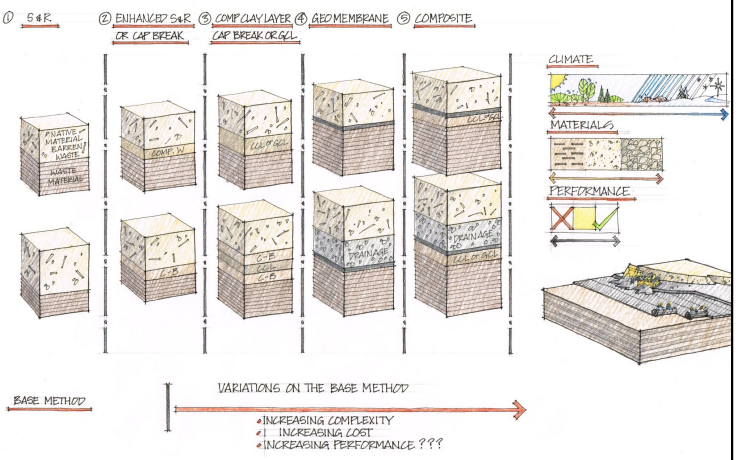
Hydraulically placed cover
20 years of data

PRESENTATION OUTLINE

- Project Objective
- Established Conceptual Model
  - Background Information review
  - Field Sampling and Characterization
  - Numerical Simulations
- Assessment of Mitigation Measures
- Presentation Summary Points

Image after Meiers G, and Bradley C. (2017). The Critical Role of Lateral Drainage Capacity in Limiting Leakage through a Low Permeability Geomembrane. Geotechnical Frontiers, Orlando, Florida March 12-15.



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PROJECT OBJECTIVE

COVER SYSTEM ASSESSMENT AND MITIGATION

- Establish multiple lines of evidence to provide an understanding of the Tailings Management Facility (TMF) cover system performance following 22-years of atmospheric forcing
- Define success criteria for the TMF in terms of geochemical stability
- Identify performance risks associated with the cover system and assess potential mitigation measures

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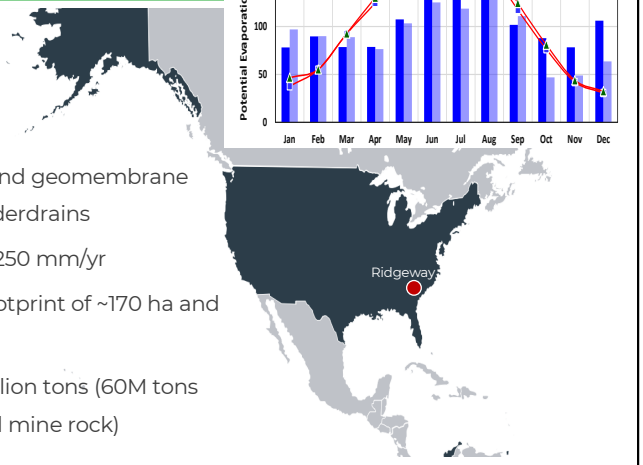
Is it working after 20 years

CONCEPTUAL MODEL – BACKGROUND INFORMATION

SITE CONTEXT

- Located 30 km north of Columbia, South Carolina
  - Situated 6 km from Town of Ridgeway
- The facility has composite liner, compacted clay and geomembrane with passive leak detection in the form of two underdrains
- Rainfall ~1,200 mm/yr & potential evaporation is 1,250 mm/yr
- Ridgeway Mine site area is ~800 ha with a TMF footprint of ~170 ha and cover system 124 ha
- TMF operated from 1988 to 1999 & contains 90 million tons (60M tons processed tailings; 30M tons embankment fill and mine rock)



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CONCEPTUAL MODEL – BACKGROUND INFO.

TAILINGS MANAGEMENT FACILITY (TMF) CLOSURE

- The tailings are potentially acid generation (PAG), hence cover performance criteria are:
  - Provide “non-contact” runoff water that can be discharged safely to the environment; and
  - Provide geochemical stability to the tailings through controls on oxygen ingress and sulfide oxidation
- A Success Criteria was established for oxygen ingress, with a stated minimum degree of saturation of 85%. Updated in 2023 to a Very Low oxygen ingress <1 mol/m^2/yr

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CONCEPTUAL MODEL – BACKGROUND INFO.

- Tailings deposition ceased in Nov 1999
- Cover system hydraulically placed from January 2000 to May 2000, four months
- Hurricane Bonnie and Earl (1998) resulting in a large ponded area
- This minimized the exposure of tailings to oxidative conditions, acid generation, and consumption of neutralization potential
- The cover layer desiccated / cracked and then healed

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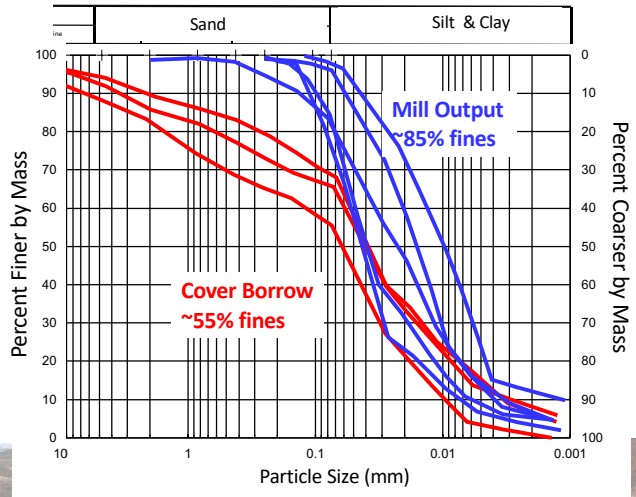
CONCEPTUAL MODEL – BACKGROUND INFO.

Borrow Area

- Weathered saprolite. Red, brown, and purple saprolite and a grey and green at depth greater depth
- Excavated material was fed into the mill where it was ground and transported as a slurry on the surface of the TMF

CONCEPTUAL MODEL – BACKGROUND INFO.

- Reduced CapEx costs for material placement
- Milling and hydraulic placement reduced gravel and sand content to less than 10% and increased fines content from ~60% to ~80%
- Ameliorated the cover material to have improved water retention properties



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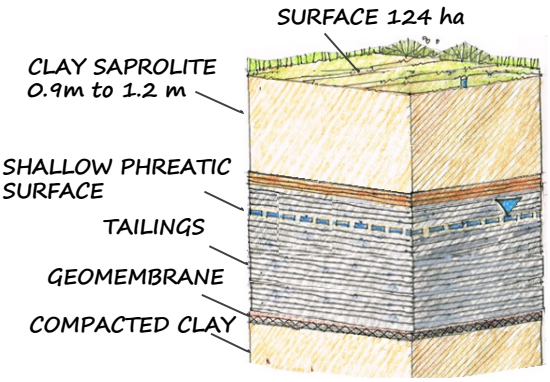
Why is it important your model

CONCEPTUAL MODEL – BACKGROUND INFO.

LANDFORM AND COVER SYSTEM



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CONCEPTUAL MODEL – BACKGROUND INFO.

VEGETATION

- There was vegetation management / mowing from 2002 to ~2004, it was discontinued from 2005 to 2019, and then again managed 2020 to current
- Bermuda grasses, Millet, and Bushclove, as well as Groundsel bush
- At climax, vegetation reached a 2m stand, limiting visibility across facility

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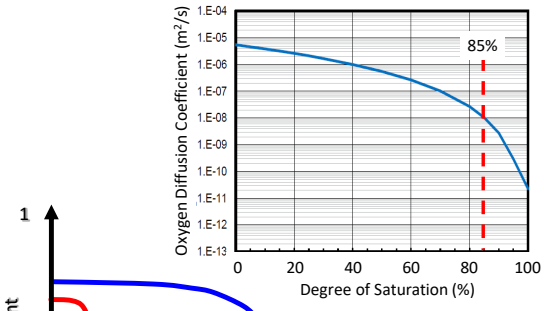
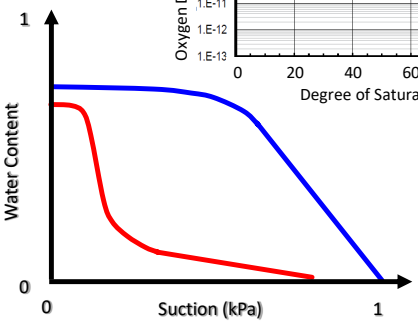
CONCEPTUAL MODEL – BACKGROUND INFO.

COVER SYSTEM DESIGN

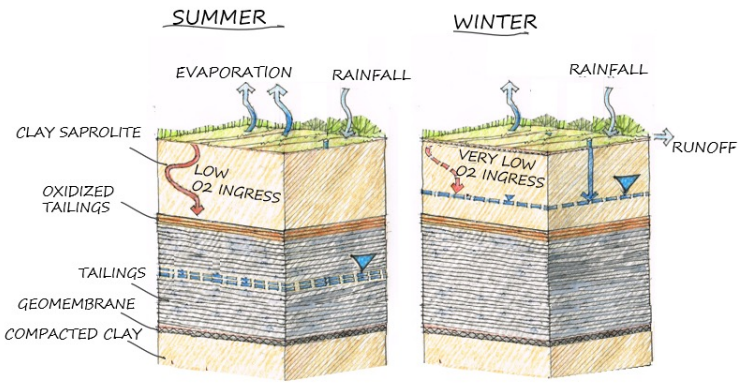
- Unsaturated Soils Engineering (USS) at the University of Saskatchewan completed initial cover system design work in 1997
- O'Kane established a field response model in 2007
  - Results suggested Very Low Rates of Oxygen <0.2 mol/m^2/yr
  - Predicted acidity generation very low at ~9 g $CaCO_3$/m^2





CONCEPTUAL MODEL – BACKGROUND INFO.

- Potential Evaporation (PE) 1,250 mm/yr & Rainfall 1,150 mm/yr
- In the summer the atmospheric demand for water draws down the phreatic surface
- In the winter net percolation through the cover system increases the elevation of phreatic surface
- Seasonal variability in oxygen ingress



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CONCEPTUAL MODEL – FIELD SAMPLING

PHREATIC SURFACE

- In the summer the phreatic surface may decrease upto 3.0 m below the cover / tailings interface
- This demonstrates the atmospheric demand for water
- There will be seasonal variability in oxygen ingress
- Based on the monitoring data it can be estimated that negative pore-water pressures generated at the base of the cover profile are likely in the range of 30 kPa, and possibly higher due to vegetation / roots

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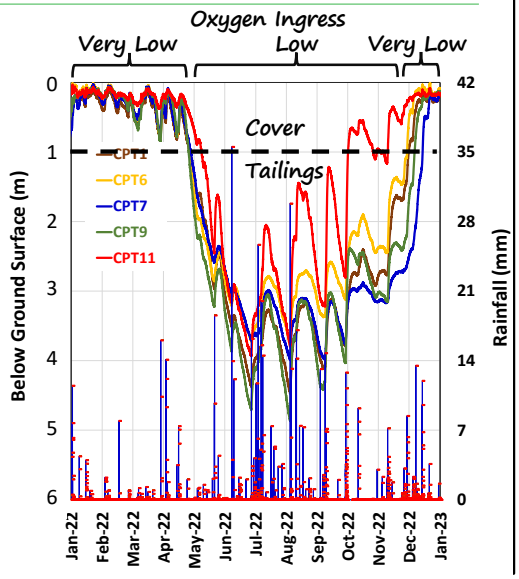
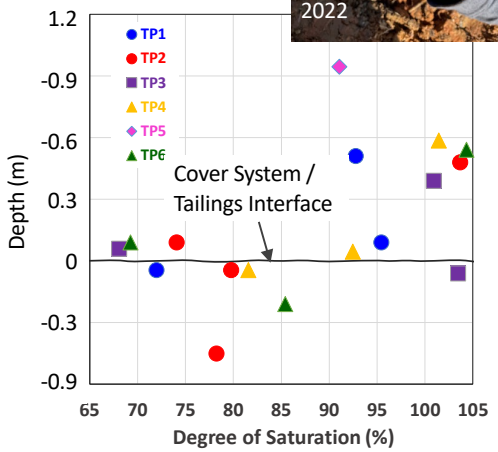


CONCEPTUAL MODEL – FIELD SAMPLING

IN SITU DEGREE OF SATURATION

- While the sampling only represents one point in time, it's a definitive measurement that sheds light on performance
  - Water Retention & Oxygen Ingress
- Degree of saturations between 68% to 100% for the cover
- From a performance perspective the key takeaway is:
  - There are areas with Very Low O_2 ingress, <1 mol/m²/yr
  - There are areas with Low O2 ingress, 1 to 5 mol/m²/yr



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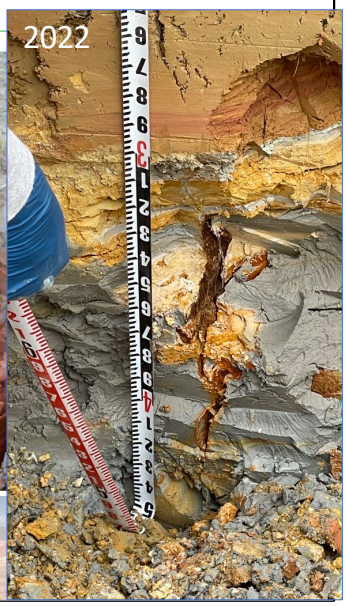
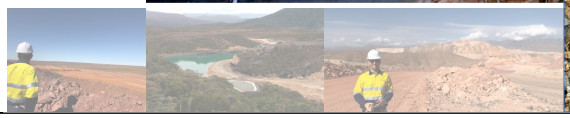
Conceptual Model – Field Sampling

Rooting / Oxidation

- Rooting primarily within the growth medium; however, fibrous roots observed in desiccation cracks extending into the tailings
- Aggregation of tailings immediately below cover interface observed due to water cycling
- Observed test pits with pH at the interface ~ 3.5 and ~ 7, hence areas where NP consumed or not available





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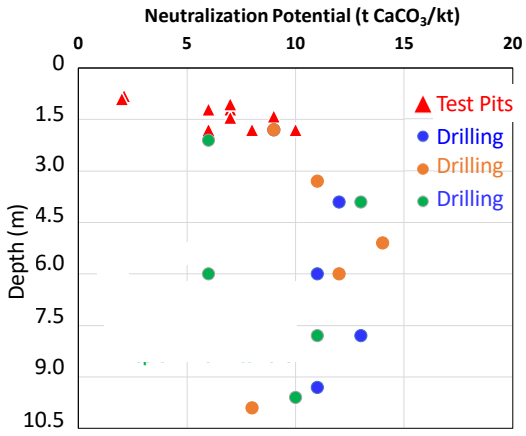
Why is it important your model

CONCEPTUAL MODEL – FIELD SAMPLING

ABA data: Neutralization Potential (np)

- Test pitting and drilling program suggest "some" depletion NP and apparent load of stored acidity at locations
- This is a positive performance aspect in that NP has been retained in the system
- Stored acidity and depleted NP was used as a surrogate to estimate potential oxygen ingress
- Melanterite-jarosite-type acidity not consider in acidic tailin
- Average oxygen ingress for the cover system is estimated to range from 1 to 5 mol/m²/yr



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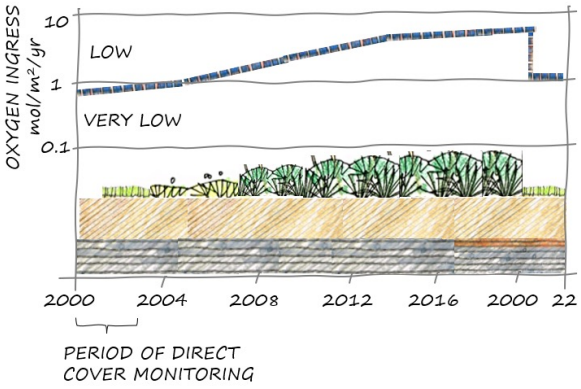
CONCEPTUAL MODEL – NUMERICAL SIMULATIONS

COVER SYSTEM TRAJECTORY

- Based on information review, field data, and numerical simulations the conceptual model of cover system performance is as follows:
  - Vegetation management can provide oxygen ingress near the Very Low range
  - The difference between implementing and not implementing vegetation management could be an order of magnitude increase in oxygen ingress



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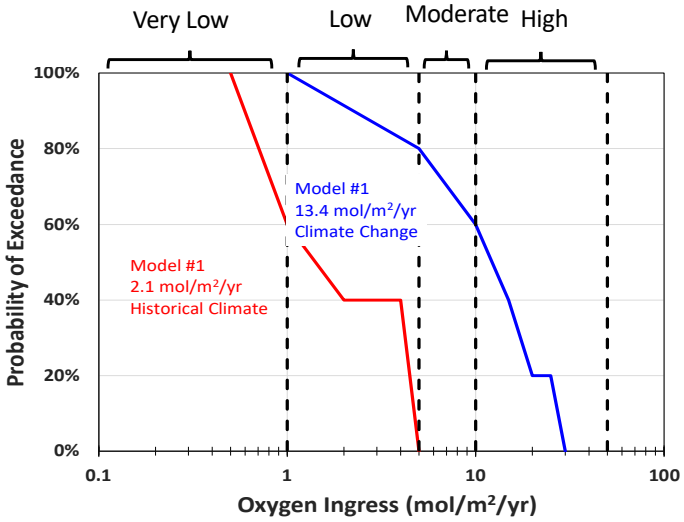
CONCEPTUAL MODEL – NUMERICAL SIMULATIONS

CLIMATE CHANGE

- Base Case model established to provide an oxygen ingress rate of ~2 mol/m²/yr
- Climate change (RCP-8.5) simulated to assess potential climate change risks;

  If there is a risk, how can it be mitigated?
- Simulations suggest that climate change may pose a risk



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MITIGATION MEASURE ASSESSMENT

Numerical Simulations – Mitigation Measures

- Vegetation management improves performance of the Historic Climate simulation
- Climate Change oxygen ingress estimated to be 13 mol/m²/yr, Risk of changing source term concentration
- Vegetation management does not appear to supress the evaporative demand imposed by Climate Change (RCP-8.5)
- Irrigation of water on the surface (June, July, and Aug) appears to be an appropriate mitigation options for Climate Change

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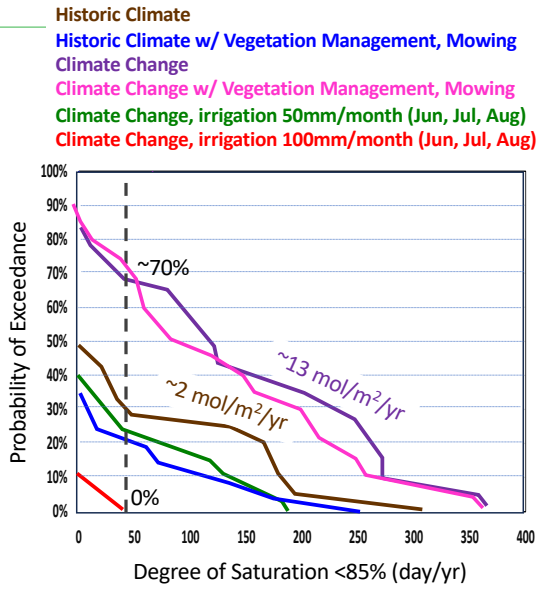
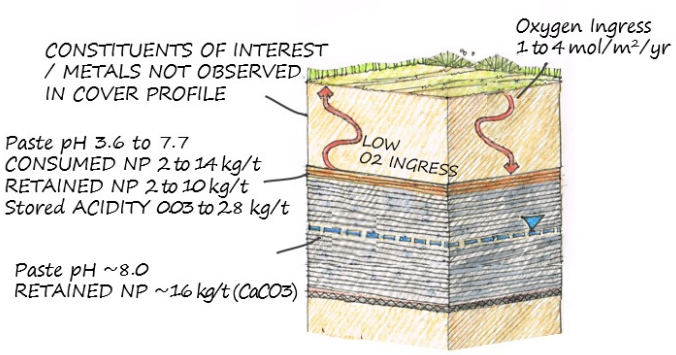


CONCEPTUAL MODEL – PERFORMANCE

- With vegetation management there is likely an additional 20 to 40 years of neutralization potential remaining
- This means that there is opportunity to verify performance and mitigation measures
- This means that the cover system is performing well, source term concentration should be retained and there is opportunity to optimize performance



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PRESENTATION SUMMARY POINTS

- The Ridgeway water store-and-release cover system, located within a high evaporative demand climate, is performing well. By placing a liner below the facility, it's almost like there is a geomembrane in the cover system!
- Oxygen ingress is approximately one order of magnitude greater than previously simulated by O'Kane in 2007, but still performing similar to a water cover
- Direct sampling of the cover and tailings was a key aspect of the established conceptual model
- There is opportunity to maintain existing tailings neutralization potential and current source term concentrations mitigating ML/ARD risks in closure

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