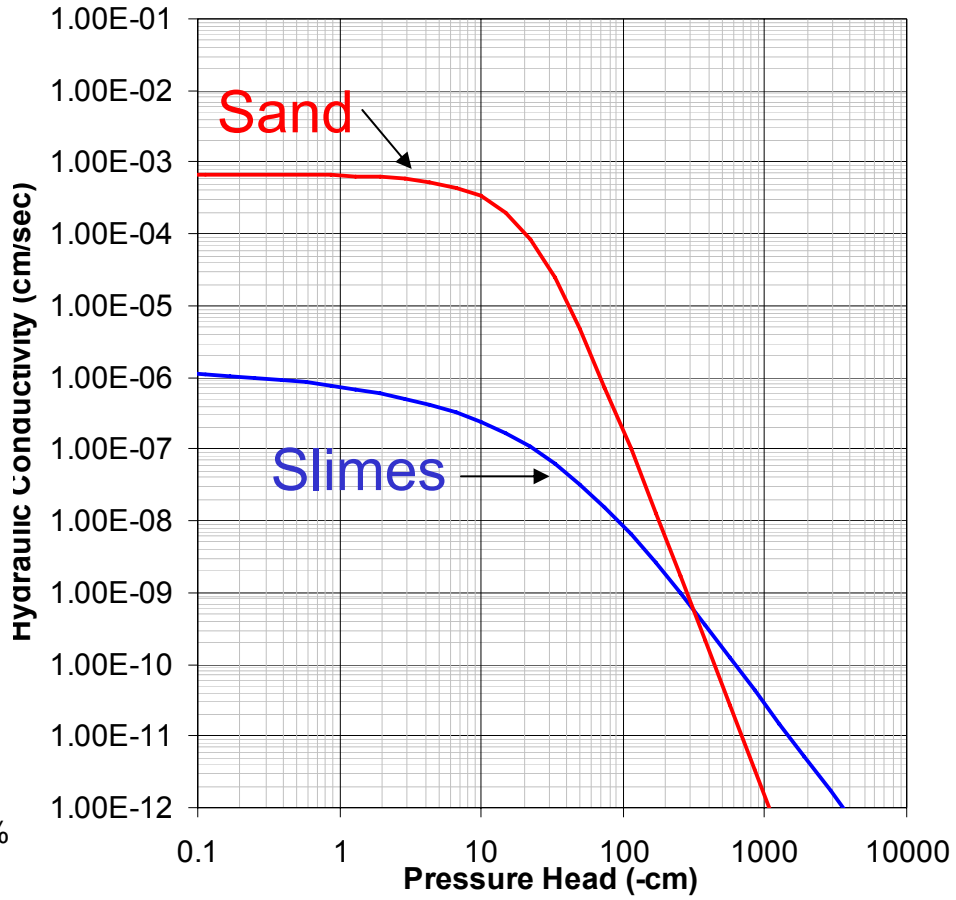


Moisture Retention Characteristics





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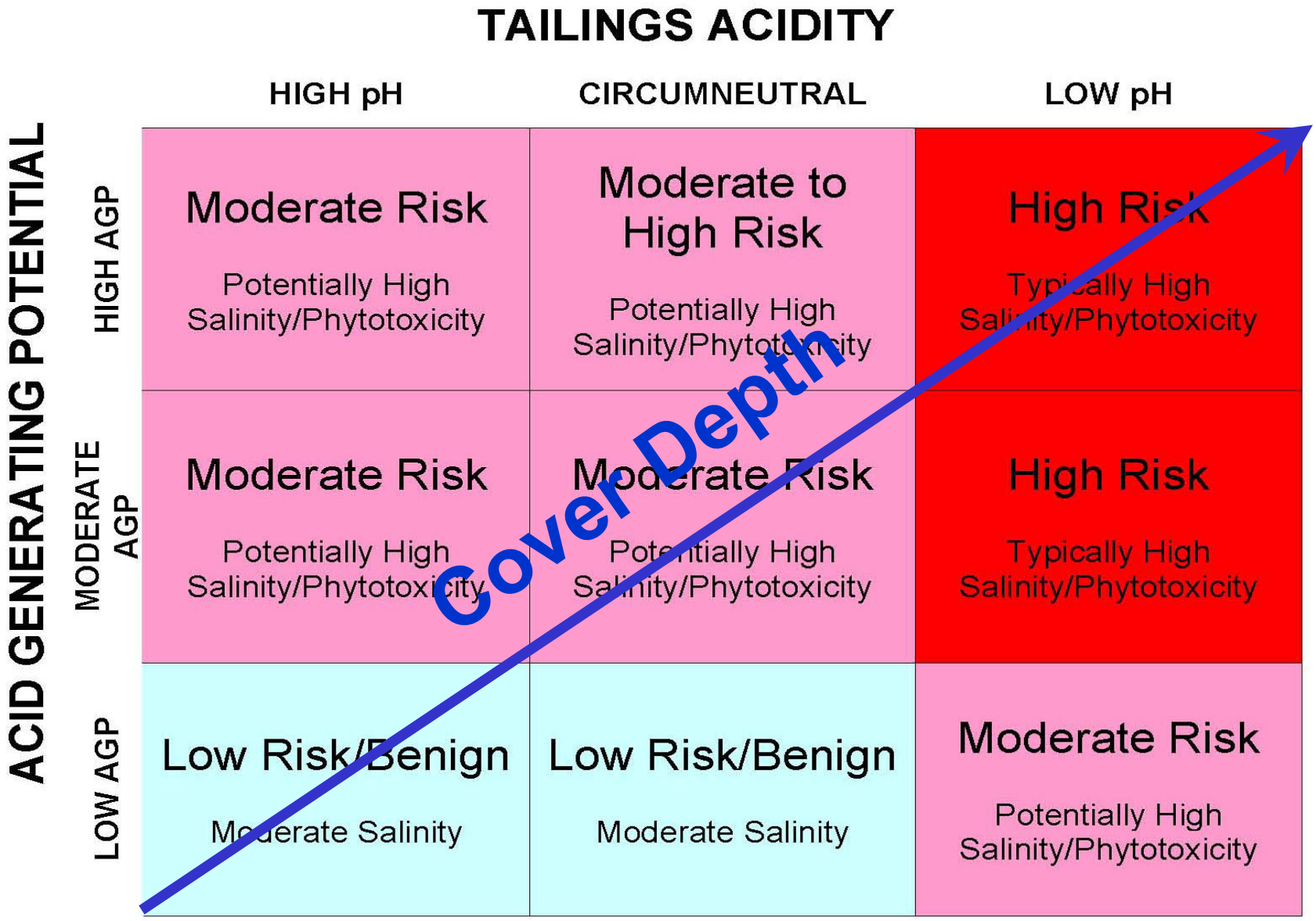
Geochemical Characteristics

- Can be saline to hyper-saline
- Ore body mineralogy can result in:
  - High acid generation potential (and acidity)
  - High plant available metals (i.e. arsenic)
- Typically low plant fertility
- Lack of organic matter and microbiota
- High moisture retention and permeability can limit infiltration and oxygen ingress

To Cap or Not To Cap?



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Vegetation Behavior

Biosolid/green waste amended circumneutral tailings


15 cm cover on moderately acidic tailings


15 cm cover on circumneutral tailings


Beach area with 8 cm cover on
circumneutral tailings


Decant pond with 8 cm cover on
circumneutral tailings


30 cm cover, no biosolids, native species, acid tailings


30 cm cover, 47 tph biosolids, native species, acid tailings

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Vegetation Considerations

- High salinity and/or acid tailings can restrict vegetation success in shallow covers
- Rooting characteristics:
  - Actively root into circumneutral tailings
  - Minor rooting into moderately acid tailings, primarily limited to cover and upper one foot of tailings
  - Form dense root mat above cover/acid tailings contact
  - Affected by tailings permeability
- Vegetative success generally greater in mixed zone than in beach areas
  - May be affected by plant available water
- Vegetation characteristics varies with location (e.g. mesic (slimes) vs. xeric (sands))

Vegetation Considerations (cont'd)

- Effect of cover depth
  - Generally no difference in vegetative cover between covers > 30 cm thick (due to endemic presence of South African grasses in SW USA)
  - BUT, greater native species success
- Effect of organic amendments:
  - Can successfully reclaim raw tailings with a biosolids/green water (compost) mix
  - Results in significantly greater mean vegetation ground cover, grass, and forb and shrub groundcover, however, less species diversity
  - In some cases observed to be sustained over 10 years

Infiltration/Net Percolation

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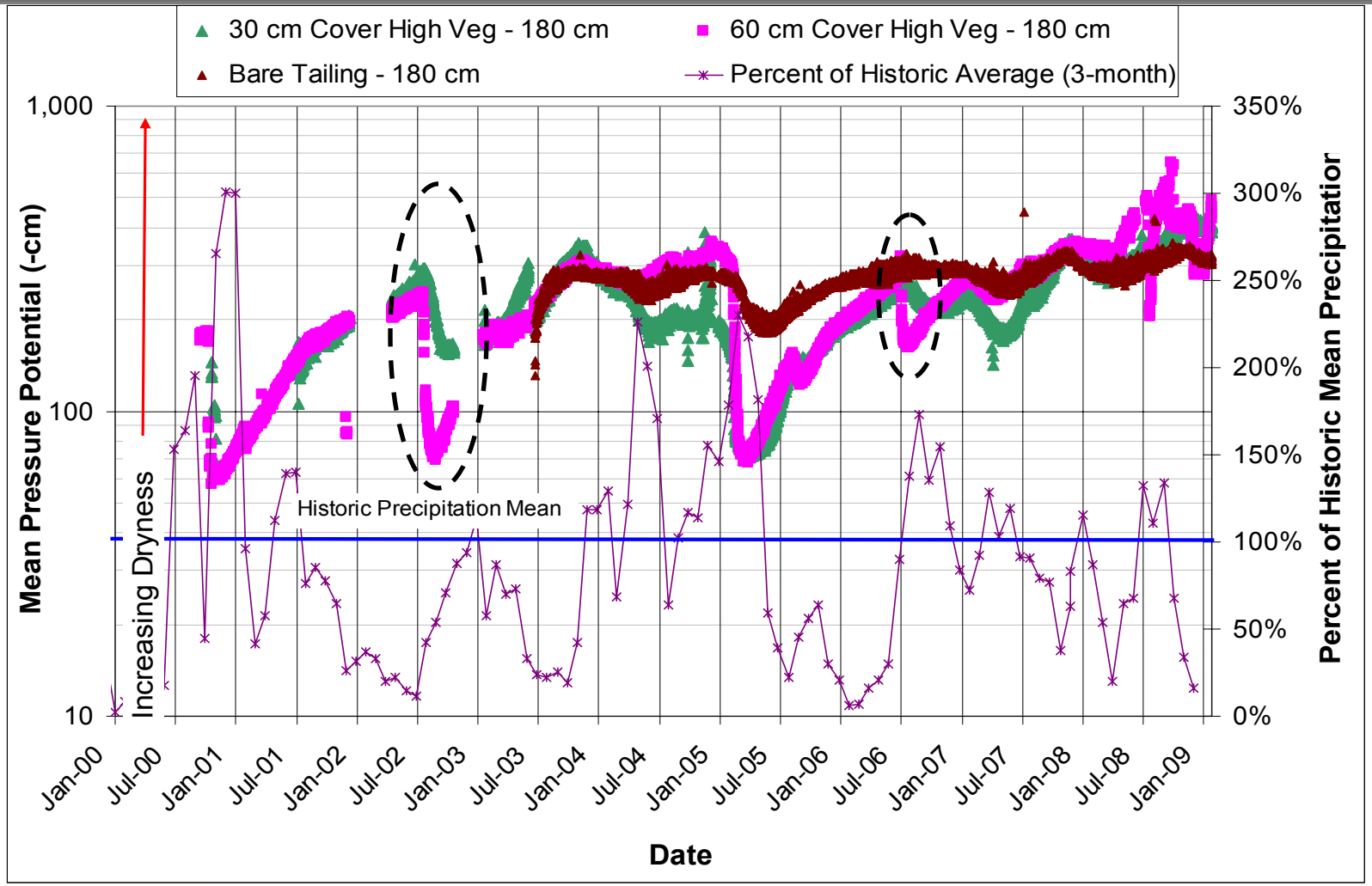
Pressure Potential



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Calculated 1D Flux

Sensor Nest/Plot Location	Total Downward Flux (cm)	Annual Flux (cm/yr)	Annual Flux Rate (cm/s)	Estimated Flux as Percent of Precipitation
30 cm cover, low vegetation				
Average (3 to 2 nests)	3.23	0.37	1.16E-08	1.29%
Standard Deviation	1.61	0.26	8.14E-09	1.04%
30 cm cover, high vegetation				
Average (3 to 2 nests)	0.84	0.12	3.80E-09	0.34%
Standard Deviation	6.52	0.07	2.24E-09	0.30%
60 cm cover, low vegetation				
Average (3 to 1 nest)	4.20	0.55	1.74E-08	1.68%
Standard Deviation	7.37	0.55	1.76E-08	1.35%
Average 60 cm cover, high vegetation				
Average (3 to 2 nests)	3.84	0.48	1.53E-08	1.53%
Standard Deviation	3.10	0.29	9.13E-09	1.24%
Bare Tailings				
Average (3 nests)	0.17	0.02	6.56E-10	0.09%
Standard Deviation	0.28	0.03	1.11E-09	0.16%

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Bare Tailings				
A	0.17	0.02	6.56E-10	0.09%
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Lower permeability tailings

Greater surface water runoff, less infiltration depth

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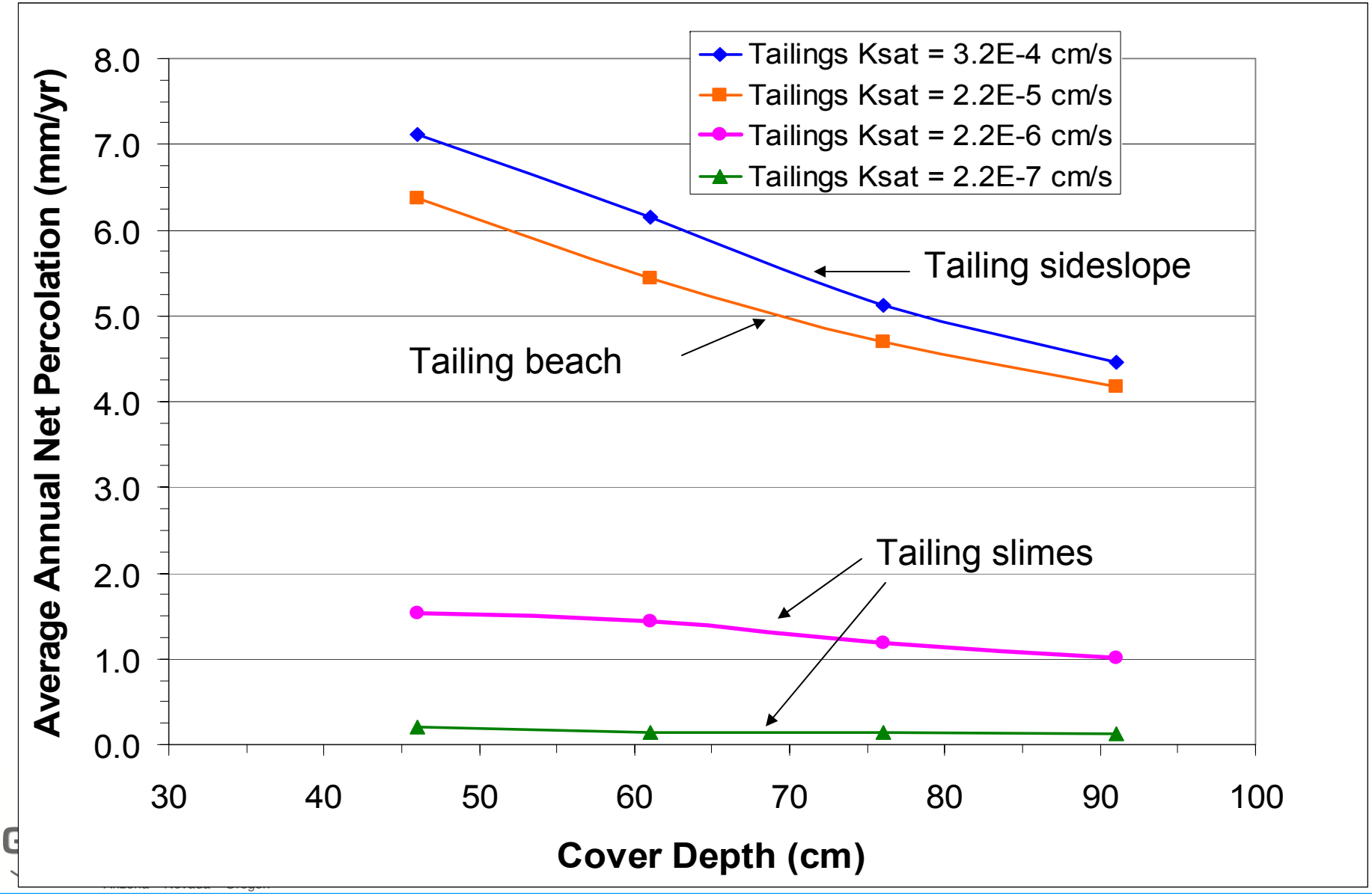
Predicted Effect of Increasing Cover Thickness



Net Percolation Considerations

- Greater wetting front depth with thicker cover can result during:
  - Periods of above average precipitation
  - After periods of drought
- Lower permeability tailings reduced net percolation
- Increasing cover thickness can have less influence on net percolation than tailings characteristics
- Shallow covers or direct reclaimed tailings can have less net percolation than deeper covers
- Tailings are an integral part of store and release and influence should be considered during cover design

Low-pH and Saline Solution Migration into Monolayer Covers

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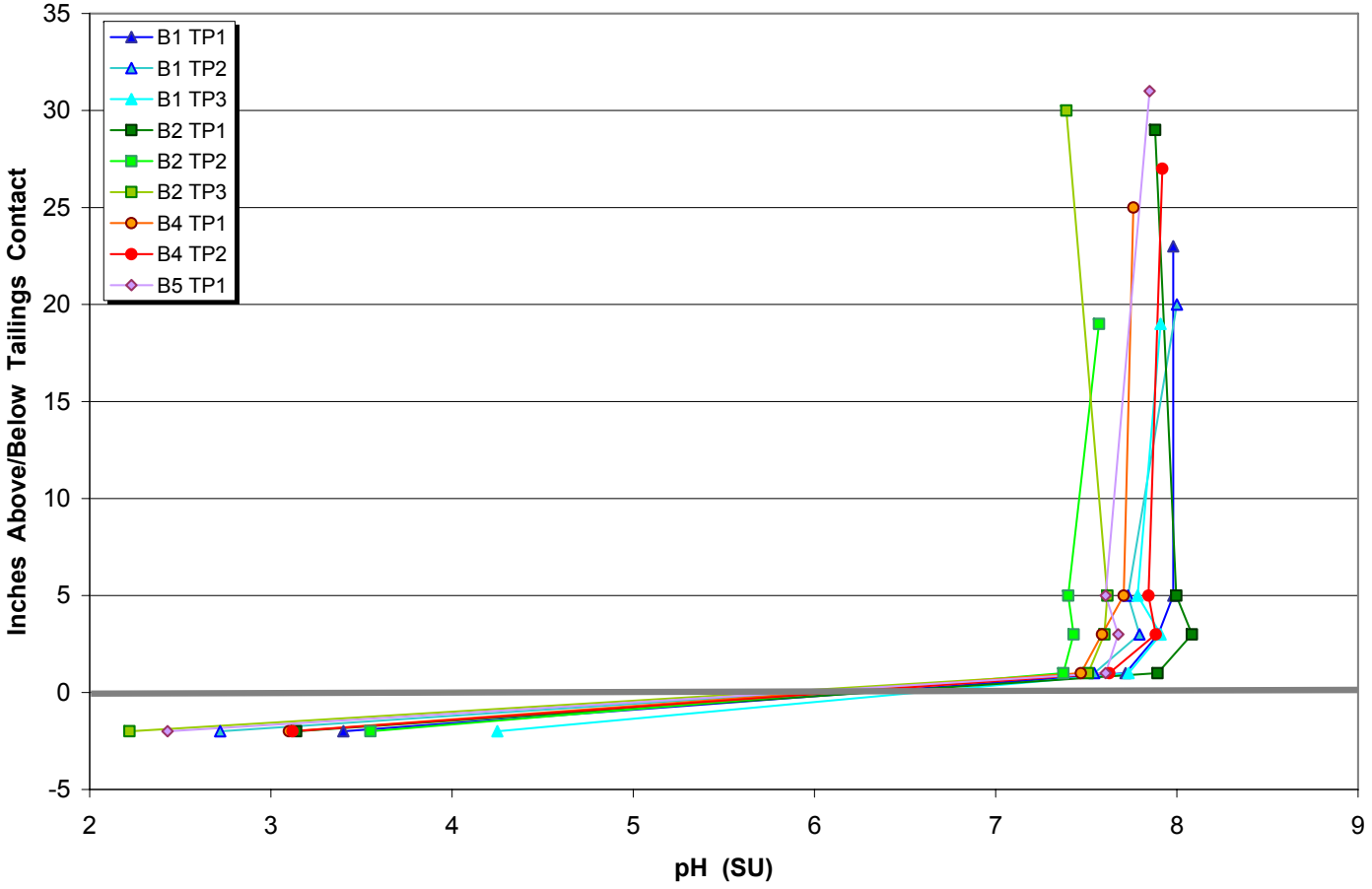
Moderately Acid Tailings (pH>3), 90 cm Cover



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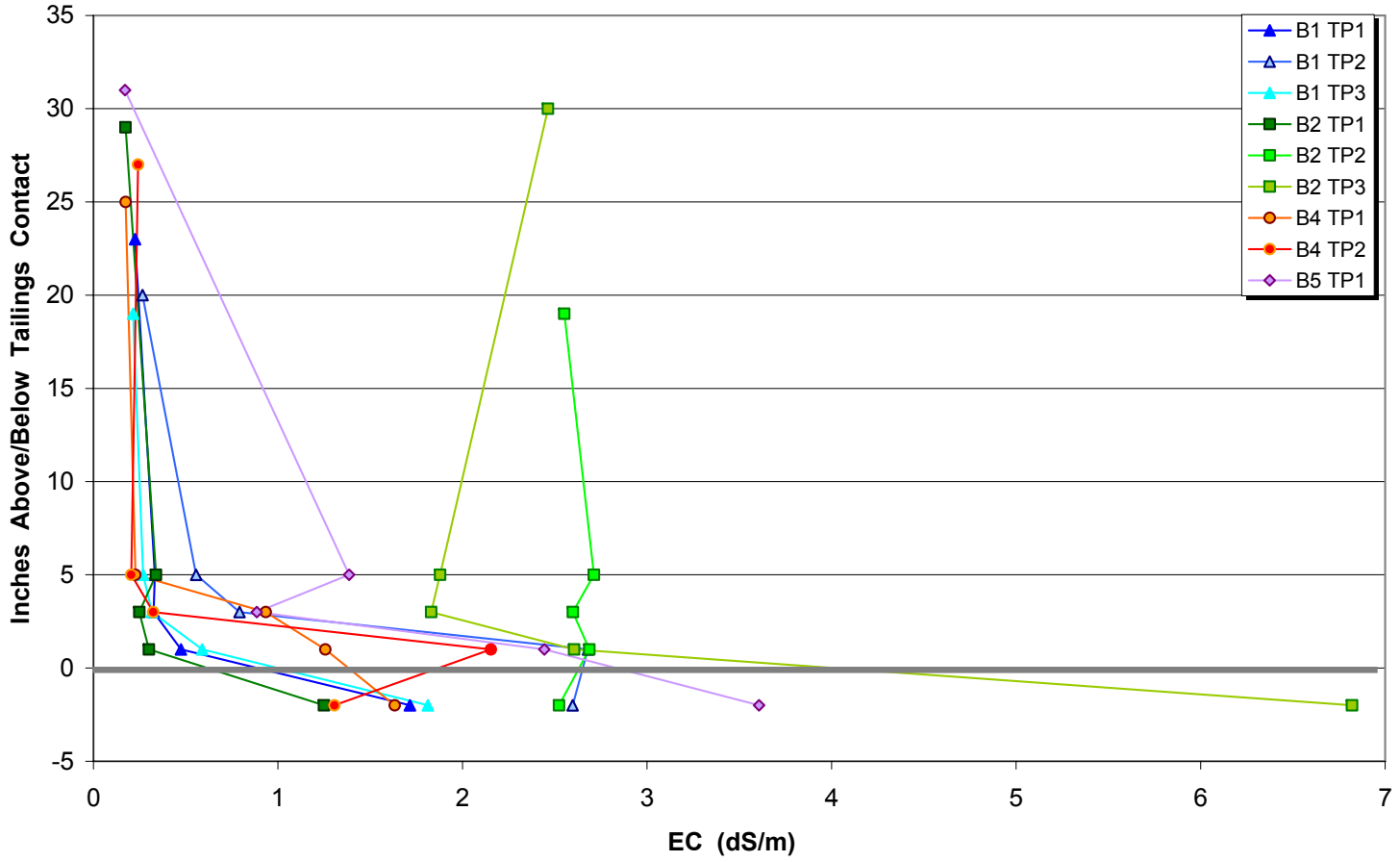

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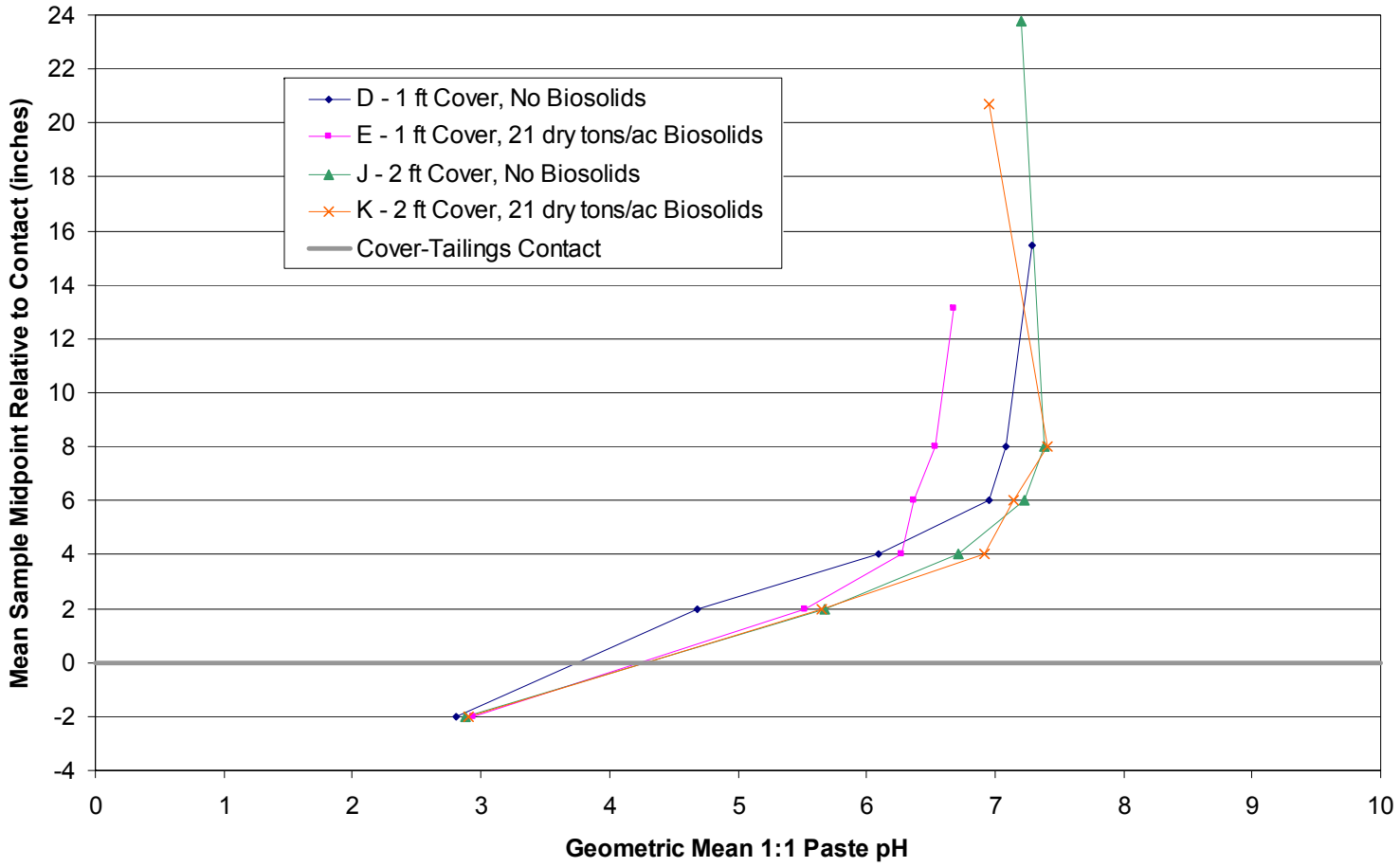
Acid Tailings (pH<3), Variable Cover Depth



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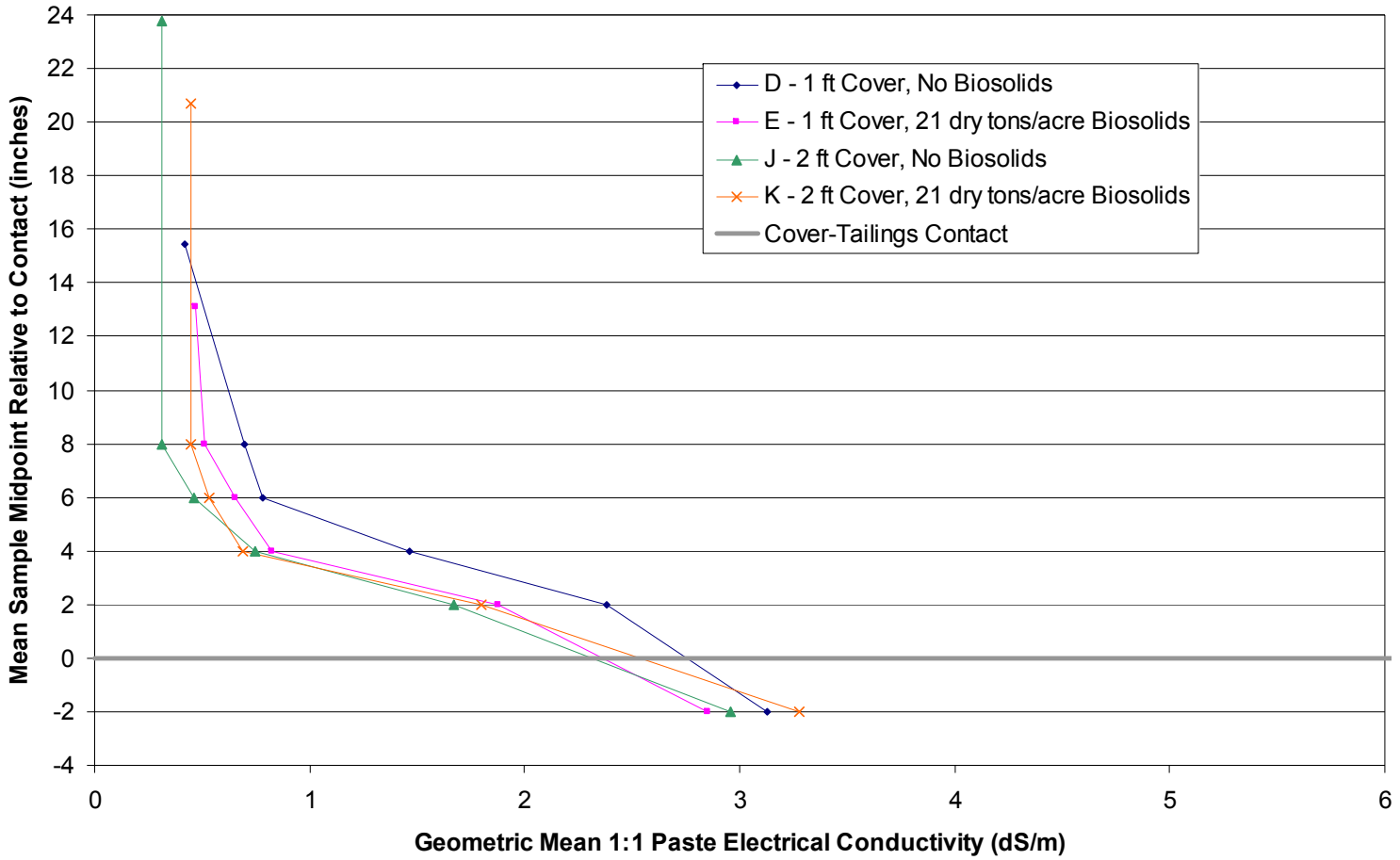

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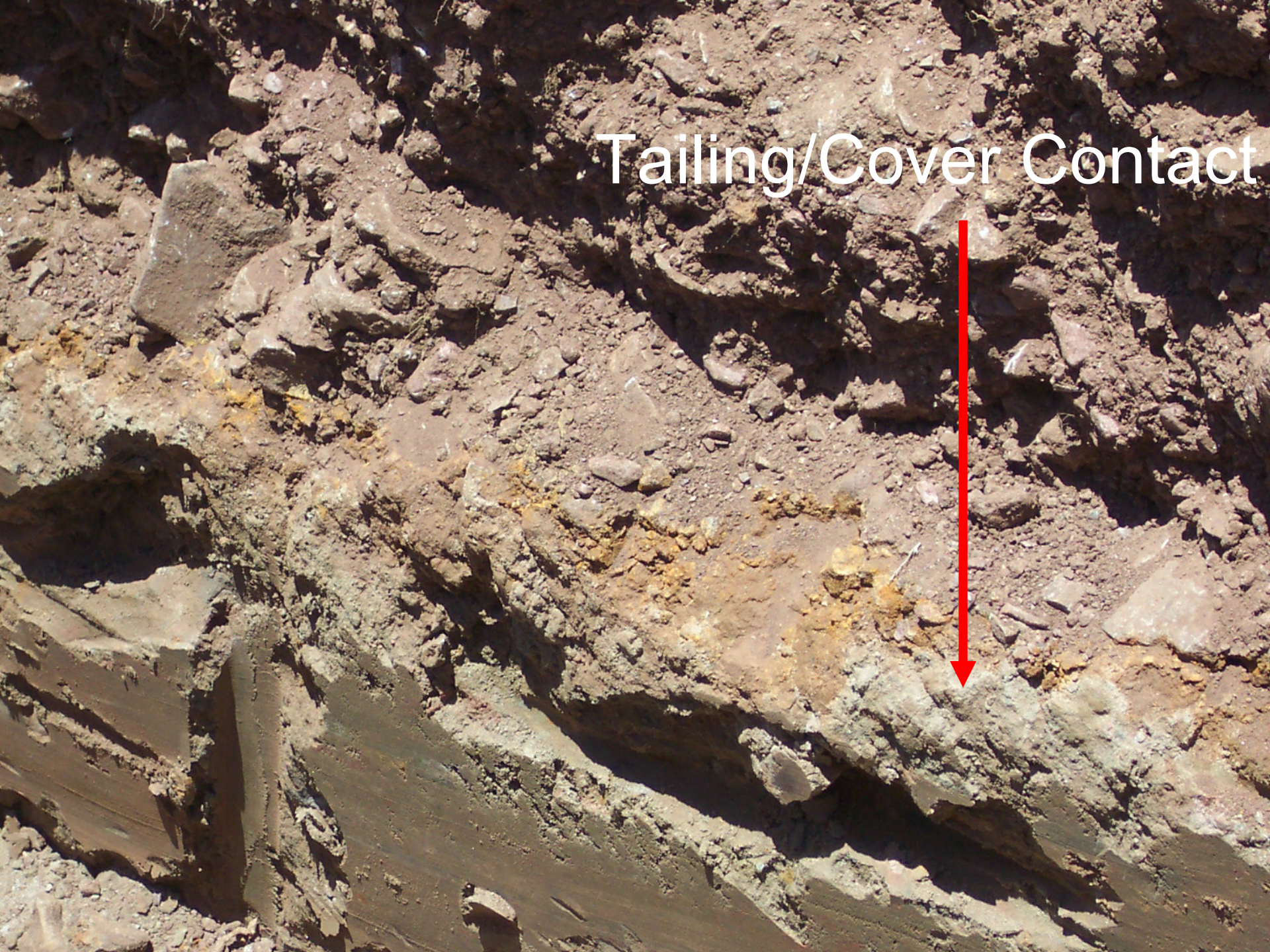
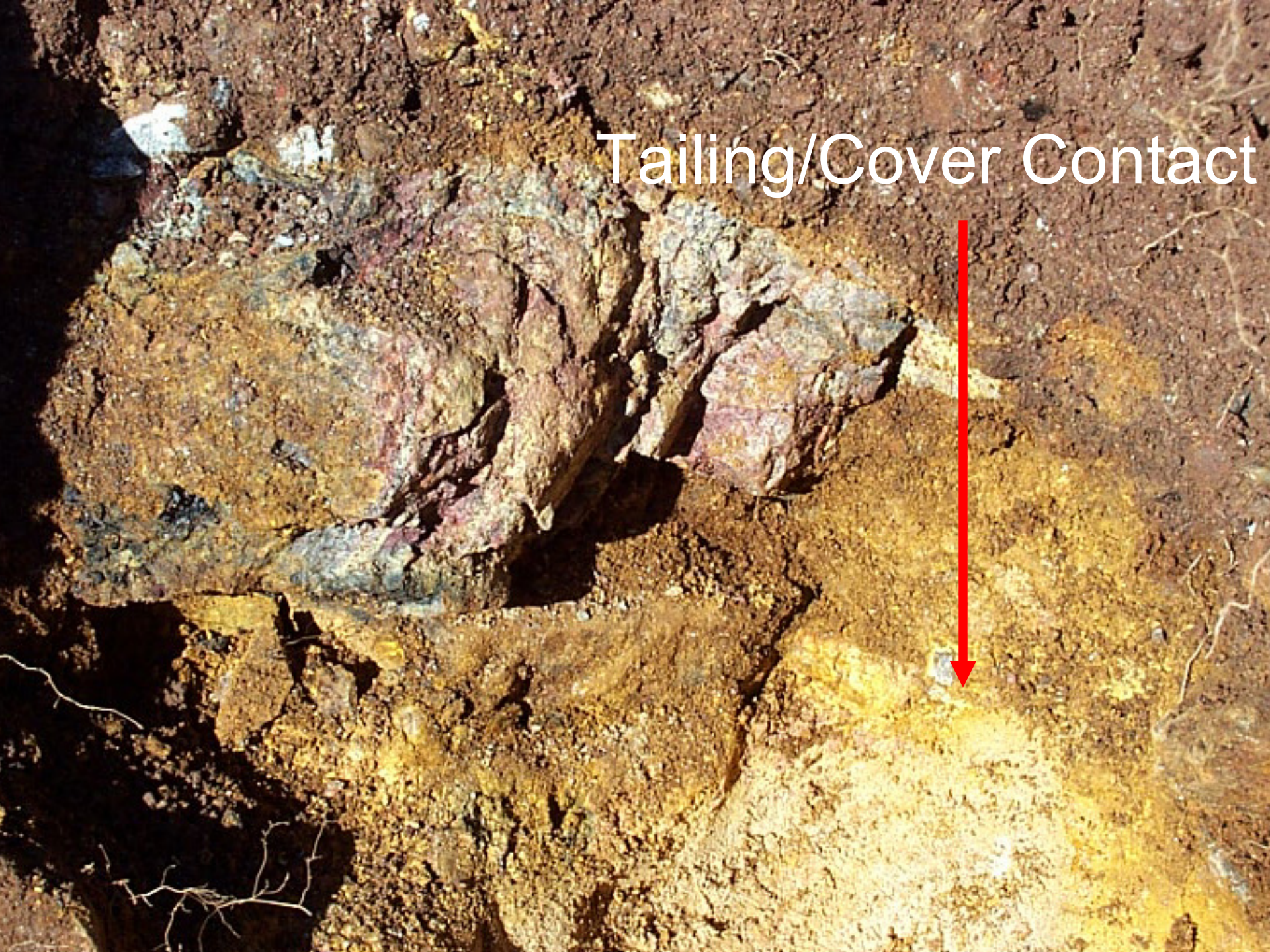

Tailing/Cover Contact


Tailing/Cover Contact

Acid and Salinity Migration Considerations

- In a semi-arid environment salinity and acid migration observed to be:
  - Negligible under moderately acidic conditions
  - Limited to ≈ 15 cm above contact over acidic conditions
- Phytotoxic levels of pH and salinity in cover material generally absent ≈ 5 cm above contact
- No distinct difference in migration with different cover thicknesses (between 30 and 60 cm)
- Acidity and salinity migration may be limited due to:
  - Unsaturated hydraulic conductivities and upward flux rates greatly diminish with distance above the contact
  - High calcium carbonate contents in the cover material neutralize low-pH solution

Conclusions

- Circumneutral tailings can be revegetated with:
  - organic amendments (if available); net percolation may actually be lower
  - shallow covers (< 30 cm)
- Low permeability tailings serve to slow down infiltration and retain water in cover; can have greater effect on net percolation than cover depth
- Revegetation seed mixes should consider differences between sand and slimes area; deeper covers are better for native seed mixes
- Cover system modeling should acknowledge ET depth into tailings
- Upward acidity and salinity migration into monolayer covers may be limited


THANK YOU!
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