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Combining hydrogeological modelling and geoelectrical monitoring to assess the performance of a multi-layer mine waste reclamation cover system

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ÉTS Engineering for Industry

1. Introduction

a) Mine waste reclamation cover to reduce water infiltration

What is its purpose ?

Prevent various types of contaminated drainage due to infiltration of H_2O in tailings released by mining activities **[1]**

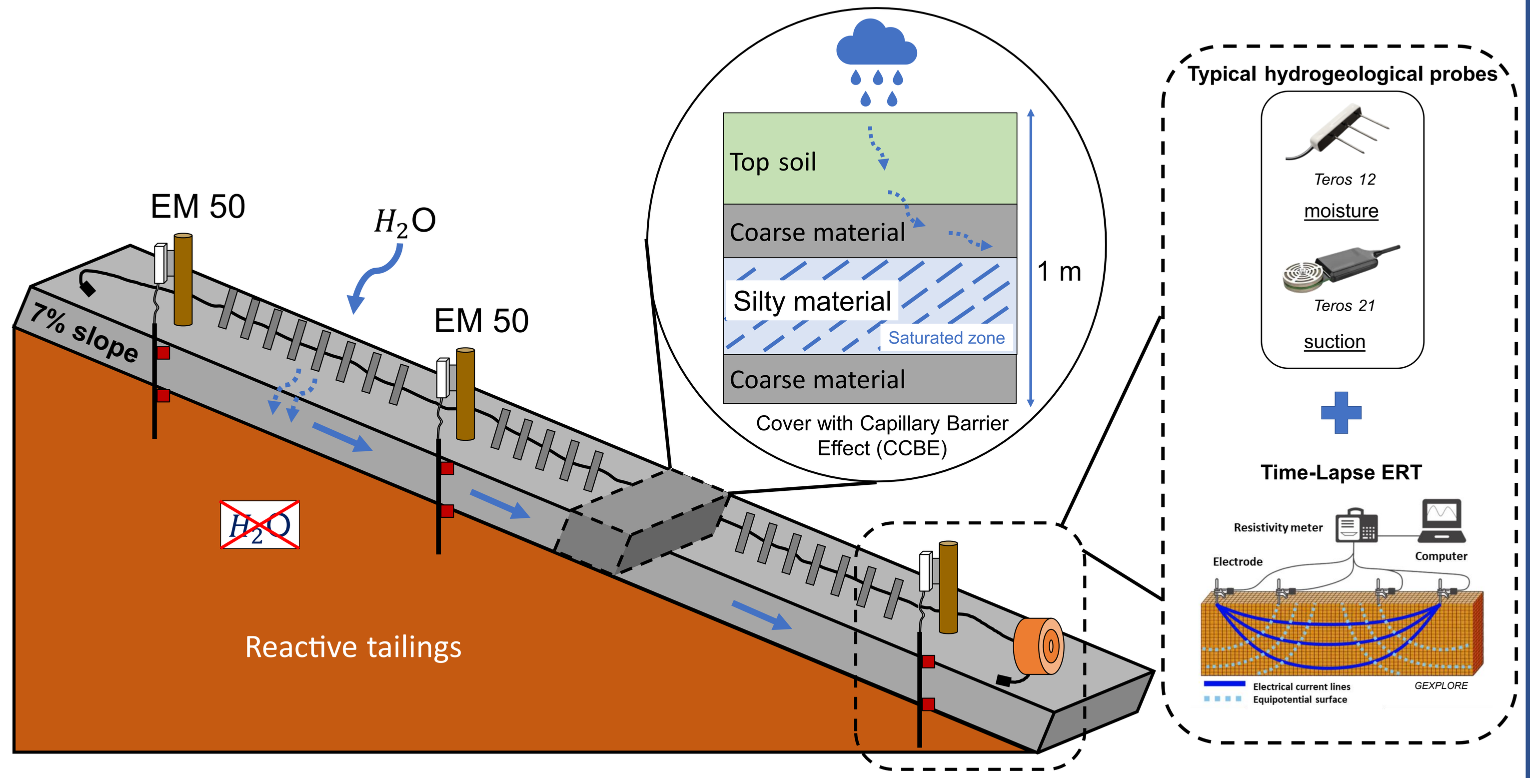
How it works ?

Divert water laterally down the slope and create a moisture-retaining layer that remains permanently saturated

What methods can be used to assess its performance ?

Different monitoring scales :

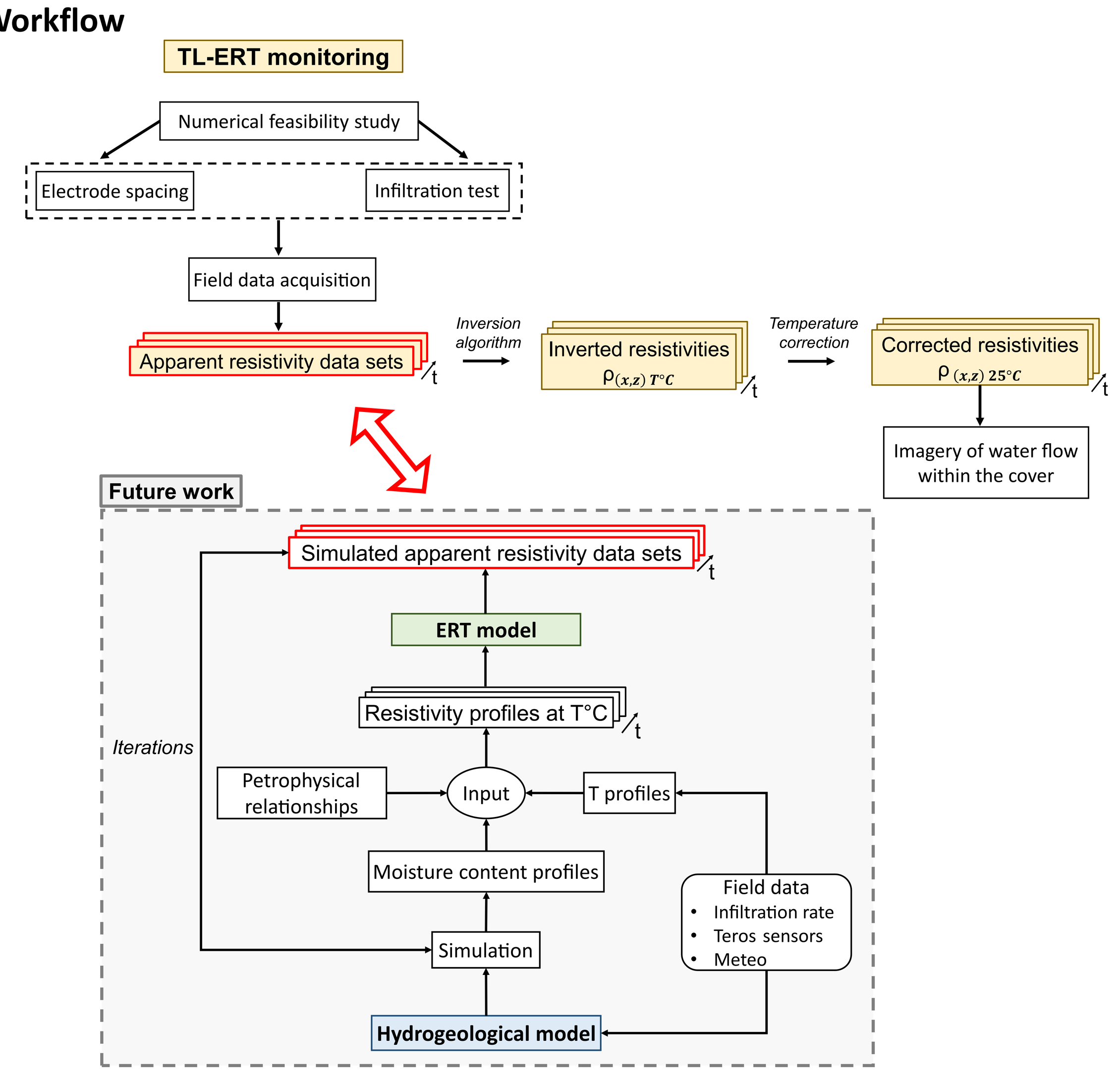
- Ponctual hydrogeological sensors to measure volumetric water content and suction
- Geoelectrical monitoring for wider spatial resolution and bigger investigation volume **[2]**



b) Objective

Applying Time Lapse Electrical Resistivity Tomography (TL-ERT) method at a Tailings Storage Facility (TSF) to monitor water flow dynamics within an inclined multi-layer cover system following an infiltration test

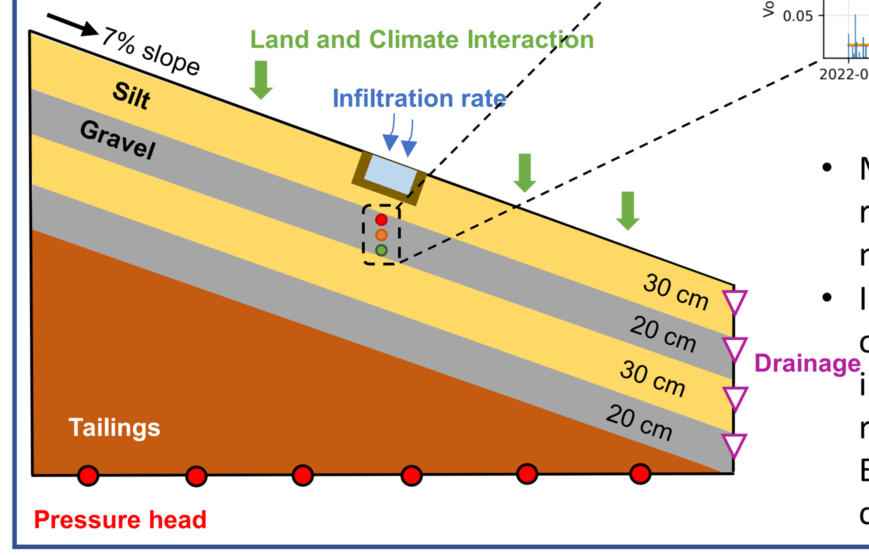
Workflow

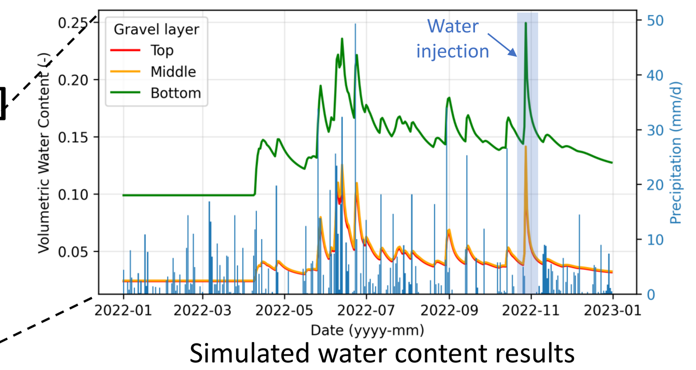


2. Methodology for field work

a) Numerical feasibility study

Hydrogeological model inputs in SEEP/w [3]





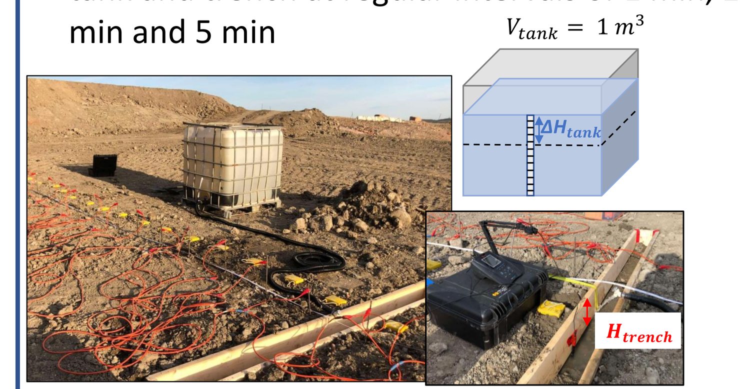
Simulated water content results

- Meteorological data **[4]** for the 2022 reference year from a weather station near the TSF
- Infiltration value of $\mathbf{2.10^{-4} m^3/s/m^2}$ over a 4-hour period selected for field infiltration test : sufficient for resistivity contrast to be visible during ERT measurement without affecting cover efficiency

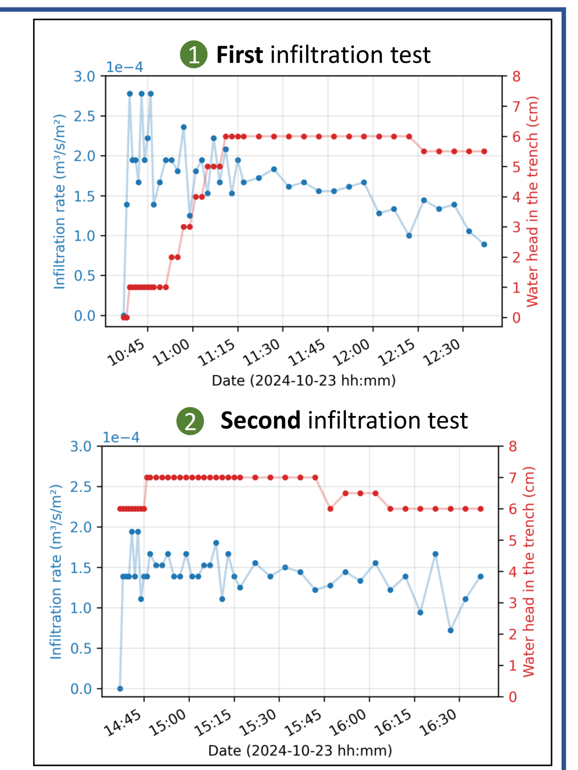
b) Infiltration test setup

Infiltration test parameters

- ≈ 2000 L of salt water (σ ≈ 1000 µS/cm) injected into the trench over a 4-hour period, with a 2-hour pause in the middle to refill the tank
- Simultaneous measurement of water level in tank and trench at regular intervals of 1 min, 2 min and 5 min



2 m (L) x 30 cm (l) x 20 cm (H) trench

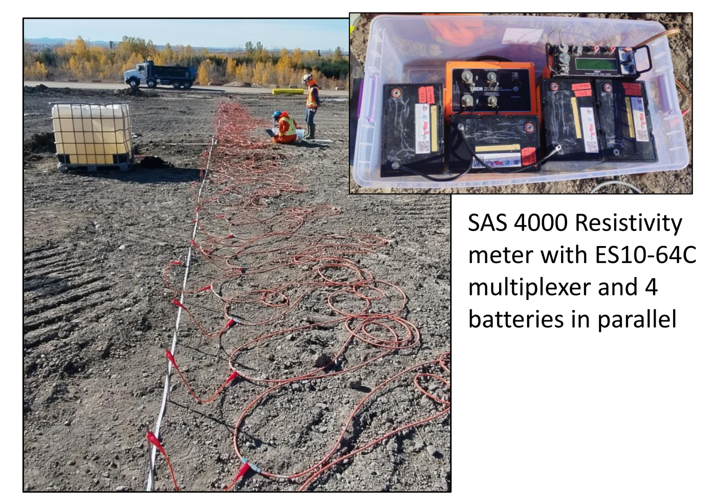


Measured data for the two successive tests

c) Field ERT set up

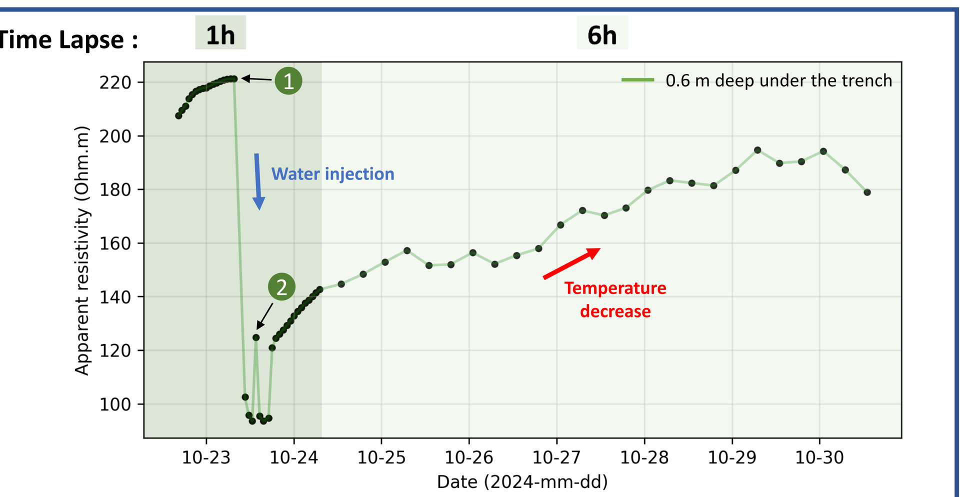
TL-ERT parameters

- Profile of 64 electrodes spaced 0.5 m apart in Wenner's 4-channel configuration
- Acquisition frequency : every 1 hour from 22/10 to 24/10 and every 6 hours until the end of the field campaign on 30/10
- 63 ERT imageries in total



SAS 4000 Resistivity meter with ES10-64C multiplexer and 4 batteries in parallel

- More than 50% reduction in apparent resistivity following infiltration test
- Subsequent increase of apparent resistivity as soil temperature measured by Teros 12 sensors decreases : 1°C temperature rise ≈ 2% increase of soil electrical conductivity



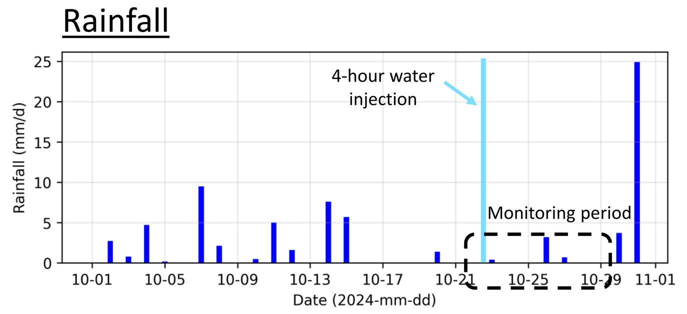
Variation in **apparent resistivity** at a specific location in the mine cover

3. Geoelectrical monitoring results

a) Inversion results

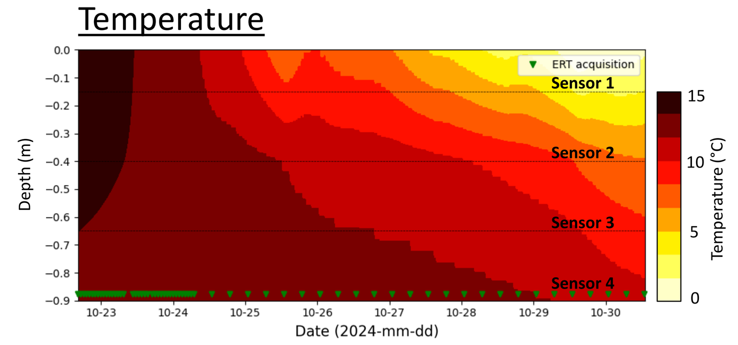
Parameters impacting TL-ERT results

Rainfall



October 2024 rainfall near the study site

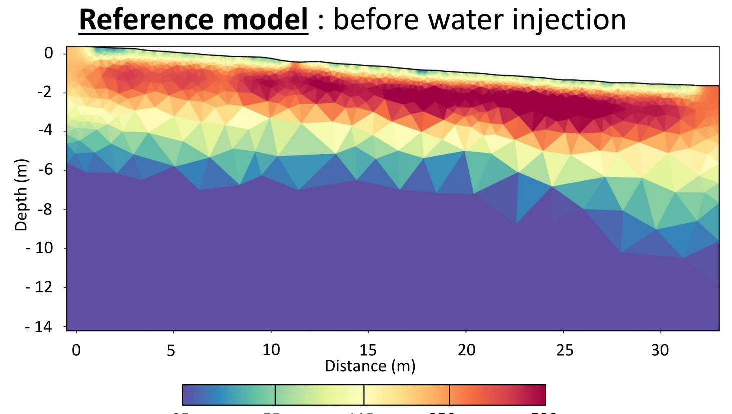
Temperature



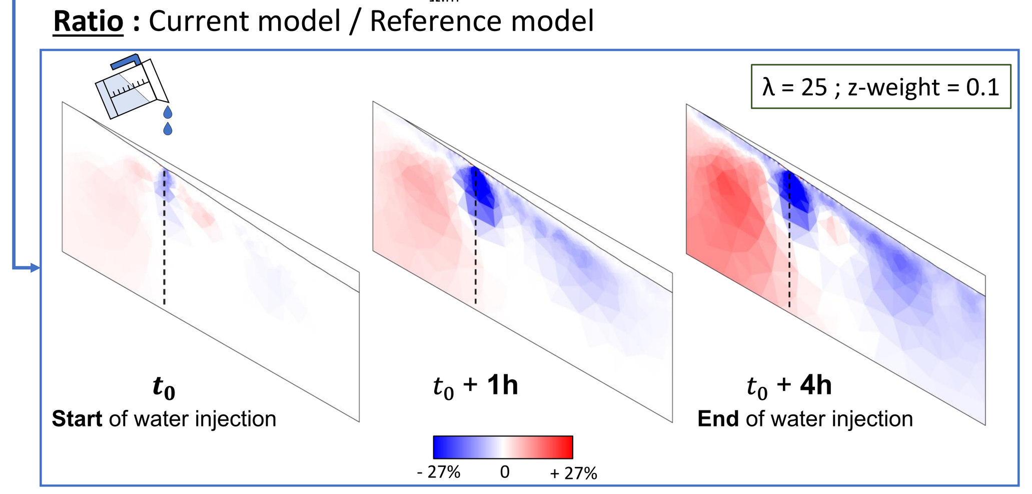
interpolated temperatures of Teros 12 sensors

TL-ERT inversion with pyGIMLI [5]

Reference model : before water injection

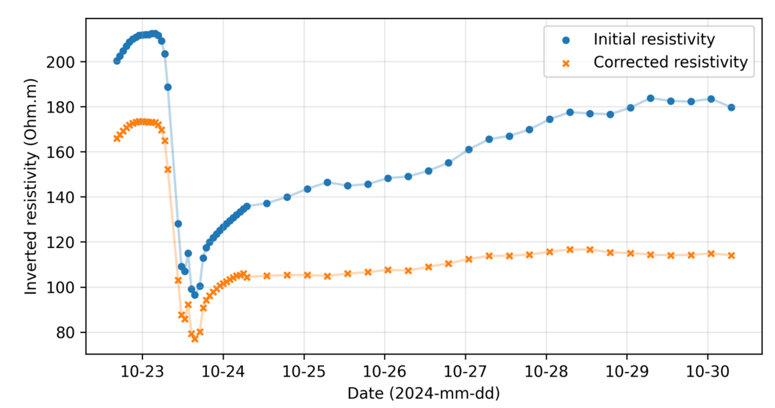


Ratio : Current model / Reference model



Water flow path in the mine cover during the infiltration test

Temperature correction



Variation in **inverted resistivity** 0.6 m deep under the trench

Formula used :

$$\rho_{corr} = \rho \,.\, [\,1 + t_c\,.\,(T - T_{std})\,]$$ **[6]**

- $t_c = 0.016\ °C^{-1}$
- $T_{std} = 25\,°C$

By removing the effect of temperature on the inverted data, resistivity no longer increases after the infiltration test.

b) Discussion

- Capacity of TL-ERT method to identify the spread of water towards the end of the slope based on inversion ratio results
- Conventional inversion process unable to recover layer thicknesses due to the high resistivity contrast and low layer thickness

⇨ Necessity to combine the usual processing of ERT data with other approaches such as :

- ✓ Generation of Vertical Electrical Sounding (VES) inversion profiles to recover the different layer thicknesses at a given position and use them as ERT inversion constraints
- ✓ Simulation of synthetic apparent resistivity data sets from combined hydrogeological and geophysical modeling, for direct comparison with field data

4. Conclusion

Key points

- A numerical feasibility study is useful prior to the field campaign to optimize the quality of the data obtained.
- Geoelectrical monitoring provides an overview of water propagation in the mine cover, complementing the information provided by point sensors.
- The integration of hydrogeological modelling in the TL-ERT data processing phase is necessary to better asses water flow paths within the mine cover.
- In the long term, this joint approach could be used to refine the accuracy of hydrogeological models and thus better predict the behavior of multi-layer mine waste reclamation cover systems.

5. References

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