United States Environmental Protection Agency
Environmental Sciences Division
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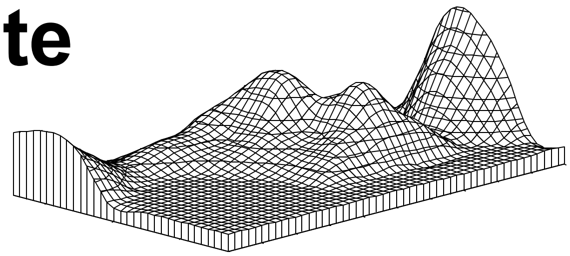
OFFICE OF RESEARCH AND DEVELOPMENT
TECHNOLOGY SUPPORT PROJECT

Groundwater Fate and Transport Modeling



Introduction

The U.S. EPA, through the DOE Idaho National Engineering and Environmental Laboratory (INEEL), has an extensive capability in the area of ground-water contaminant fate and transport analysis and modeling that is applicable to sites across the country. The INEEL has conducted several successful modeling studies at Superfund sites for the EPA Technology Support Center in Las Vegas. These have included predicting dense non-aqueous phase liquids (DNAPL), DNAPL vapor and dissolved DNAPL transport at a California site and modeling of a creosote and pentachlorophenol (PCP) contaminated site in Texas. In these studies, modeling personnel have worked with EPA, state, and other parties to achieve project goals.

Modeling Process

The modeling process employed involves several interrelated steps with appropriate feed-back. The first step is to understand the overall goals and define objectives for the fate and transport analysis that support the goals. Next, available data are used to develop a preliminary conceptual model of the system. A preliminary model analysis consistent with the conceptual model improves understanding, identifies data gaps and inconsistencies in the system and may result in collecting further data or upgrading the conceptual model. Because predicting flow and transport in subsurface environments are inherently uncertain, sensitivity and uncertainty analyses are needed to properly evaluate risk or performance for all but the simplest systems. Once the final model is acceptable, it can be used to predict concentrations used in risk analysis and/or to evaluate various remediation options.

Conceptual Model

A conceptual model is a simplified representation of the site that captures the key site features important to the goals. Developing the conceptual model is often the most important step in the modeling process. Simplifications and assumptions about the site and processes are necessary to obtain a workable model that includes the key features. Key features of the conceptual model include the descriptions of the contaminant source, the path to the receptor, and the physical, chemical, and biological processes that may significantly affect contaminant movement. As an example, the source may be a spill at the land surface. The transport path to the receptors may include the near surface, the vadose zone, and the aquifer(s). Transport mechanisms may include vapor contaminated water or NAPL transport. Dispersion, diffusion, sorption, NAPL dissolution, and natural biodegradation may be important processes.

Numerical Models/Codes

A suite of numerical models, codes, and data analysis tools are available which apply to progressively more complex conceptual models. These tools range from simple analytical or semi-analytical one-dimensional (1-D) flow and 1-D or multi-dimensional contaminant transport codes, linked to represent various parts of the flow path, to 3-D, multiphase, multicomponent reactive transport codes for the most complex sites and processes. Sophisticated data analysis tools are also used to estimate model parameters and present the results. Code selection depends upon the complexity of the conceptual model. Often a simple tool is used to assist in the conceptual modeling followed by a more complex tool in the final analysis.

Results

The results of the modeling study are usually in the form of predicted contaminant concentrations at groundwater receptor locations and a comparison with action levels. If remedial action is indicated, the model can assist in evaluating the effectiveness of various remedial action alternatives. Such alternatives include ground-water pump and treat, vapor source removal, and hydraulic or chemical barriers. More complex strategies, such as enhanced bioremediation or surfactant enhanced NAPL recovery, can also be examined. Often early results of the modeling can help guide additional data collection efforts. Sensitivity and uncertainty analysis allow better use of the model results in assessing risk or performance.

Examples

DNAPL vapor contaminating the vadose zone above the water table was suspected of contaminating the aquifer below a California site. Figure 1 shows the results of a multiphase model used to simulate DNAPL, vapor phase and dissolved liquid phase transport in the vadose zone and dissolved liquid phase transport in the aquifer. The study concluded that multi-phase transport was a viable mechanism for contaminating the aquifer from the vadose zone.

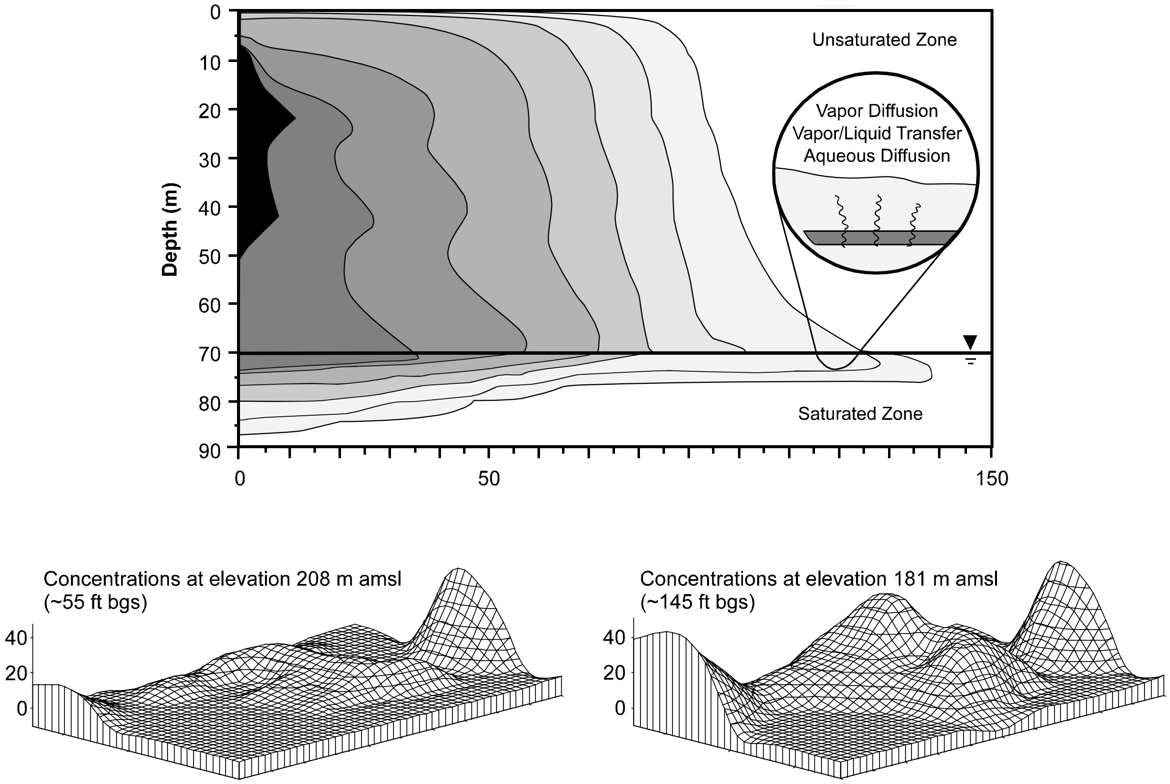


Figure 1. Predicted DNAPL Dissolved Aqueous Phase Concentrations

Figure 2 shows the results of a TCE remedial design system being developed at the INEEL. The system combines pump and treat with enhanced in situ bioremediation. The addition of hydrocarbon (electron donor) and nutrients to the aquifer have accelerated biodegradation. Degradation rate and Monod half-saturation constants determined in lab studies have assisted in the model prameterization. The objectives of the effort are (1) to estimate hydraulic, transport, and biodegradation properties.

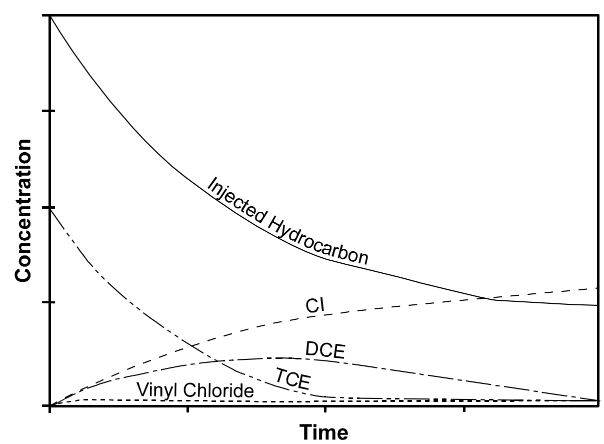


Figure 2. Batch Biodegradation of TCE/DCE/VC

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