Integration of geophysical methods into hydrogeologic studies: the issues with spatially variable method resolution

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Abstract

This research has established a systematic procedure to accurately track the migration of a groundwater solute tracer using cross-well electrical resistivity tomography (ERT). Based on original experimental data collected for this project at the Massachusetts Military Reservation, it is shown that the migration of a saline tracer was readily detected in 3D using ERT, and that the mass, center of mass, and spatial variance of the imaged tracer plume were estimated from modified moment analysis of the electrical resistivity tomograms. Conversion of the inverted electrical resistivities to solute concentrations via Archie's law resulted in significant underestimation of tracer mass and greater apparent dispersion than that suggested by reasonable advection-dispersion simulations.

However, the center of mass estimated from ERT inversions was accurately tracked when compared to 3D transport simulation. Underestimated tracer mass from ERT and overestimated tracer plume dispersion is shown to be an effect of two properties of ERT surveys: 1) reduced measurement sensitivity to electrical resistivity values with distance from the electrodes and, 2) spatial smoothing (regularization) resulting from tomographic inversion. Analyses suggest that no single petrophysical relation, such as Archie's law, exists between concentration and electrical resistivity. The "correct" petrophysical model must vary both in space and time. We calculate this non-stationary petrophysical model by employing numerical simulation of both solute transport and electrical flow to create local non-stationary linear relations between resistivities and tracer concentrations. These relations are used to convert field electrical resistivity tomograms into estimated concentrations. In both synthetic and field data, tracer mass and concentration estimates obtained using this non-stationary estimation approach were superior to those obtained using direct application of Archie's law applied to 3D tomograms from ERT. Through dynamic geophysical imaging of a groundwater tracer combined with quantification of the spatially variable resolution of ERT, a more accurate description of tracer behavior was achieved than previously possible.