3D Characterization and Real-Time 4D Electrical Resistivity Monitoring at Complex Sites

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Monitoring and Characterization at Complex Sites

• Bottom Line
  • Electrical Resistivity Tomography (ERT) advancements are enabling unprecedented access to the inaccessible subsurface for remediation performance monitoring
  • Even more important at Complex Sites where standard approaches may be limiting

• Objectives
  • Demonstrate DOE and DoD ERT applications related to remediation monitoring at Complex Sites
  • Identify opportunities for collaboration and technology transfer
ERT Field Systems: Robust and Deployable

Surface Electrode Array

Borehole Electrode Array

320 Electrode ERT System

Control Visualization

Field Site

Wireless transfer

Parallel Inversion

Wireless

Autonomous data collection

Wireless transfer
What Are We Imaging and Why Do We Care?

- ERT images the electrical conductivity distribution of the subsurface
- Electrical conductivity is governed by properties that important to remediation performance

\[
\sigma_{\text{earth}} = \frac{1}{\rho_{\text{earth}}} = \sigma_w(T)^m \phi_{\text{int}}^n S_w^n + \sigma_{\text{surf}}(S_p, \sigma_w, S, T)
\]

\(m\) and \(n\) are exponents related to pore space connectivity/tortuosity
3D Vadose Zone Contaminant Plume Imaging

Hanford B-Complex Subsurface Contaminant Imaging

Time-Lapse Imaging of Stage-Driven River Water Intrusion

Enabled by fluid conductivity contrast between river water and groundwater

4D Monitoring of Vadose Zone Desiccation Remediation: Hanford BC Cribs

Dry nitrogen injection system
Instrument panels
Extraction Blower

Baseline ERT Image

Time-lapse 3D imaging of Engineered Subsurface Desiccation

3D Auto-monitoring of Bioremediation Performance: Brandywine MD DRMO

Baseline ERT Image

Direct Push Bio-Amendment Injections

4D ERT Monitoring

3D Characterization and 4D Imaging of Fluid Flow in a Natural Fracture System: Naval Air Warfare Center

ERT Array with Isolated Sampling Ports

Conductivity Change Isosurfaces Superimposed on Baseline Image


Borehole Installation (Rutgers University)
Real-Time 4D Imaging of Tracer Transport in an Energetically Stimulated Fractured Rock System

Wellbore and ERT Layout

High Speed Footage of Energetic Stimulation

Courtesy Mark Grubelich Sandia National Laboratory

large bi-wing fracture in
4D Imaging of Tracer Transport in a Stimulated Rock System
Problem:
• Monitoring/verification of amendment delivery

Supplementary Information:
• Amendment increases saturation and pore fluid conductivity

Objective
• Use time-lapse ERT monitoring to image amendment distribution over time
• Two surface ERT lines (@ 2.5 m)
• Real-time website delivery for duration of treatment
Monitoring Vadose Zone Remedial Amendment Delivery: Imaging Results
Coupled simulators are used to simulate the expected performance of time-lapse ERT imaging/monitoring.
More information ...

- PNNL ERT Imaging Software (E4D)
  - https://e4d.pnnl.gov

- Rutgers/USGS ESTCP Webinars

- USGS Fractured Rock Geophysical Toolbox
  - http://water.usgs.gov/ogw/frgt

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Thank you