Project Number 70267

A Hydrologic-Geophysical Method for Characterizing Flow and Transport Processes within the Vadose Zone

6/15/2001

RESEARCH OBJECTIVE

The objective of this study is to analyze flow and transport within the vadose zone during a mid-scale hydrologic infiltration experiment to characterize in-situ transport processes. This project will employ numerical and experimental tools developed under a previously funded EMSP proposal (project number 55332) to provide 3-D unsaturated hydrologic property distributions. In the present project, geophysical imaging techniques will be employed to track an analogue contaminant plume. The results will provide a better understanding of transport modes including the influence of natural heterogeneities and man-made structures within the vadose zone at DOE sites. In addition the data will provide checks against which numerical flow and transport simulations can be compared.

RESEARCH PROGRESS AND IMPLICATIONS:

As of the 21st month of a 36-month project, we continue to monitor the progress of an infiltration experiment that was begun under a previously funded EMSP project (see report on project 55332 for more information). In the former project, potable water was infiltrated to develop a steady state flow field; the current project introduces a sodium chloride tracer into the infiltrometer to investigate transport processes. The ongoing analysis of data from the first project has resulted in improved methods of estimating moisture content from geophysical data, and the use of animation both hydrologically and geophysically derived moisture contents has brought new insight to the analysis of unsaturated flow. The results also show decreasing moisture content along the peripheries of the flow field; work is underway to determine if this phenomenon is an artifact of the data analysis or actual hydrological feature.

The flow system has been modified to accommodate tracer infiltration. These modifications include installing a second supply system for the tracer solution and modifications to the water distribution system such that either fresh water or the tracer solution can be fed to any combination of the nine infiltration panels. The tracer supply system is almost a duplicate of the fresh water supply system and is comprised of a water tank, submersible mixing pump, solenoid valves, timers, and flow monitoring system.

The tracer experiment was initiated on June 4 at 1:00 am after the geophysical and hydrological data indicated that the flow field had reached steady state conditions, all hydrologic sensors (time-domain reflectrometry and suction lysimiters) used to monitor tracer concentrations were tested and calibrated, and background tracer concentrations were collected. In addition flow monitoring systems were thoroughly calibrated and flow rates cross-verified between different measurement. Thus we have considerable confidence in the measured volume of infiltrated water. A new group of students have been trained to operate the acquisition equipment at the site, and produce the geophysical images.

It was observed that the quality of the electrical resistivity tomography (ERT) data had decreased. This was most likely due water infiltrating into the connectors. This problem was corrected by cleaning and drying the connectors and placing them above ground. A full review of system accuracy and data acquisition methods has been completed and a number of changes made to improve data quality and increase the resolution in the center of the infiltration area. Several data sets have been completed using the new procedures and compared with the older data.

We recently finished up a group of papers that describes the experimental site, and the results of the infiltration experiment. These papers include an error analysis of the geophysical measurements, how these errors translate to the geophysical images, the differences between the different geophysical imaging techniques, and how the hydrologic/geophysical measurements made on laboratory samples

collected from the site might also be in error. In addition an in depth report that describes the site, what instruments are installed, and documents the data is near completion.

Preliminary three-dimensional hydrogeologic parameter fields for unsaturated flow and solute transport processes have been estimated using tensiometer, neutron log data, the geophysical measurements, and core samples. To enhance the resolution of the parameter fields, we are developing various methods to filter noise and to recover data. A three-dimensional model for flow and solute transport in variably saturated media has been implemented and is undergoing various phases of testing to ensure convergence of solutions for both steady and transient flow. During the next phase of the study, this model will be used in conjunction with the enhanced hydrologeological parameter fields to simulate water and solute transport at the field experimental site.

New processing techniques have been test and applied to the geophysical data. For the electrical resistivity tomography imaging, it has been determined that electrical anisotropy may be affecting the results. Data is being reinterpreted using an algorithm that incorporates this effect. A new difference based inversion technique is also being applied to the ERT data that provides better images of the time variations of in-situ resistivity. The method of estimated moisture contents from ERT data has also been improved. For the cross borehole ground penetrating radar imaging, a software package that provides both attenuation and velocity imaging has been tested and implemented. This has shown to yield similar images of velocity compared to the existing 'Pronto' software package that was employed. The attenuation images have been demonstrated to mimic the velocity images in terms of reproducing the basic geologic structure. However, the attenuation imaging is not sensitive enough to image the changes in moisture content that have been caused by the infiltration experiment. In addition, the attenuation imaging has been found to require special processing to provide data that yield consistent results.

## PLANNED ACTIVITIES

Processing has begun on the initial ERT and GPR data for the transport experiment and will continue. Infiltration will continue at the existing concentration for 30 days. ERT, GPR, and electromagnetic induction logging data will be used to evaluate the extent the in-situ changes. Based on this evaluation, the present infiltration rate and concentration will be continued or a second round of infiltration at a higher salinity will be started. Once the solute 'plume' reaches steady state the geophysical imaging results will be compared to flow and transport simulations that will be computed using the geologic/hydrologic models that have been constructed from the preinfiltration images. In addition, if time permits a second tracer experiment may be initiated using a different configuration of infiltration panels and/or different flow rates.