

Optimizing Electrical Resistivity Tomography Surveys for Targeted Subsurface Characterization: An Integrated Computational Framework

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Abstract

The work develops an integrated computational framework for optimizing Electrical Resistivity Tomography (ERT) surveys through advanced numerical modelling, laboratory validation, and sensitivity-driven survey design. Conceived for the non-invasive monitoring of Municipal Solid Waste Landfills (MSWLFs), the methodology addresses the early detection of liner degradation and leachate migration, supporting groundwater protection and long-term environmental monitoring.

A key outcome is the development of an innovative mixed-dimensional model for direct-current geoelectrical simulations, where thin geomembranes are represented as two-dimensional elements and electrodes as one-dimensional objects within a three-dimensional domain. This formulation substantially reduces computational costs and the ill-posedness of the inverse problem while preserving modelling accuracy, enabling efficient simulations of large and geometrically complex systems. The framework has been validated against analytical solutions, established geophysical software, and controlled laboratory experiments.

Building on this model, the work introduces a sensitivity-analysis approach for optimizing ERT acquisition design. By computing three-dimensional sensitivity distributions, the methodology identifies electrode configurations that maximize resolution within predefined target volumes, improving investigation depth and spatial resolution while reducing the number of measurements, field time, and computational effort. Following validation through numerical and simplified experimental benchmarks, the approach proved particularly effective in detecting localized subsurface anomalies, including landfill liner defects and preferential pathways for contaminants.

The sensitivity-based methodology has subsequently evolved into a general framework for targeted geophysical investigations. Its applicability has been exploited in the optimization of ERT surveys for fault detection in highly urbanized environments, highlighting its

transferability beyond landfill monitoring. Overall, the project provides a versatile tool for designing optimized geophysical surveys for environmental, hydrogeological, engineering, and geological applications requiring efficient and high-resolution subsurface characterization.

Keywords: Electrical Resistivity Tomography (ERT), Sensitivity-based survey optimization, Mixed-dimensional numerical modelling, Environmental and engineering geophysics