INTEGRATED FIELD CHALLENGE SITE - Hanford 300 Area

U.S. Department of Energy Office of Science

Environmental Remediation Sciences Program

Geohydrology of the Hanford 300 Area and Pre-Modeling of IFC Experiments

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ABSTRACT

The focus of the Hanford 300 Area IFC is on mechanisms responsible for the long-term persistence of a groundwater uranium plume, in spite of the excavation and removal of contaminated sediments from all known source areas. This presentation gives an overview of the geologic and hydrologic characteristics of the 300 Area and preliminary modeling activities associated with the design of the IFC well field and experiments. Data from an automated well network for water level monitoring were used in conjunction with particle tracking calculations, and with considerations for monitoring by geophysical methods (cross-well ERT and GPR), to design the configuration of the IFC well field. Small-scale, high-resolution 3D models of the IFC experimental domain are being developed using the STOMP simulator. A 3D uranium plume-scale STOMP model of the 300 Area has also been developed and calibrated. Comparisons of observed and simulated water levels and selected pre-experiment modeling results are presented.

GEOLOGY

Geologic units underlying Hanford's 300 Area are shown in Figure 1. From bottom to top, these units are the Miocene-aged Saddle Mountains Basalt, which is overlain by the fine-grained Ringold formation lower mud unit (u8), the semi-consolidated, upper coarse-grained Ringold units B, C, and/or E (u5), an unconsolidated and discontinuous fine-grained Ringold sand unit (u4), and the Pleistocene-aged, unconsolidated, gravel-dominated Hanford formation (u1). In undisturbed parts of the 300 Area, the Hanford fm is overlain by a relatively thin (<3 m thick) mantle of Holocene-aged alluvial and eolian sediments.

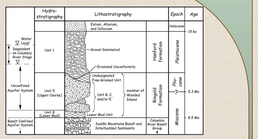

Figure 1. Generalized profile of geologic units underlying Hanford's 300 Area.

Figure 2 shows split-core photographs of representative samples of Hanford and Ringold fm sediments from the 300 Area. In general, the Hanford fm sediments are significantly coarser textured than the Ringold fm sediments. The Hanford fm sediments also have higher percentages of basaltic lithic fragments, compared to the Ringold sediments, which have more granitic lithic fragments and quartz.

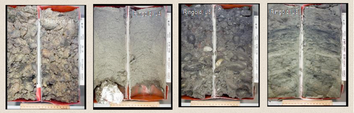

Figure 2. Split-core photographs of representative samples of Hanford and Ringold fm sediments.

The Ringold and Hanford formations are separated by an erosional unconformity caused by cataclysmic flooding from ancient Lake Missoula. Figure 3 shows the interpreted elevation of this erosional surface.

Figure 3. Elevation of top of Hanford/Ringold fm contact.

EarthVision® model

All available geologic and borehole geophysical data have been compiled and used to develop a 3D model of the 300 Area using EarthVision® (Meyer et al. 2007). This model, shown in Figure 4, has been periodically updated as new data become available (Williams et al. 2007). This EarthVision® model forms the basis for all current 3D groundwater flow and transport models of the 300 Area (Williams et al. 2008).

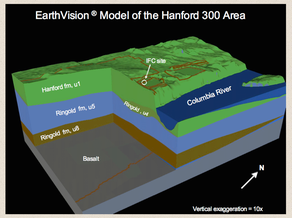

Figure 4. EarthVision™ model of the Hanford 300 Area.

HYDROLOGY

The 300 Area is immediately adjacent to the Columbia River, whose stage can vary by 3 m or more seasonally (Figure 5). Data from two automated well water level monitoring networks are available for the 300 Area. One of these well networks collected hourly water level data between 1991 and 1993 (Figure 6a). The other well network (Figure 6b), which has been operating since 2004, collects hourly or sub-hourly (15-min) water level data, and temperature and EC data in some of the wells. Sensors were added to four additional wells for the current well network in 2007 to support IFC experimental site design and modeling.

Aquifer tests in the 300 Area indicate that the hydraulic conductivity of the Hanford fm sediments (u1) range from several hundred to >5000 m/d. The hydraulic conductivity of the underlying Ringold units (u4 & u5) are ~2-3 orders-of-magnitude lower, ranging from ~2 to 51 m/d. The hydraulic conductivity of the lower Ringold mud unit (u8) is one to two orders-of-magnitude lower than that of the Ringold E unit (u5).

STOMP flow and transport models

3D plume-scale and IFC plot-scale flow and transport models have been developed from the EarthVision® model (Figure 4) using the STOMP simulator (White and Oostrom, 2006). Figure 7 shows plan-views of the STOMP 300 Area plume-scale model grid and the primary hydrostratigraphic units. The IFC plot-scale model represents a sub-domain of the plume-scale model with refined spatial discretization in the area of the planned IFC well field.

Boundary forcing for the plume- and plot-scale models is based on hourly river stage and hourly or sub-hourly (15-min) water level data from the automated well networks. Figure 8 shows comparisons of observed and simulated water levels for two wells (Williams et al. 2008).

Parameterization of the current 300 Area STOMP flow and transport models is based on assimilation of all available core (densities, grain-size distributions, porosity), borehole geophysical (spectral gamma and neutron moisture), and aquifer test data. Figure 9 shows comparisons of observed and calculated porosity and hydraulic conductivity values for three borehole/well locations. Geostatistical analyses of gamma log data have also been performed on data from ~50 boreholes in the 300 Area. These analyses have been used to generate spatially-distributed estimates of physical and hydraulic parameters for both the plume- and plot-scale models using petrophysical relationships (e.g. grain size-gamma log correlations) and pedotransfer functions (Williams et al. 2008).

Design of IFC well field

Data from the current automated well network were used to compute head gradients and flow directions. This information was used with particle tracking calculations and with considerations for cross-well ERT and GPR measurements to design the IFC well field. Figure 10 shows particle tracking results representing transport of a hypothetical tracer plume for different times based on water level data from October, 2007. These calculations suggest a residence time within the monitored IFC experimental domain of 5-7 days for a tracer injected into the aquifer during low river stage conditions (Fall).

Figure 5. Columbia R. stage observations.

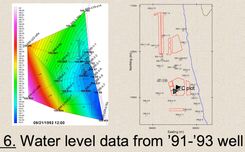

Figure 6. Water level data from '91-'93 well network (left figure) and wells that are instrumented (purple symbols, right figure) in current well network.

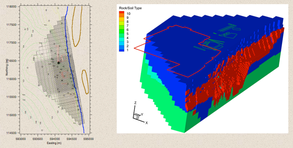

Figure 7. STOMP 3D uranium plume-scale model.

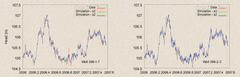

Figure 8. Observed and simulated water levels.

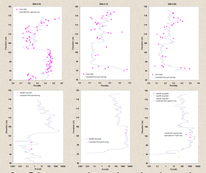

Figure 9. Observed and calculated porosities and hydraulic conductivities.

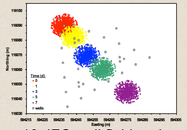

Figure 10. IFC well field and particle tracking results.

EXAMPLE PRE-EXPERIMENT MODELING

Pre-experiment modeling of a hypothetical infiltration experiment was performed using an axi-symmetric STOMP model. Model parameterization was based on physical property, borehole geophysical, and aquifer test data from well 399-3-18 (Williams et al. 2007).

Figure 11 shows snapshots of the infiltrating water plume for a 60 m/d infiltration rate case. For this flux it takes just over 0.3 hr for the infiltration front to travel ~7.5 m to reach the water table. After about 24 hours the saturation profile becomes relatively constant.

Figure 12 shows snapshots of the simulated tracer plume. The tracer was applied from 24-36 hours, after a quasi steady-state flow field was established. With the specified infiltration rate, it takes just over 6 hours for the simulated tracer plume to reach a 20-m radius away from the center of the infiltration plot in the saturated zone. Note that the simulated tracer penetrates more than 1.5 m into the Ringold fm. At 72 hrs, which is after 36 hours with no tracer being applied, a significant mass of tracer still resides in the vadose zone, around the perimeter of the wetted area of the infiltration plot. These observations have implications for lingering sources of process uranium in the subsurface of the 300 Area.

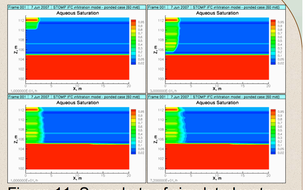

Figure 11. Snapshots of simulated water saturation for hypothetical infiltration exp.

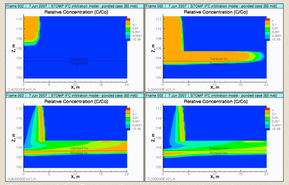

Figure 12. Snapshots of simulated tracer concentrations.

PROJECT COORDINATION AND LINKAGES

Site characterization data have been provided to Yoram Rubin (UC-Berkeley). The 300 Area EarthVision® model, water level data, and physical and hydraulic property estimates used with STOMP have been provided to Glenn Hammond (PNNL) and Peter Lichtner (LANL).

IFC modeling efforts will be coordinated between PNNL, UC-Berkeley, LANL, and Univ. of Alabama to develop multiple conceptual/mathematical models of flow and reactive transport at the site. These alternative models will be parameterized and calibrated using a common set of field characterization and experimental tracer test data. The alternative models will then be applied in a predictive mode to simulate other tracer and reactive transport experiments for model evaluation and hypothesis testing. Joint inversion of hydraulic, transport, and cross-well geophysical data will also be performed by project participants.

REFERENCES

Meyer P.D., M. Ye, M.L. Rockhold, S.P. Neuman, and K.J. Cantrell. 2007. Combined Estimation of Hydrogeologic Conceptual Model, Parameter, and Scenario Uncertainty with Application to Uranium Transport at the Hanford Site 300 Area. NUREG/CR-6940, PNNL-16396, U.S. Nuclear Regulatory Commission, Washington, D.C.

White, M.D., and M. Oostrom. 2006. STOMP – Subsurface Transport Over Multiple Phases, Version 4.0 User's Guide. PNNL-15782, Pacific Northwest National Laboratory, Richland, Washington.

Williams, B.A., C.F. Brown, W. Um, M.J. Nimmons, R.E. Peterson, B.N. Bjornstad, D.C. Lanigan, R.J. Serne, F.A. Spane, and M.L. Rockhold. 2007. Limited Field Investigation Report for Uranium Contamination in the 300 Area, 300-FF-5 Operable Unit, Hanford Site, Washington. PNNL-16435, Pacific Northwest National Laboratory, Richland, Washington.

Williams, M.D., M.L. Rockhold, P.D. Thorne, and Y. Chen. 2008. Three-dimensional Groundwater Models of the Hanford 300 Area. (in review), Pacific Northwest National Laboratory, Richland, Washington.

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