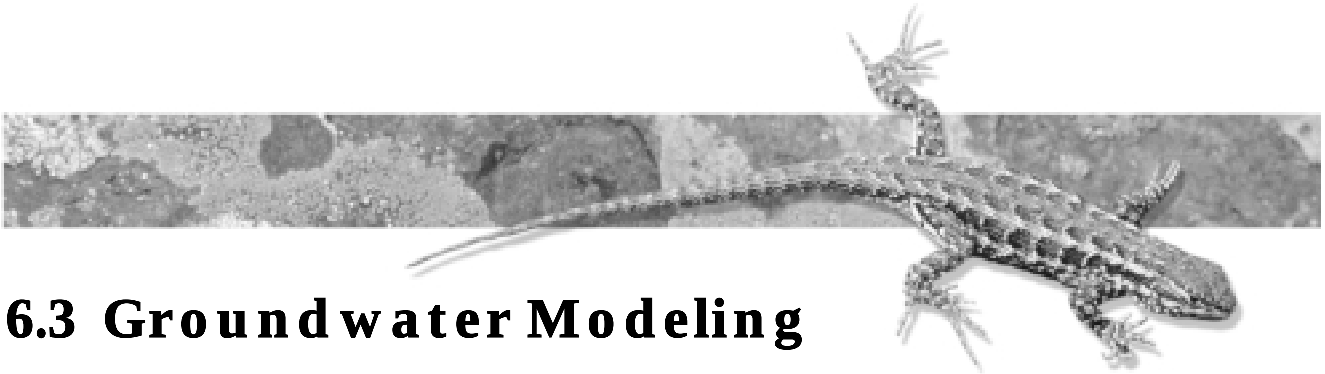

6.3 Groundwater Modeling

D. R. Newcomer

Researchers use numerical modeling of groundwater flow and contaminant transport to simulate future groundwater flow conditions and predict the migration of contaminants through the groundwater pathway. DOE consolidated multiple versions of sitewide groundwater flow and contaminant transport models into one model to eliminate redundancies and promote consistency in addressing sitewide groundwater problems (DOE/RL-2000-11). The code used to implement the consolidated groundwater model is the Coupled Fluid, Energy, and Solute Transport (CFEST-96) code, which was developed by CFEST Co., Irvine, California (Gupta 1997). During 2001, progress on development of the consolidated groundwater model focused on sources of uncertainty and how to address uncertainty in groundwater modeling (PNNL-13641). During 2001, the consolidated model was used for the following applications:

- updating the Hanford Site Composite Analysis
- producing an initial assessment using the System Assessment Capability
- modeling the 200-West Area carbon tetrachloride plume.

6.3.1 Consolidated Groundwater Model Progress in 2001

A major objective in the development of the consolidated groundwater model is to improve contaminant transport predictions by addressing uncertainty in the model (PNNL-13641). Major uncertainties can be estimated by developing alternate conceptual models (sensitivity analysis) and by establishing probability distributions for key parameters (uncertainty analysis). Each conceptual model is then calibrated based on historical observations of hydraulic head measurements and contaminant concentrations. Results of the calibrated alternative models will span the range of likely future contaminant movement through groundwater. During 2001, calibration of the existing groundwater flow model and one alternative conceptual model was completed.

A three-dimensional transient version of the baseline groundwater flow model was re-calibrated in 2001 (PNNL-13447). The calibration period was extended over a longer period (1943 to 1996). The calibration incorporated new estimates of artificial discharges and river stages before 1979 and a complete set of hydraulic head measurements from 1943 to 1996. The transient inverse calibration procedure significantly improved the model's ability to simulate changes in the water table over the entire Hanford Site. However, the calibration indicated that other conceptual model components are needed to improve the historical aquifer system behavior. One of these components is recharge to the unconfined aquifer system from the underlying basalt-confined aquifer system. Thus, the first major alternative conceptual model included the effects of groundwater movement between these two aquifer systems.

The investigation on the effects of groundwater leakage between the upper basalt-confined aquifer and the overlying unconfined aquifer system is described in PNNL-13623. The objective of this study was to determine whether inclusion of groundwater leakage between these two aquifers could improve model calibration. The results of the investigation indicated that, over the entire prediction period of 1948 to 1996, the overall model fit of the water-level measurements was a slight improvement over the baseline model fit. The calibrated model with basalt leakage is a more realistic conceptual model and incorporates parameter estimates that are closer to expected ranges. However, best-fit estimates of some parameters such as specific yield continued to be unrealistic, indicating that additional improvements in the conceptual model are needed.

6.3.2 Update of the Hanford Composite Analysis

The consolidated groundwater model was used to simulate groundwater contaminant transport from selected waste sites to support an addendum to the Composite Analysis (PNNL-11800, Addendum 1). The addendum analysis was required for continued authorization of low-level waste disposal at the Hanford Site. The analysis addressed the impact of these selected waste sites on groundwater. These waste sites, which were not included in the first Composite Analysis (PNNL-11800) conducted in 1998, included the Plutonium Uranium Extraction Plant tunnels, the chemical separations plants, and some CERCLA sites in the 200-East and 200-West Areas. Technetium-99 and iodine-129 were used as representative mobile constituents.

Results of the addendum analysis indicated that the effects of the additional sites pose no significant increases in radiological doses during the next 1,000 years, and that conclusions of the 1998 composite analysis remain valid. Predicted radionuclide concentration estimates and resulting doses in groundwater from the composite analysis demonstrate the need for continued control of land use and monitoring programs at the Hanford Site. These are necessary to meet the long-term objective in protecting human health and the environment. This analysis supports the concept of retiring the Hanford Site boundary to the proposed buffer zone boundary at the time of Hanford Site closure in 2050.

6.3.3 System Assessment Capability

The System Assessment Capability (Section 2.3.11.2) is a tool being developed to predict the cumulative sitewide effects from all significant contaminants at the Hanford Site. This tool uses several linked models to simulate the movement of contaminants from waste sites through the vadose zone, groundwater, and Columbia River to receptors. It then assesses the risk to humans, other living organisms, the local economy, and cultures. The consolidated sitewide groundwater model was used as the groundwater component of the System Assessment Capability to simulate contaminant transport through the groundwater. During 2001, an initial assessment was performed using the System Assessment Capability.

The major objective of the initial assessment was to demonstrate the linkage of models. For the initial assessment, a two-dimensional groundwater model with variable aquifer thickness was determined to be suitable for calculating transport of contaminant constituents. The model simulated the transport of 10 different radionuclide and chemical constituents released from 890 waste sites for the period 1944 through 3050.

6.3.4 Carbon Tetrachloride Plume Modeling

The consolidated groundwater model was used to simulate the migration of carbon tetrachloride from the Z crib in the 200-West Area to an assumed compliance boundary ~5,000 meters (~16,400 feet) from the source (PNNL-13560). The purpose of the study was to provide upper and lower estimates of the amount of carbon tetrachloride at the source area that will most likely result in carbon tetrachloride concentrations exceeding 5 µg/L at the boundary. The modeling study concluded that for amounts between 7,500 and 75,000 kilograms (16,500 and 165,000 pounds) of carbon tetrachloride, the concentration of 5 µg/L may be exceeded depending on source removal efforts. If 75,000 kilograms (165,000 pounds) or more of carbon tetrachloride reaches groundwater, then concentrations of 5 µg/L would be exceeded at the compliance boundary. Carbon tetrachloride concentrations would not likely exceed 5 µg/L at the boundary if 7,500 kilograms (16,500 pounds) or less carbon tetrachloride reached groundwater at the source area.

In 2001, additional modeling of the 200-West carbon tetrachloride plume was conducted to predict the carbon tetrachloride concentration distribution using both realistic and conservative natural attenuation parameters. Natural attenuation parameters are important in predicting the movement of the carbon tetrachloride plume from the 200-West Area. The sitewide model grid was refined in the area between the source area and the Columbia River. Three modeling cases were evaluated:

- a continuing source of carbon tetrachloride in contact with the groundwater

- the effect of complete removal of the carbon tetrachloride source
- the effects of assuming that no continuing source ever existed.

For the first case with a continuing source in contact with the groundwater, the effect of using conservative and realistic natural attenuation parameters is illustrated in Figures 6.3.1 and 6.3.2. Figure 6.3.1 shows that carbon tetrachloride concentrations exceed 5 µg/L outside the Central Plateau waste management area if conservative parameters are assumed (natural attenuation values set to zero). Under these conservative conditions, the size of the plume will continue to grow until the mass rate of carbon tetrachloride entering the Columbia River reaches the source release rate. If realistic natural attenuation parameters are used, then carbon tetrachloride concentrations will not exceed 5 µg/L outside the Central Plateau waste management area (see Figure 6.3.2). Under these realistic conditions, natural attenuation limits the growth of the plume.

For the second case with complete source removal and the third case with no continuing source using conservative natural attenuation parameters, carbon tetrachloride concentrations will not exceed 5 µg/L outside the Central Plateau waste management area.

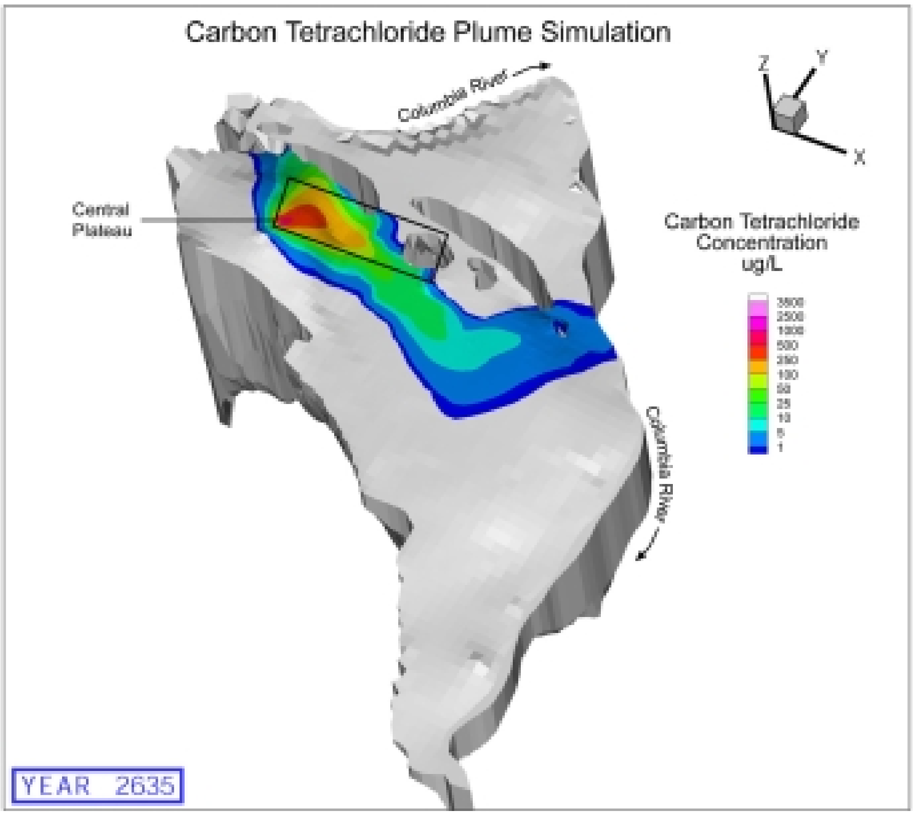

Figure 6.3.1. Predicted Carbon Tetrachloride Plume using Conservative Natural Attenuation Parameters

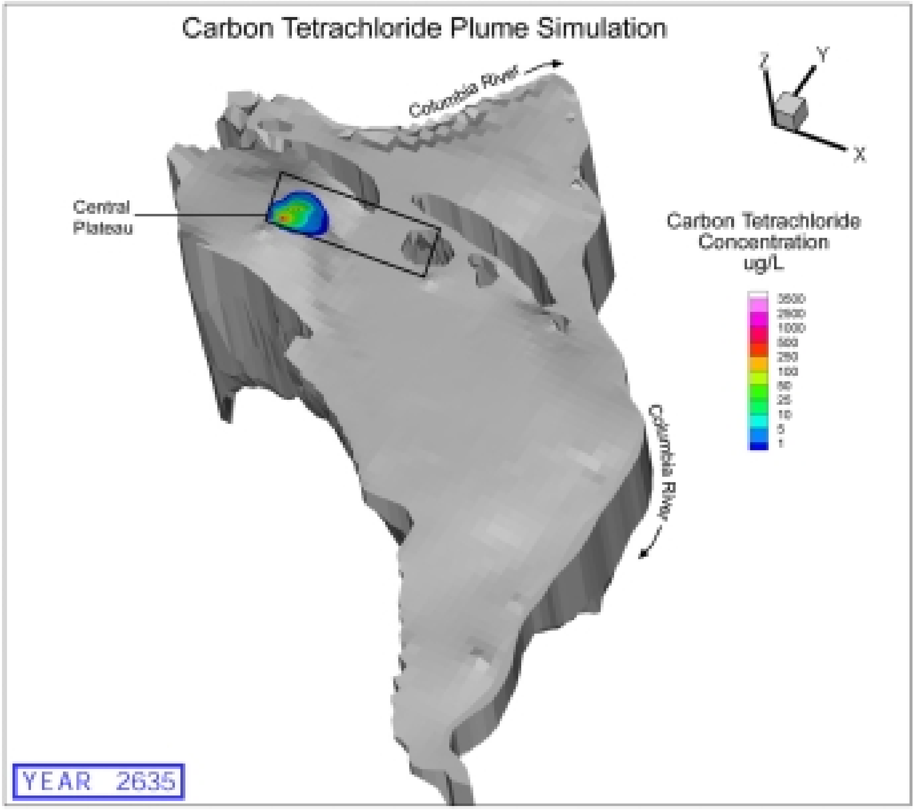

Figure 6.3.2. Predicted Carbon Tetrachloride Plume using Realistic Natural Attenuation Parameters