Sandia National Laboratories

Environmental Field Geophysics

Hybrid Hydrologic-Geophysical Inverse Technique for Assessment and Monitoring in the Vadose Zone

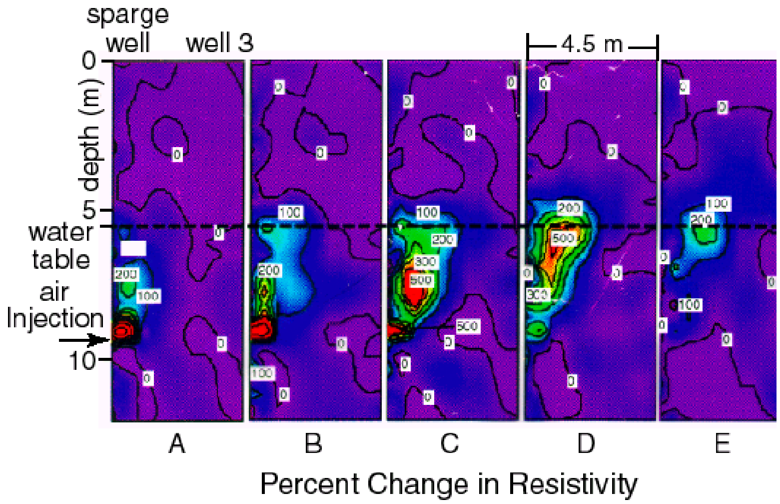
Need

At many DOE facilities, particularly those in the western half of the country, the presence of toxic or radioactive wastes within the vadose (unsaturated) zone poses a serious and ongoing threat to public health and safety. There are two basic approaches being pursued to reduce the risk associated with these wastes: active remediation methods such as pump-and-treat, and waste immobilization techniques such as those using subsurface grout barriers. Effective monitoring techniques are essential to demonstrating the success of either of these two remediation strategies. New and innovative techniques to monitor the moisture content of the vadose zone and determine how fluid migration occurs within the unsaturated regime, would greatly aid the remediation effort by providing reliable information on subsurface properties through time. The Hybrid Hydrologic-Geophysical Inverse Technique will combine information from electrical resistance tomography (ERT), statistical information about the site geology, and sparse data on moisture and contaminant distributions to provide improved estimates of hydraulic properties and three-dimensional contaminant distributions.

Description

The Hybrid Hydrologic-Geophysical Inverse Technique (HHGIT) is a fundamentally new approach to site monitoring and characterization. It will provide detailed knowledge about hydrological properties, geological heterogeneity, and the extent and movement of contamination. HHGIT combines electrical resistivity tomography to geophysically sense a three-dimensional volume, statistical information about fabric of geological formations, and sparse data on moisture and contaminant distributions. Combining these three types of information into a single inversion process will provide much better estimates of spatially varied hydraulic properties and three-dimensional contaminant distributions than could be obtained from interpreting the data types individually. Furthermore, HHGIT will be a geostatistically based estimation technique; the estimates represent conditional mean hydraulic property fields and contaminant distributions. This will provide quantitative uncertainty estimates of the hydrologic parameters. These uncertainty estimates are very important for determining the likelihood of success of remediation efforts and the risk posed by the hazardous materials themselves.

The hydrologic inverse technique used here is the recently developed geostatistics based inverse technique, called cokriging. It uses linear predictor theory, which takes advantage of the spatial correlation between the flow process and the cross-correlation between the flow and hydraulic properties of the soil. It has



Example of ERT image of change in resisitivity for an air sparging experiment at Florence, Oregon

been widely applied in recent years, however, its application to the problem of determining vadose zone hydraulic conductivity has received little attention. Successful application of this technique requires extensive knowledge of the moisture distribution in the vadose zone. HHGIT will use the ERT method to non-intrusively determine 3-D moisture distribution. ERT is a DC resistivity technique in which electric potentials generated by a current source (either on the earth's surface or in the subsurface) are measured by a similarly positioned receiver. These potentials are sensitive to the bulk electrical properties, which are primarily diagnostic of porosity, the amount and connectivity of pore fluid, and the pore fluid chemistry. The ERT data require an inversion algorithm for producing a subsurface image. In this project, two inversion algorithms are being developed: the first a statistically-based ERT inversion scheme, and the second an iterative geostatistical hydrologic inverse algorithm. Finally, these two pieces of the approach will be joined by forming the combined inversion technique, and testing it with numerical simulations.

The project also involves extensive field testing and verification. Two controlled field flow and transport experiments will be conducted in unconsolidated vadose zone sediments with concurrent intensive geophysical characterization. The field data will be inverted using HHGIT and compared to the known field conditions.

This three-year project, conducted jointly by Sandia and researchers at the University of Arizona, commenced in late 1996. In the initial year of the project, the ERT and hydrologic inversion algorithms have been under development; field site selection and development has also been a major activity.

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