Identifying Water Flow Paths Through, Under and Around Tailings Impoundments

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The technology exists to make TSFs safe if there is proper

- integration
- planning
- design
- construction
- operations
- maintenance
- surveillance
- oversight
Groundwater Key Stability Factor

- How do we better understand tailings dams, and reduce their risk of failure and improve tailings management?
  - Seepage
  - Instability
  - Piping

- Understanding groundwater is a key factor in ensuring the stability of tailings dams:
  - Contaminants escape with seepage water
  - Phreatic surface rises in dam so stability decreases
  - Internal erosion becomes possible as piping develops
Non-Intrusive Investigative Technology

• A geophysical technology that uses a low voltage, low ampere, alternating electrical current to energize subsurface water by electrodes placed in tailings water and seepage discharge.

• With one electrode in the tailings and the other in contact with water below the tailings dam, an alternating current electrical circuit is established between the two water bodies.

• The magnetic field that is generated is measured and mapped from the surface to render 2D and 3D maps and Electric Current Distribution (ECD) models of seepage paths.

• The technology maps and models preferential groundwater flow paths like Magnetic Resonance Imaging (MRI) / angiogram that lets doctors to “see” blood vessels in a human body.
Medical Industry Analogy
Magnetic Resonance Imaging (MRI) / Angiogram
Enlightened Application of Technology
Survey Setup Section View

- Tailings Pond Electrode
- Power Supply
- Circuit Wire
- Tailings Pond
- Magnetic Field
- Electric Current Concentrates in Preferential Seepage Flow Paths Beneath Dam
- Distribution of Electric Current through Subsurface Study Area
- Tailings Dam
- Toe Electrode
Survey Setup Plan View

- 337 Measurement Stations
- 279 Land Measurements
- 58 Water Measurements
- Grid 7.5m by 7.5m (25ft by 25ft)

Legend:
- Seepage Location
- High Power Line
- Smaller Power Lines
- Petroleum Pipeline
- Culvert
- Measurement Point
- Water Measurement
- Circuit Wire
- Electrode
- Electric Field
- Electrode Influence

Electrode in Seep
Electrode in Lake
Circuit Wire ~5,000 Feet
Steps to Data Results & 2D Maps

- **Layout**
- **Predicted Magnetic Field**
- **Observed Magnetic Field**
- **Ratio Response**
Application to Tailings Dams

- Water increases the conductivity of soil and rock through which it flows. As the signature current travels between electrodes, it concentrates in more conductive zones or seepage flow paths.

- An electric circuit is established along a seepage flow path. The resultant magnetic field measured at the surface reveals the electric current flow and distribution.

- Data is processed and compared to a predicted magnetic field from a theoretical homogenous earth model to highlight deviations from the uniform model.

- 2D maps and 3D models are generated and combined with sub-surface data to enhance the definition of preferential seepage paths.
Successful Project Case Histories

• This presentation uses four tailings dam case studies to illustrate the technology procedures, findings and benefits.

• Results range from confirming design decisions to identifying new seepage paths, and updating designs to provide a more safe and stable tailings dam and reduce risk of failure.

• The survey report graphics span a shading spectrum from **purple** to **green**.

  • Purple shows actual flow that is less than flow predicted by the “uniform” model.
  • Green shows actual flow that is more than flow predicted by the “uniform” model, so likely represents a seepage path.
Project 1 – Valley Fill TSF and Dam
P1 - No Observed Seepage Paths
P1 - Seepage Paths Identified
Surveys 4-6 indicate generally stronger but diffuse electric current flow in this area, with two subtle preferential paths manifesting slightly above the diffuse background flow. All is below native ground level.
P1 – 3D Model Seep Locations & Depths
P2 – Seepage Area Dimensions
P2 – Two Seepage Paths Under Dam
P2 – Seepage Path Elevations
Project 3 – TSF and Waste Rock Dump
P3 – Surveys With Flow Path
P3 - Plan View of Seepage Paths
P3 – Section View of Seepage Paths

- Circuit Wire
- Power Supply
- Well
- Waste Rock Dump
- Study Area
- Access Road
- Tailings Pond
- Down-gradient Electrode
- Magnetic Field
- Electric Current Concentrates in Preferential Groundwater Flow Paths
- Up-gradient Electrode
- Drainage Collection Trench

No Scale
Project 4 – TSF Seepage and Sinkholes
P4 - Survey Setup Plan View

- 337 Measurement Stations
- 279 Land Measurements
- 58 Water Measurements
- Grid 7.5m by 7.5m (25ft by 25ft)

Legend:
- Seepage Location
- High Power Line
- Smaller Power Lines
- Petroleum Pipeline
- Culvert
- Measurement Point
- Water Measurement
- Circuit Wire
- Electrode
- Electric Field
- Electrode Influence

- Electrode in Seep
- Electrode in Lake
- Circuit Wire ~5,000 Feet
P4 - Surprize Seepage Path Findings
Overarching in Agreement

• We are all collectively challenged to do what we can to ensure TSFs are designed and operated in a societal responsible way that protects the environment and land stewardship.

• Each mine site has a best solution for its setting in terms of human implementation – each site is different with unique geologic, groundwater, climate and operation challenges.

• Designing, constructing, operating and closing stable TSFs benefits the mining industry by maintaining mining company’s economic stability, reputation and social license to operate.

• The non-intrusive investigative technology just described is a tool that can help identify water flow paths through, under and around tailings impoundments and hence enhance TSF safety.
Thank You – Questions?