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Hydrogeologic Characterization of the Hanford 300 Area IFRC Site, Observed and Simulated Tracer Test Results, and Plans for Future Refinements

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Research Objectives: 1) Generate high-quality site characterization data and lasting experimental data sets that provide a robust foundation for development and testing of field-scale reactive transport models, 2) Develop novel approaches for data assimilation, parameter estimation, and scaling that are applicable to Hanford and other DOE sites, and 3) Advance our mechanistic understanding of the role of heterogeneity on reactive transport and mass transfer processes governing uranium (U) mobility in the subsurface.

Results: Laboratory data collection has included grain-size distributions, density, porosity, relative permeability-saturation-capillary pressure relations, and U transport experiments on intact cores. Field data includes borehole geophysical logging (i.e. spectral gamma, neutron moisture), aquifer pump and electromagnetic borehole flow-meter tests, and multiple large-scale tracer tests. Ongoing field data collection includes hourly and sub-hourly measurements of water level, temperature, and specific conductance in a network of automated monitoring wells and at a monitoring station for the Columbia R. (Fig 1). Monitoring data and field experimental datasets have been compiled and distributed to project participants for collaborative use. Selected experimental and modeling results are presented (Figs. 2-8).

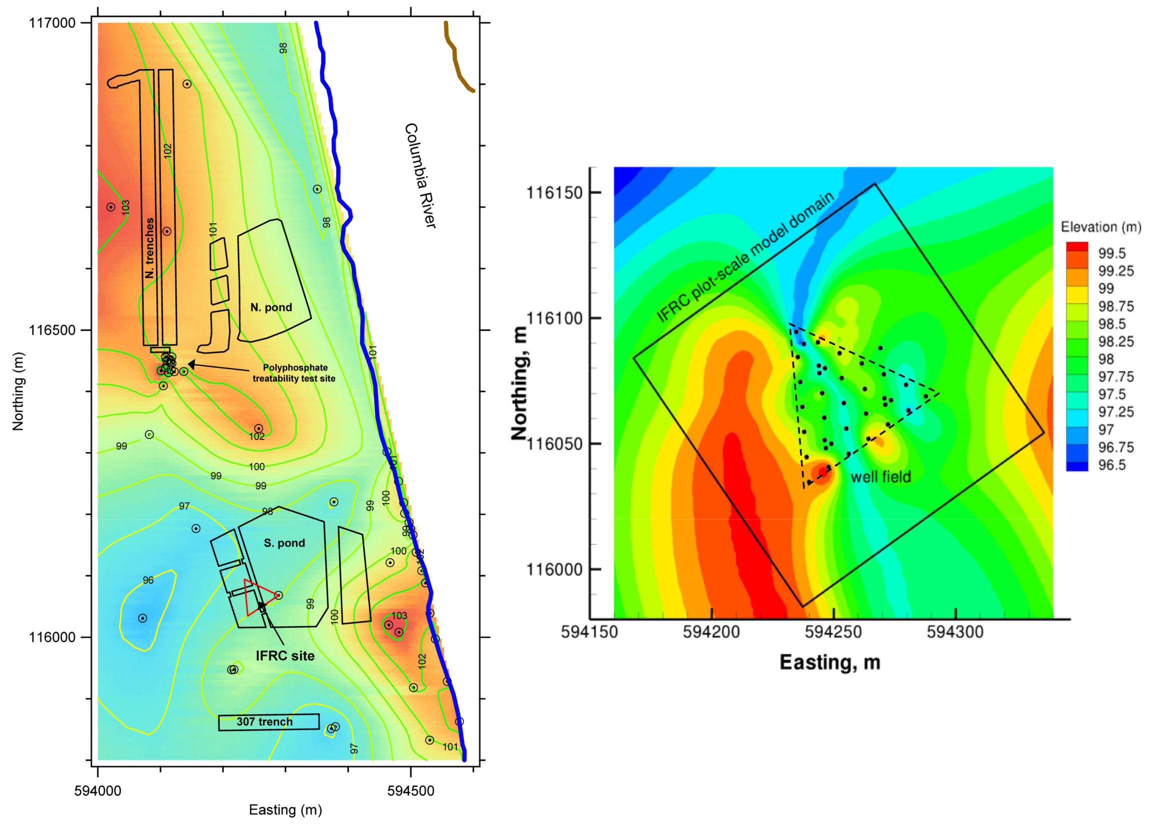

Figure 1. Far-field monitoring wells and outlines of former waste disposal sites (left side) and IFRC well field with interpreted elevation of Hanford/Ringold Fm contact (right side).

Laboratory Data

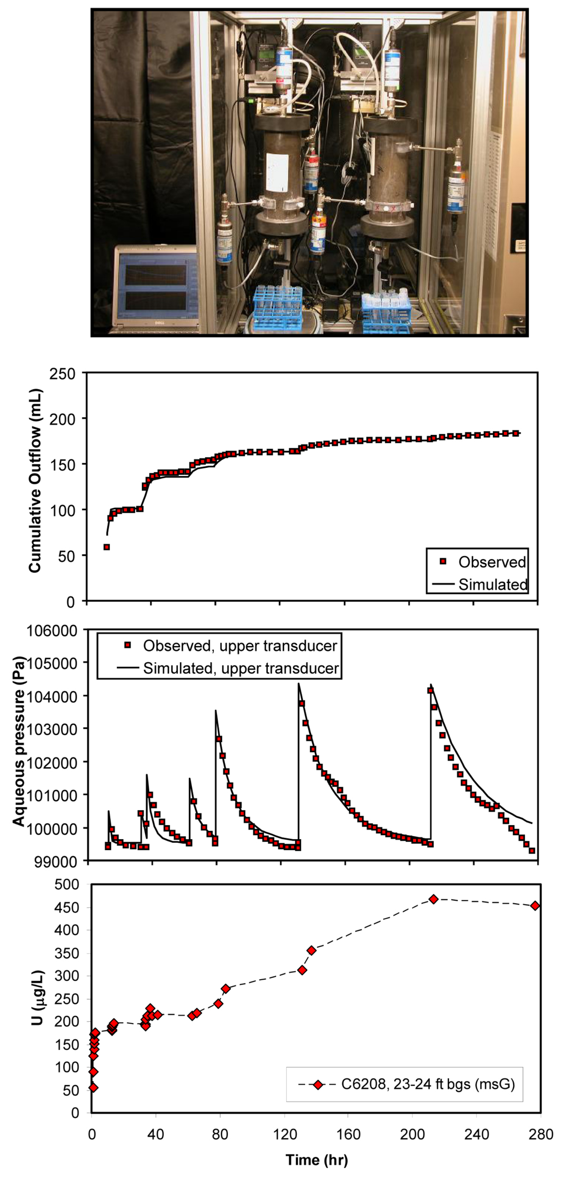

Figure 2. Example of data from multistep outflow experiment used to determine pressure-saturation-permeability relations. Borehole C6208 (well 2-19), sample depth 23-24 ft bgs

Property Correlations

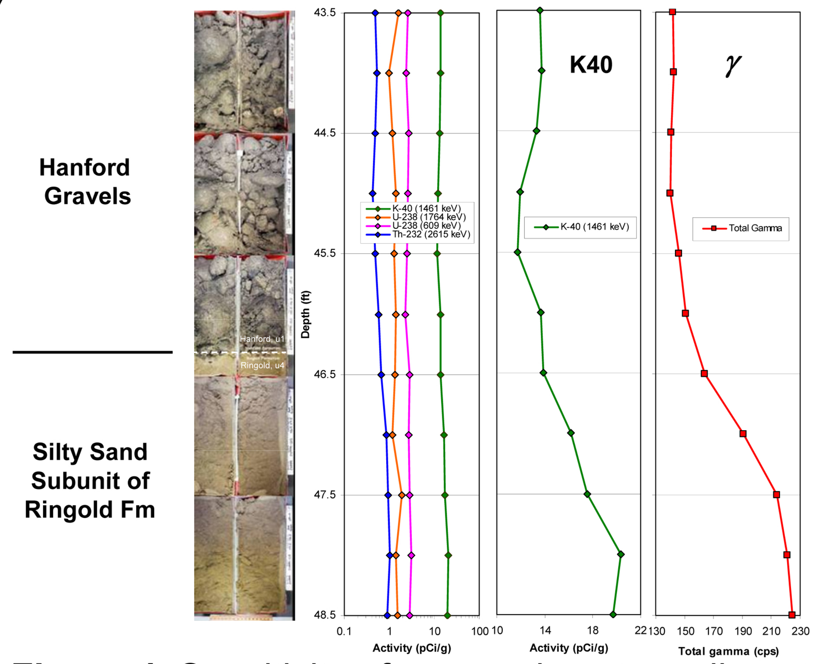

Figure 4. Sensitivity of gamma logs to sediment texture and assoc. mineralogy (Williams et al. 2008).

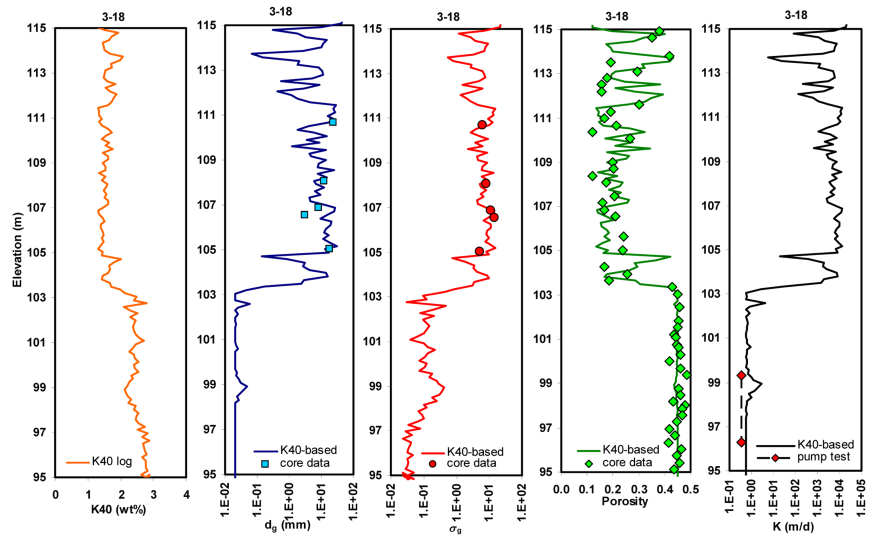

Figure 5. Petrophysical transform results. d_g, $\sigma_g = f$ (K40); porosity $= f(\sigma_g)$; $K_s = f$ (d_g, porosity)

Field Data

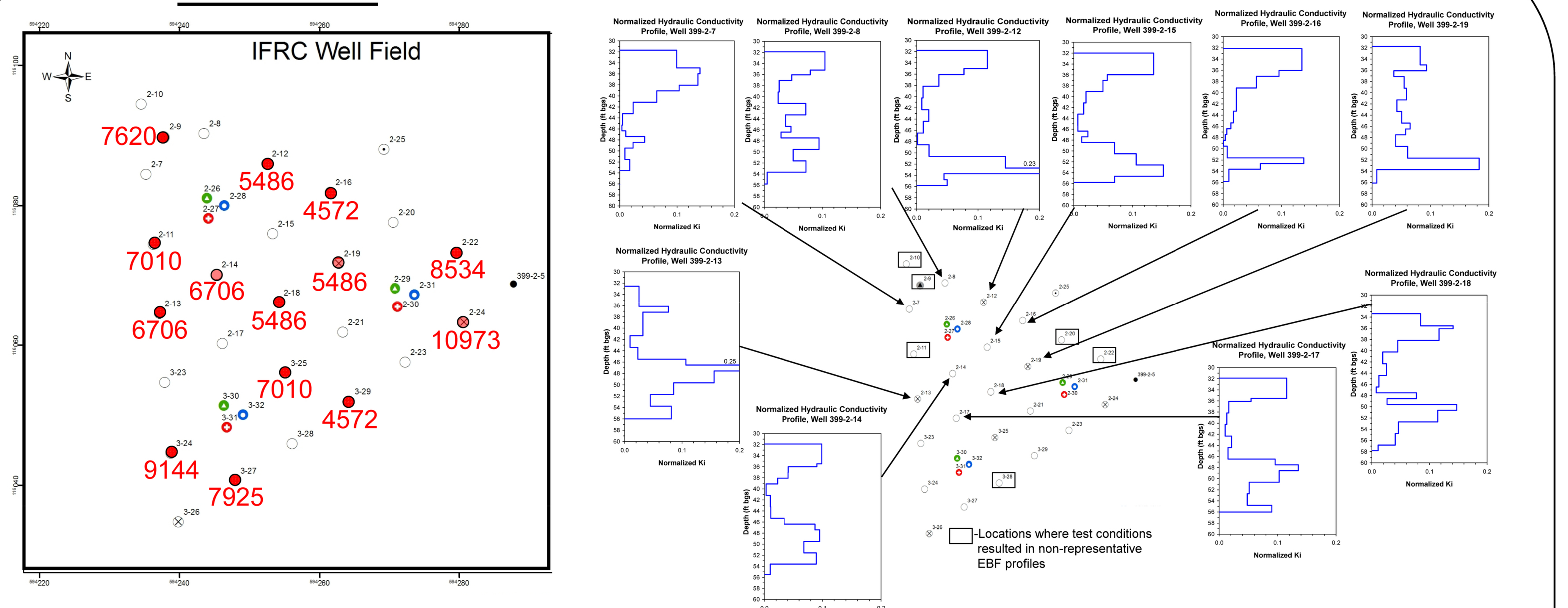

Figure 3. Bulk Hanford formation hydraulic conductivity (m/d) from constant-rate injection tests in 14 wells (left side) and normalized relative K profiles from electromagnetic borehole flow-meter (EBF) testing in 26 wells (right side).

Tracer Tests

Table 1. Summary of operational parameters for November 2008 and March 2009 tracer tests performed at Hanford 300 Area IFRC site.

	November 2008	March 2009
Injection well	2-9	2-9
Screened interval (elevation, m)	104.7 - 97.1	104.7 - 97.1
Injection volume (gal)	160,000	40,600
Injection rate (gpm)	180	71.7
Average Br conc (mg/L)	56	95
Total injected Br mass (kg)	33.87	14.58
Temperature of injectate (°C)	~16.7 (ambient)	~10 (chilled)

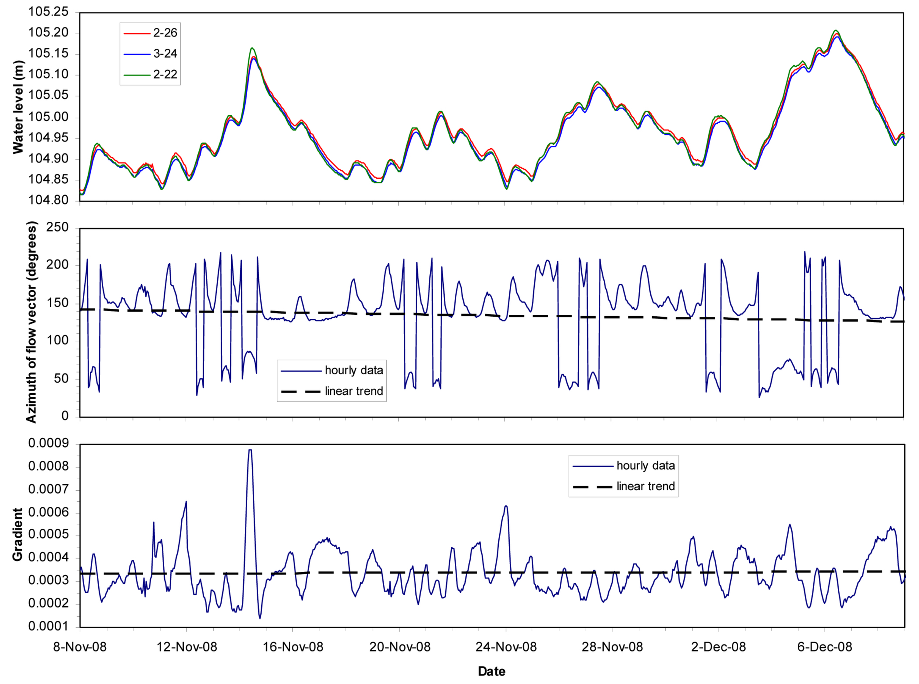

Figure 6. Measured water levels, and computed flow directions and gradients for Nov. 2008 tracer test. See Poster 10 for Mar. 2009 tracer test and modeling.

Simulation Cases (see Figs. 7, 8)

Sim1 - EBF-based K data with porosity determined from gamma log correlations

Sim2 - Same as above but with inverse parameter estimation using PEST, optimizing
- Mean and variance of ln(K) by scaling EBF K data
- Variogram model parameters for K (λ_1, λ_2, λ_3, θ)
- K_{low} - low-permeability regions at locations of intermediate depth screened wells (pilot points)

Sim3 – Properties from petrophysical correlations generated at high resolution and upscaled (Rockhold, 2010; Hammond et al. 2010) to coarser model grid blocks

Flow and Transport Modeling Results

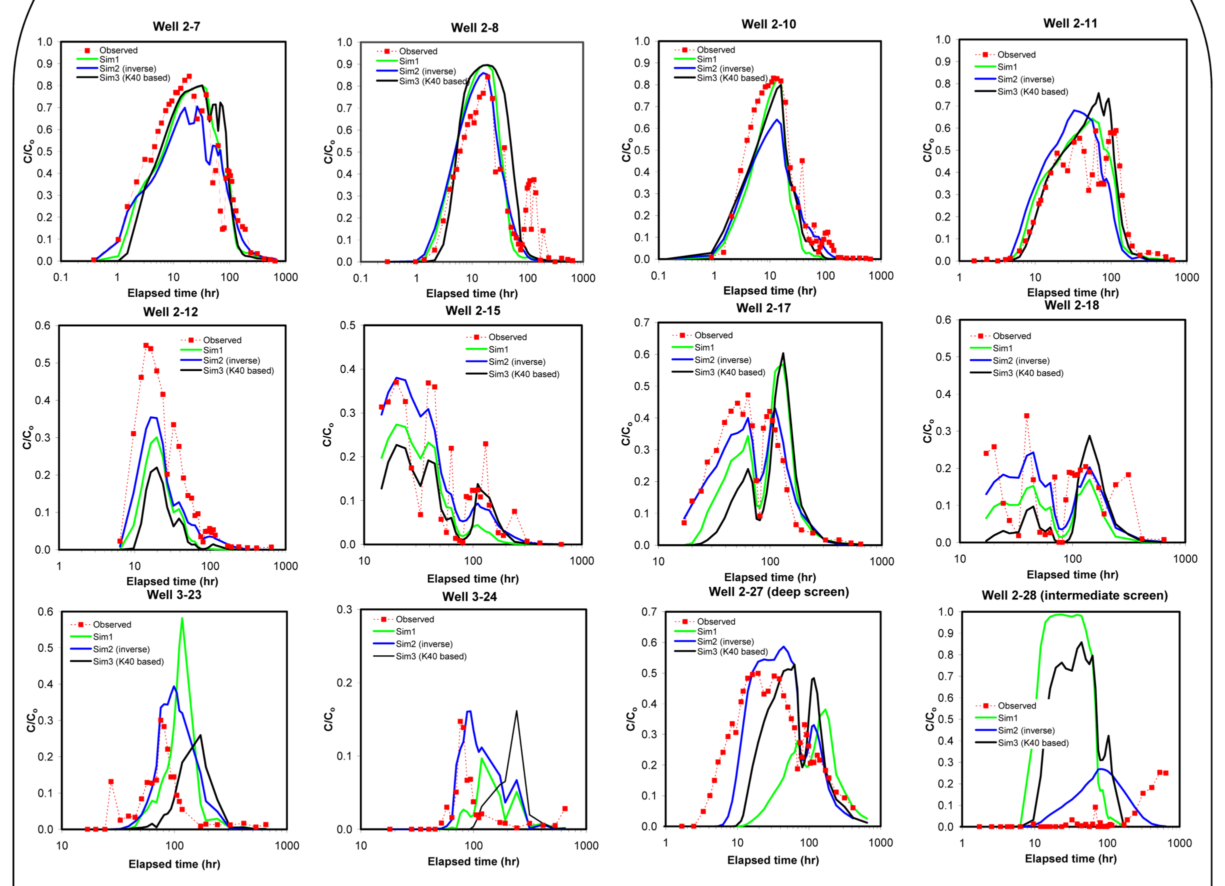

Figure 7. Observed and STOMP Simulated Results for Nov. 2008 Tracer Test (highly dynamic flow conditions; see Fig 6.)

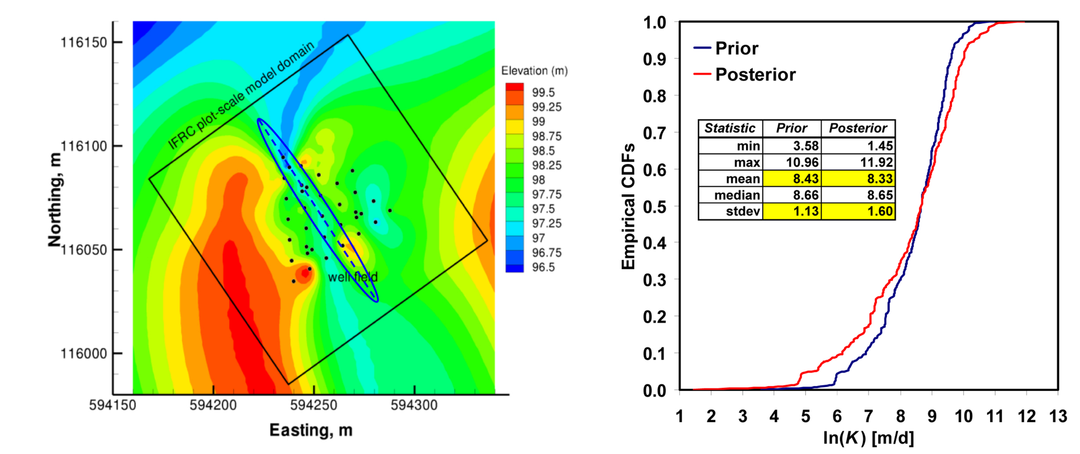

Figure 8. Horizontal anisotropy ellipse (left fig.) and prior and posterior ln(K) distributions (right fig.) estimated for simulation case Sim2.

Conclusions:

- Multi-step outflow experiments show vadose zone-U pore water concentrations up to 100X > DWS of 30 ppb
- Higher U concentrations in vadose zone associated with finer-grained sediments / smaller pore size classes
- Inverse modeling of Nov. 2008 tracer test using STOMP with PEST suggests EBF-based K data underestimate true field variability and paleochannel has dominant influence on transport behavior (Rockhold et al. 2010)
- Well-bore flow effects (not accounted for in simulations shown here) complicate interpretation of both EBF and tracer test results (see Posters 6 and 10)

Future Research: Future data collection and associated model refinements include: 1) drilling new wells to provide improved boundary condition and structural information (i.e. elevation of contact between Hanford and Ringold Fm) outside the current well field, and more depth-discrete monitoring within the well field (Poster 12), 2) updating the EarthVision model (Fig. 9) of the 300 Area, 3) adding packers to existing, fully screened wells for future experiments to reduce or eliminate intra-well flow (Poster 6), 4) incorporation of additional geophysical data into model parameterization and inversion (Poster 1), and 5) continued analyses of intact core samples to measure physical, geochemical, and hydraulic properties, including k-S-P relations, and correlations for future vadose zone experiments and modeling (planned for FY11).

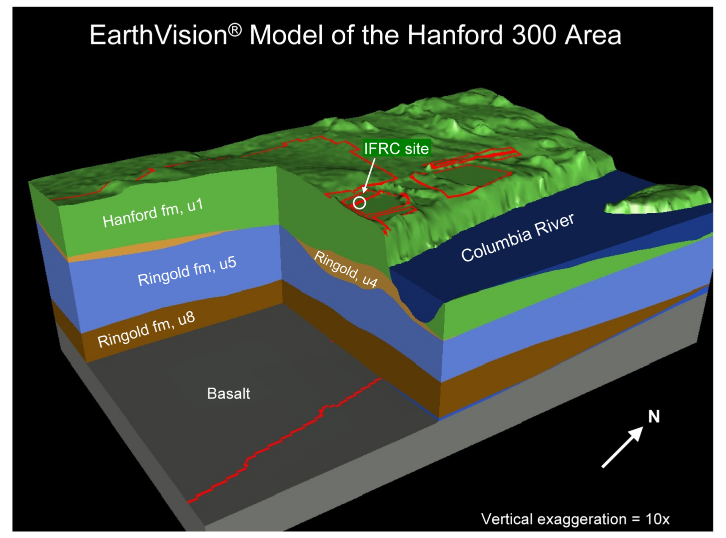

Figure 9. EarthVision model of the Hanford 300 Area showing major hydrogeologic units.

References:

Hammond GE, PC Lichtner, and ML Rockhold. 2010. Stochastic Simulation of Uranium Migration for the Hanford 300 Area. *Journal of Contaminant Hydrology (accepted)*

Rockhold ML, VR Vermeul, RD Mackley, BG Fritz, EM Newcomer, DR Newcomer, CJ Murray, and JM Zachara. 2010. Hydrogeologic Characterization of the Hanford 300 Area Integrated Field Research Challenge Site and Inverse Modeling of the First Field Tracer Test. *Ground Water (submitted)*.

Rockhold ML. 2010. UPSCALE3D – A Program for Upscaling 3D Permeability and Porosity Fields. *Computers and Geosciences (in preparation)*.

Williams MD, ML Rockhold, PD Thorne, and Y Chen. 2008. Three-Dimensional Groundwater Models of the 300 Area at the Hanford Site, Washington State. PNNL-17708, Pacific Northwest National Laboratory, Richland, Washington.

Acknowledgments:

Multistep outflow data in Figure 2 generated by Tom Wietsma and Mart Oostrom (PNNL).

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