PNNL-SA-59502

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Multi-Scale Mass Transfer Processes Controlling Natural Attenuation and Engineered Remediation: An IFC Focused on Hanford's 300 Area Uranium Plume

January 2007 to January 2008

Annual Report to the
DOE Office of Science, Environmental Remediation Sciences Division

J.M. Zachara, Principal Investigator

February 2008

Chemical & Materials Sciences Division
Fundamental & Computational Sciences Directorate
Pacific Northwest National Laboratory

Prepared for the U.S. Department of Energy
under Contract DE AC05 76RL01830

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Annual Report: January 2007 – January 2008

Principal Investigator:

John Zachara, Pacific Northwest National Laboratory, PNNL, ($180,000) is IFC Principal Investigator and lead geochemist.

Field Site Manager:

Mark Freshley, PNNL ($100,000) is field site manager and primary EM contact.

PNNL Co-Principal Investigators (FY-08 Funding):

Jim Fredrickson, PNNL ($100,000) is the IFC lead microbiologist, co-lead for Hypothesis 4, "Polyphosphate and Microbiology," and co-lead with Alan Konopka on the *Characterization* element for microbial characterization. He and Alan have developed a microbiological characterization plan for the deep Hanford-Ringold formation borehole that will be installed in collaboration with PNNL's ERSD Scientific Focus Area (SFA)

Allan Konopka, PNNL ($50,000) is responsible for microbiology research and is co-lead on the *Characterization* element for microbial characterization and will collaborate on Hypothesis 4, "Polyphosphate and Microbiology." This activity is being performed in collaboration with PNNL's ERSD-SFA research.

Chongxuan Liu, PNNL (No FY08 Activity) is responsible for investigation of mass transfer within the *Interpretation* element.

Jim McKinley, PNNL ($123,750) is co-lead for Hypothesis 4, "Polyphosphate and Microbiology," co-lead on the *Characterization* element for geochemical characterization and co-lead in the *Interpretation* element for geochemical/biogeochemical interpretation. Jim has taken the lead in designing the geochemical monitoring array for the IFC experimental site.

Mark Rockhold, PNNL ($162,000) is the lead IFC hydrologist, and is responsible for leading Hypothesis 1, "Vadose Infiltration," and is as co-lead on the *Interpretation* element for geohydrologic interpretation. He is also the PNNL-IFC coordinator for flow and transport modeling with individual focus on the STOMP code, and is working with external participants to develop an integrated modeling strategy for the IFC.

Bruce Bjornstad, PNNL ($108,750) is the IFC site geologist responsible for field site preparation, well drilling and monitoring system installation, and geologic characterization.

Vince Vermeul, PNNL ($95,000) is responsible for infrastructure, field hydrologic measurements, logistics, and field operations before and during field injection experiments at the IFC site. He is the most experienced and knowledgeable individual at Hanford in the performance of field injection experiments, and is P.I. on EM-20 supported field investigations of various potential remediation strategies at different contaminated Hanford sites. Vince functions as lead consultant in the design of all proposed IFC injection experiments.

Anderson Ward, PNNL ($400,000) is the lead for the *Characterization* element responsible for geohydrologic characterization and also is responsible on the *Interpretation* element for geohydrologic interpretation and conditional simulations. He has worked closely with Mark Rockhold (PNNL) and Roelof Versteeg (INL) to develop a geophysical monitoring strategy and approach for the IFC field site.

External Co-Principal Investigators (FY-08 Funding):

Fluor Hanford is responsible for the groundwater operable unit beneath the 300 Area. They provide well installation (and closure) services and have been provided $1,350,000 of the current project budget to install the IFC vadose zone and saturated zone monitoring array in FY 08. After initial installation of the monitoring well network, a contingency fund is provided for additional construction and well installation as necessary in FY09, FY10, and FY11.

Don DePaolo and colleagues, Lawrence Berkeley National Laboratory (LBNL) (No FY08 Activity) is responsible for uranium isotopic geochemical research in support of Hypothesis 2, "Mass Transfer Limitation. Their subcontract will begin in FY 09.

Yoram Rubin, University of California Berkeley ($125,000) is responsible for stochastic hydrology research. He is co-lead investigating the *Interpretation* element "Conditional Simulations," and is responsible for parts of the *Interpretation* element for geohydrologic interpretation and mass transfer.

Roy Haggerty, Oregon State University ($154,000) is responsible for research in mass transfer process characterization and modeling. He is co-lead on the *Interpretation* element for mass transfer interpretation," and collaborates on Hypothesis 2, "Mass Transfer Limitation," and Hypothesis 4, "Polyphosphate and Microbiology."

Douglas Kent, US Geological Survey (USGS) ($100,000) is responsible for research in saturated zone field investigations with emphasis on mass-transfer limited surface complexation processes of uranium, and their influence on uranium reactive transport through adsorption/desorption. He is co-lead in Hypothesis 2, "Mass Transfer Limitation," collaborates on Hypothesis 4, "Polyphosphate and Microbiology," and is the key external participant in the design of field injection experiments.

Peter Lichtner, Los Alamos National Laboratory (LANL) ($100,000) is responsible for geochemical modeling of uranium reactive transport processes with the FLOTRAN code. He is co-lead on the *Interpretation* element responsible for the integrated process model and collaborates on the *Interpretation* element for conditional simulations, geochemical/biogeochemical interpretation, and mass transfer.

Roelof Versteeg, Idaho National Laboratory (INL) ($275,000) is responsible for geophysical research/monitoring in collaboration with Andy Ward, and the IFC data management program. He leads the *Data Management* element, and collaborates on the *Characterization* element activities for site preparation and well installation, as well as the *Interpretation* element for geohydrologic characterization.

Chunmiao Zheng, University of Alabama ($100,000) is responsible for mass transfer, reactive transport, and hydrologic modeling using the MT3DMS, PHT3D, MODFLOW suite of codes. He is co-lead on the *Interpretation* element for the integrated process model and collaborates with Chongxuan Liu (PNNL) on the *Interpretation* element for geohydrologic interpretation, conditional simulations, and mass transfer.

Note: Total FY07 funding carried over was $1.29M. Funding for FY 2008 is anticipated at $3.5M. FY 2008 funds not provided to Co-Principal Investigators and/or their associated staff was used for site operations ($197,000), field equipment and well installation ($358,000), site characterization ($290,000), project management ($295,000), and two tracer experiments ($200,000).

Key Collaborations:

Harvey Bolton, John Zachara, Jim Fredrickson (PNNL) with other PNNL, national laboratory, and university collaborators. PNNL SFA to perform fundamental subsurface science research on the hydrology, microbiology, and geochemistry of microenvironments and transition zones at the 300 A and other Hanford locations with ERSD/ERSP funding. Research will develop conceptual models of the microbial ecology of the near river aquifer (Hanford and Ringold formations) in the 300 A, and upscalable numeric models (through Scheibe and Rockhold) of different micro- and macro-scale relevant processes influencing uranium fate and transport for ultimate application to new generation reactive transport modeling at the IFC site.

John Fruchter, Dawn Wellman, and Vince Vermeul, PNNL, collaborate through the EM-20 Polyphosphate Demonstration Project, which has performed one non-reactive tracer experiment and one polyphosphate injection experiment in the saturated zone. Future plans call for vadose zone infiltration experiments to immobilize uranium above the water table. Collaborations and knowledge sharing with this group are key for investigation of Hypothesis 4, "Polyphosphate and Microbiology". Their project and the EM-20 research generally provides an important science application point for fundamental IFC research findings.

Ron Smith and others (PNNL) and Jane Borghese (Fluor Hanford). Collaborate through the DOE-Richland Operations funded 300-FF-5 CERCLA Remedial Investigation/Feasibility Study investigation of the 300 Area with ultimate objective to establish a cost effective remediation strategy for the 300 A uranium plume. To date, samples containing uranium and uncontaminated vadose zone and aquifer sediments, and derived characterization and scientific study results, have been shared between teams with great mutual benefit.

John Zachara, Andy Ward, and Mark Freshley (PNNL) and Scott Petersen (Fluor Hanford). Collaborate through the DOE-Richland Operations funded Remediation Science and Technology Project to perform laboratory investigations of micro- and macroscale uranium geochemistry in 300 Area sediments, and large-scale geophysical characterization in support of remediation technology investigation.

John Christensen and Mark Conrad (LBNL). Collaborate on isotopic measurements of uranium in the 300 Area and other locations on the Hanford Site with ERSD/ERSP funding to assist in source term delineation, and flux quantification between environmental compartments (e.g., sediment/water; groundwater/river). Specific IFC funding will be provided in FY 09.

Haluk Beyenal (Washington State Univ.) and Jim Fredrickson (PNNL). Collaborate on microscale field research metabolic, redox, and abiotic reactions in Hanford 300 A influencing uranium speciation and transport with ERSD/ERSP funding.

Lee Slater (Rutgers Univ.), Roelof Versteeg (INL), Andy Ward (PNNL), Fred Day-Lewis and John Lane (USGS), and Andrew Binley (Lancaster University, UK). Collaborate on geophysical characterization and monitoring strategies for determining and quantifying hydrologic transport processes in the hyporheic corridor at the 300 A with ERSD/ERSP funding.

Abstract

The Integrated Field-Scale Subsurface Research Challenge (IFC) at the Hanford Site 300 Area uranium (U) plume addresses multi-scale mass transfer processes in a complex hydrogeologic setting. A series of forefront science questions on mass transfer are posed for research which relate to the effect of spatial heterogeneities; the importance of scale; coupled interactions between biogeochemical, hydrologic, and mass transfer processes; and measurements/approaches needed to characterize and model a mass-transfer dominated system. Three site specific hypotheses are being evaluated that take advantage of the unique hydrogeologic attributes of the site and focus on multi-scale mass transfer processes in the vadose zone and saturated zone, their influence on field-scale U(VI) biogeochemistry and transport, and their implications to natural attenuation and remediation.

The project was initiated in February 2007. Project efforts during the first year have focused on creating management systems and controlling documents for the project, establishing a field site capable of delivering forefront experimental data, and planning robust experimental, modeling, and interpretational activities. Considerable progress has been made in establishing the experimental site, completing design of the well and monitoring network, defining drilling and sampling specifications to meet long-term project objectives, initiating a drilling contract within budget, and creating infrastructure and field analytical facilities to enable large volume injection experiments. Drilling of the well array is scheduled to start in March 2008. All required project documentation, NEPA permits, and well registration have been completed for a site that is hydrogeologically complex and most challenging from the regulatory perspective.

Characterization and modeling activities during the first year of the project have been focused on supporting the location and design of the IFC experimental site. The project used geophysical surveys, groundwater modeling, and site hydrologic and geochemical characterization data to finalize a location for the experimental site that was beyond influence of an EM-20 supported remedial demonstration site. The project cannot error on this selection because of the large costs involved in well drilling and site development. Initial hydrologic characterization was used to provide input to design of the well array and orient the field site within the footprint of a historical waste disposal site, the South Process Pond (SPP). The SPP along with the nearby North Process Pond (NPP), contain the Hanford site's second largest inventory of disposed hexavalent uranium [~ 46,000 kg of U(VI)]. Geochemical characterization was performed on uranium-bearing sediments from a new collaborative EM-IFC monitoring well in the southeast corner of our proposed well-array using a variety of extraction methods to refine an approach that can be used for characterization of all IFC core materials. Detailed characterization and multi-year experimental plans are currently being developed by the IFC project.

Final versions of required operational and project controlling documents were completed and are posted on the Hanford IFC Website. NEPA approvals have been obtained and the permitting process is underway for registering the IFC wells and planned experimental discharges with the Washington State Department of Ecology.

Project Status: A Five-Year Perspective

Project funding was received in February 2007, rather than the October 2006 start date assumed in the original proposal schedule. The efforts during the first year have focused on assembling the project team; establishing the field site and associated monitoring and injection systems; planning the experimental, modeling, and interpretational activities; creating management systems (documents and data) and controlling documents for the project; and obtaining permits for injection wells and proposed experiments.

The first challenge for the 300 Area IFC was to establish the location of the experimental site because it was determined that the originally proposed location within the North Process Pond (NPP) had a high potential for being impacted by activities at the nearby EM-20 funded polyphosphate injection well network. The potential impacts were remnant dissolved phosphate and Ca from their in-situ precipitation strategy, as well as unnatural transients in dissolved uranium concentrations. These complications were determined by 3-dimensional hydrologic modeling of the site by EM-20 and IFC collaborators. Desiring to avoid these complications in our primary field site, the project used geophysical surveys, groundwater modeling, and site characterization data to relocate the IFC experimental site to a location within the footprint of the South Process Pond (SPP). The IFC completed initial hydrologic characterization to enable design of the well array and orient the field site within the SPP footprint, and outside of the flowpath of EM-20 influence. Geochemical characterization was performed on uranium-bearing sediments from a new monitoring well placed at the southeast corner of our proposed well-array (299-2-5) to affirm that sufficient uranium concentrations existed at the chosen location to satisfy our project objectives. The geochemical measurements were performed using a variety of extraction methods to refine an approach that can be used for characterization of all IFC core materials.

Detailed characterization and multi-year experimental plans are being developed by the IFC project now that the experimental location and well-field and monitoring array have been finalized, and initial information on uranium concentrations and site stratigraphy is available from placement of 299-2-5 (to be discussed in more detail later in the report). Final versions of required operational and project controlling documents were completed and are posted on the Hanford IFC Website. The project was granted a categorical exclusion from further NEPA review and documentation on September 24, 2007 and both cultural and ecological reviews were successfully completed for the IFC experimental site located within the SPP footprint. Required applications for formal permitting of vadose zone and saturated zone injection wells as Underground Injection Control wells have been submitted to the Washington State Department of Ecology (Ecology) as required. The discharges to these wells will be permitted under State Waste Discharge Permit ST 4511. Once the injections and tracers are fully defined as part of the detailed experimental plan, the project will work with the Ecology staff to ensure they are allowed under ST 4511. This schedule will allow our proposed performance of two tracer experiments (one vadose zone and one saturated zone) in late FY 08.

There have been no significant changes to the project science theme, scope, or overall approach since the project recost and scope revision in February 2007. At that time, the proposed experimental campaign focused on the groundwater river interface (Hypothesis 3 in the original proposal) was eliminated because of financial considerations. However, this particular biogeochemical zone and oxic/anoxic transition zones in the deeper Ringold formation afford fruitful opportunities for research, and potential collaborations between the IFC and the PNNL Subsurface Science Focus Area (SFA) focused on "subsurface microenvironments and transition zones" have been recently proposed to ERSD. Continued experimentation at the 300 A site by EM-20, EM-40, and ERSD researchers since proposal submission has affirmed the importance of the mass transfer theme, and is providing important new information that is helping in experimental design at this naturally and historically complex site. One significant change to the IFC project has been a marked increase in the sophistication of the design of our field site monitoring system that will lead to more robust field data sets for both controlled injection and passive field experiments.

Hypothesis/Experiment Year	**FY 2007 Year 1**				**FY 2008 Year 2**				**FY 2009 Year 3**				**FY 2010 Year 4**				**FY2011 Year 5**			
Quarter	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Establish Field Site																				
Select site, establish field plot, define drilling specifications			blue	blue	blue	blue														
Well drilling and completion							yellow													
Field Site Experiments																				
Hypothesis 1 Planning						yellow	yellow	yellow												
Hypothesis 1 Experiments								red	red	red	red	red	red	red						
Hypothesis 2 Planning						yellow	yellow	red	red	red										
Hypothesis 2 Experiments										red	red	red	red	red	red	red	red	red		
Hypothesis 4 Planning								red	red	red										
Hypothesis 4 Experiments										red	red	red	red	red	red	red	red	red		
Data Management				blue	blue	blue	yellow	yellow	red	red	red	red	red	red	red	red	red	red	red	red
Modeling and Interpretation																				
Geohydrologic model			blue	blue	blue	blue		red	red	red	red	red								
Geochemical/biogeochemical model						yellow	red	red	red			red	red	red		red	red	red		
Multiscale mass transfer							red	red	red			red	red	red		red	red	red		
Conditional Simulations								red	red	red	red	red	red	red	red	red	red	red	red	
Integrated Process Model							red	red	red	red	red	red	red	red	red	red	red	red	red	
Management Activities																				
NEPA documentation			blue	blue																
Project documents				blue	blue	blue														
Project management			yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow
Reporting			blue	blue	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow

blue = Completed; yellow = In progress; red = Not started

Figure 1. 5-Year schedule from proposal (updated).

Since the initiation of the Hanford IFC, the EM-20 Polyphosphate Demonstration Project has performed one non-reactive tracer experiment and one polyphosphate injection experiment involving over 10^6 gallons. The planning of IFC site has benefited significantly from these experiments, as we have coordinated closely with them. Their results have improved understanding of seasonal groundwater flow paths and velocities in the central region of the U-plume. However, the results of their field campaign have lead to questions about the effectiveness and viability of the polyphosphate remedial strategy. The rapid progress of the EM-20 team and the extent to which they seek scientific input to refine and improve their methodology may impact the eventual scope of our Hypothesis 4 experimentation. Hypothesis 4 is focused on the role of field-scale mass transfer in controlling the long-term effectiveness of the polyphosphate concept, and its alternative if proven to be ineffective. Decisions on the manner in which we partner with EM-20 will be made over the course of FY 08 in collaboration with ERSD management.

The research schedule included in the IFC proposal has been updated (Figure 1) to illustrate tasks that are complete (blue), in progress (yellow), and remain to be started (red) in accordance with the instructions provided in the ERSD IFC Management Plan.

Major Accomplishments: Last 12 Months

Efforts during the first year of the 300 Area IFC have focused on project startup activities including: assembling the project team (e.g., research scope refinement and subcontracting); establishing the field site, monitoring array and infrastructure, and injection system; initiating site characterization; planning the experimental, modeling, and interpretational activities; and development of management systems and required documents for the project. For this annual report, we establish the following as reportable project tasks: Site Design and Installation, Web Site and Data Management, Field Site Characterization, Vadose Zone Experiments, Saturated Zone Experiments, Modeling and Interpretation, and Project Management.

Site Design and Installation

The first challenge for the 300 Area IFC was to establish the location of the actual experimental site. In the IFC proposal, the field experimental site was depicted within the footprint of the North Process Pond (NPP). However, this location was established before the final configuration of the EM-20 funded polyphosphate injection well network was established. Since the time of the 300 Area IFC proposal, the EM-22 project completed installation of their well network as well as tracer and injection experiments. The tracer and injection experiments demonstrated that the proposed location for the IFC experimental site in the NPP footprint could potentially be impacted by activities at the EM-22 well network, so the IFC project initiated activities to evaluate an alternative location.

To help establish the optimal location for the IFC experimental site, criteria were developed for its selection including uranium concentration in sediments and groundwater, depth and uniformity of the Hanford formation saturated zone, fines concentration of saturated zone sediments, and prominent directions of

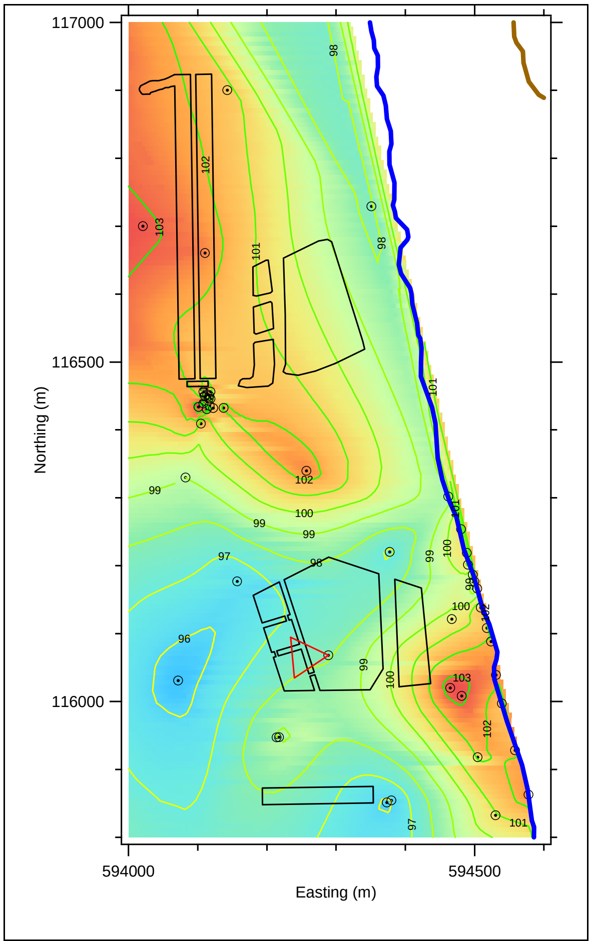

Figure 2. Map showing the interpreted elevation (m) of the Hanford/Ringold formation contact in the 300 Area based on borehole data and the location of the IFC experimental site (red triangle).

seasonal flowpaths. Geophysical surveys [electromagnetic induction (EM), ground penetrating radar (GPR), and electrical resistance tomography (ERT)] were then performed around locations of previous excavations and sampling in the SPP along with groundwater modeling of hypothetical injection experiments at periods of high and low river stage. The geophysical surveys provide information on the topography of the Hanford – Ringold formation contact, consequent locations of transmissive subsurface channels, and the approximate content of fines in the saturated Hanford formation that is targeted for field injection experiments. This work, performed in collaboration with EM-40 investigations, was done to refine the description of the hydrogeologic structure of the Hanford/ Ringold formation contact in 300 Area (Figure 2). This interpretation of the structural surface is important for selection of the IFC experimental plot where the aquifer thickness is relatively constant. Based on the geophysical and modeling investigations, a location (shown in Figure 2) within the footprint of the South Process Pond (SPP) was selected for the IFC experimental site. Significant ERSP and EM-40 supported geochemical research has been performed on sediments obtained by excavation nearby the selected IFC site.

The design of the field site (e.g., configuration, length, and well number) was based on variability of the 300 Area hydrologic system, approximate daily travel velocities inferred from the EM-20 injection experiments, project objectives, and cost. Because of the proximity of the field site to the Columbia River and significant river stage fluctuations (range of 2-3 m seasonally), flow directions and hydraulic gradients in the 300 Area can vary substantially. Data from an automated well network (described in the Characterization section) were used to compute head gradients and flow directions under "natural" conditions (albeit those imposed by operation of the hydroelectric dams on the Columbia River) to help design the IFC well network, shown in Figure 3. The configuration of the IFC well network was designed to capture some of the potential variability in flow directions, under budgetary constraints dictating the maximum number of new wells (35) that can be installed in FY 2008. The well configuration was also designed to allow for near-optimal (again with constraints on the maximum number of wells) cross-well electrical resistivity tomography and ground-penetrating radar (XW-ERT and XW-GPR) measurements, with ~10-m spacing between wells that will be instrumented with ERT electrodes.

The experimental site has been designed in terms of 28 - 4" completed wells with specified configuration and spacing (overall distance of ~200 ft), well construction and development, and in-situ sampling and monitoring equipment. As required, the well-field and monitoring system design was reviewed by the Washington State Department of Ecology prior to submission for injection well permitting. A subcontract was negotiated with Flour Hanford for well drilling, borehole sampling, geophysical logging, and well completion, as is required at the Hanford Site. This subcontract was based on drilling specifications which are published on the IFC website at http://ifchanford.pnl.gov/pdfs/17199_well_specs.pdf.

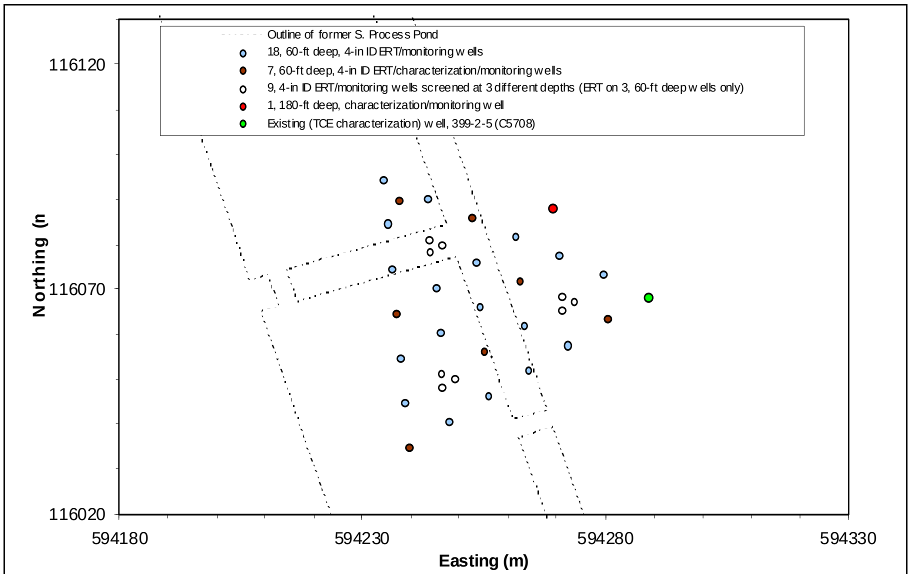

Figure 3. Planned layout of Hanford 300 Area IFC well array.

The FREC has commented on the drilling specifications regarding well completion and the extent of multi-level monitoring. Our current design (Figure 3) includes only three multi-level well clusters, and the FREC has suggested that this be increased through several different potential routes. We have carefully considered their suggestions, but have concluded that the above design is optimal for the site given cost constraints; rapid groundwater flow velocities and potentially large volumes of water that will have to be sampled from numerous wells over short periods of time during experimentation; and desire to monitor multiple, seasonally variant flowpaths.

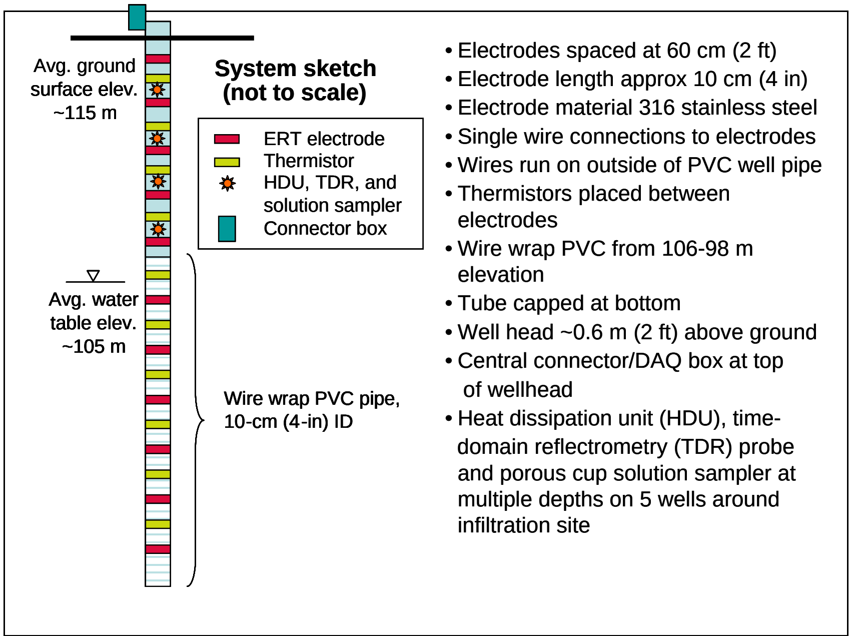

Figure 4. Schematic of ERT/monitoring wells.

Each well in the IFC well array will include electrodes for the collection of electrical resistivity/IP data, temperature sensors, multiple vadose zone or groundwater samplers (Figure 4), and in-well multi-sensor assemblies for continuous monitoring of temperature, electrical conductivity, and water level. This monitoring system significantly exceeds in complexity and robustness our original proposal plans, but has been adopted to provide the most comprehensive suite of field experimental data for the 300 A hydrologic system that our budget can afford. It will support tracer experiments with conservative solutes, reactive solutes, and injected waters of different temperature. Monitoring equipment (ERT and temperature sensors) that needs to be placed on the well casings at the time of installation has been ordered and received by the IFC project, and well drilling is scheduled to be initiated in early March, 2008. The installation of this well array is a complicated activity that has required significant planning, and its completion will be a major project milestone.

Website and Data Management

The Hanford IFC website (http://ifchanford.pnl.gov/) is operational and contains comprehensive background information about the 300 A uranium plume; information on project participants; background and project scientific publications; IFC documents including required project documents, field site design and drilling specifications; and inventories of samples available to project participants and ERSD investigators. Characterization and experiment plans, and schedules, objectives, and descriptions of planned field experiments are forthcoming. Significant additions in the form of photographs, well logs, geologic descriptions, much expanded sample inventories, and results from soil physical and chemical characterizations will be made to the website as well-drilling and installation of the experimental site begins in March 2008. A password protected link for project participants and ERSD management to the IFC data base at INL (described below) will soon be activated.

The data management task was initiated at INL in FY 07 and has accelerated with establishment of the website. The data base was initiated by establishing “data models” for a series of prototype data sets of geologic, hydrophysical, geochemical, and other measurement types on 300 Area materials (collected by ERSD and EM-40 investigators) that represent: i.) data needs by current project investigators, and ii.) data structures likely to be developed by future IFC project research. These data sets were significantly expanded to include additional hydrologic, geologic, and soil physical data; site and well location maps; and results of geophysical measurements performed in the South Process Pond where our site is to be located. The data base has been effectively set up to accept, manipulate, and display site geophysical measurements of different type; remotely collected hourly hydrologic data from the field; and historic hydrologic, hydrogeologic, and monitoring data for the 300 A that is being used for geostatistical and hydrologic modeling by project participants (Rubin and Zhang primarily).

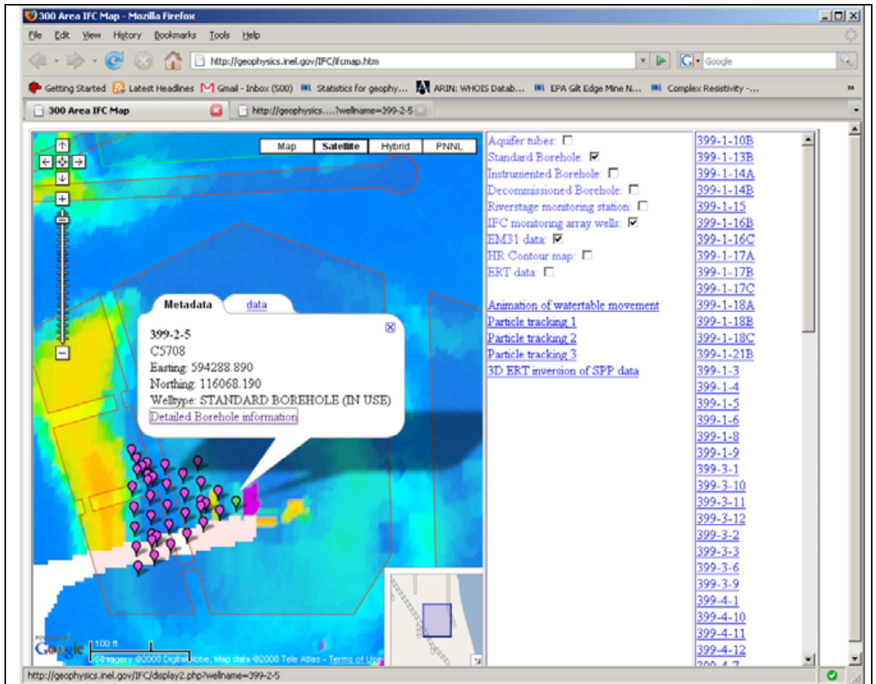

Figure 5. Google Maps based interface to the INL developed databases.

The recent focus of data management has been on the creation of data models for priority datasets that are in need or being developed by project participants, including: 1.) borehole data from the 28 IFC wells (e.g. geologic and geophysical logs; sample identifications and other observations, well completion details, post completion hydrologic characterization, etc.), 2) characterization measurements on any of the >400 planned samples to be collected during well installation (physical, hydrologic, geochemical, microbiological), 3.) hydrological monitoring data from an array of 14 monitoring wells in the 300 area, and 4.) groundwater compositional data (pH, electrical conductivity, uranium, bicarbonate, calcium, and other relevant solutes) from a database maintained by the Hanford Site (HEIS - Hanford Environmental Information System,). These data models follow industry and academic standards where possible (e.g. for hydrological monitoring data the CUAHSI developed data model is utilized). A prototype visual interface which uses the Google Maps 2.0 API (Figure 5) allows for easy access to, and presentation of the data in different site-referenced formats.

Field Site Characterization

A Characterization Plan is currently in internal review that describes field and laboratory characterization activities that will be performed on the field site and materials collected during well installation. The plan describes: i.) in-situ geohydrologic measurements and derived properties by down-hole geophysical logging during well installation, ii.) measurement of field hydrologic properties in newly completed IFC monitoring wells, ii.) laboratory measurements of geologic, hydrophysical, and geochemical properties of intact core samples and bulk sediments collected during well installation, ii.)

laboratory chemical extractions of uranium and subsequent analyses to define its depth distribution through the vadose zone and saturated zone, and iii.) microbiologic characterization measurements to be performed in collaboration with PNNL's Scientific Focus Area (SFA). Microbiologic characterization will be performed on aseptically collected sediments from a single deep borehole (on the northeast side of the triangular monitoring array, red, see Figure 3) that will be double the depth of the others and that will sample the Hanford formation and oxic and anoxic zones in the Ringold formation to the top of basalt. The total number of samples and their location and method of collection are summarized in Table A-1 of the drilling specifications (http://ifchanford.pnl.gov/pdfs/17199_well_specs.pdf) and in PNNL's SFA plan submitted to ERSD in January, 2008 (Role of Microenvironments and Transition Zones in subsurface Reactive Contaminant Transport,).

Initial hydrologic characterization that enabled final IFC site selection and preliminary injection experiment modeling for both the EM-20 polyphosphate treatability study and the IFC consisted of placing automated monitoring equipment in four existing wells (399-3-18, 399-3-19, 399-3-20, and 399-2-5) to collect hourly (or sub-hourly) measurements of water levels, temperature, and electrical conductivity in wells surrounding the South Process Pond. This new instrumentation augment an electronic monitoring system in the 300 Area (Figure 6) funded through an existing EM-40 project. This IFC supported expansion to the monitoring network will provide comprehensive upgradient and downgradient hydrologic measurements for the IFC experimental site.

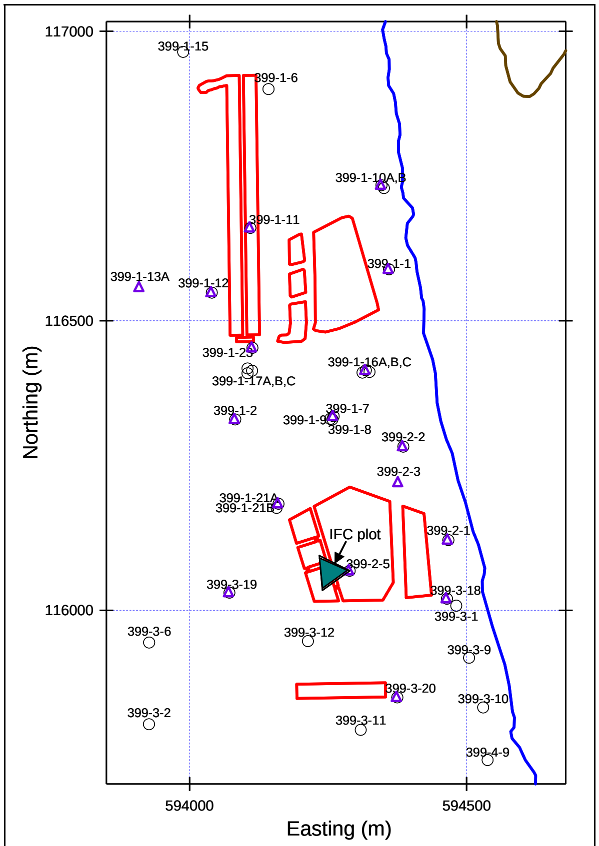

Figure 6. Map showing automated well network (purple triangle symbols), CERCLA monitoring wells (open circle symbols), outlines of the four primary liquid waste disposal areas (red polygons) and IFC plot in the Hanford 300 Area. Wells 399-3-18, 399-3-19, 399-3-20, and 399-2-5 were instrumented and are being maintained by the IFC project.

The IFC collaborated with EM-40 in the placement of a new monitoring well in the southeast corner of our proposed well-field (Figure 3, green, well 399-2-5). This well has provided necessary insights on the stratigraphy, facies distribution, saturated zone thickness, and distribution of uranium in the vadose and saturated zone at our site (Figure 7). The saturated zone occurs at 33' in the Hanford formation and the contact with the finer-grained Ringold formation at 56'. The uranium plume exits primarily within the Hanford formation which contains mixture of coarse (~55%) and finer grained (~45%) facies over the targeted depth interval of our saturated zone injection experiments (33-56'). Different uranium extractions were tested on sediments from this borehole to perfect an affordable total contaminant U quantification procedure for application to all core samples. This testing provided comparative data that allowed us to select a 24 h weak-acid sediment extraction as the primary characterization measurement for total, sorbed contaminant uranium in IFC site sediments. This extraction does not access background uranium that is significant, but present as U(IV) in primary titano-silicates. The extraction results (Figure 8), in combination with past laboratory research on sediments from this site with similar concentrations, indicate that contaminant U concentrations in the vadose zone and aquifer are well within the range needed for successful adsorption/ desorption mass transfer field experiments at this particular location. All contaminant U in the sediments sampled to date has been in the adsorbed state, with a concentration maximum observed near the water table.

Geophysical field measurements continued on the acquisition of resistivity data to map sedimentary facies in the South Process Pond area where the IFC experimental site is located. New resistivity transects have been measured through and adjacent to the location of the IFC experimental site, providing the first vertical control on sediment facies variation and heterogeneity at this important location. A resistivity transect was set up parallel to the river to collect time-lapse data, and to provide insight into the dynamics of river-aquifer interaction near the IFC injection site. Such information is critical to allow quantitative linkage between river stage changes and groundwater flow directions. IFC scientists are now working with the Hanford Patrol, Fire Marshall, and the DOE site steward to gain approval to bring seismic sources (explosive) on site as necessary for the performance of a high resolution seismic survey of the IFC well array and surrounding area in the spring.

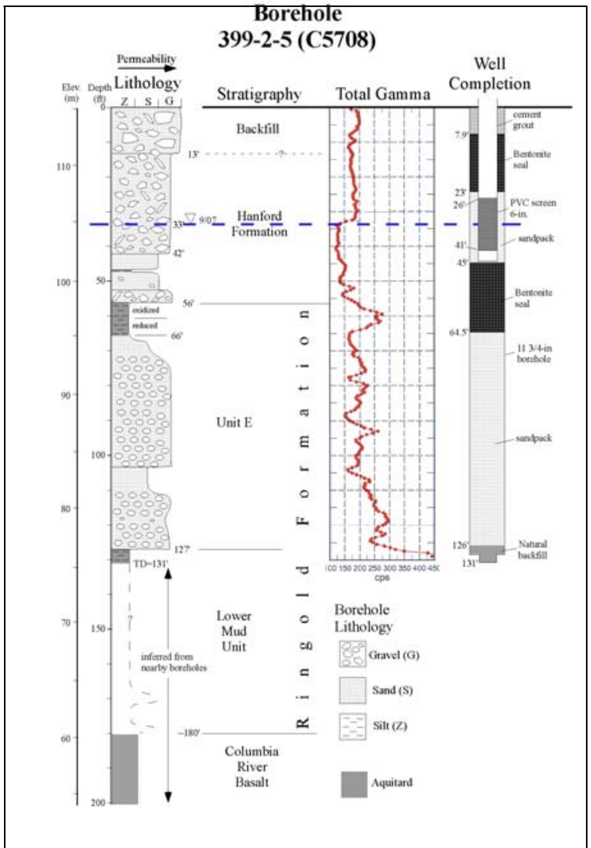

Figure 7. Geology log for new SPP borehole.

Significant progress has also been made in the design of a time-lapse geophysical monitoring strategy for the field injection experiments that will utilize our dedicated down-hole geophysical monitoring electrodes (Figure 4) in combination with surface geophysical measurements. The planned injection experiments will use a combination of real-time geophysical measurements, down-hole ion-selective electrode measurements, in-trailer flow-cell measurements, and direct chemical analyses to monitor tracer movement (solutes and waters of different temperature). In order to finalize our geophysical monitoring strategy, a comparison of three different ERT acquisition systems is planned for April-May, 2008 in collaboration with Rutgers University, the USGS and INL.

Formation	Notes	Depth (ft)	U(μg/g)
BF		4.5-7	3.4
HF	vadose zone injection depth	15-17	1.03
		20-22	1.24
		23.5-26	3.09
	smear zone	28-31.5	5.17
	water table	32-33	3.29
	upper screen	33.8-36.8	0.99
	middle screen	40.8-42.8	0.93
		45-47	0.64
	lower screen	49.5-51.5	0.56
RF	C.W. upper screen	55-56	1.43
	C.W. lower screen	73-75	0.58
		74-76	0.57

Figure 8. Weak-acid extractable U(VI) form C5708.

A characterization framework is being developed for the IFC site hydrogeology using a spatial stochastic model that is being calibrated by assimilating various types of historical data, and new information from the IFC well-field as it becomes available. The framework is general in that it may incorporate a broad range of relevant data resources including direct measurements, well tests, tracer tests, geophysical logs and surveys, and so on. The calibration procedure is Bayesian so that prior information is accounted for, data that become available sequentially are routinely accommodated, and thorough analysis of prediction uncertainties is possible. Overall the framework can be characterized as general, unifying, yet practical; Bayesian; and computation intensive. As technical details and computational challenges are being addressed, historical data for the 300 A site are incorporated in order to establish a preliminary parameterization consistent with existing knowledge. The model formulation as well as parameter evaluation will be updated as new observations are made during IFC well placement in March-April 2008, and multiple field and laboratory characterization measurements are completed during the spring and summer of 2008. Eventually, this framework attempts to support numerical predictions of physical, chemical, and biological processes at the 300 A IFC site by providing sound representations (in the form of conditional simulations) of the hydrogeological background, and by assisting with statistical evaluations of the predictions.

Vadose Zone Experiments

A sequence of proposed vadose zone experiments (Phase I) is currently under planning to establish the objective/hypothesis, injection volume, tracer identity and concentration, uranium concentration, density of analytical measurements, and schedule. These plans are contingent upon the conditions found in the vadose zone during well installation with respect to facies distributions, uranium concentrations, and other variables; and will be a primary subject of discussion at our all-hands IFC project meeting on April 29-30, 2008. Our characterization strategy emphasizes the early measurement of these key parameters to allow finalization of plans for an initial vadose zone tracer experiment in the late summer or fall, 2008.

Saturated Zone Experiments

A sequence of proposed saturated zone experiments (Phase I) is currently under planning in terms of objective/hypothesis, injection volume, tracer identity and concentration, uranium concentration, density of analytical measurements, and schedule. We have also recently decided to use water temperature as an additional subsurface tracer in select experiments to aid in the mapping of subsurface heterogeneities and flow-path contributions to well-water composition, and to provide additional data sets for geostatistical model calibration. In consequence, additional thermistors are being added to our down-hole monitoring arrays to increase spatial resolution of temperature differences in saturated zone waters. The injection experiment infrastructure is being evaluated for its ability to alter and control injection water temperature, and may be modified accordingly to allow such manipulations. Two chemical tracer experiments are planned for the summer and early fall months. The experimental design and sequence for Phase I experiments will be reviewed and debated by all project participants during our April project meeting.

The IFC project has also made agreements to use the injection experiment equipment and infrastructure of the PNNL-EM injection team. This equipment includes large tanks for injectate solutions, various pumps for tracer mixing and for injection, and a specialized field trailer. This agreement will allow leveraging of relatively expensive field equipment by multiple projects, and afford the IFC considerable cost savings.

Modeling and Interpretation

External participants (Zheng, Lichtner, Rubin) have initiated the modeling program in collaboration with PNNL team-members (Rockhold and Ward). Two activities are underway. In the first, a deterministic geohydrologic model of our experimental site and associated environs is being developed based on historical river stage – groundwater elevation data, new and continuous hydrologic measurements being made in EM-monitoring wells surrounding the IFC site (e.g., (399-3-18, 399-3-19, 399-3-20, and 399-2-5), hydrogeologic data and parameters from the nearby EM-20 site (Mark Williams), recent geophysical measurements, and subsurface stratigraphy as displayed by well 399-3-5 (Figure 7). These modeling activities will utilize the STOMP (PNNL); FLOTRAN (LANL); and MT3DMS, PHT3D, MODFLOW (University of Alabama) simulators that will be ultimately compared to one another in their ability to describe complex multi-scale mass transfer and reactive transport processes that occur at the IFC site and within the 300 A uranium plume.

The deterministic IFC site models, that will be iteratively upgraded in detail as new hydrologic, geologic, soil physical, and geochemical characterization results become available, is being imbedded in a larger 300 A plume model to allow calculations of seasonal head gradients, groundwater levels, and flow directions within the IFC site as influenced by river stage. Groundwater modeling has evaluated potential trajectories and advective velocities of injected tracers at different candidate IFC sites, and the nearby polyphosphate field demonstration site during periods of high and low Columbia River stage. These calculations have sought to identify IFC site locations that are not influenced by the polyphosphate experiments, and that provide suitably long travel paths for evaluation of different vadose zone and saturated zone mass transfer hypotheses.

The second modeling activity is developing geostatistical correlations between known 300 A sediment properties and hydrologic parameters as a first step in the establishment of a 3-D geostatistical model for the IFC experimental site. This activity has been described above in "**Field Site Characterization.**" A Modeling Plan will be developed in late FY 08 that describes the goals, strategies, and anticipated outcomes of the deterministic and stochastic modeling activities; the IFC project rational for supporting the application of multiple reactive transport simulators; and the anticipated uses of the various models in experiment pre-modeling and final experiment interpretation.

Project Management

The project management activity is responsible for: 1.) communications with ERSD as necessary for optimal project performance and positive, sustained contributions to ERSD short- and long-term measures, 2.) communications with other ERSD investigators and interested parties through maintenance of the IFC web-site, 3.) progress reporting consistent with ERSD guidelines, 4.) financial tracking and sound budgeting to accomplish project objectives, 5.) subcontract oversight to assure external participant contributions of desired scope and quality, 6.) metering research productivity; and assuring scientific quality; the attainment of project goals, milestones, and research products; and timely and quality publication, 7.) generating management and operations documents; and characterization, experimental, and modeling plans that help govern IFC project activities, and 8.) initiating and completing permitting activities in timely fashion. Selected accomplishments in project management are described below.

All subcontracts have been established and detailed research scope agreements negotiated with each external participant. The subcontract has been established for experimental site development with Flour-Hanford within budget, and a sophisticated well array and state-of-the-art monitoring system designed that will enable rigorous and robust field experiments that will serve both project participants and the scientific community with data sets of lasting quality.

Final versions of the Field Site Management, Health and Safety, Quality Assurance/Quality Control, and Communication Plans have been completed and are posted on the Hanford IFC Website. The project was granted a categorical exclusion from further NEPA review and documentation on September 24, 2007; and both cultural and ecological reviews were successfully completed for the IFC experimental site located within the SPP footprint. Required applications for formal permitting of our vadose zone and saturated zone injection wells as Underground Injection Control wells have been submitted to the Washington State Department of Ecology (Ecology) as required. The discharges to these wells will be permitted under State Waste Discharge Permit ST 4511. Once the injection experiments and tracer concentrations are fully defined in the Experimental Plan that is currently under development, the project will work with Ecology staff to ensure they are allowed under ST 4511.

Detailed budgeting has been completed for well installation and monitoring system testing, laboratory characterization, site-setup and development of the field injection system, and for the first two FY08 tracer experiments and associated solute analyses. The field injection system will be used to pump large volumes of waters of different composition from different contaminated regions of the plume through a field trailer for selected analyses and for tracer spiking, and then meter their re-injection into the IFC well field and monitoring array. The initial volume estimate for each saturated zone injection experiment is approximately 60,000 gallons (252,000 L). This estimate is based on an assumed saturated zone thickness at our injection point and measured groundwater velocities at the nearby EM-20 polyphosphate injection site. During the injection experiment, waters will be pumped from wells along the plume trajectory (monitored by surface geophysical measurements) by dedicated, downhole, high-volume pumps. Well waters will be circulated through the field trailer by a sophisticated manifold system, and subjected to real-time ion selective electrode analyses for select analytes or tracers, and then sampled for additional laboratory analyses.

An Experimental Plan is currently being developed to address: 1.) unresolved infrastructure and equipment requirements, 2.) the identity and concentrations of both conservative and reactive tracers needed to interrogate the various targeted field scale processes (multi-scale mass transfer, adsorption/desorption, and biogeochemical reactions of U and associated microbiologic activities) as a permitting requirement, and 3.) the identity and phasing of approximately ten field-scale experiments that meet project goals, resolve impactful scientific objectives and hypotheses, and maximize potential external ERSD investigator involvement.

Research Plans: Next 12 Months

Research plans and field activities for the 300 Area IFC will accelerate with installation of the well array and establishment of the experimental site. A full meeting of the project participants is planned for April and will coincide with completion of the characterization plan and multi-year experimental plans. The following are research activities that will be conducted over the next 12 months:

- Complete characterization plan for experimental field site and post on IFC website (May 2008).
- Develop multi-year experiment plan with objectives, details, costing, and schedule. Post on IFC website (May 2008).

- Well drilling, field-site characterization, and well/monitoring system completion and testing (March-May 2008). Testing of different ERT acquisition strategies (April –May 2008) for field site monitoring.
- Begin geochemical, hydrophysical, and microbiologic characterization of sediments retrieved from boreholes. Distribute samples to team members (April-June 2008). Initiate collaboration with PNNL SFA on microbiologic characterization of aseptically collected Hanford and Ringold formation sediments.
- Full IFC investigator meeting (April 29-30, 2008).
- Finalize design for first two injection experiments (April-May 2008).
- Perform well testing (pump tests, groundwater flowmeter measurements). Integrate all continuous monitoring equipment with Web-based data management system (June-August 2008).
- Conduct detailed surface and cross-hole geophysical measurements of experimental domain (June-August 2008).
- Multiple team-members premodel injection experiments with different codes and compare/digest results (June-July 2008).
- Perform high-river flow, non-reactive tracer experiment in saturated zone (July-August 2008).
- Perform low-river flow, non-reactive tracer experiment through a vadose zone, capillary fringe, saturated zone flowpath (September-October 2008).
- Complete laboratory analyses of water samples collected from saturated zone and vadose zone tracer injection experiments (September-December 2008).
- Assemble characterization measurements on borehole sediments and detailed geophysical measurements into an integrated geostatistical model of the experimental domain, and an improved hydrologic model for experiment simulation (October 2008-January 2009).
- Begin formal interpretation of first two injection experiments, and initiate planning for second tier of injection experiments based on results and experience (November 2008-February 2009).

Outreach Activities

We have been contacted by several ERSD investigators inquiring about the availability of IFC site materials. We have asked these individuals to wait until our drilling campaign begins in March, as sediment samples from different Hanford and Ringold formation facies will be obtained during that activity. As shown in Table A-1 of the drilling specifications (http://ifchanford.pnl.gov/pdfs/17199_well_specs.pdf), both bulk and core samples collected during the IFC drilling campaign that will range significantly in uranium concentrations from background to contaminated levels. There will also be significant, but as yet unknown differences in texture, mineralogy, redox status, and microbiology. A subset of these sediments will be available for distribution to external ERSD investigators within the constraints identified in our QA/QC Plan. In the interim, we have prepared an inventory of all available 300 A materials collected by past ERSD, EM-20, and EM-40 300 A studies for posting on the web. We have not yet received any requests for these historic materials from ERSD investigators, although some have been widely distributed to other scientific collaborators (based on their requests) and have served as subjects of publication.

Challenges/Opportunities/Concerns

Challenges

Several challenges have arisen with efforts to establish the field experimental site in the 300 Area. The first challenge was to establish a location for the experimental site that was beyond hydrologic and geochemical influence of the EM-20 funded polyphosphate injection well network given uncertainties in seasonally variant flowpaths. The first polyphosphate injection experiment involved over 10^6 gallons of high concentration P injectate and impacted a large area. The final location of the 300 A IFC within the footprint of the SPP will be sufficiently far away from the EM-20 project location to prevent interference and also has the advantage of leveraging a new characterization and monitoring well recently drilled by EM-40.

Another significant challenge was the effort required to negotiate a drilling contract to meet rigorous IFC science needs, and the associated high cost of that contract ($1.35M). The high cost of drilling at Hanford that results from coarse sediment texture and poor cohesion has limited the number of wells that can be included in the IFC well array, and the numbers of samples that can be analyzed in the associated characterization program. The true cost of this activity is still uncertain, and is dependent on IFC team efficiency in assembling the complicated well strings with associated down-hole monitoring equipment during the drilling program. Be assured that we will be prepared, but there are always complications. Drilling costs and our need for a monitoring network to assess multiple, and seasonally variable flowpaths has placed limitations on the number of multi-level monitoring wells. Our out year budget will allow the installation of additional multi-level clusters if deemed necessary.

The non-reactive tracer experiment and polyphosphate injection experiment performed by the EM-20 Polyphosphate Demonstration Project have demonstrated very high groundwater velocities (on the order of 50 ft/day) in the 300 A uranium plume. Calculations by the IFC project demonstrate that at high river stage (spring-early summer), executing field injection experiments focused on mass transfer may be difficult because injected plumes may move rapidly through the well array and exit the experimental site. However, these periods provide important opportunities for passive experiments to study mass transfer processes that occur: 1.) along water composition gradients that form in the saturated zone as dilute, low conductivity Columbia River water infiltrates the experimental site, and 2.) in the capillary fringe or smear zone as high river stage pushes the water table into the uranium enriched lower vadose zone (e.g., Figure 8) driving seasonal uranium mobilization. At low river stage (fall-winter), the preliminary calculations demonstrate that injected plumes can be expected to remain within the well array for 5 days to over three weeks depending on local retardation, allowing plenty of time for field-scale mass transfer kinetic studies with relatively constant groundwater composition and flow direction. The timing and design of field experiments to exploit these major seasonal differences will consequently be critical to success.

Opportunities

A major opportunity exists at the Hanford IFC to transfer fundamental research findings on field-scale mass transfer and reactive transport processes to EM for the development of effective, long-term remedies for the 300 A uranium plume and the numerous contaminated sites that currently exist in Hanford's Columbia River corridor, or that may form in the future as a result of contaminant migration from reprocessing sites and leaked high-level waste tanks in the 200A. Our linkage with the EM-20 Polyphosphate Demonstration Project, in spite of challenges, demonstrates this commitment on our part.

River corridor sites have marked similarities and great complexities in hydrologic, geochemical, and microbiological processes; and are the final discharge points for Hanford contaminants to the Columbia River, and human and ecologic receptors. If properly conceptualized and performed, Hanford IFC science and resulting field-scale models could lead to unprecedented cost savings in remediation, and much improved long term reductions in risk. With proper planning, this huge positive impact to site closure can be achieved while simultaneously making strong and lasting fundamental scientific contributions via publication and accessible field experiment data sets for understanding of coupled mass transfer, geochemical, biogeochemical, and transport processes in subsurface environments. Achieving these important multiple and synergistic impacts is a primary project goal.

Publications

Note: There have been no new presentations or publications resulting from IFC research since the last quarterly report in October, 2007 as our project focus has been on site design and installation. Funding for project travel to scientific meetings has been nonexistent because of site installation, monitoring equipment, and injection infrastructure costs. The IFC team will develop a publication plan after the well field installation is complete. Peer-reviewed publications published or submitted through February 15, 2008 result from associated ERSD research.

Arai, Y., M. A. Marcus, N. Tamura, J. A. Davis, and J. M. Zachara. 2007. Spectroscopic evidence for uranium bearing precipitates in vadoze zone sediments at the Hanford 300-Area site. *Environ. Sci. Technol., 41(13)*:4633-4639.

Bond, DL, JA Davis, and JM Zachara. 2007. *Uranium(VI) Release from Contaminated Vadose Zone Sediments: Estimation of Potential Contributions from Dissolution and Desorption* PNNL-SA-58541, Pacific Northwest National Laboratory, Richland, Washington. Adsorption of Metals to Geomedia II.{Add full and correct citation}

Gee GW, M Oostrom, MD Freshley, ML Rockhold, and JM Zachara. 2007. *Hanford Site Vadose Zone Studies: An Overview*. PNNL-SA-53273, Pacific Northwest National Laboratory, Richland, Washington. Vadose Zone Journal 6:985-1003.

Liu, C., J. M. Zachara, N. Qafoku, and Z. Wang. 2008. Scale-dependent desorption of uranium from contaminated subsurface sediments. *Water Resources Research* (Accepted).

McKinley JP, JM Zachara, J Wan, DE McCready, and SM Heald. 2007. *Geochemical Controls on Contaminant Uranium in Vadose Hanford Formation Sediments at the 200 Area and 300 Area, Hanford Site, Washington.* PNNL-SA-54463, Pacific Northwest National Laboratory, Richland, Washington. Vadose Zone Journal 6:1004-1017.

Williams BA, CF Brown, W Um, MJ Nimmons, RE Peterson, BN Bjornstad, DC Lanigan, RJ Serne, FA Spane, ML 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.

Zachara JM, C Brown, J Christensen, JA Davis, E Dresel, C Liu, S Kelly, JP McKinley, RJ Serne, W Um. 2007. *A Site-Wide Perspective on Uranium Geochemistry at the Hanford Site.* PNNL-17031, Pacific Northwest National Laboratory, Richland, Washington.

Zachara JM, RJ Serne, MD Freshley, FM Mann, FJ Anderson, MI Wood, TE Jones, and DA Myers. 2007. *Geochemical Processes Controlling Migration of High Level Wastes in Hanford's Vadose Zone.* PNNL-SA-53273, Pacific Northwest National Laboratory, Richland, Washington. Vadose Zone Journal 6:985-1003.

Peer-Reviewed Publications (papers submitted to journals for review)

None at this time.

Scientific Meeting Abstracts

None at this time.

Presentations

300 Area IFC Team. 2007. *Breakout Session on the 300 Area IFC at the ERSD Annual Program Meeting*. April 16-19, 2007, National Conference Center, Lansdowne, VA.

Zachara JM. 2007. *Multi-Scale Mass Transfer Processes Controlling Natural Attenuation and Engineered Remediation: An IFC Focused on Hanford's 300 Area Uranium Plume.* PNNL-SA-58090, Pacific Northwest National Laboratory, Richland, Washington.

IFC Project Kick-Off Meeting - March 21-22, 2007

Fruchter JS, DM Wellman, VR Vermeul. 2007. *Uranium Stabilization through Polyphosphate Injection.* PNNL-SA-54473, Pacific Northwest National Laboratory, Richland, Washington.

Johnson T, R Versteeg, Y Wu, S White, and C Fenimore. 2007. *Data Management for the 300 Area Integrated Field Challenge Site.* Idaho National Laboratory.

McKinley, JP. 2007. *Saturated Zone Injection Array.* PNNL-SA-57704, Pacific Northwest National Laboratory, Richland, Washington.

Peterson RE. 2007. *300 Area Uranium Plume: Monitoring System and Seasonal Trends.* PNNL-SA-54634, Pacific Northwest National Laboratory, Richland, Washington.

Rockhold, ML and AL Ward. 2007. *Experimental Site Design Vadoze Zone Infiltration Plot and Pre-Modeling.* PNNL-SA-54548, Pacific Northwest National Laboratory, Richland, Washington.

Williams BA. 2007. *300-FF-5 Hydrogeology.* PNNL-SA-16435, Pacific Northwest National Laboratory, Richland, Washington.

Williams, MD, ML Rockhold, PD Thorne. 2007. *Hydrologic Modeling of the 300 Area Aquifer.* PNNL-SA-54607, Pacific Northwest National Laboratory, Richland, Washington.

Williams MD, JS Fruchter, DM Wellman, VR Vermeul. 2007. *Uranium Stabilization through Polyphosphate Injection Field Studies.* PNNL-SA-54632, Pacific Northwest National Laboratory, Richland, Washington.

Yabusaki S, Y Fang, S Waichler. 2007. *Uranium Reactive Transport in the Hanford 300 Area Vadose Zone-Aquifer-River System.* PNNL-SA-54465, Pacific Northwest National Laboratory, Richland, Washington.

Zachara JM and MD Freshley. 2007. *Introduction - IFC Kick-Off Meeting.* PNNL-SA-54330, Pacific Northwest National Laboratory, Richland, Washington.

Zachara JM, C Liu, JP McKinley. 2007. *Geochemical and Mass Transfer Processes in 300 Area Sediments.* PNNL-SA-54329, Pacific Northwest National Laboratory, Richland, Washington.

Annual ERSP PI Meeting - IFC Breakout Session: April 16-19, 2007, Lansdowne, VA

Fredrickson JK. 2007. *Hanford 300 Area Subsurface as Microbial Habitat.* PNNL-SA-54843, Pacific Northwest National Laboratory, Richland, Washington.

Freshley MD. 2007. *300 Area IFC Site and Data Management.* PNNL-SA-54894, Pacific Northwest National Laboratory, Richland, Washington.

Lichtner PC. 2007. *Modelling Approaches and Issues.* PNNL-SA-58425, Pacific Northwest National Laboratory, Richland, Washington.

Liu C. 2007. *Multi-Scale Mass Transfer as the Key Science Issue at the Hanford IFC.* PNNL-SA-54885, Pacific Northwest National Laboratory, Richland, Washington.

Rockhold ML. 2007. *Infiltration and Injection Sites and Example Experiments.* PNNL-SA-55862, Pacific Northwest National Laboratory, Richland, Washington.

Zachara JM. 2007. *Multi-Scale Mass Transfer Processes Controlling Natural Attenuation and Engineered Remediation: An IFC Focused on Hanford's 300 Area Uranium Plume.* PNNL-SA-55280, Pacific Northwest National Laboratory, Richland, Washington.