Hanford 300 A IFRC

New Results from the Hanford Integrated Field Research Challenge (IFRC)

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http://ifchanford.pnl.gov

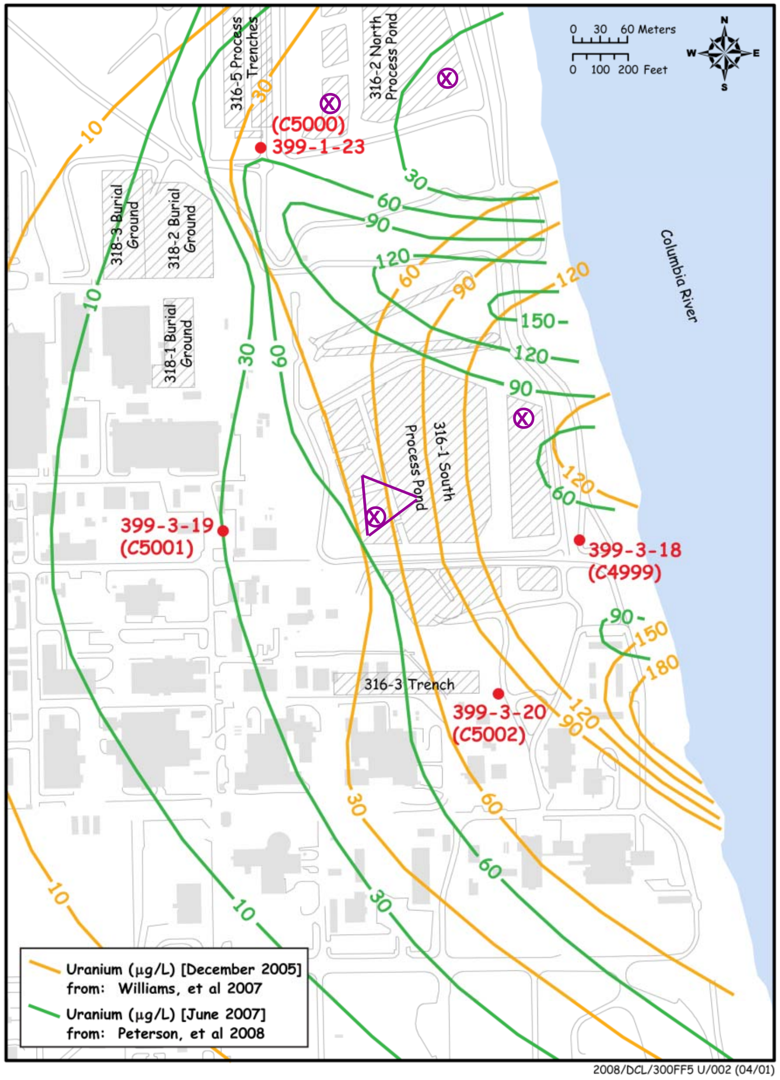
Hanford IFRC Meeting
February 24, 2009

PNNL-SA-64863

Presentation Focus and Content

- A little background
- Completed saturated zone experimental site
- Initial results of field and laboratory characterization
- Evolving experimental plans and rationale
- Challenges and opportunities

Hanford's 300 A Uranium Plume



- Large volumes of process waste from fuel fabrication resulted in extensive U groundwater contamination
- Highly contaminated waste pond sediments excavated, Cu- and U-containing vadose zone sediments remain
- MNA selected as an interim remedy for groundwater contamination in 1996
- Persistent U groundwater contamination remains above regulatory limits
- Complex seasonal concentration trends associated with river stage changes and WT rise and fall
- Investigations ongoing to understand hydrogeochemical behavior of VZ-SZ system and select appropriate remedy

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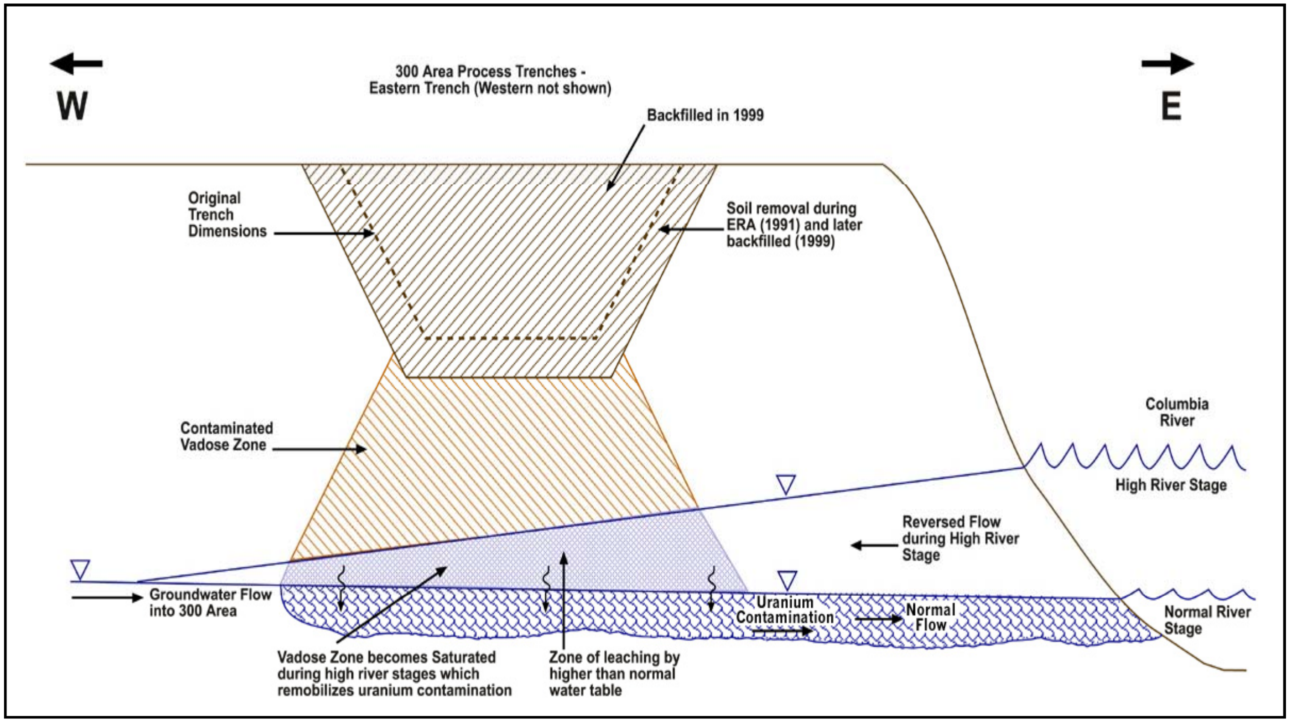
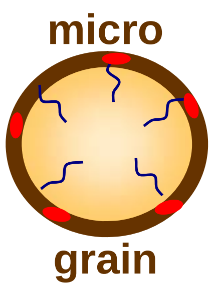
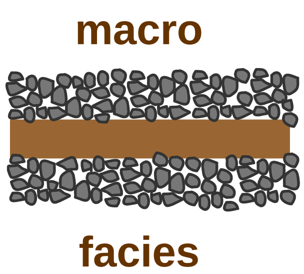
Hypothesized Vadose Zone Release Model



Hanford Integrated Field Research Challenge Science Theme

Multiscale mass transfer processes influencing sorbed contaminant migration



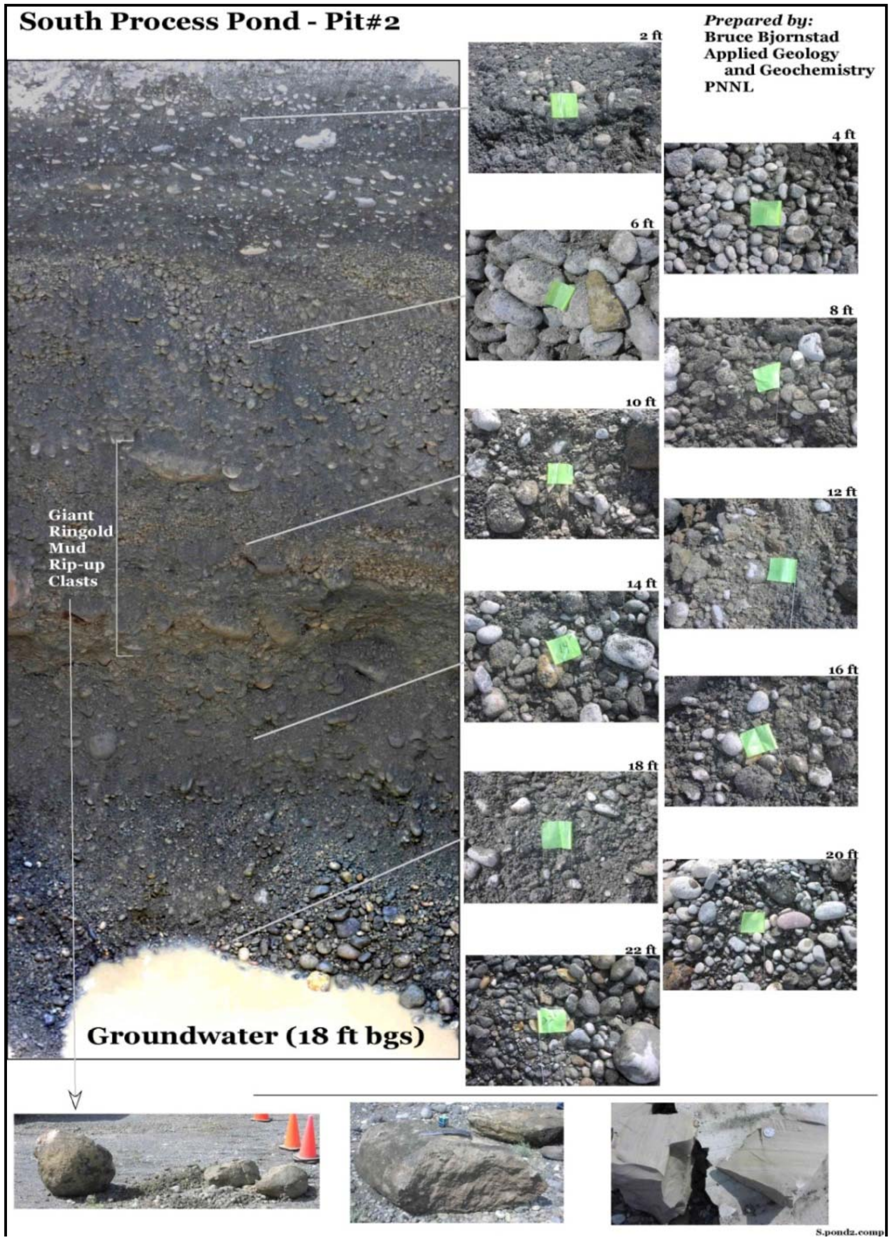


- Mass transfer is controlled by diffusion, and is influenced by the path length, tortuosity, thickness, and surface charge of immobile, water-filled pore space.
- It controls contaminant release at the particle scale from intragrain domains to porewater, and at the aquifer scale from fine-textured to coarse-textured aquifer facies.
- Kinetic behavior results, as well as long-term contaminant resupply after remedial activities.

<u>Associated Practical Issues</u>

1. Accurate projection of dissipation times for groundwater plumes
2. Optimal delivery of remediation reactants
3. Effectiveness of remediation

South Process Pond – Pit #2 – From ERSP



Significant ERSP research on 300 A sediments (~10 papers)

- molecular speciation of adsorbed and precipitated species
- adsorption/desorption and dissolution kinetics
- bulk, surface, and microscopic mineralogy
- mass transfer behavior and models
- remaining mysteries

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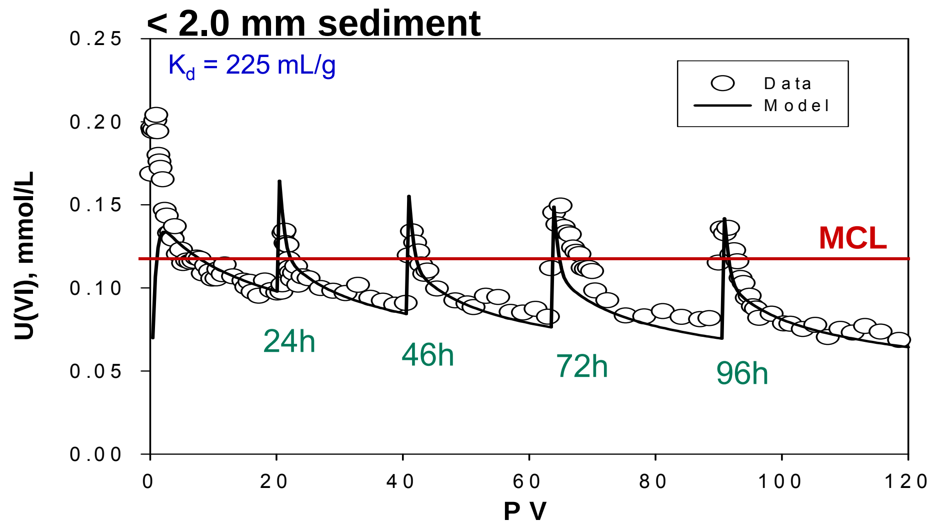
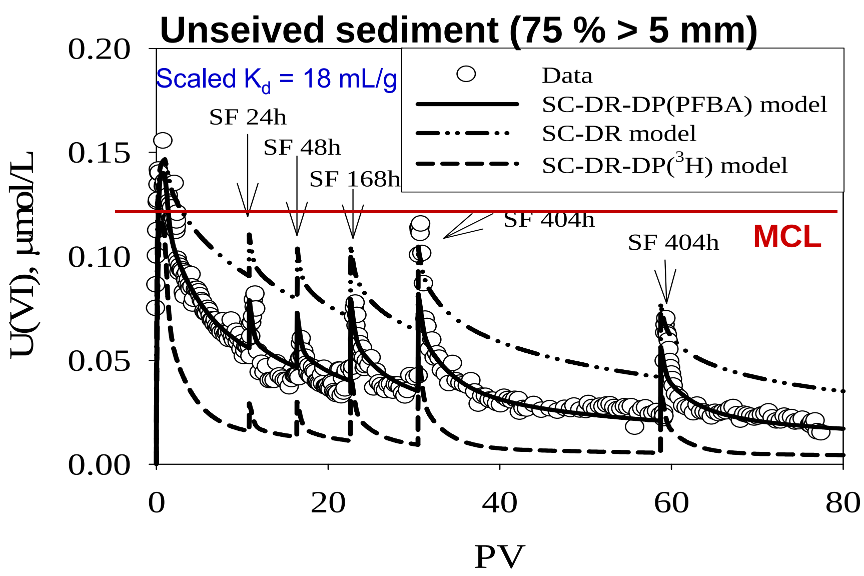
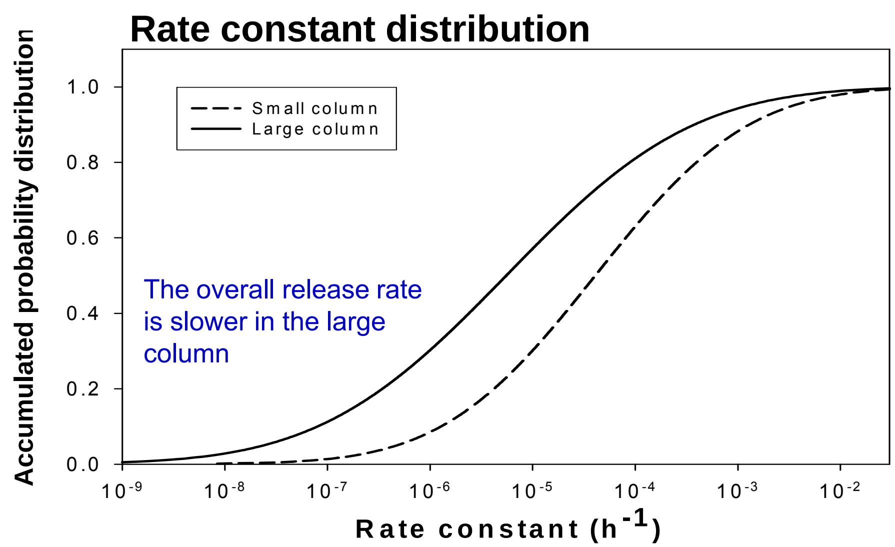
Mass Transfer: Importance, Modeling, and Scaling







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Liu et al. (2008)

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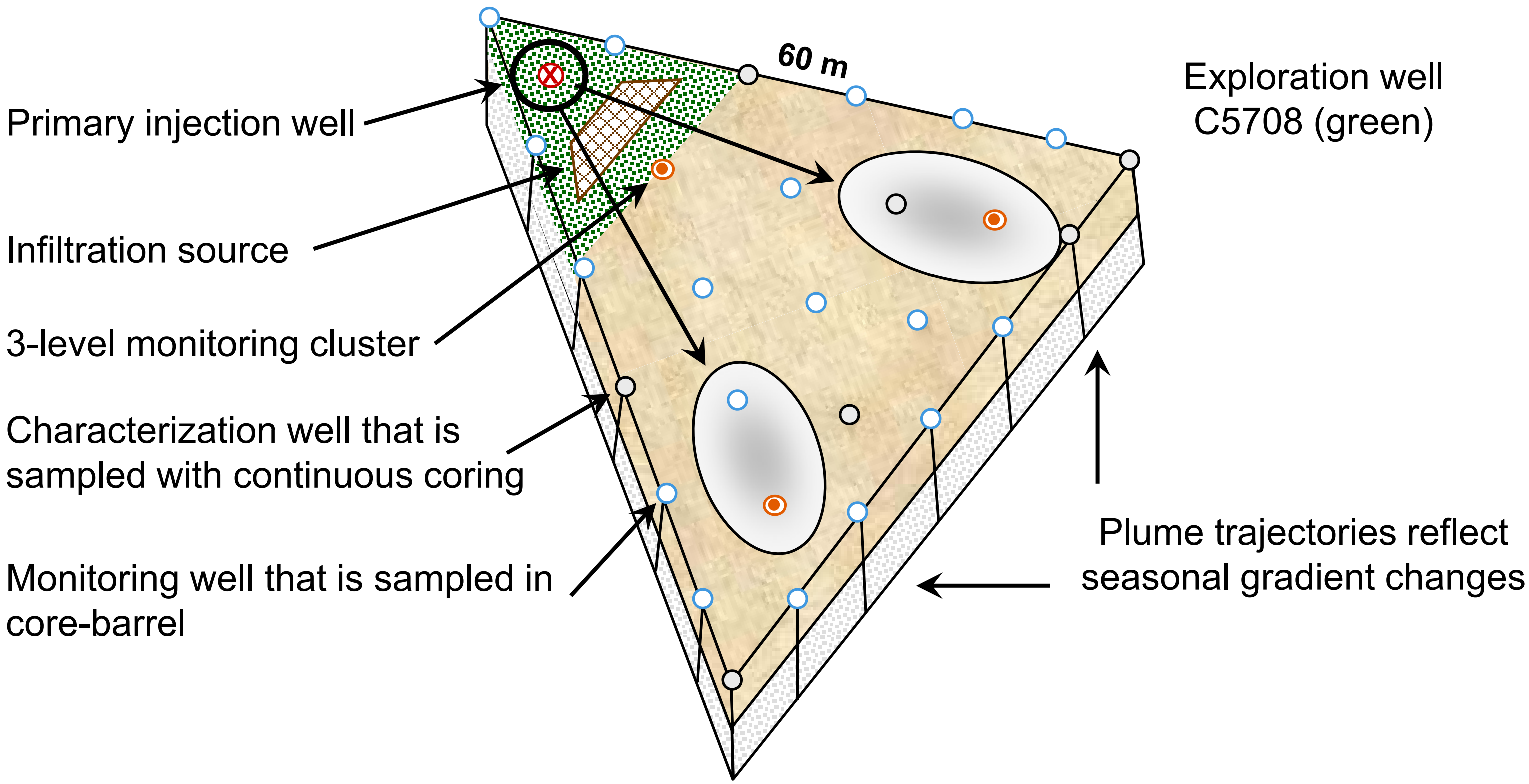
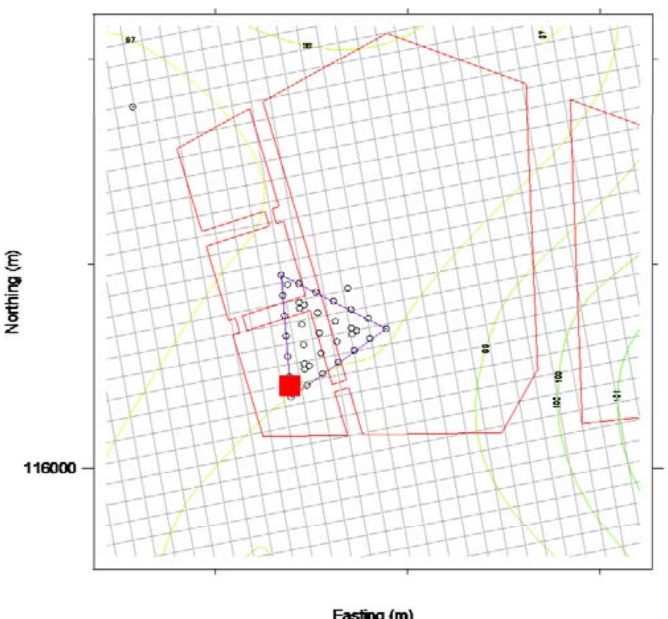
Hanford IFRC Site Concept



- Wells spaced 10 m to allow cross-hole geophysical interrogation for inter-well properties determination.
- Injection experiments (10^5 gallon) in the 6 m saturated zone under different seasonal gradients using site groundwaters.
- Passive experiments will exploit natural gradients and WT fluctuations
- Continual water level monitoring at 12 locations to quantify boundary conditions.

IFRC Site and SPP2



- 60 m site with 37 wells (extensive borehole documentation and logging, reports on web)
- Rigorous geophysical and hydrologic field site characterization and measurements (described by "Plan")
- Carefully selected laboratory measurements on many sediments retrieved from wells (geostatistical relationships)
- Focus on upscaling of microscopic reaction information (from ERSP) and identifying physical/geologic features causing kinetic behavior at m+ scales
- Attempt to characterize and model multi-process effects at multiple scales.

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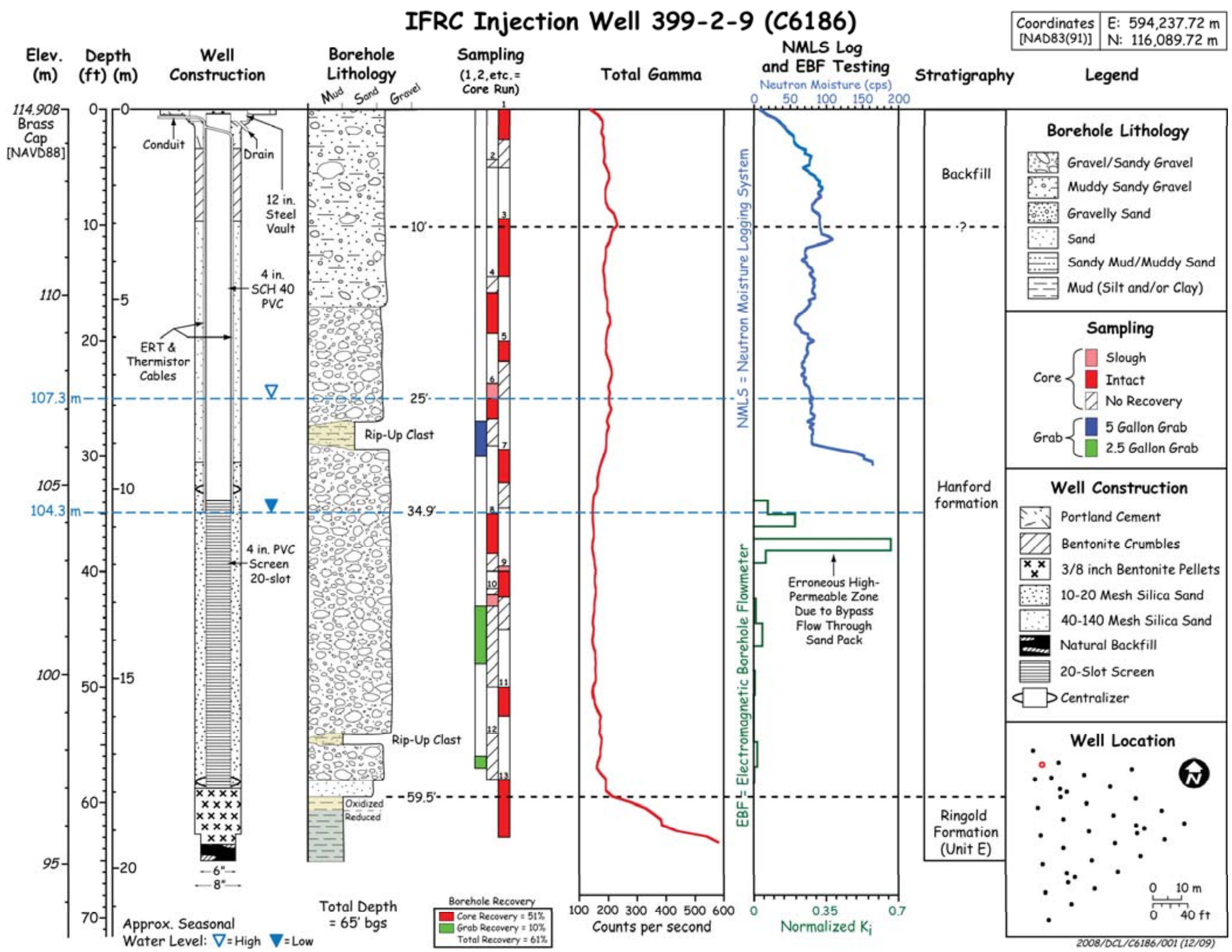
Example Compilation Borehole Summary Log for Well 399-2-9 (C6186)



Hydrologic/Groundwater Characterization

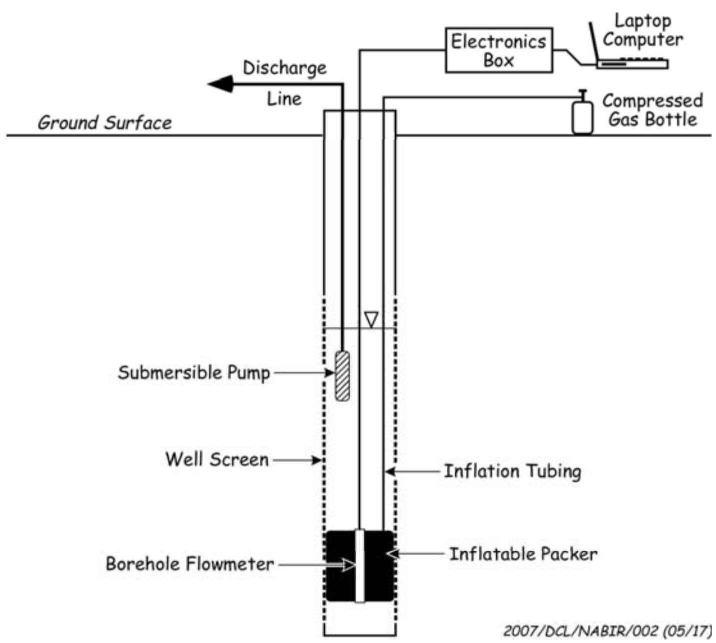
Described in Plan on website

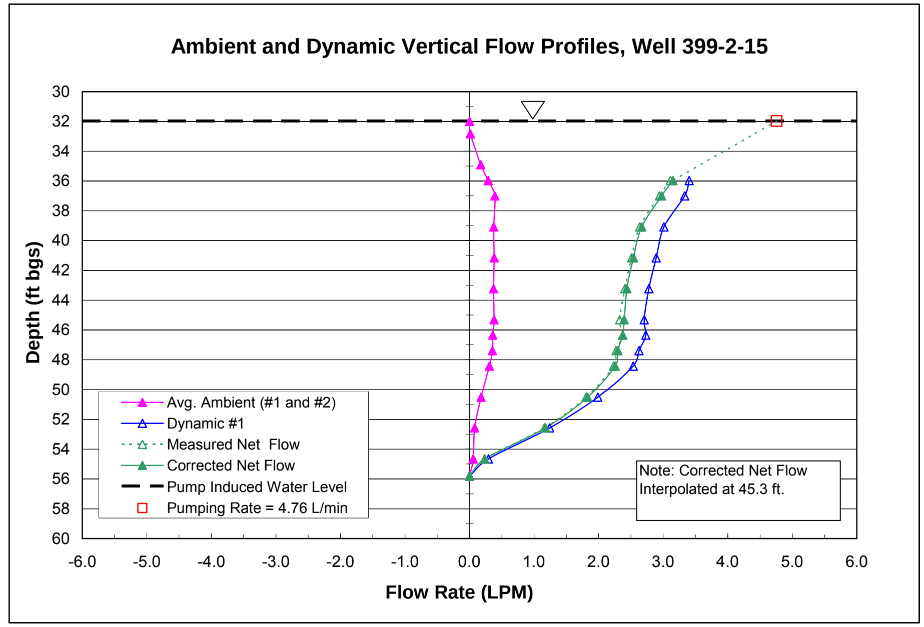
- Hydrologic
  - Electromagnetic borehole flowmeter (EBF) surveys (vertically, temporally)
  - Constant rate injection experiments (enable vertical K profiles)
  - Solute tracer injection experiments
  - ΔT injection experiments (March 2009)

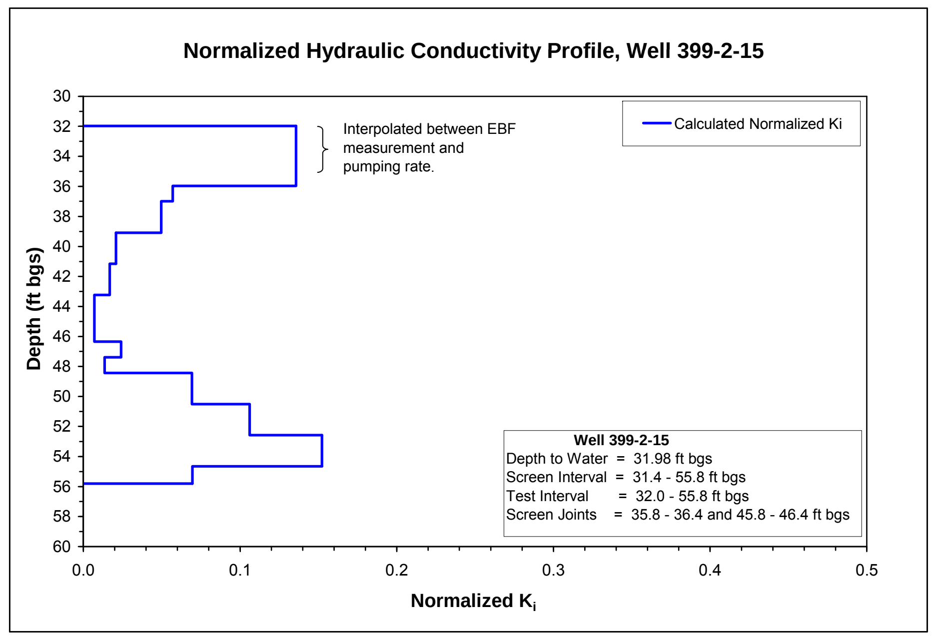
- Geochemical
  - Quarterly all well survey
  - Monthly 12 well survey (9 ML + 3 FS)
  - Seasonal select MLS deployment (early March 2009)
  - Comprehensive passive experiment (April-June 2009)
  - Downhole monitoring of T and EC

Electromagnetic Borehole Flowmeter (EBF) Testing

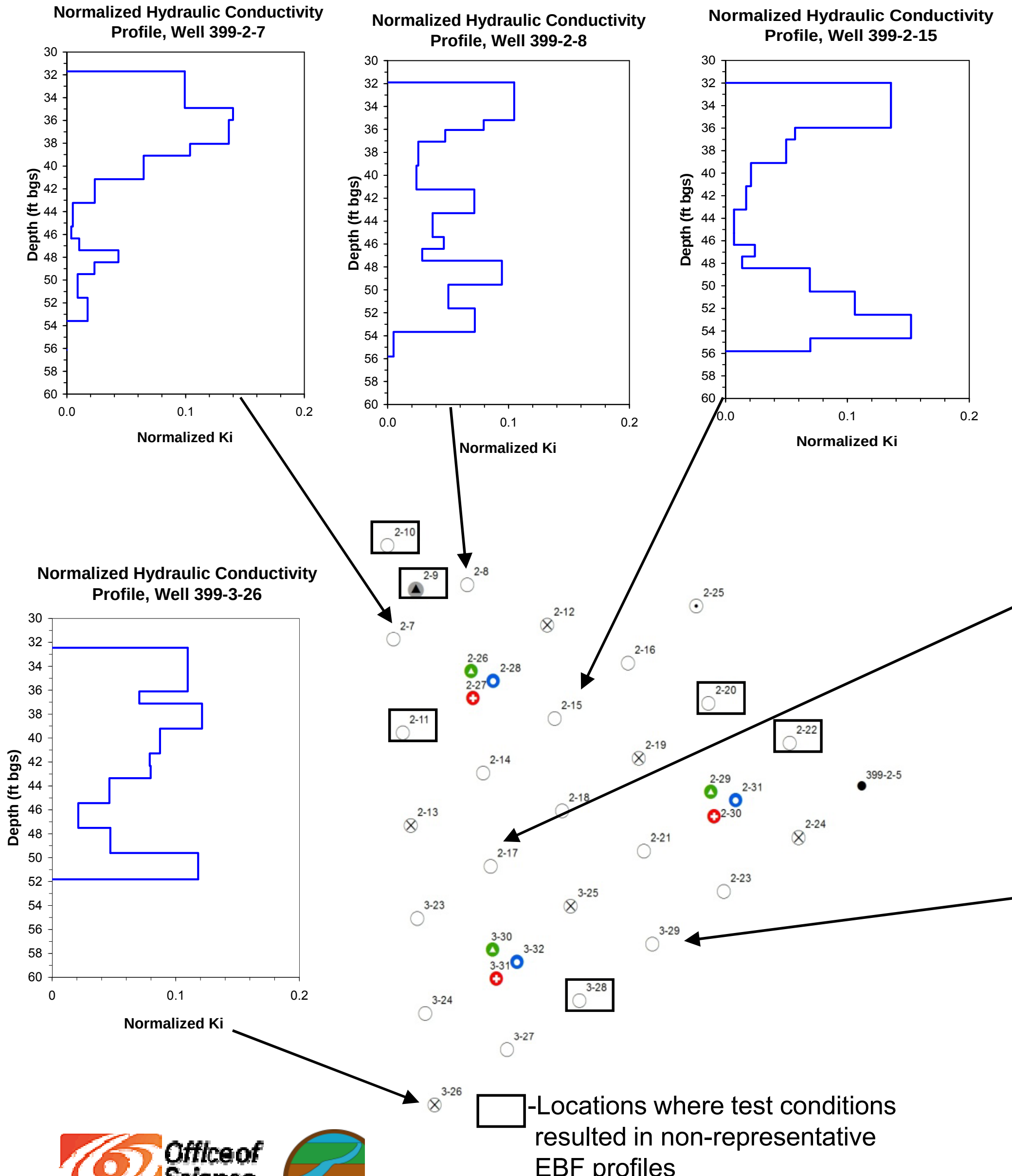
- Both ambient and dynamic tests conducted
- Net flow corrected to account for effects of ambient flow
- Incremental contribution of each depth interval to flow used to estimate relative K



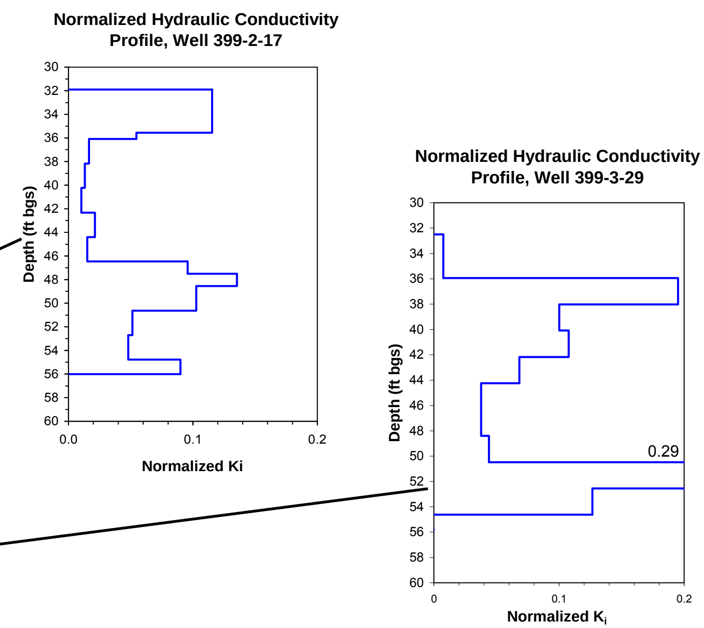




Selected Examples of EBF Profiles



- General (although non-uniform) EBF profile structure indicating lower permeability materials over the middle portion of the aquifer
- Consistent with tracer arrival response in middle zone of northern multi-level well cluster



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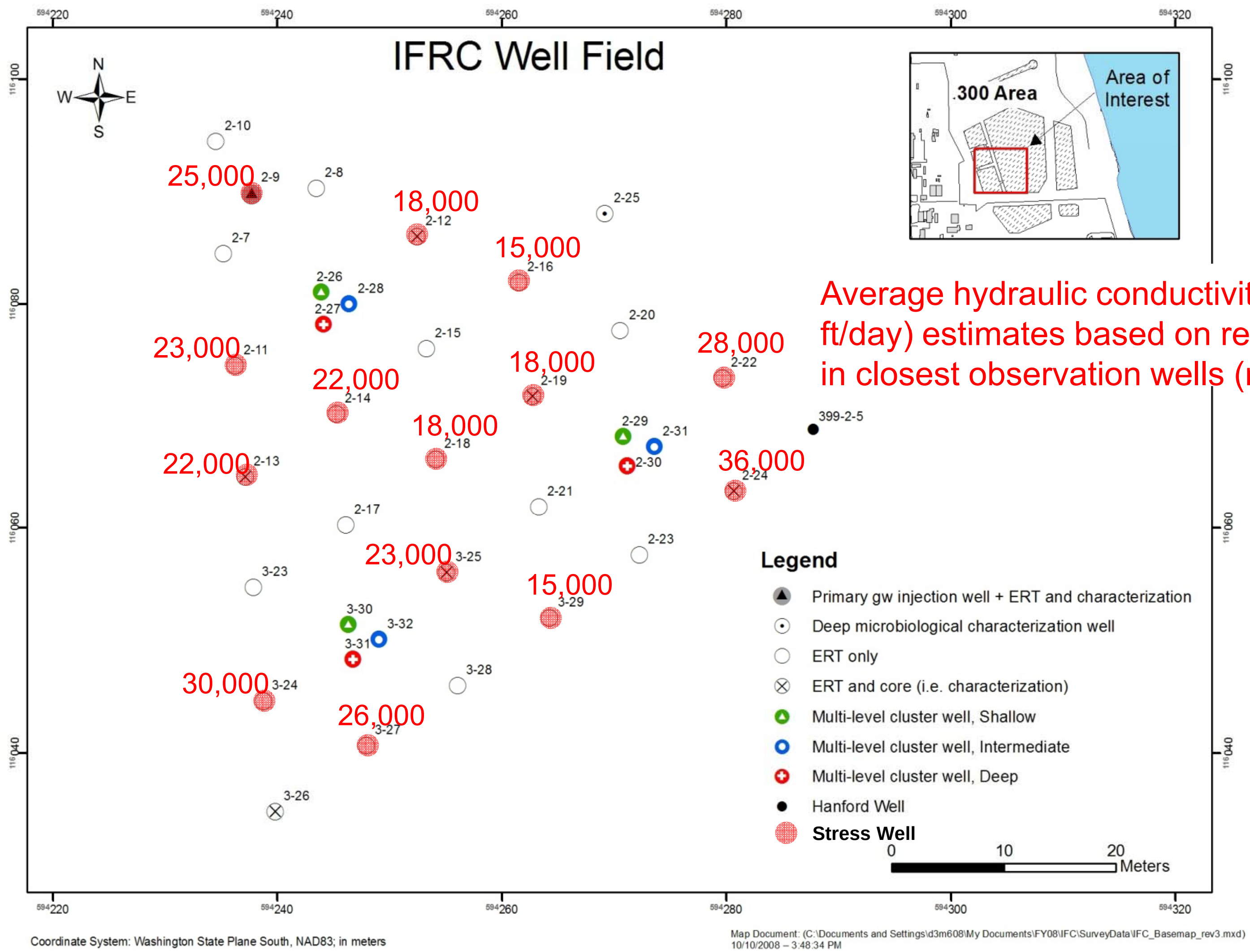
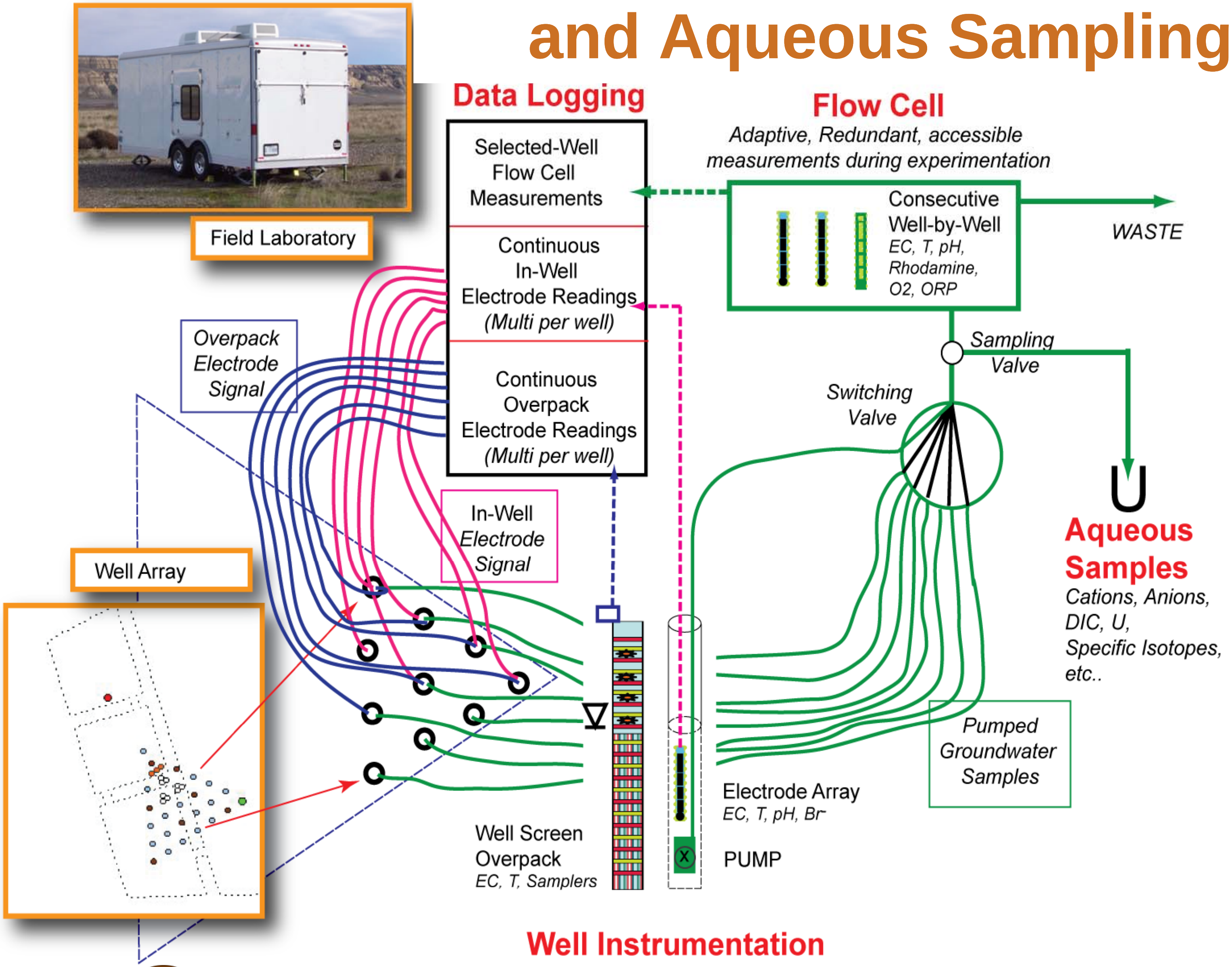
Hydraulic Conductivity from Short-Duration Constant Rate Injection Testing

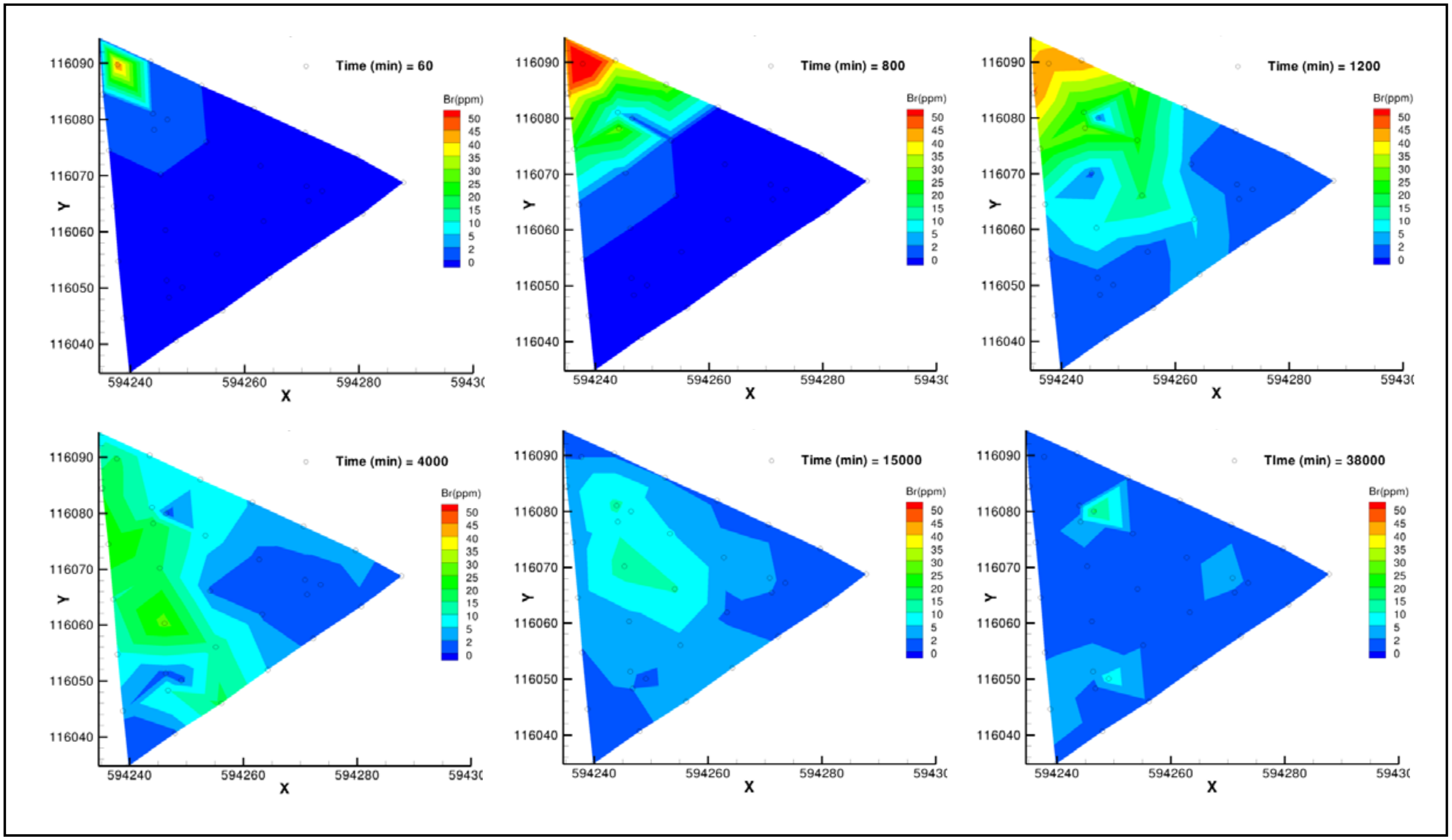


Average hydraulic conductivity (K; ft/day) estimates based on responses in closest observation wells (r ≤ 50 ft)

Field Electrode Measurements and Aqueous Sampling



Results of November 2008 Tracer Test for Hydrologic Characterization



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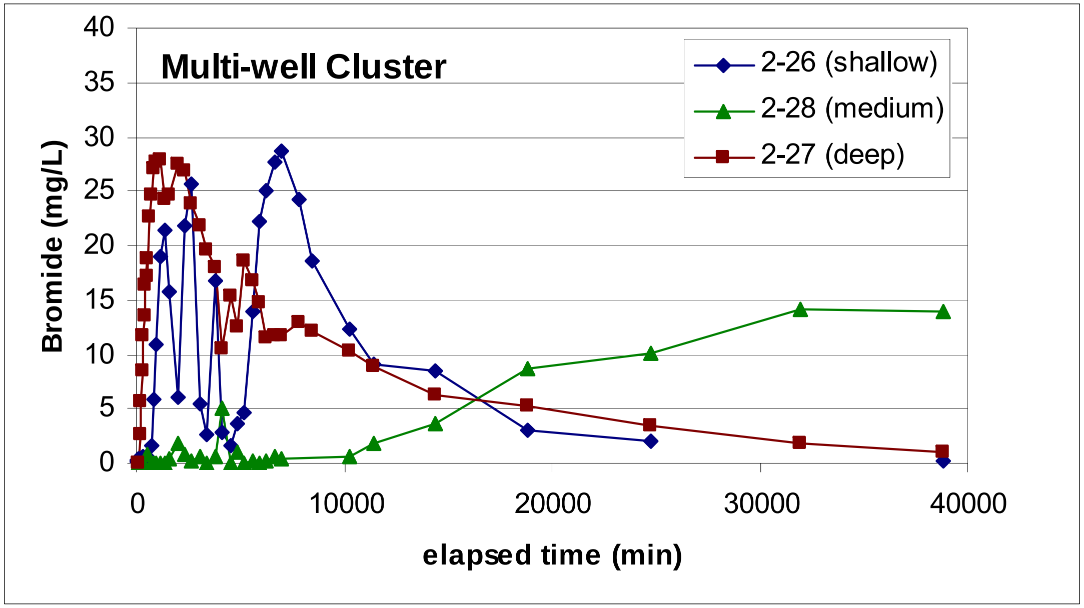
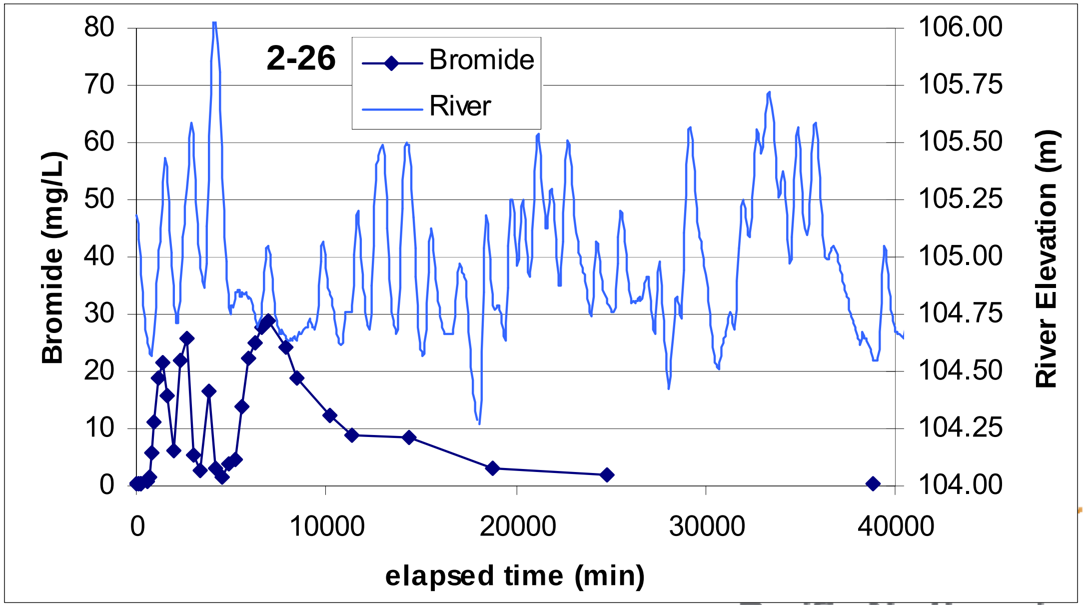
Tracer Response in Northern Multi-Level Well Cluster

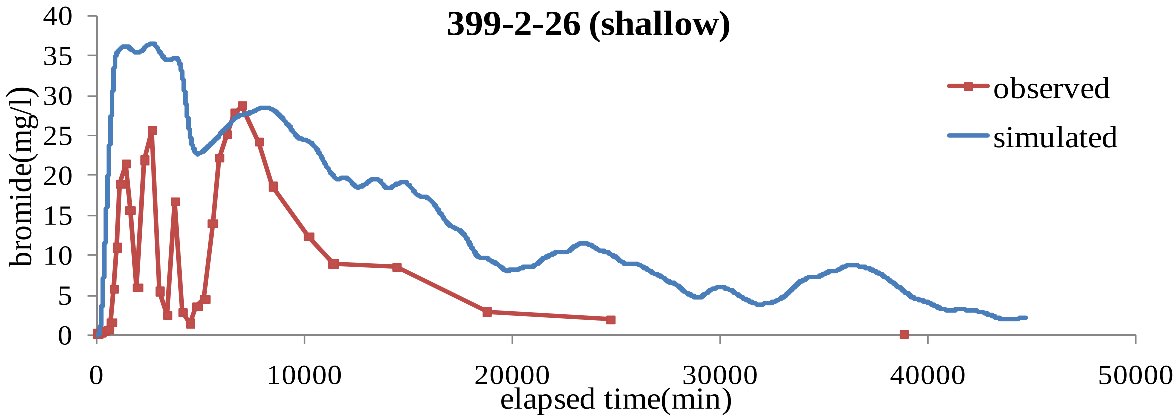
- Tracer arrival and elution significantly lagged in middle zone
- Consistent with EBF results
- Earliest arrival in lower zone - closely followed by upper zone

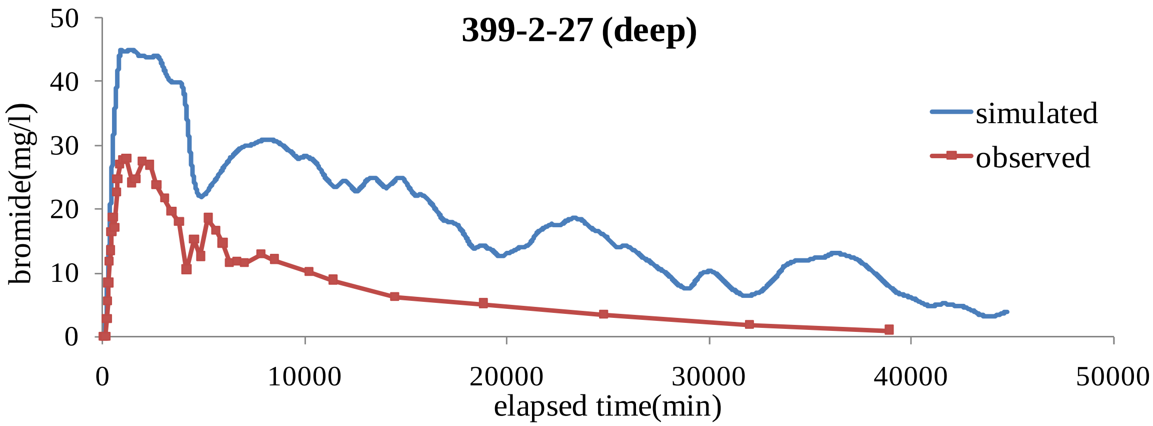


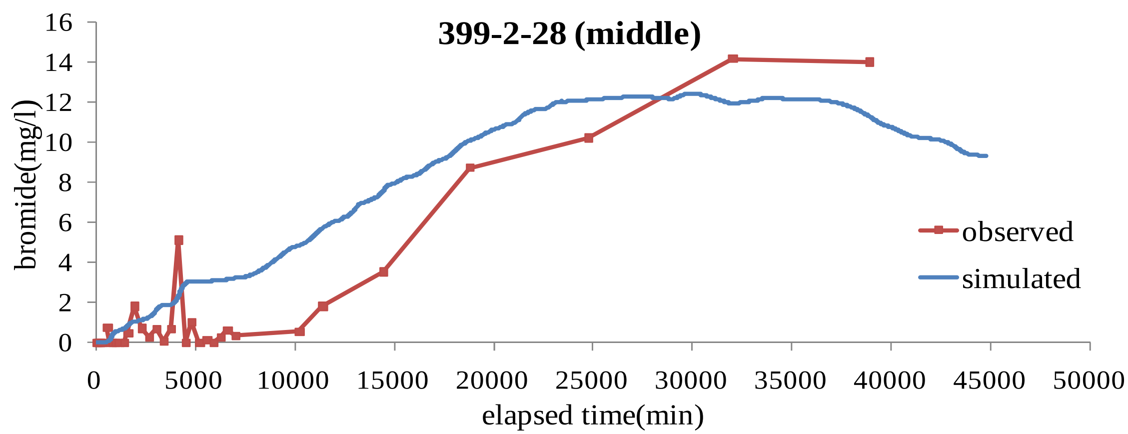
- Upper zone well exhibits stronger tracer response to river stage variability than lower zone – more connected
- This difference in connectivity likely explains the strong ambient flow observed during EBF testing



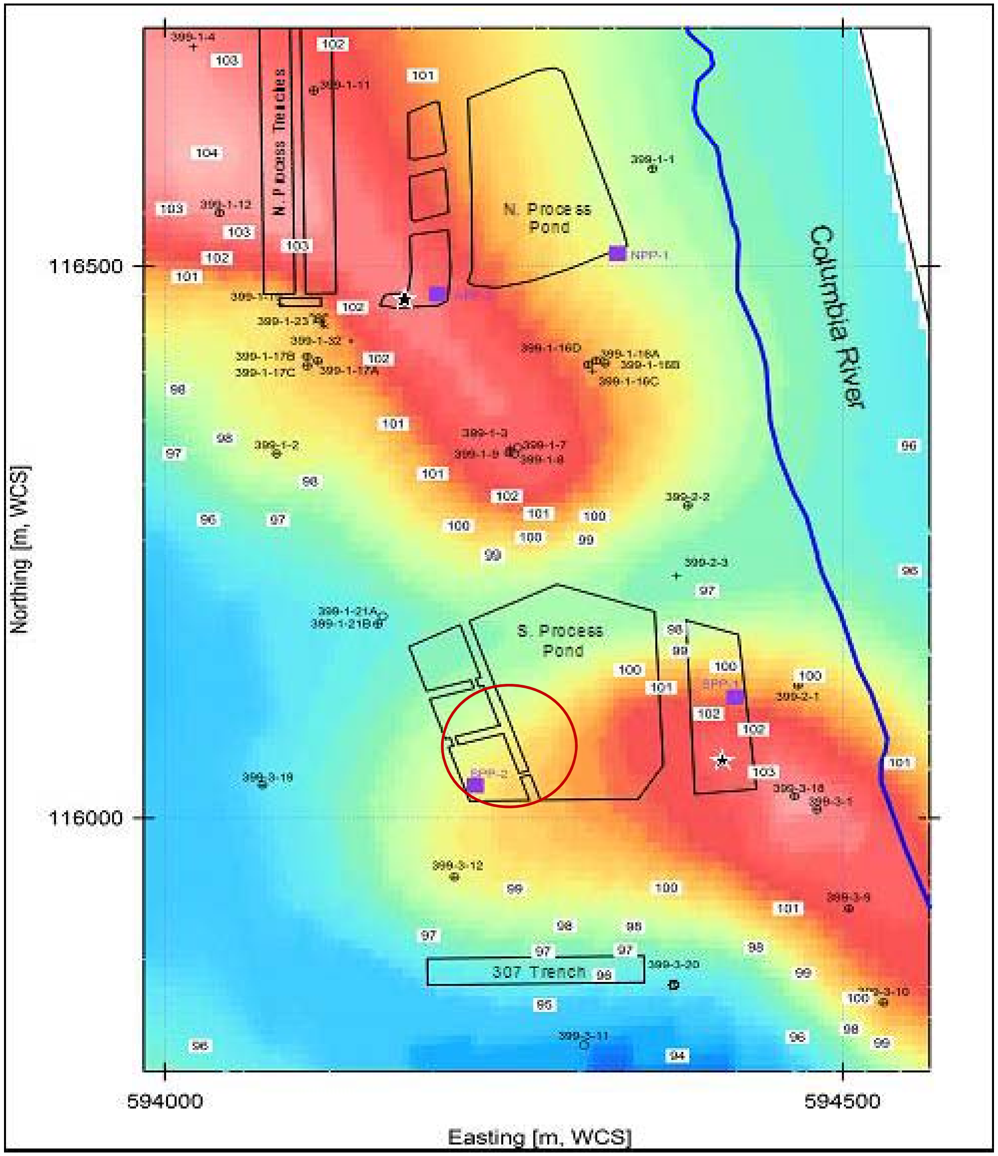
Well Cluster 1



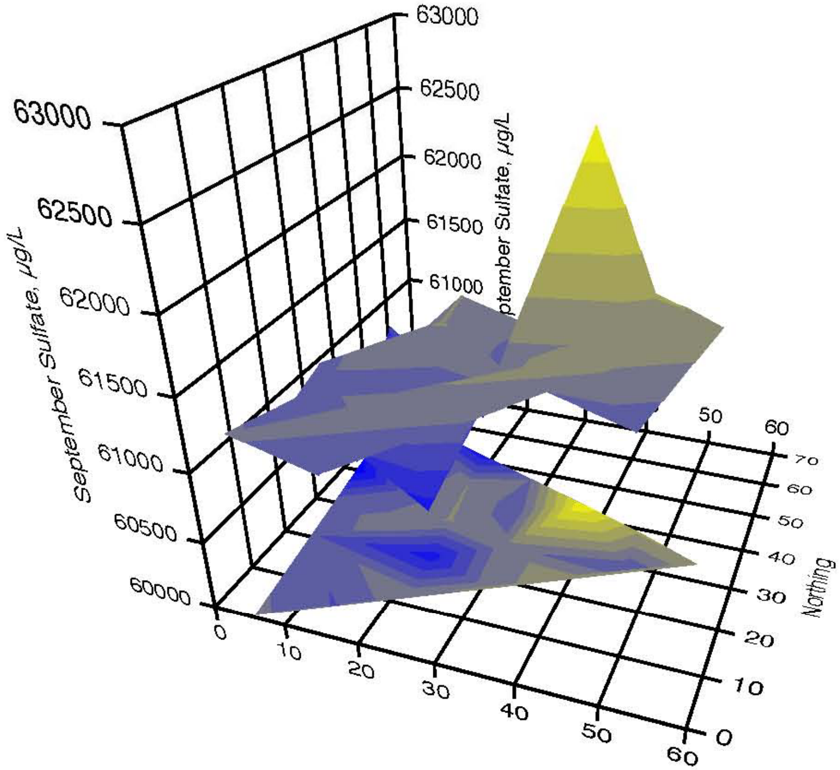


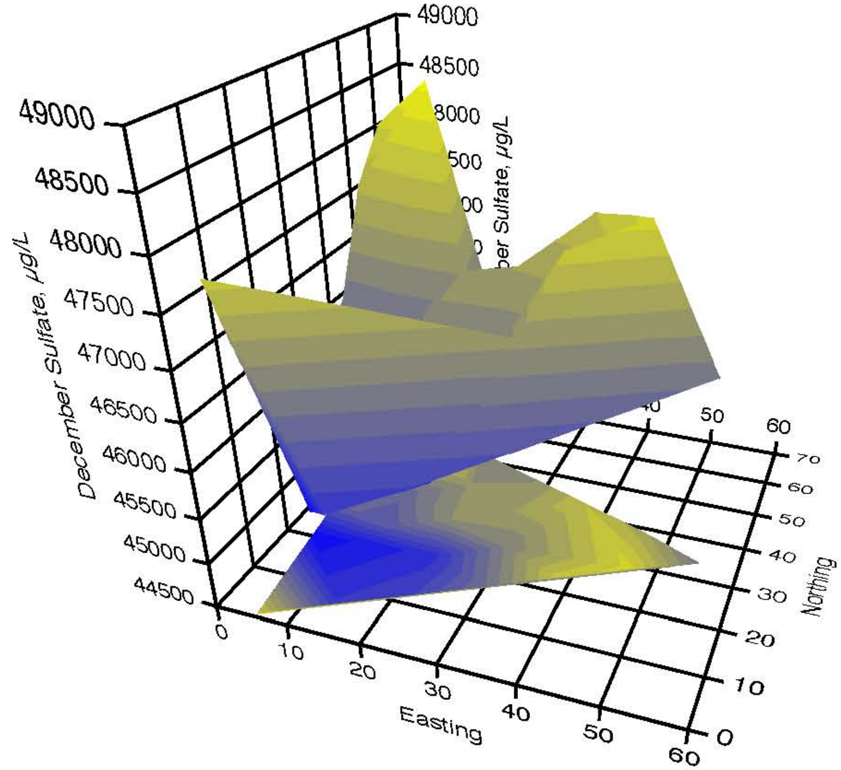


Shaded Relief of Hanford Ringold Contact

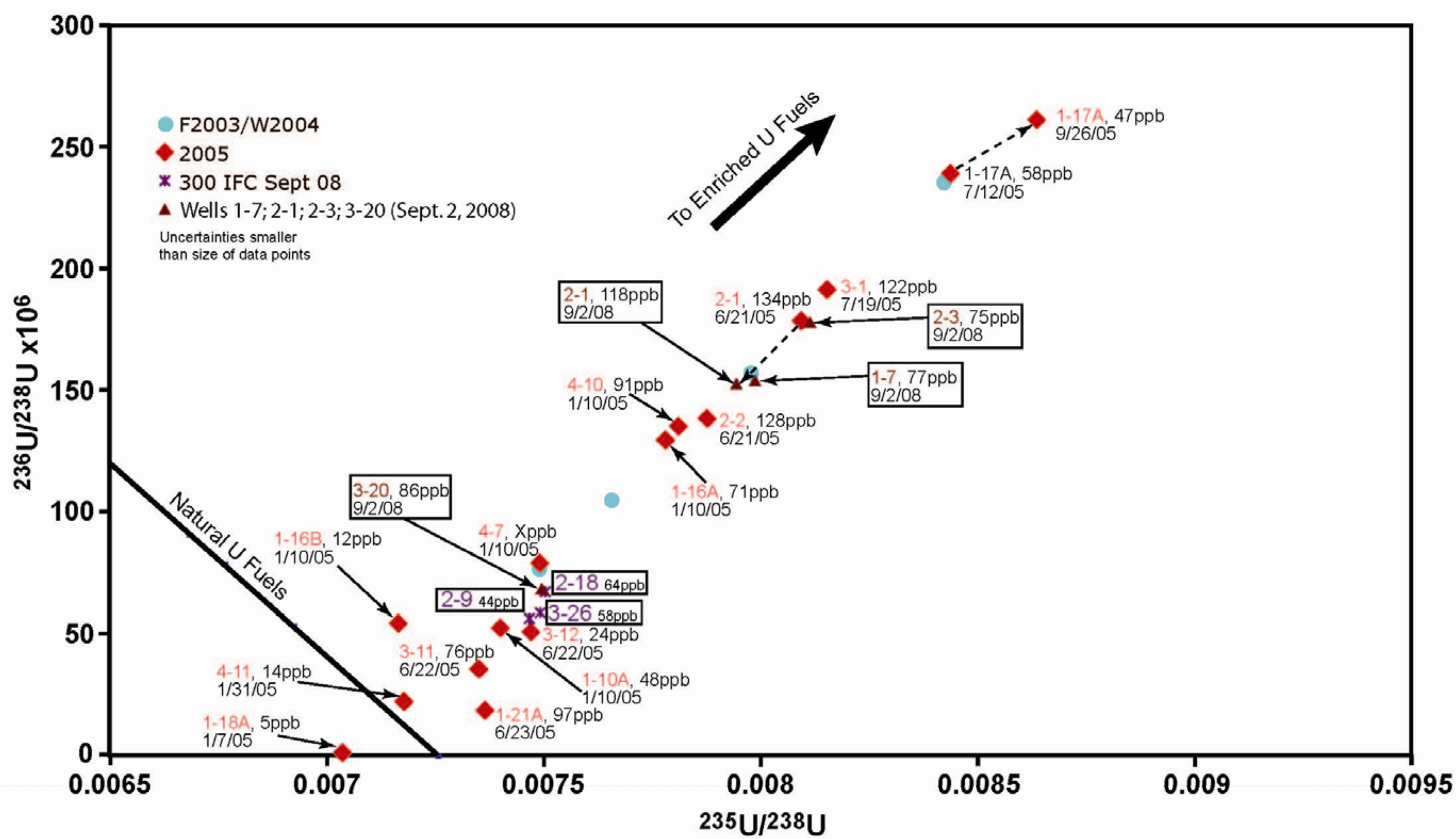


Sulfate in IFRC Well Waters





Uranium Isotopes in 300 A Groundwaters



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Sediment Characterization Strategy

Based on field-scale surface complexation RTM

$$SOH + UO_{2(aq)}^{2+} + CO_{3(aq)}^{2+} = SOHUO_2HCO_3$$

$$[SOH]_T, [U]_T, [CO_3]_T, K, k$$

and 3-D properties/parameter distributions

- <u>Transport properties</u>
  K_{sat}, porosity, density

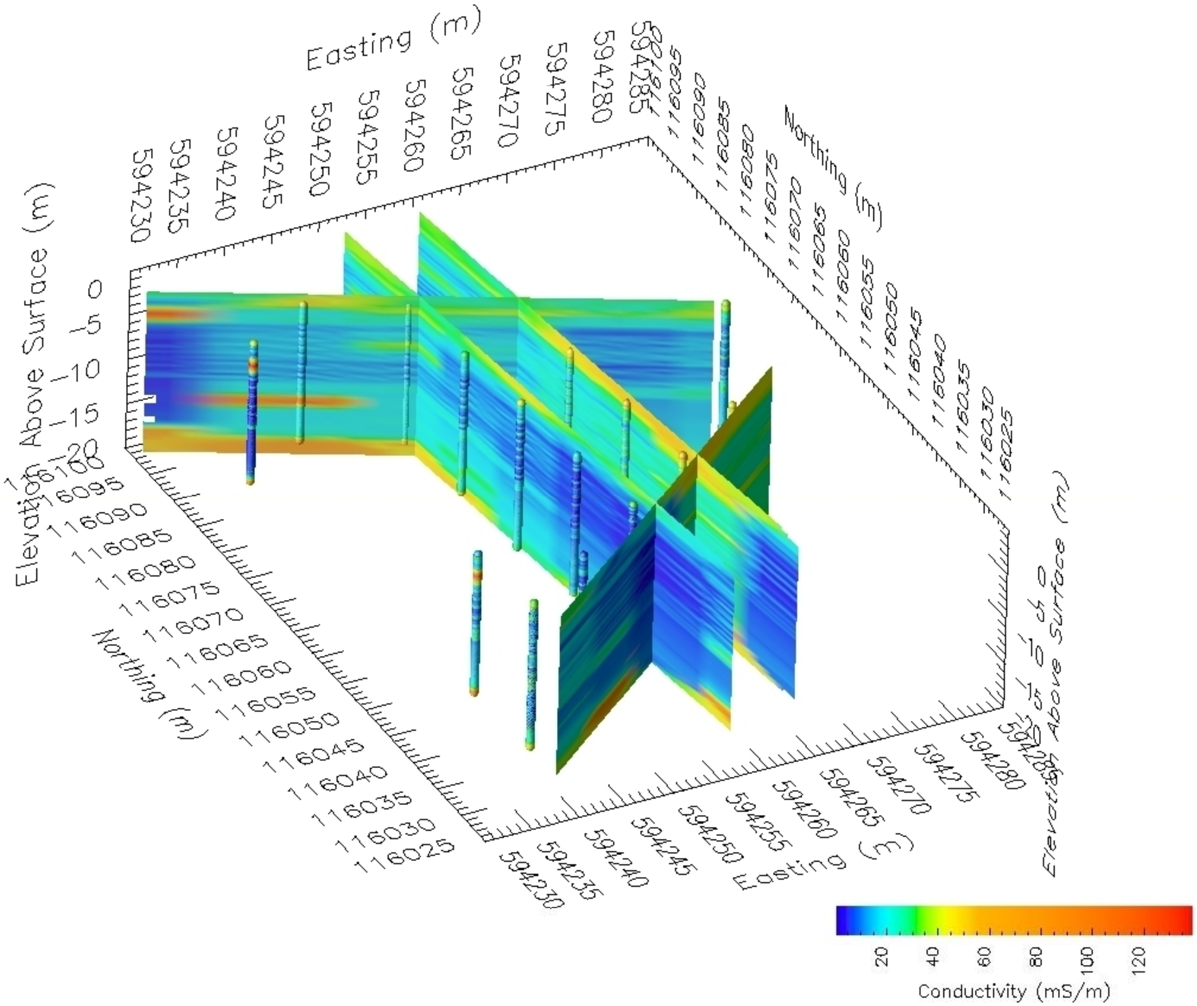
- <u>Reaction parameters</u>
  K, k, SOH, CO_3^{2-}

- <u>U distribution</u>
  $U(VI)_{ads}$, $U(VI)_{aq}$

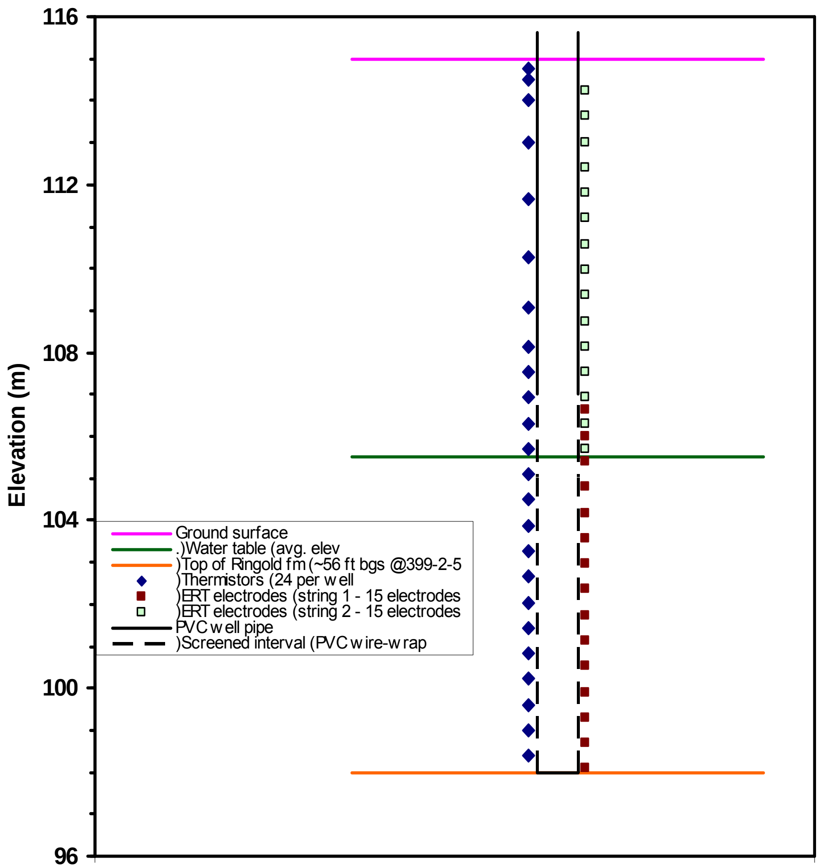
Sediment Characterization Approach

- Interpolation between boreholes
  - Down-hole geophysical measurements (uncharacterized boreholes)
    - Porosity, density, EC, MS, K-U-T
  - Cross-hole measurements (intervening space)
    - Radar, ERT
  - Correlations between geophysical measurements and physical/chemical properties (SFA)
- Direct measurements on select cores/samples
  - Physical
    - PSD [200], SA [50]
  - Chemical
    - U_T, U_{ads}, U_{des}, K_d-SGW1&2, $AAO_{Fe(III)}$ [200]
    - K, k [select, establish correlations with properties]

Downhole Electrical Conductivity Measurements



Schematic of ERT / Monitoring Wells



- Electrodes spaced at 60 cm (2 ft)
- Electrode length approx 10 cm (4 in)
- Electrode material 316 stainless steel
- Single wire connections to electrodes
- Wires run on outside of PVC well pipe
- Thermistors placed between electrodes
- Wire wrap PVC from 106-98 m elevation
- Tube capped at bottom
- Well head ~0.6 m (2 ft) above ground
- Central connector/DAQ box at top of wellhead
- Heat dissipation unit (HDU), time- domain reflectrometry (TDR) probe and porous cup solution sampler at multiple depths on 5 wells around infiltration site

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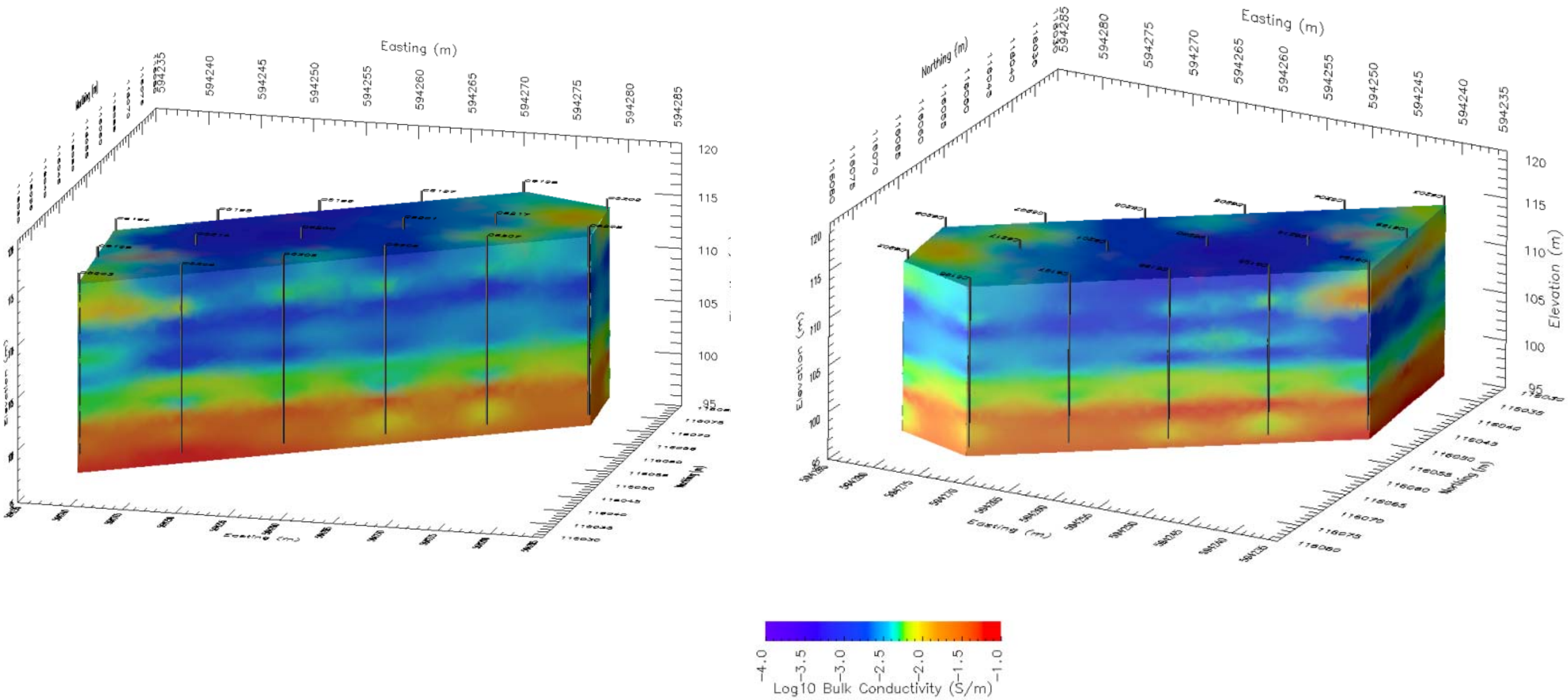
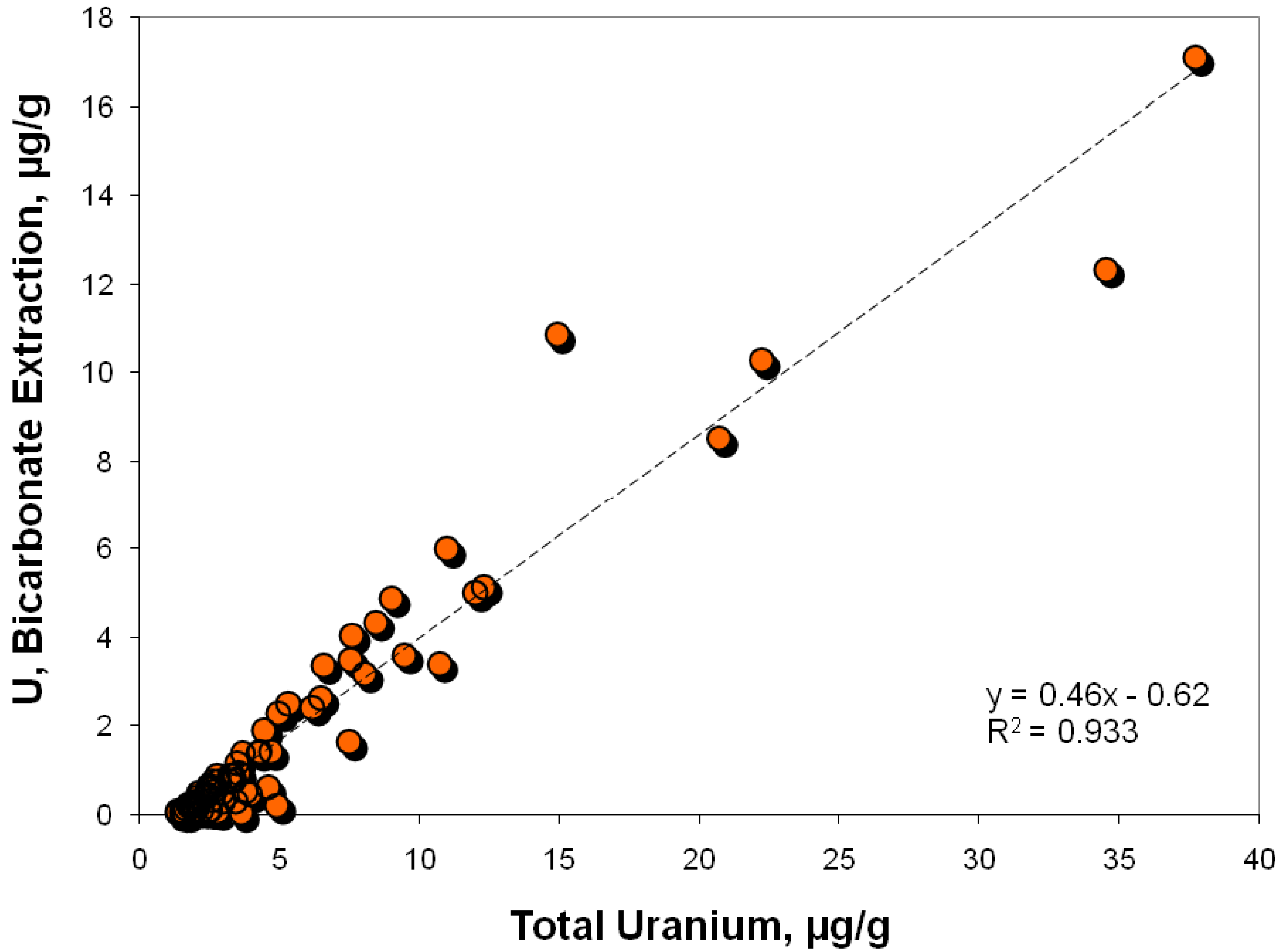
Calibrating Electrodes in the IFRC Well Field

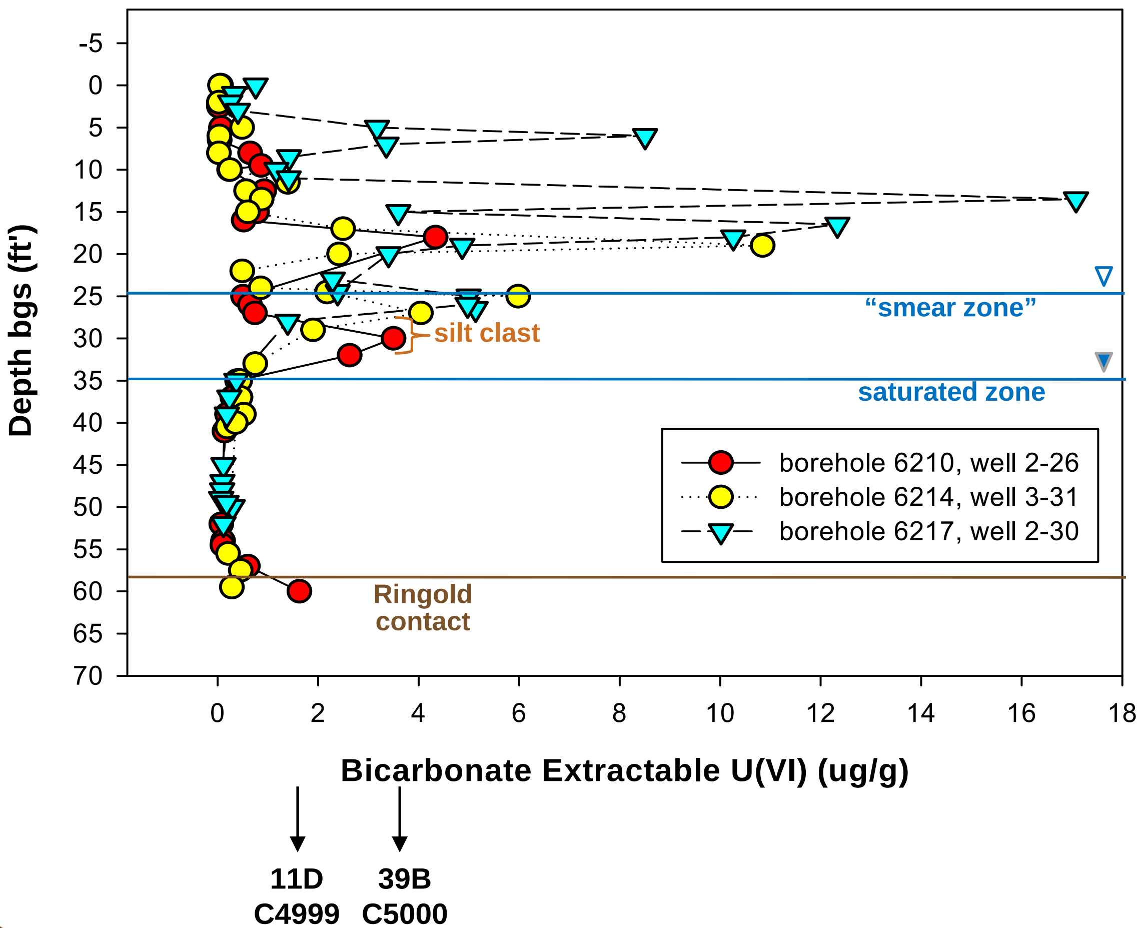
IFRC ERT Inversion Results



Relationship Between Total and Bicarbonate Extractable U(VI)



Bicarbonate Extractable U(VI) from Three Boreholes



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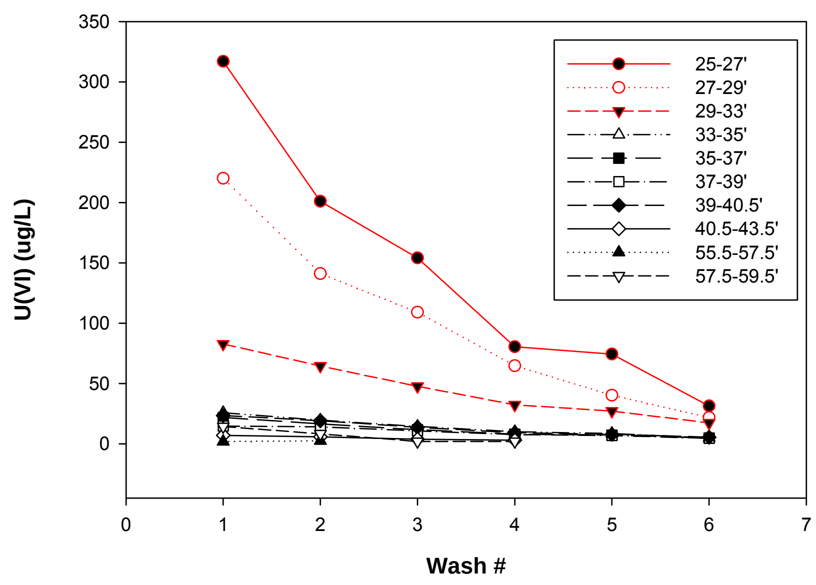
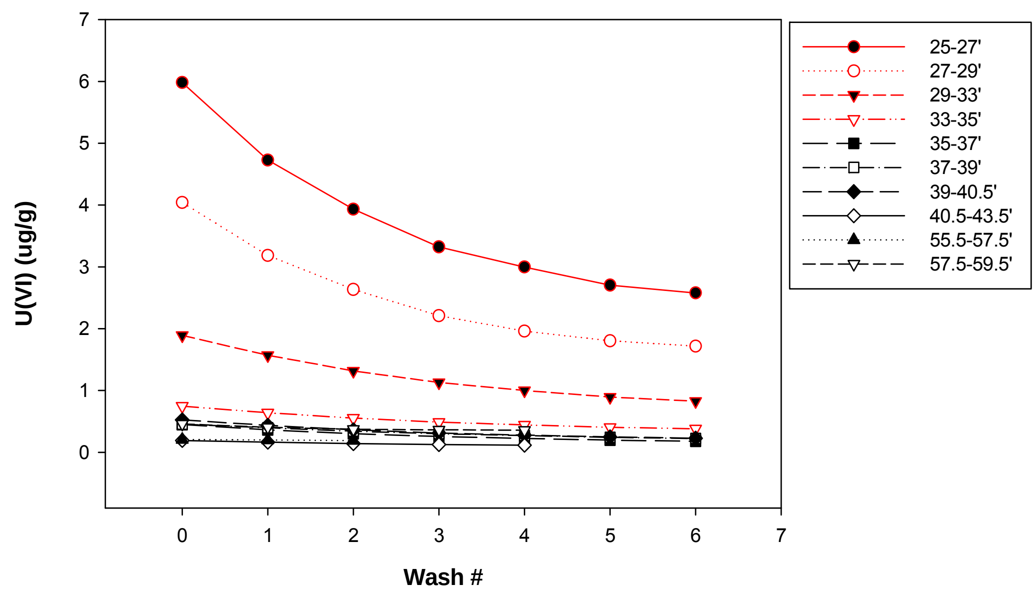
Forced U(VI) Desorption for Kd Measurement from Well 3-31 Sediments





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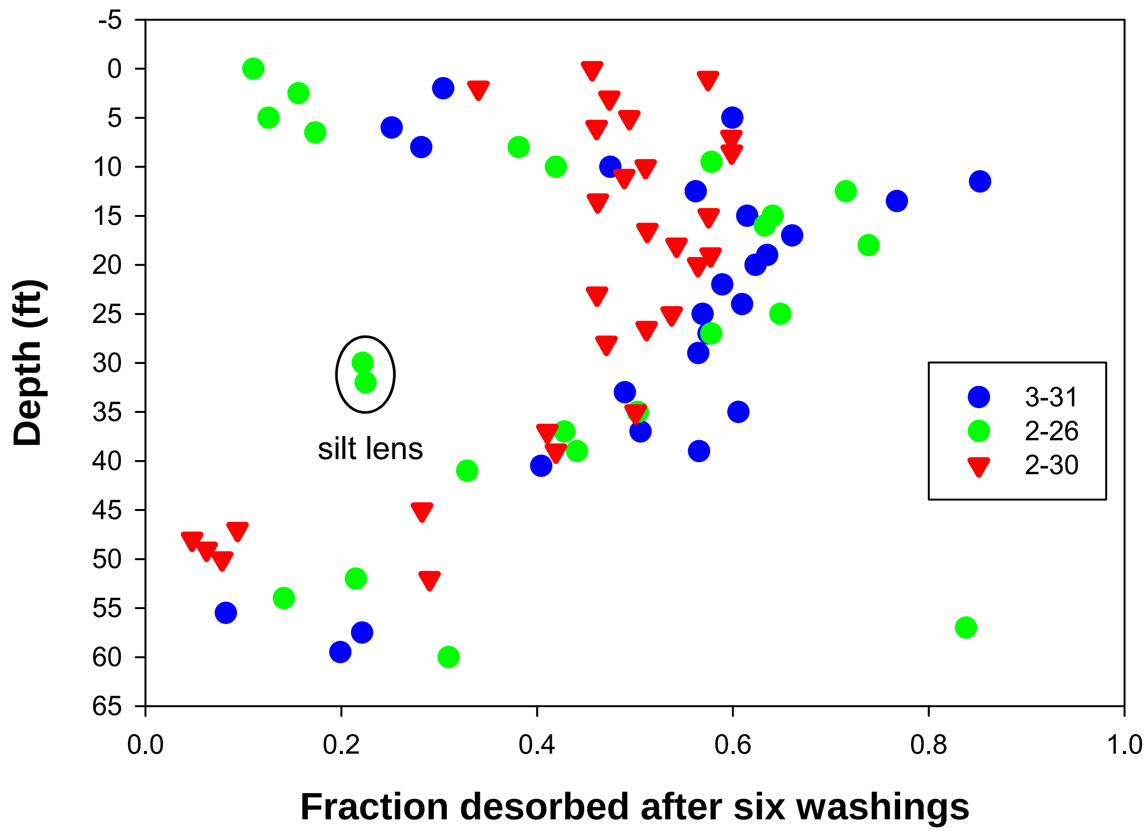
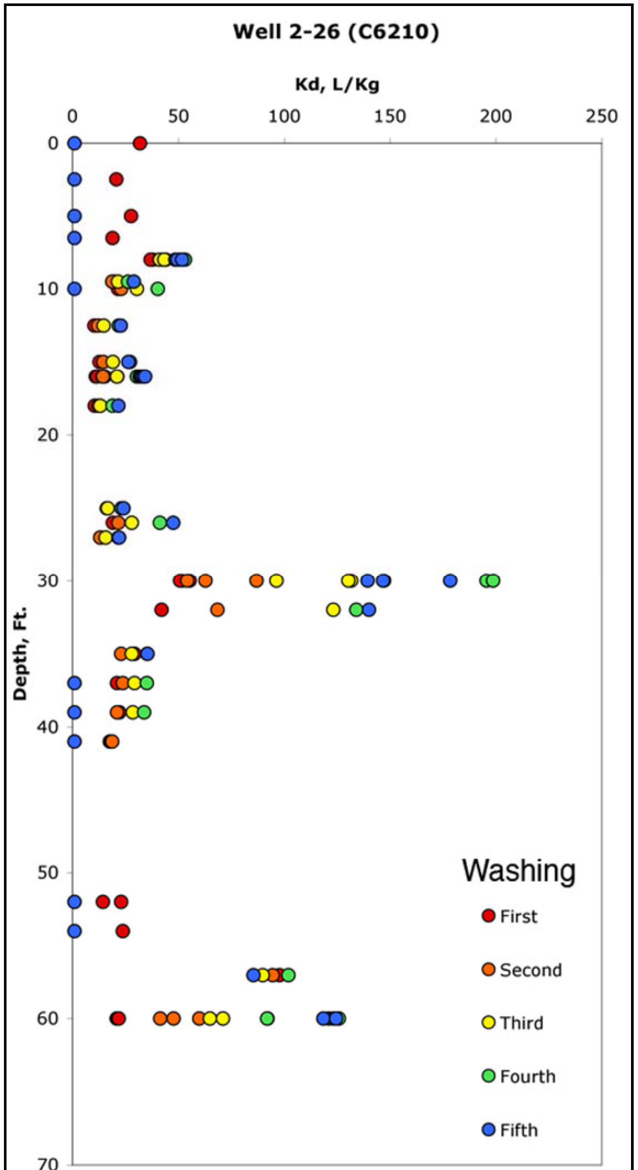
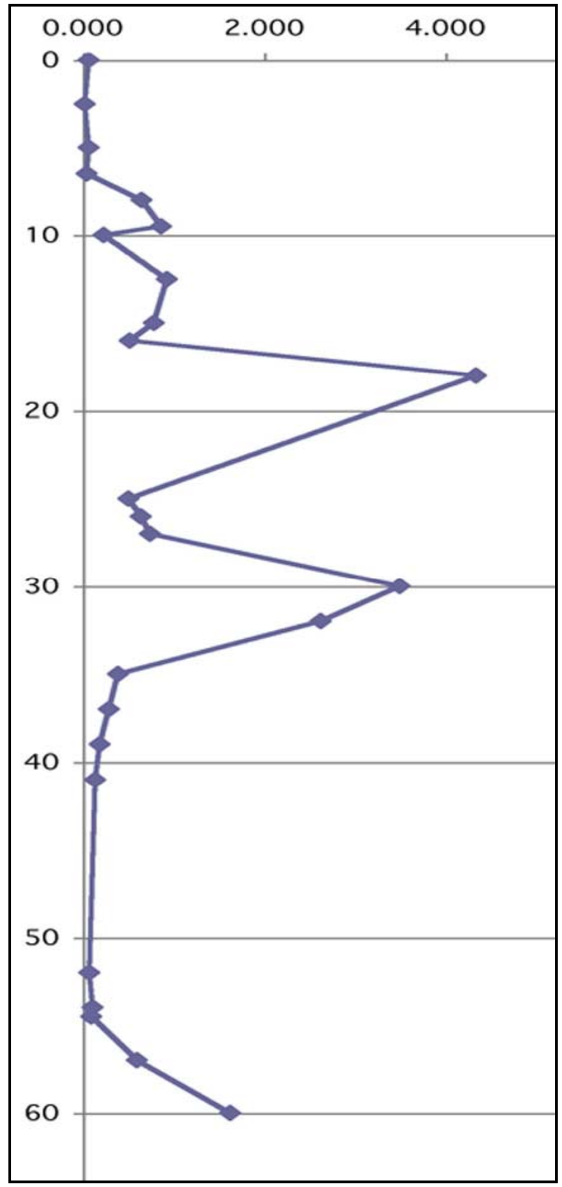
Lability of Adsorbed U(VI) in IFRC Site



Influence of Desorption Cycle on <2mm Kd for Core 2-26





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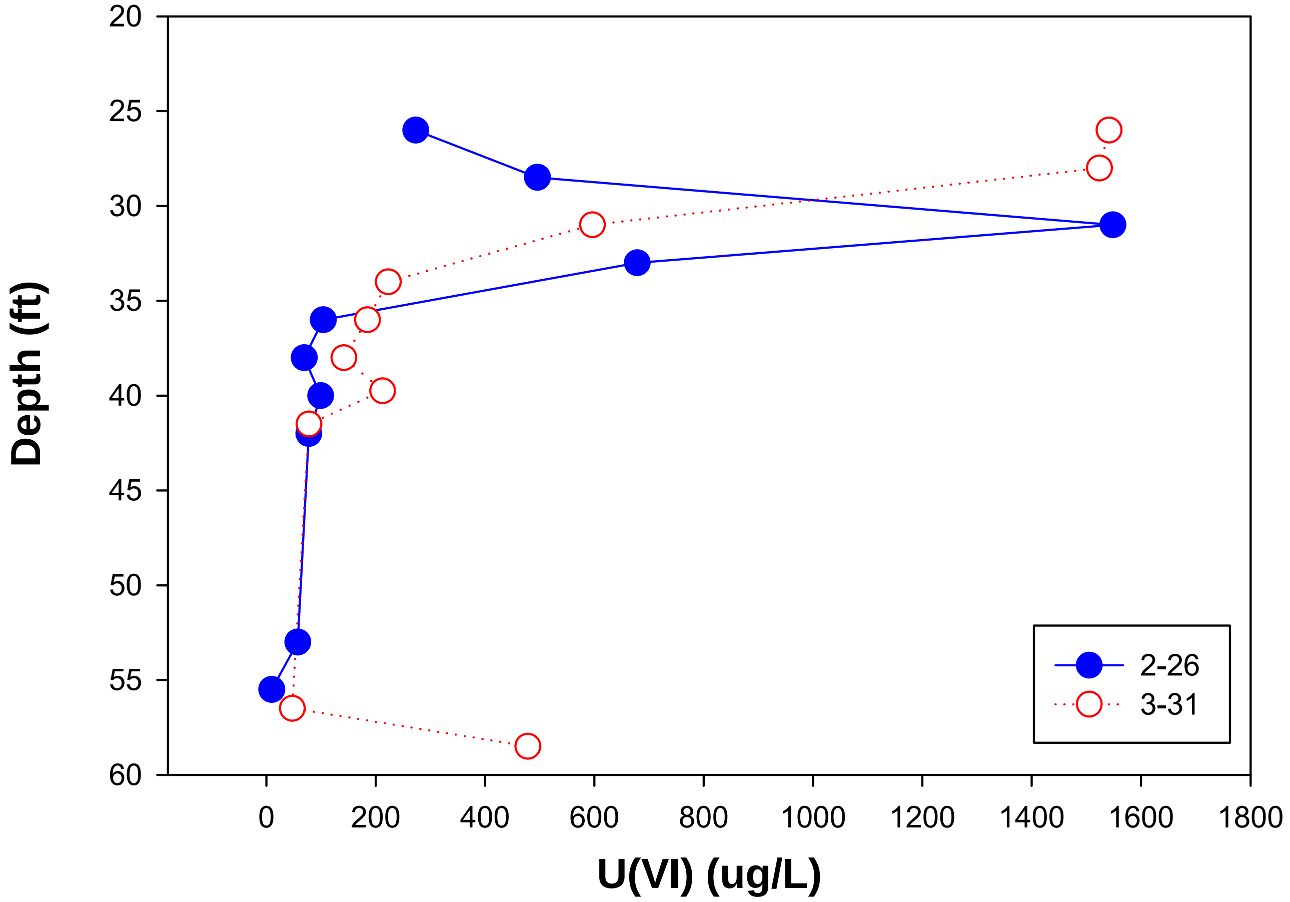
Extrapolated Groundwater U(VI) Concentration from First Desorption Event



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Ex-situ/In-Situ Reaction Parameters *[PNNL SFA]*

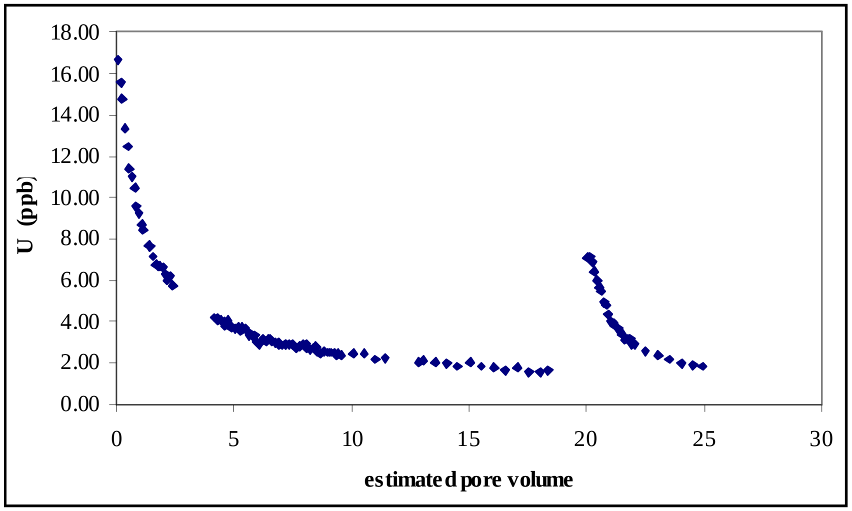
Intact Column Studies

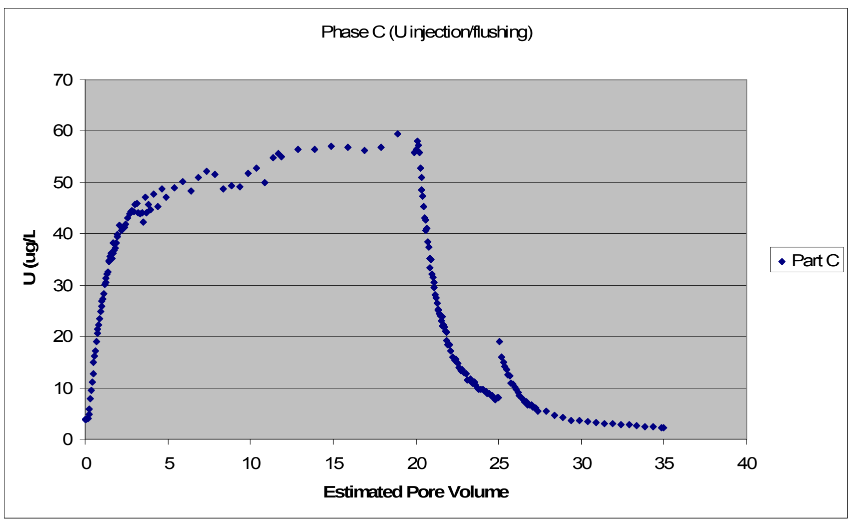
- RT experiments at 10'/d, 3 cores from different aquifer depths
  - A-desorption, B-tracer, C-adsorption/desorption SGW-1, D-hydrologic properties

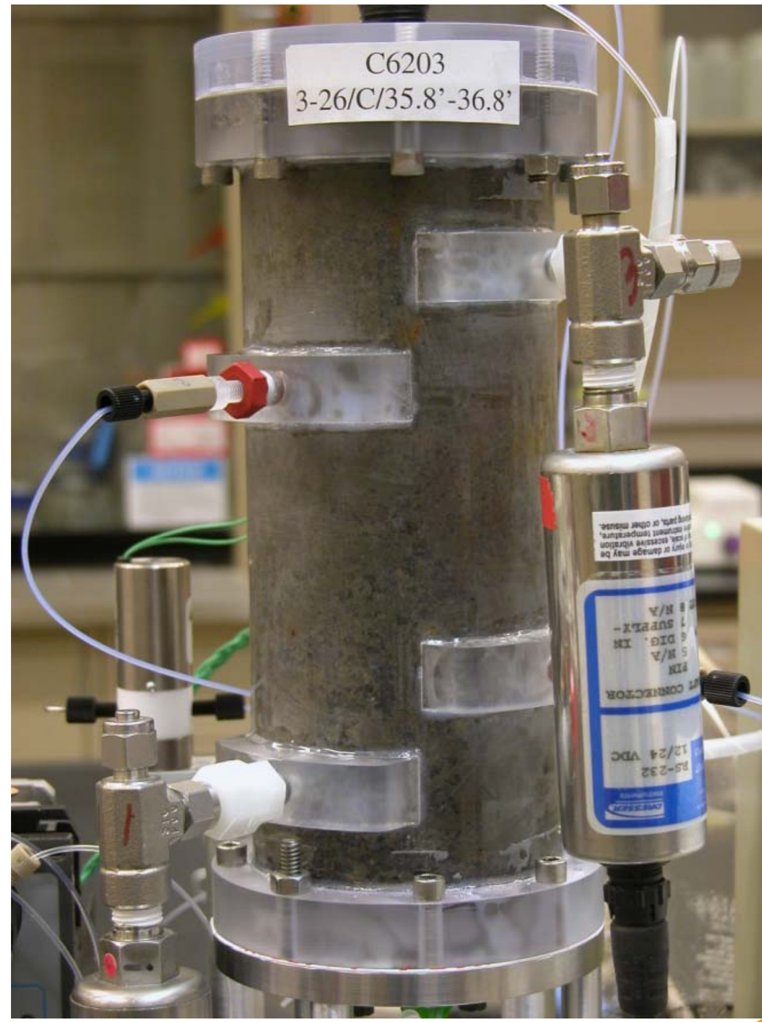
- Deconstruction
  - psd, SA (< 2 mm), < 2 μm mineralogy
  - Low [U(VI)] isotherm (< 2 mm)
  - Mass transfer parameters by flow cell (< 2 mm)
  - AAO Fe(III) (< 2 mm)

- Upscaled modeling
  - SC-DR-DP (PFBA)

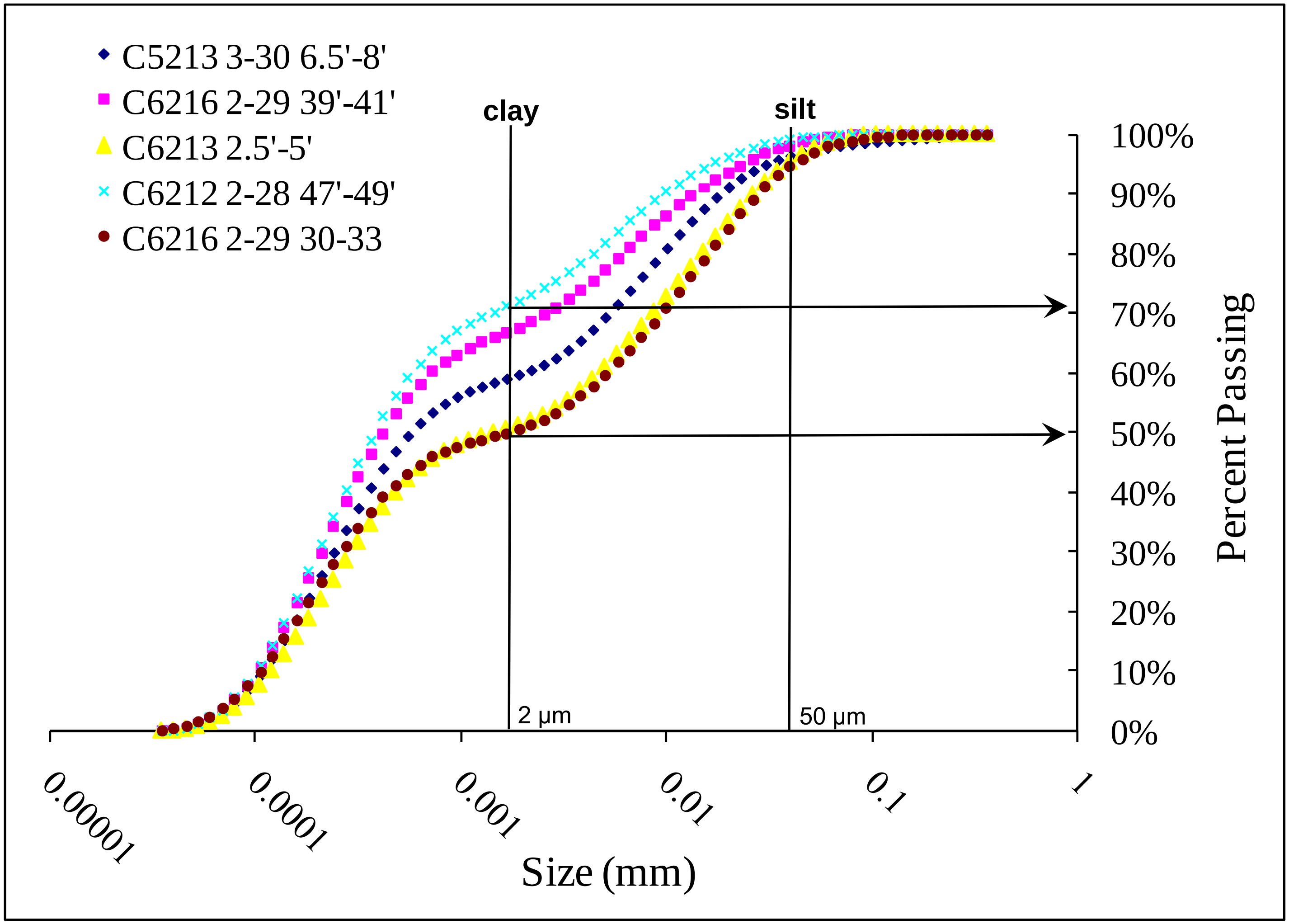
U(VI) Desorption and Adsorption/Desorption from Intact IFRC Core 3-26/35.8-36.8’



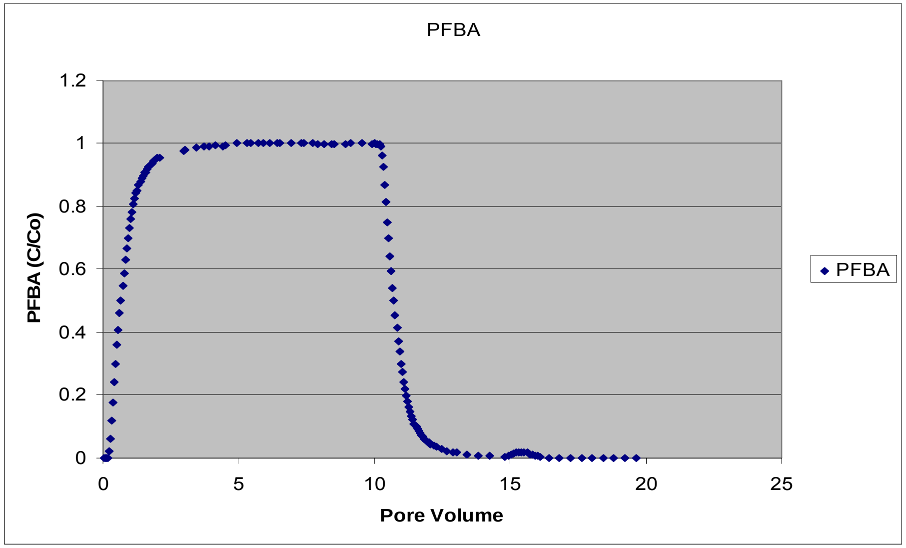


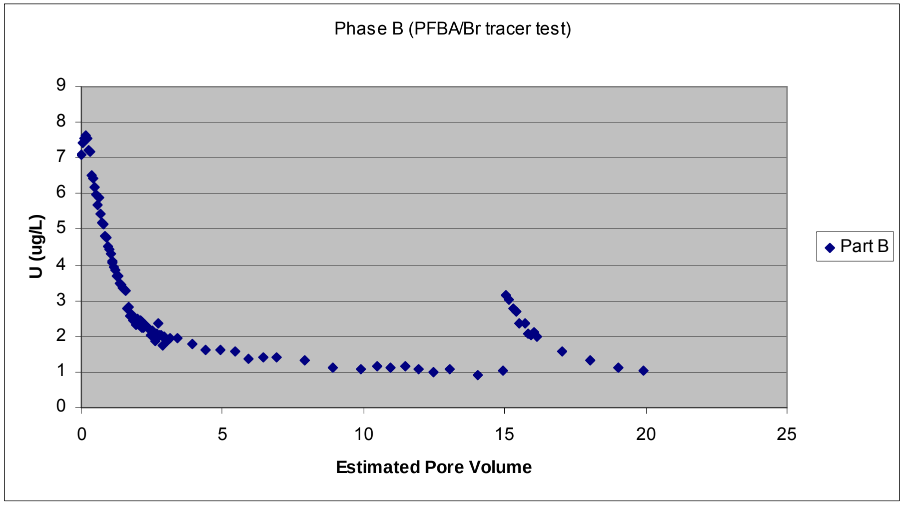


Particle Size of Coatings on Gravel (32 mm)



Tracer Behavior and U(VI) Desorption During Phase B





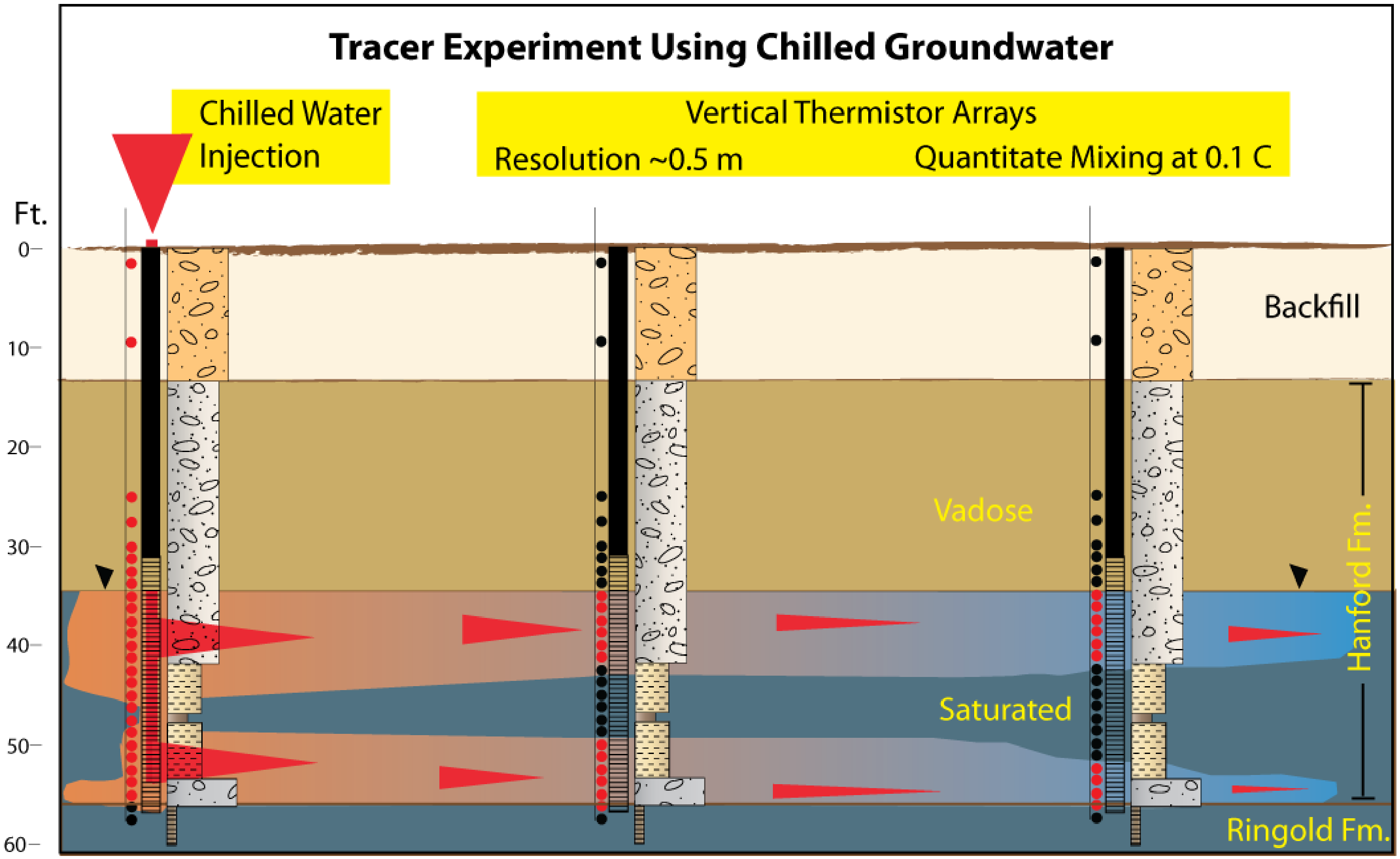
Field Experimental Plan is in Progress

New characterization data will allow completion

<u>Expected Experimental Campaigns</u>

- Multi-tracer, cold water injection (March, 2009)
- Passive during rising and falling water table (May - July, 2009)
- Desorption U(VI) injection (September, 2009)
- Adsorption U(VI) injection (March, 2010)
- Passive during rising and falling water table (May - July, 2010)
- In-situ microbiologic activity (August, 2010 – February 2011)
- Isotopic exchange (March, 2011)

Defining Heterogeneities in Hydrologic Properties and Flow



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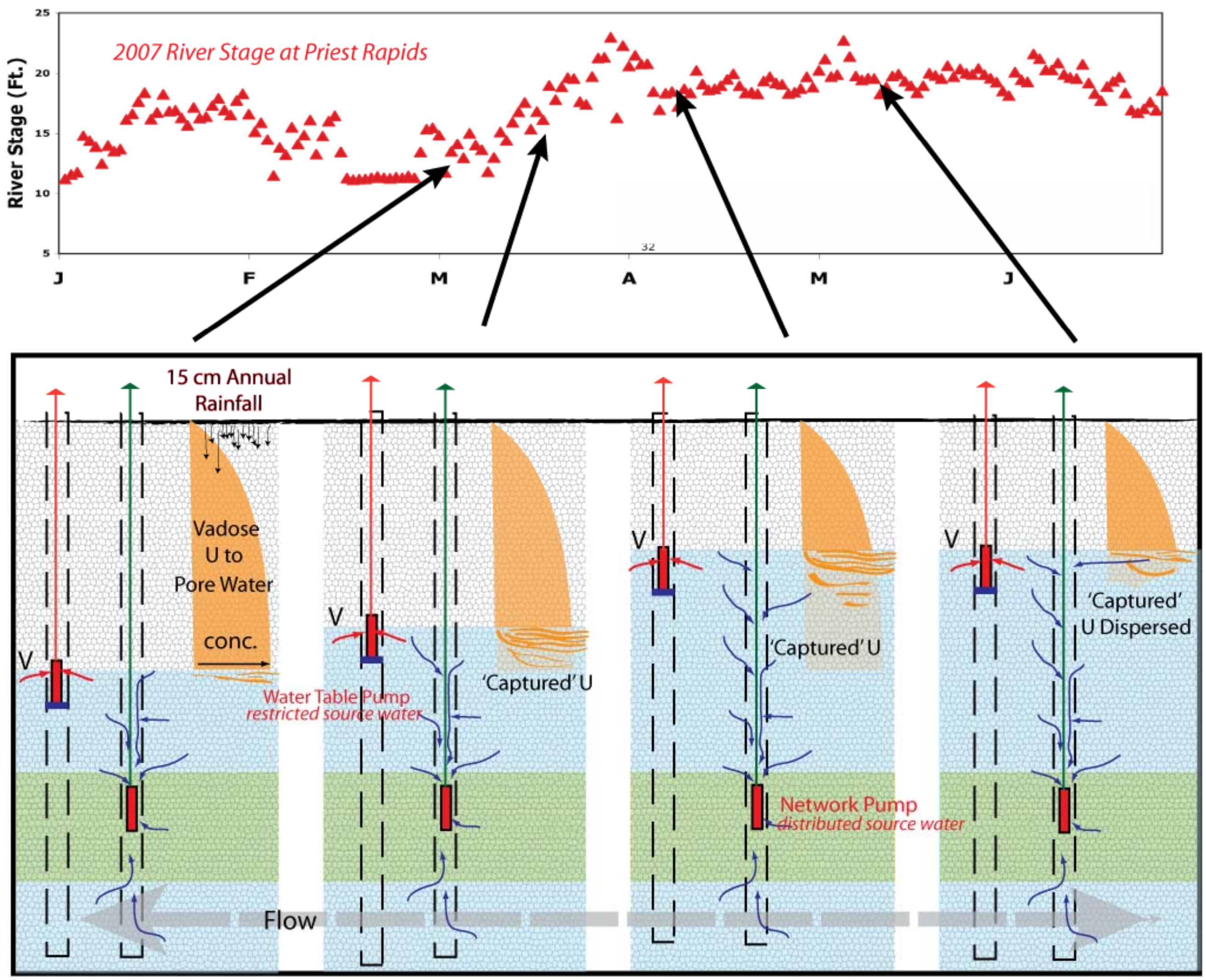
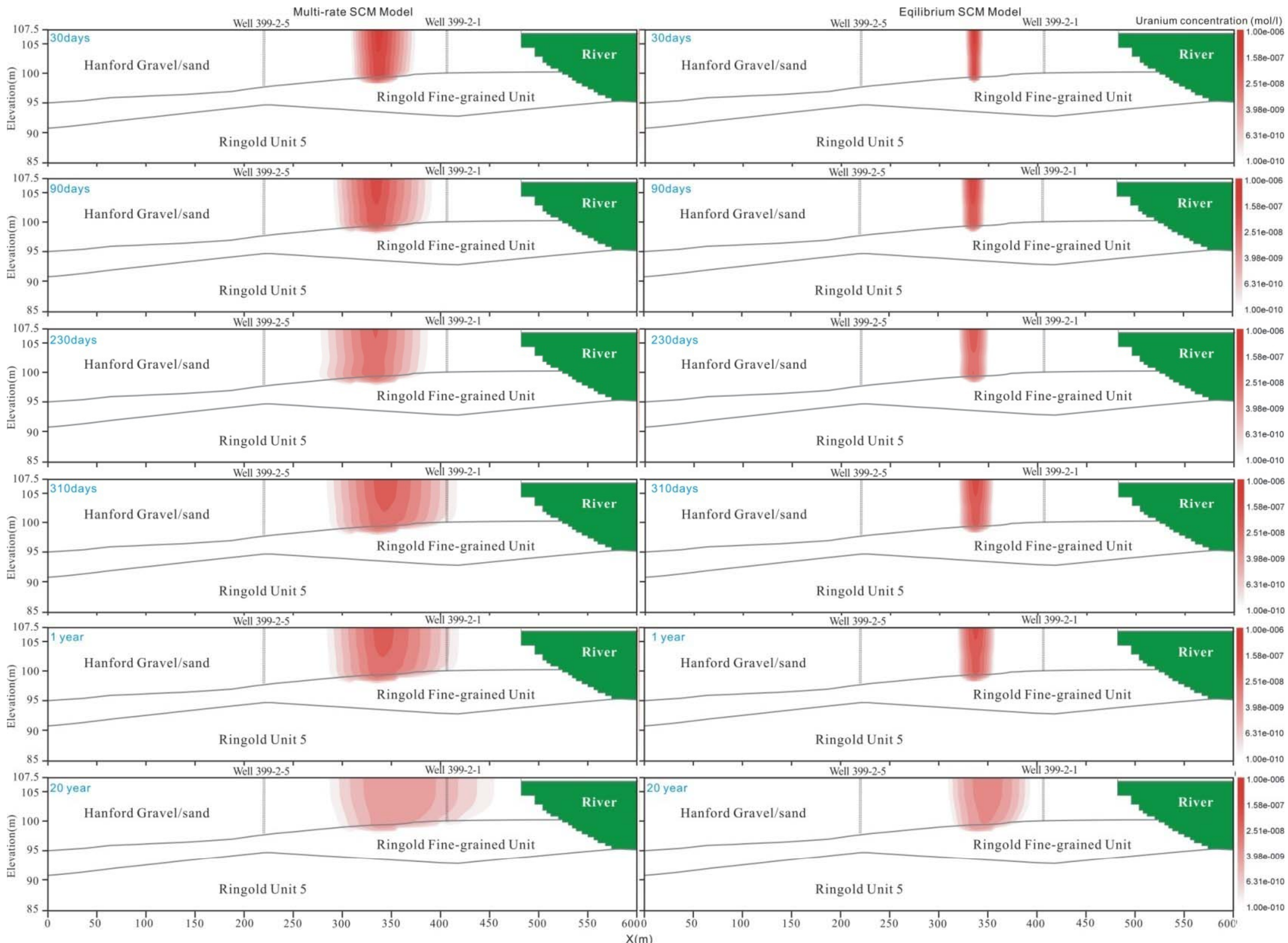
Concept for Passive Groundwater Experiments



Uranium Injection Plumes Simulated with Two Models



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Important Progress

- State of the art well field and monitoring system installed and tested
- Extensive hydrologic testing completed that has modified the site hydrologic model
- Significant progress made toward the site 3-D geostatistical model ("Characterization Plan")
  - Laboratory chemical, physical, and electrical measurements
  - Surface, downhole and cross-hole geophysical measurements
  - Inversion modeling and geostatistical analysis
- Modeling Plan nearly completed
  - Data collection sequences
  - Sequential modeling goals
  - Roles and responsibilities
- High quality samples obtained for microbiologic characterization that have shown surprising results
- Established collaborative strategy and experiments with PNNL SFA
- Ready for the experimental program to begin in March

Challenges and Opportunities

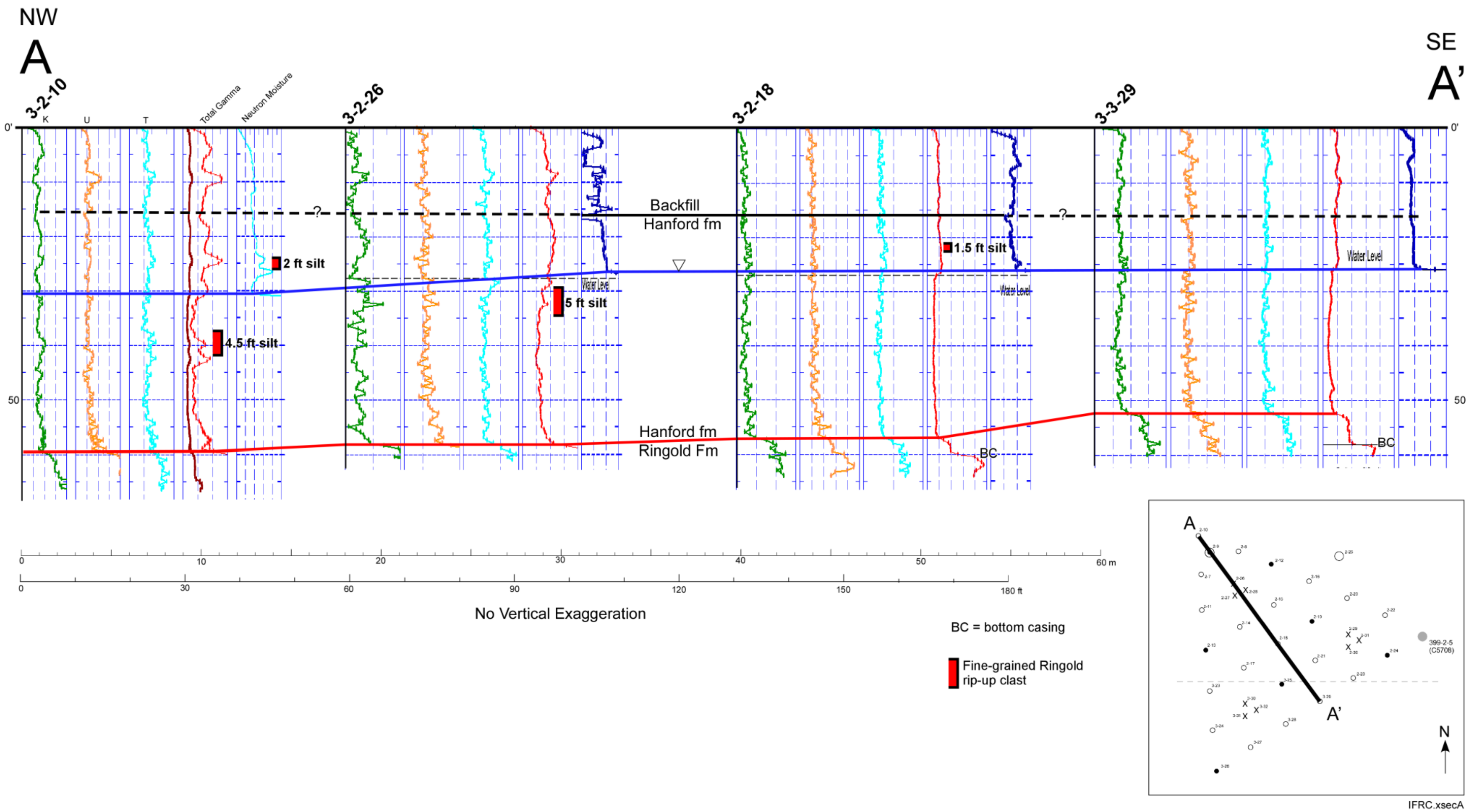
- Challenges
  - Experimental planning for maximum scientific and programmatic impact given system hydrologic complexities
  - Vertical resolution of solute breakthrough in the IFRC well-field
  - Maximizing the contribution of the modeling team
  - Meaningful collaborations with EM

- Opportunities
  - Original mass transfer hypothesis holds with qualification
  - Site is a "gold-mine" for coupled process, "upscaling“, and systems-level research
  - Site infrastructure will support many experiment types, has sophisticated attributes
  - Unique field laboratory for study of contaminant migration and microbiology of the groundwater-river interaction zone

Linkage to Site Remediation and Closure

- Operational model for infusion of DOE fundamental science into the closure mission
  - In-ground contaminant status and behavior
  - Understanding of processes and complexities of specific sites
  - Evaluation and testing of new models and measurement techniques
  - Knowledge to reduce uncertainty
  - Websites updated every 6 mo. to include new findings and publications
- 300 A site is representative of Hanford River Corridor locations
  - Applicability of conceptual and numeric models to other locations
- Scientific context for evaluation of remediation strategies and concepts
  - Critical characterization needs
  - MNA versus active approaches
  - Expectations for long-term remediation efficiency

IFRC Well-Field Cross Section



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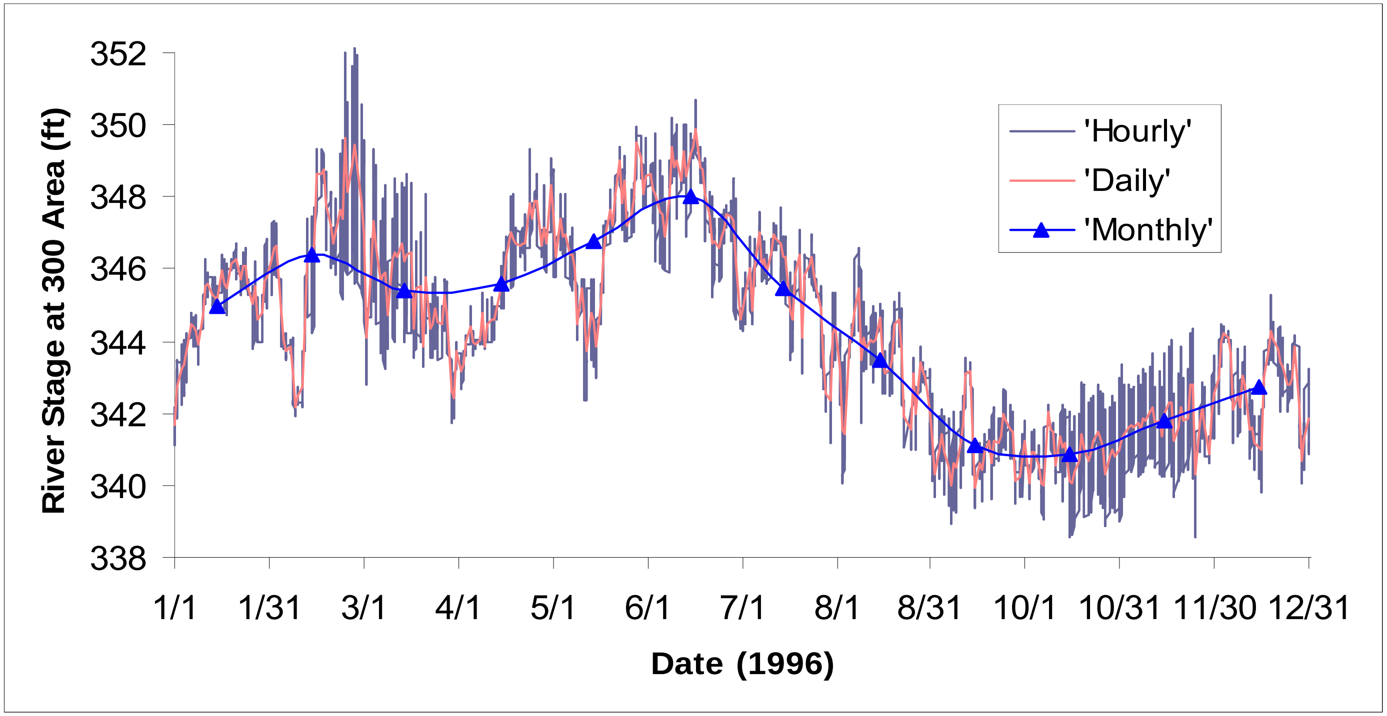
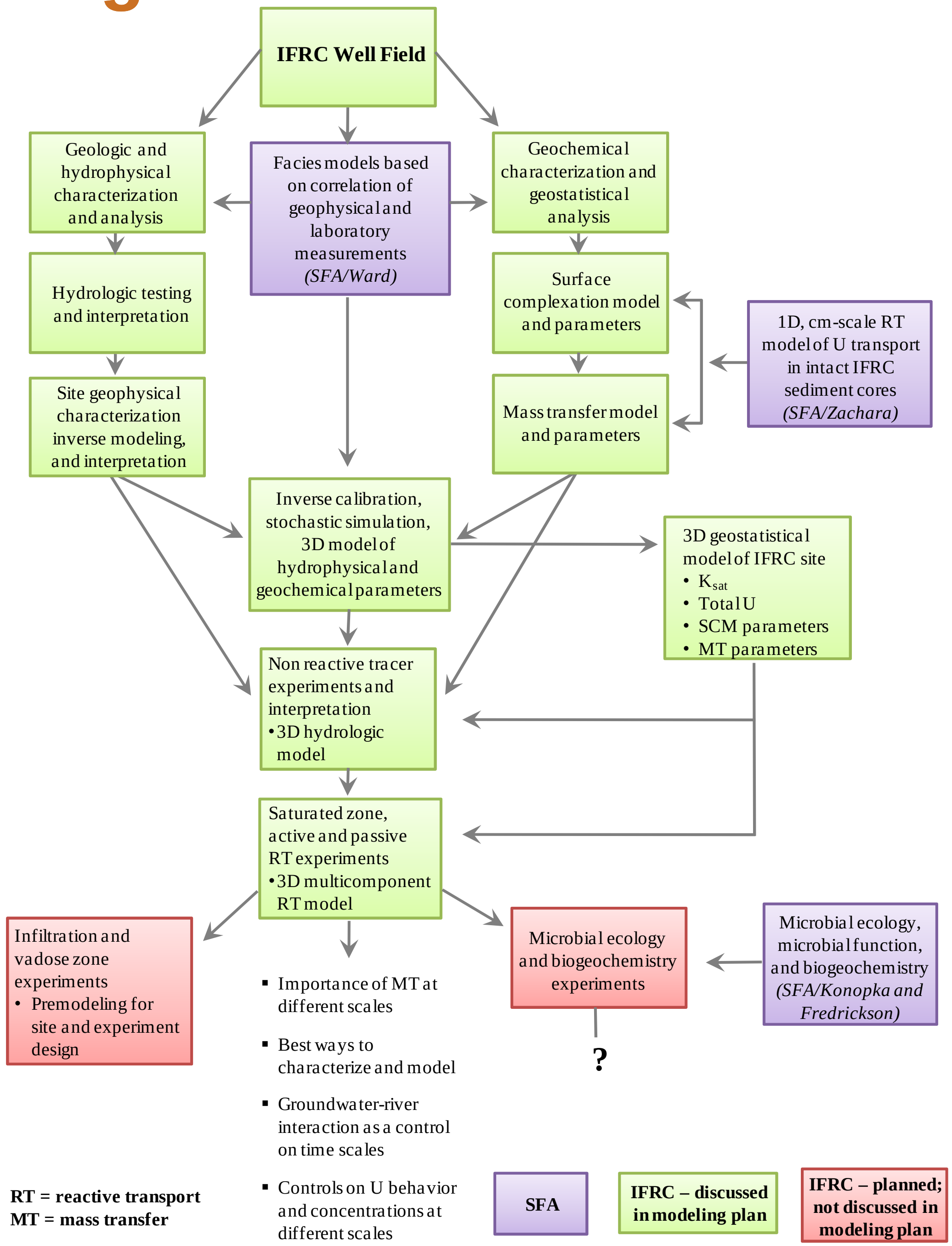
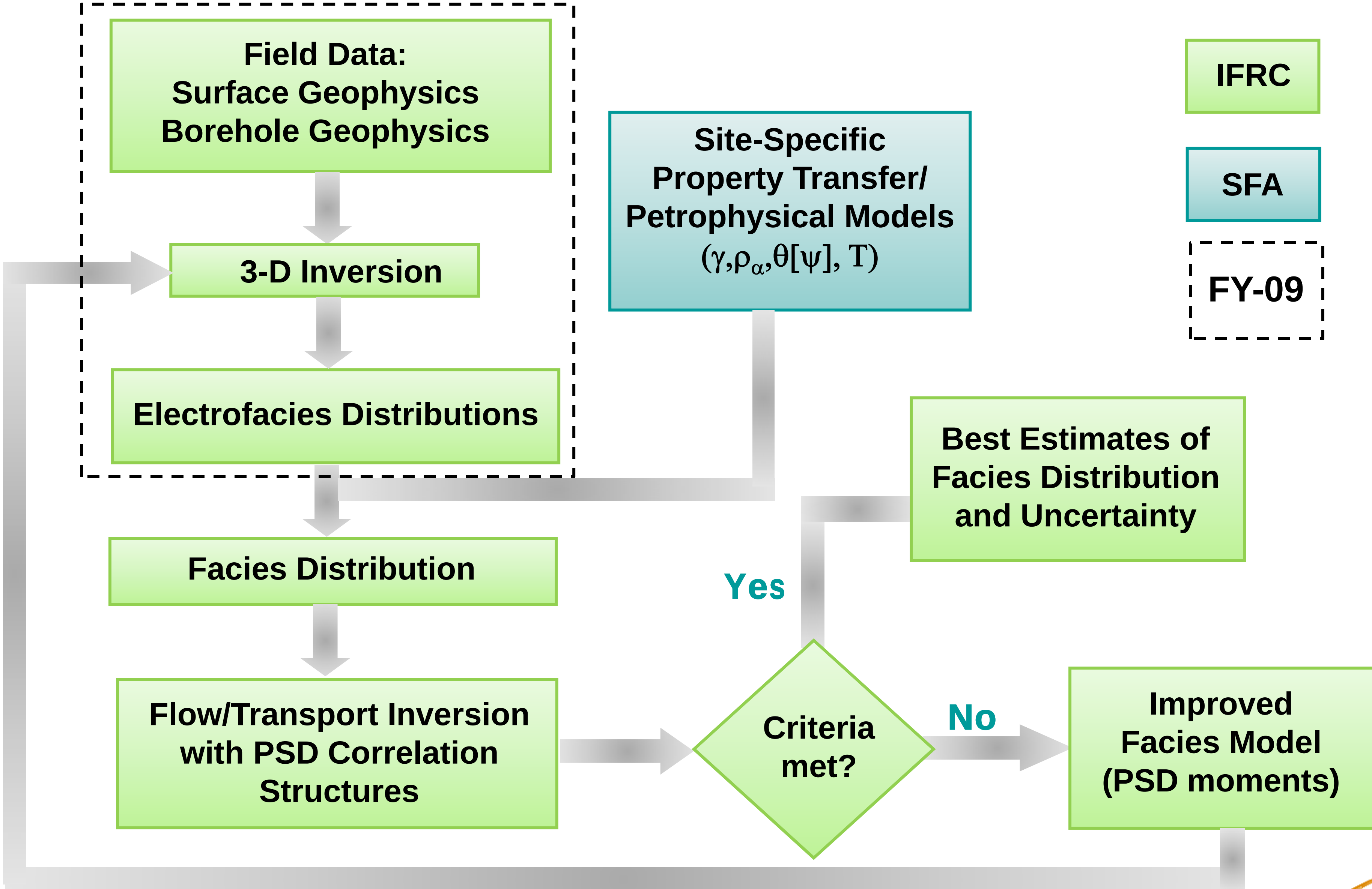
Hourly, Daily Average, and Monthly Average River Stage at the 300 Area in 1996



IFRC Modeling and Parameterization Workflow



Geo-/Petro- Physics Workflow



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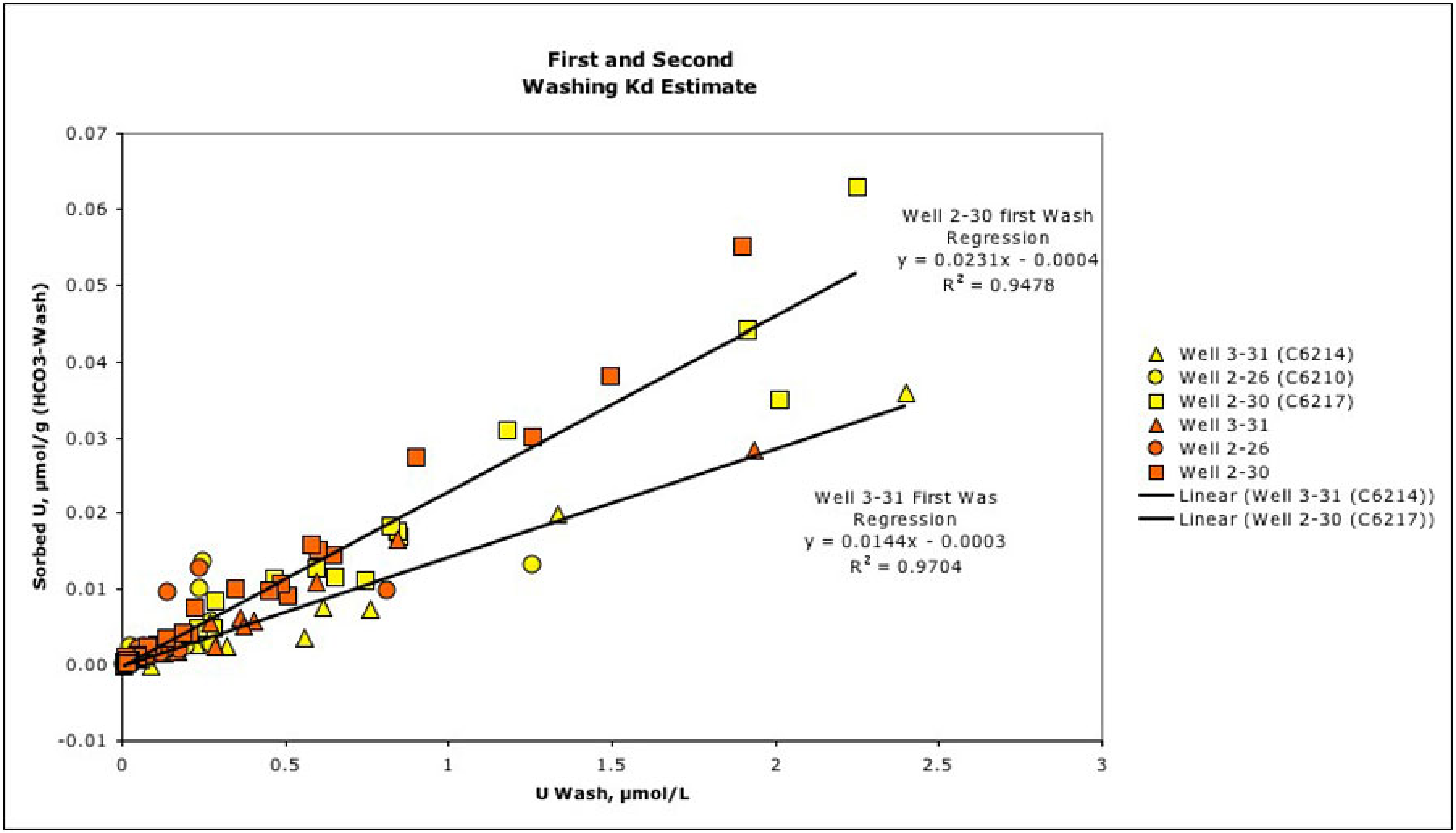
Distribution Coefficients for Well Sediemts



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