6.3 Groundwater Modeling

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Computer models are used to predict the movement of contaminants in groundwater beneath the Hanford Site. These predictions are important for planning waste management and cleanup activities. For large-scale problems, such as contaminant movement from the Central Plateau to the Columbia River, a three-dimensional site-wide model was developed. This model is being improved to represent groundwater flow more realistically and to quantify the uncertainty in model predictions. Other groundwater models are used for problems at a local scale (i.e., <~10 kilometers [<~6.2 miles]), such as the design and evaluation of pump-and-treat systems for groundwater. Groundwater modeling for 2002 included the following activities:

- Continuing development of a site-wide groundwater model.
- Completing the System Assessment Capability initial assessment.
- Creating a site-wide model for the Hanford Site Solid Waste Environmental Impact Statement.
- Modeling potential releases from each of the tank farm areas.
- Evaluating groundwater pump-and-treat systems

6.3.1 Development of the Site-Wide Groundwater Model

The site-wide groundwater model was developed from information about the hydrogeologic structure of the aquifer, spatial distributions of hydraulic and transport properties, aquifer boundary conditions, and the distribution and movement of contaminants. Model results are uncertain because of incomplete knowledge of the groundwater flow system and because the calculations used in groundwater models only approximate the processes of groundwater flow and transport. Quantifying the uncertainties in model results is a major objective of the consolidated groundwater-modeling task. Understanding and quantifying the uncertainties in model predictions will strengthen the technical defensibility of groundwater transport predictions and lead to a better basis for waste management and cleanup decisions.

As described in PNNL-13641, uncertainty in the site-wide groundwater model is being quantified through both sensitivity analysis and uncertainty analysis. Sensitivity analysis involves developing alternative conceptual models that encompass identified uncertainties, then calibrating each model based on historical observations of water-level changes and contaminant movement. Results of the different calibrated models will then span the range of results expected based on different assumptions. Uncertainty analysis uses a probability distribution rather than a single value for selected model input parameters. The model then produces a range of results reflecting the uncertainty in the input parameters.

During 2002, alternative conceptual models were developed that address (1) uncertainty in the extent and distribution of major mud units (low-permeability layers) within the unconfined aquifer system, and (2) uncertainty in the distribution of hydraulic conductivity zones within the Hanford formation. The distribution of mud units within the aquifer affects vertical migration of contaminants and also affects lateral movement, particularly where mud units exist at the water table. Three major mud units have been identified at boreholes, but their extent and continuity are uncertain. The Hanford formation is important in transport of groundwater contaminants to the Columbia River because of its relatively high hydraulic conductivity. Therefore, within the groundwater model, the distribution of Hanford formation zones that have unique values of hydraulic conductivity may have a large effect on contaminant movement from the Central Plateau on the Hanford Site to the Columbia River.

Advanced geostatistical techniques were applied to develop the new alternative conceptual models, partially

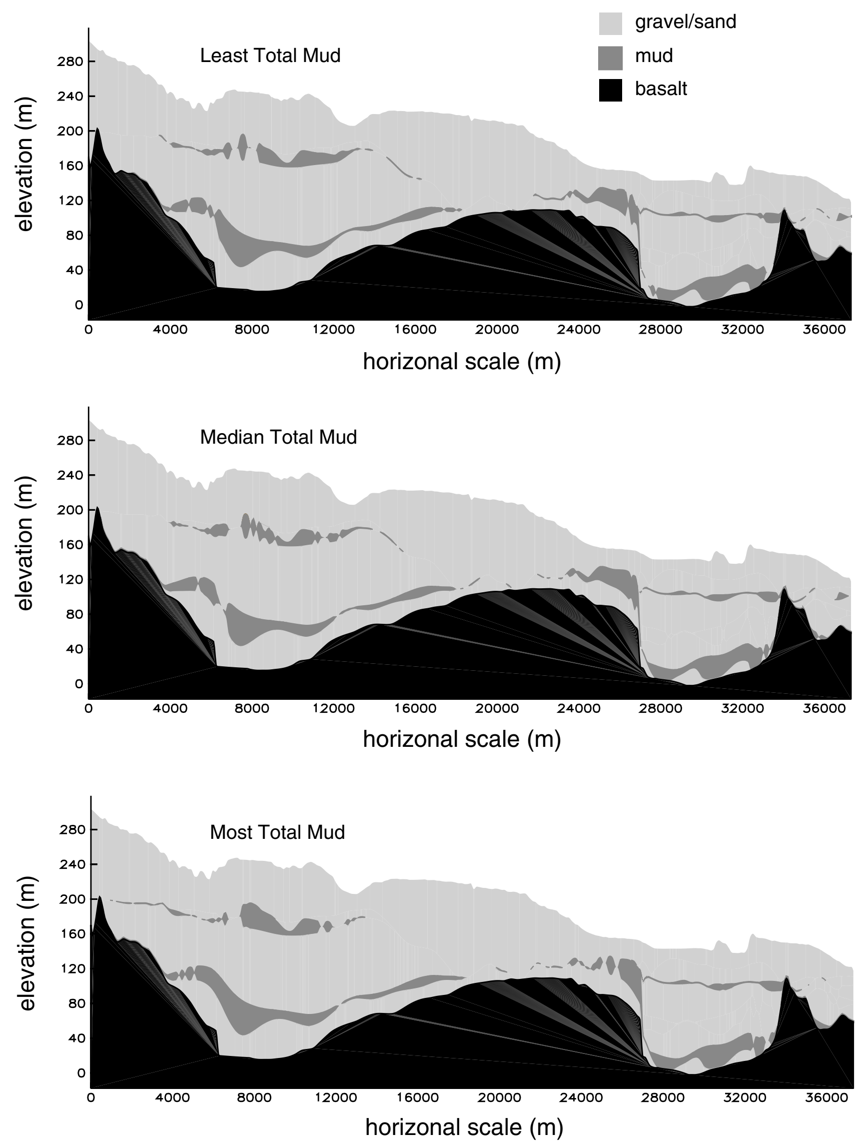

Figure 6.3.1. Cross Sections of Alternative Conceptual Models with the Least Total Mud Extent, Median Total Mud Extent, and Most Total Mud Extent

through a cooperative project between Pacific Northwest National Laboratory and the Russian Academy of Sciences Institute for Nuclear Safety. To address uncertainty in the extent and continuity of mud units, a stochastic simulation method was applied to create a set of 100 realizations that span the range of likely extent/distribution for each of the three mud units. Each realization is an equally probable spatial configuration of the mud unit based on the available borehole data. The realizations for each of the units were merged to create a set of 10,000 different possible combinations. The merged realizations were ranked according to the total area of mud present and the tortuosity (a measure of continuity) for each mud unit. Ranking provided a range of cases to select from for model calibration. Figure 6.3.1 shows cross sections of alternative conceptual models generated from the extreme (least mud and most mud) and median cases. These and other cases will be used in the inverse model calibration to create calibrated alternative conceptual models. The calibrated models will then produce a range of results for hydraulic head and contaminant transport that can be compared to historical measurements.

To address uncertainty in the distribution of hydraulic conductivity zones for the Hanford formation, 100 different realizations were created that span the range of likely sediment-type distributions. The realizations were ranked according to overall hydraulic conductivity and tortuosity. Figures 6.3.2 through 6.3.4 show the distribution of different sediment types for the extreme (lowest and highest) and median conductivity realizations. These and other realizations will be calibrated to create alternative models. The calibrated models will produce a range of results for hydraulic head and contaminant transport that can then be compared to historical measurements. Additional details of the geostatistical methods and results are available in PNNL-14187.

Improvements were also made during 2002 to the site-wide model with the objective of producing more realistic hydraulic parameter estimates and better fits to historical water-level data. The following changes were included in the model:

- Accounting for delay of discharged wastewater caused by transit-time through the vadose zone.

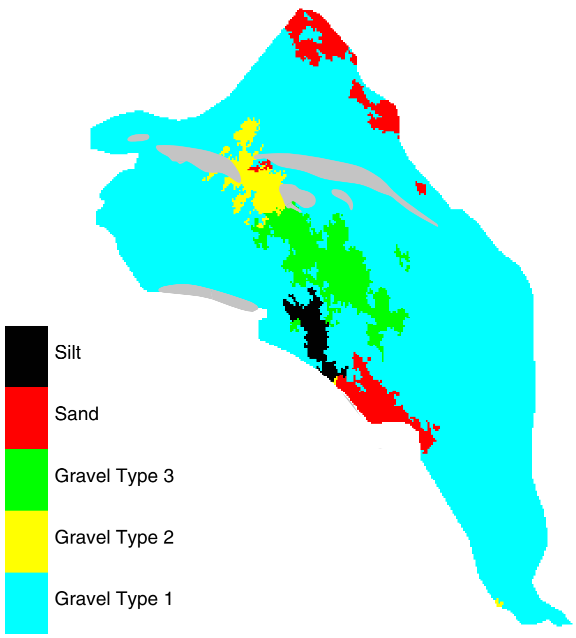

Figure 6.3.2. Alternative Distribution of Hanford Formation Sediment Types with the Lowest Overall Hydraulic Conductivity

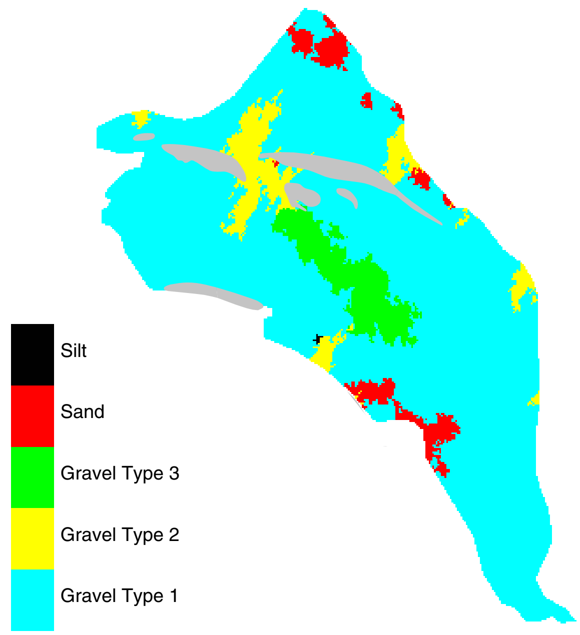

Figure 6.3.4. Alternative Distribution of Hanford Formation Sediment Types with the Highest Overall Hydraulic Conductivity

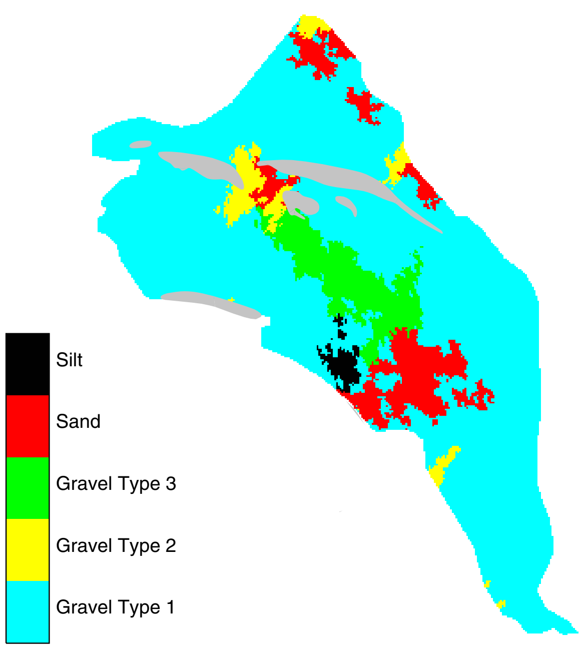

Figure 6.3.3. Alternative Distribution of Hanford Formation Sediment Types with the Median Overall Hydraulic Conductivity

- Creating a separate hydrogeologic unit composed of gravels deposited on top of the Ringold Formation but prior to the Missoula floods. These gravels are found in the east-central portion of the Hanford Site and were previously lumped with Hanford formation (Missoula flood) sediments to form model unit 1.
- Adjusting contacts between layers representing different hydrogeologic sediment types in the area southeast of 200-East Area to make the model more consistent with well data and to create a channel where saturated Hanford formation sediments exist below the water table.
- Adjusting the extent of hydraulic conductivity zones used in the model to represent different sediment types within the Hanford formation.

Significant improvement to the model calibration, compared to an earlier calibration, resulted from the above modifications. However, refinement of the model is continuing, particularly with regard to the distribution of hydraulic conductivity zones within the Hanford formation (model unit 1).

6.3.2 System Assessment Capability

An initial assessment performed using the System Assessment Capability was completed during 2002. Results including those for the groundwater module are presented in PNNL-14027.

The System Assessment Capability is an integration of several linked computer models that simulates the movement of contaminants from waste sites through the vadose zone, groundwater, and Columbia River. It then assesses the impact of the contaminant releases on human health, other living organisms, the local economy, and cultures. The assessment uses a stochastic analysis, which means that selected parameters are represented by probability distributions from which values are selected.

The initial System Assessment Capability assessment met its primary objectives. The original scope of the effort was to develop and successfully test a site-wide assessment capability addressing composite risks from a suite of representative Hanford contaminants for subsurface and surface water pathways over a 1,000-year period. For the initial assessment, the transport of 10 different radionuclide and chemical contaminants released from 890 waste sites from 1944 through 3050 was simulated. Completion of the initial assessment demonstrates that a site-wide analysis can be accomplished.

6.3.3 Modeling to Support the Receptor Risk Model for Tank Farms

The site-wide groundwater model was applied to determine the flow path and travel time to the Columbia River for potential contaminant releases at each of the tank farms located in the 200-East or 200-West Areas. Eighteen tank farms were assessed in this evaluation. Because of the model grid spacing (~375 meters [~1,230 feet]) in the Central Plateau area, releases from some tank farms were combined at single locations, resulting in consolidation of the 18 tank farms to 8 different combined locations, 5 in the 200-East Area and 3 in the 200-West Area.

The groundwater simulations were performed using the base-case site-wide groundwater model that had been calibrated to water-level changes from 1944 to 1996. Because of the long-term nature of the simulations being made, the flow system was assumed to reflect natural steady-state conditions after the effect of Hanford operational discharges have ceased. The simulations were based on a unit release at each tank farm location for five discrete sorption coefficient (K_d) classes at each location. The sorption coefficient classes applied were 0, 0.2, 0.5, 0.8, 1, and 3. The K_d (Appendix C) classes represent contaminants with different degrees of adsorption to sediments in the aquifer. The 0 K_d class represents a contaminant that moves with the groundwater flow (no adsorption). A K_d class of 3 represents an upper limit at which the contaminant is strongly adsorbed to the sediment and does not move with groundwater in a reasonable amount of time.

Simulated results showed that for all sites, the majority of the contaminant plumes move to the north, through the gap between Gable Mountain and Gable Butte toward the Columbia River. A lesser component of the plumes move to the east toward the Columbia River south of Gable Mountain. Earlier groundwater modeling by Cole et al. (PNNL-11801) suggested that as the water table drops in the central part of the Hanford Site and the saturated thickness of the unconfined aquifer decreases, groundwater flow northward from the 200 Areas may be cutoff by relatively impermeable basalt in the area just north of the 200-East Area. The water table is within a few meters of the currently interpreted basalt surface in this area. However, there is uncertainty in both the elevation of the basalt surface and in the natural recharge and boundary fluxes that control predictions of future water-table elevation. Therefore, the potential for movement of contaminants northward through the gap between Gable Butte and Gable Mountain is also uncertain. These issues are currently being investigated as part of the site-wide groundwater modeling task.

6.3.4 Modeling for the Solid Waste Environmental Impact Statement

A version of the site-wide model described in PNNL-11801 was applied to predict transport from low-level burial grounds located in the 200-West and 200-East Areas. This version of the model utilizes a distribution of hydraulic conductivity based on a steady-state calibration of the model. The contaminant source terms for the modeling included both low-level waste that have been previously placed in the burial grounds and waste that are forecast to be placed in the burial grounds before 2046. Results are presented in DOE/EIS-0286D.

6.3.5 Local-Scale Modeling of Pump-and-Treat Operations

The Hanford environmental restoration contractor has performed local-scale modeling during the past several years to design and evaluate pump-and-treat systems for groundwater. Capture and injection zones of extraction and injection wells were determined, and the areas affected by the pump-and-treat systems over time were estimated. During 2002, these models were only updated to reflect the changing water-table elevation in the aquifer and changes in pumping rates. Additional information on these models is provided in DOE/RL-99-79 and DOE/RL-2000-01.