INTEGRATED FIELD RESEARCH CHALLENGE SITE
Hanford 300 Area

U.S. Department of Energy Office of Science
Environmental Remediation Sciences Program

River Induced Wellbore Flow Dynamics in Hanford IFRC Monitoring Wells: Evidence, Implications, and Mitigation

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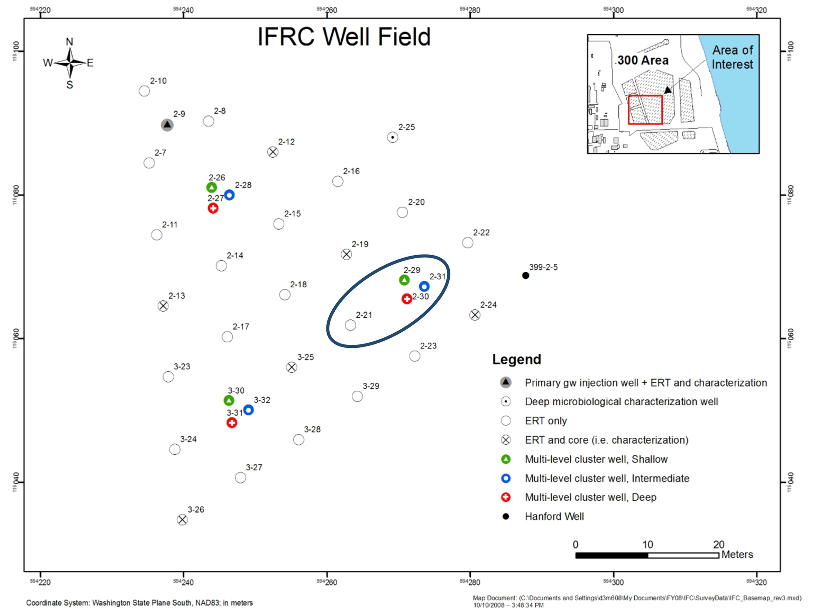
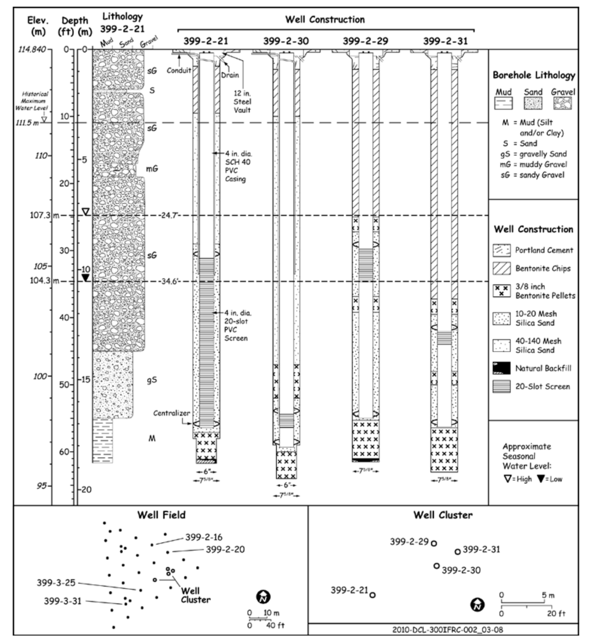
Background: Hanford's IFRC Site was established in summer 2008 in the 300 Area just North of Richland, Washington, The southeast most multi-level well cluster and adjacent fully-screened well were used in this study. Simultaneous measurements of wellbore flow, water-level elevation (well and river), and aqueous uranium concentration were monitored over a 1 month period during spring/summer high water conditions in 2009. This study demonstrates the utility of continuous (i.e., hourly measurements for ~ one month) ambient wellbore flow monitoring and shows that relatively large wellbore flows (up to 4 LPM) can be induced by aquifer hydrodynamics associated with a fluctuating river boundary located approximately 250 m from the test well. The observed vertical wellbore flows were strongly correlated with fluctuations in river stage, alternating between upward and downward flow throughout the monitoring period in response to changes in river stage.

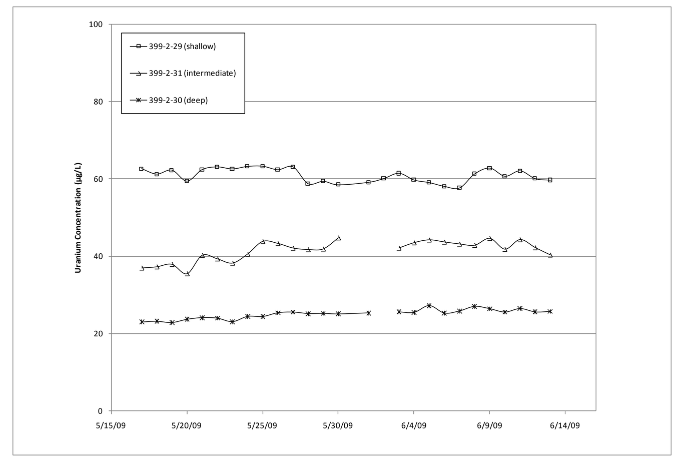
Motivation: Evidence for river induced wellbore flow in long-screen wells, and their impact on aqueous sampling results, have been observed in Hanford IFRC monitoring wells during both active and passive field-scale experiments. The objective of this study was to characterize the observed wellbore flows and their relationship to a nearby dynamic river boundary, assess the implications of wellbore flow on sampled aqueous concentrations, and evaluate an approach for mitigating these impacts.



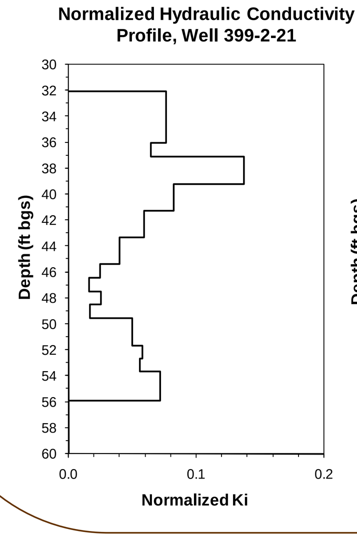


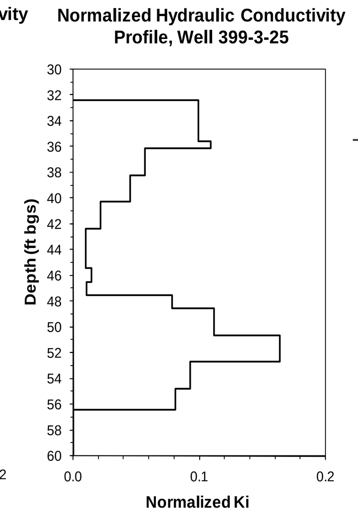
Characterization of Study Area

- See **Poster 5** for discussion of IFRC geohydrologic characterization
  - Test interval contained within the high permeability sediments of the Hanford formation (K = 4,600 – 11,000 m/d)
  - EBF and tracer transport response data indicate K over central third of aquifer is much lower than the top and bottom thirds
    - Thickness and contact depth of this low K material varies across the site, but general distribution relatively consistent
    - Study area EBF profiles fit this conceptual model
  - A source of contaminant U is present in the deep vadose zone and zone of water table fluctuation - decreasing U concentration with depth in aquifer

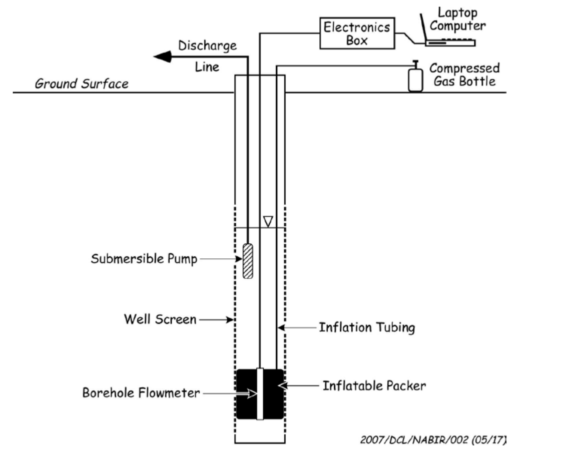


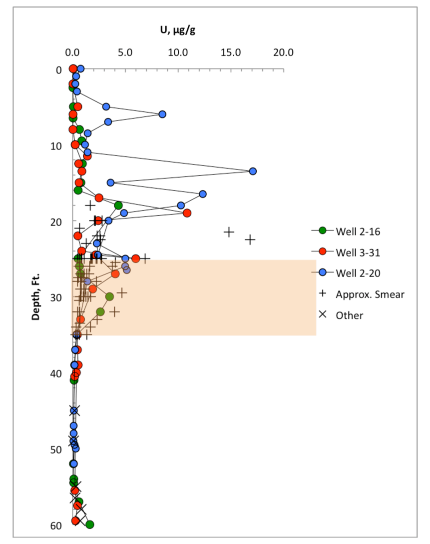
Depth discrete aqueous U concentrations during study period





EBF system and testing schematic

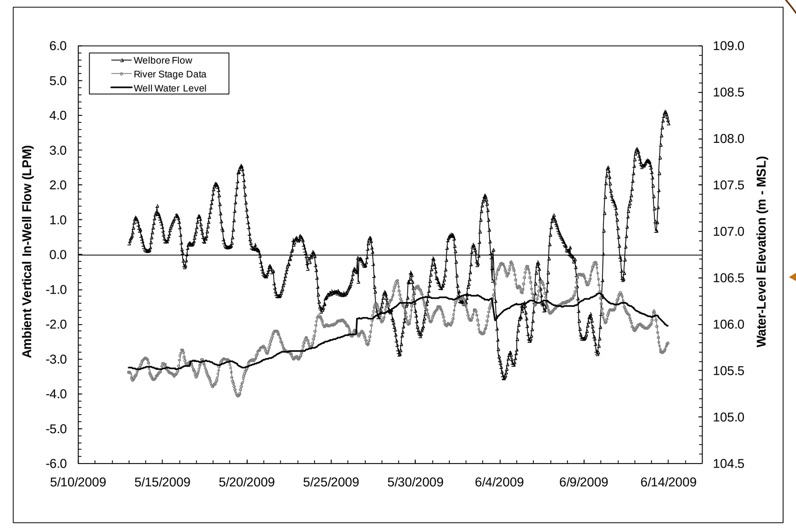




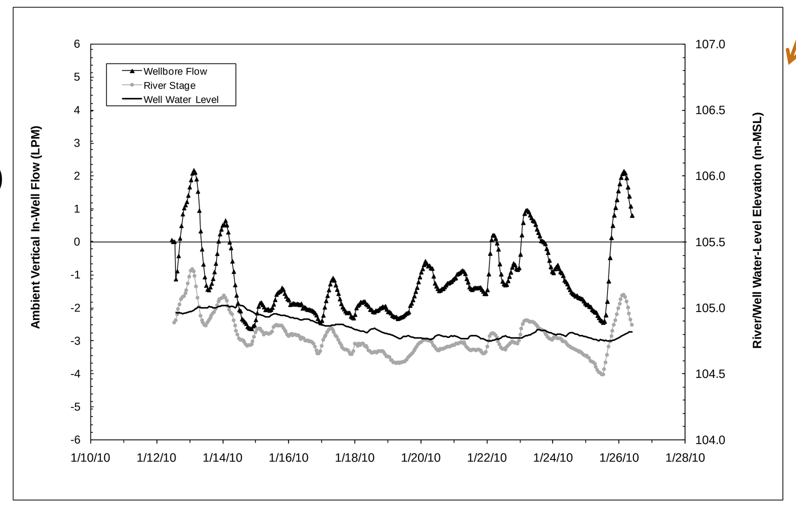
Core sample U profile

Wellbore Flow Measurements

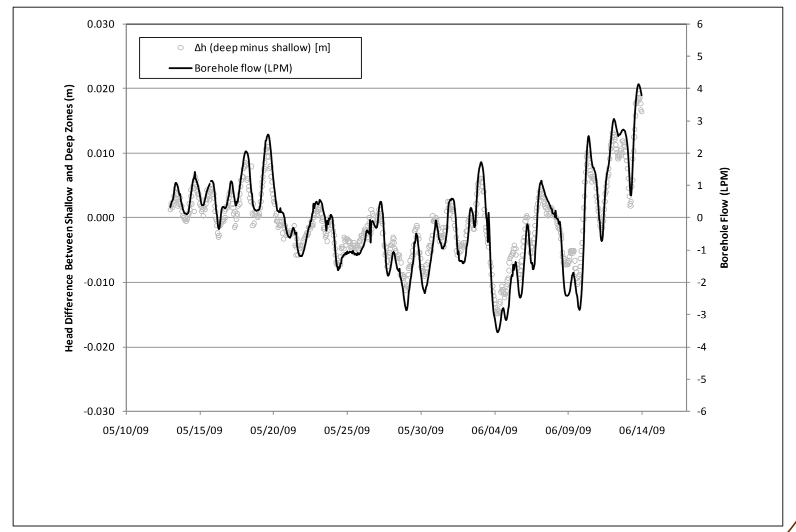
- Ambient wellbore flows were monitored in Well 399-2-21 and plotted along with well water-level and Columbia River stage elevations
  - Positive flow values indicate upward flow
  - Wellbore flows are inversely correlated with river stage at this location



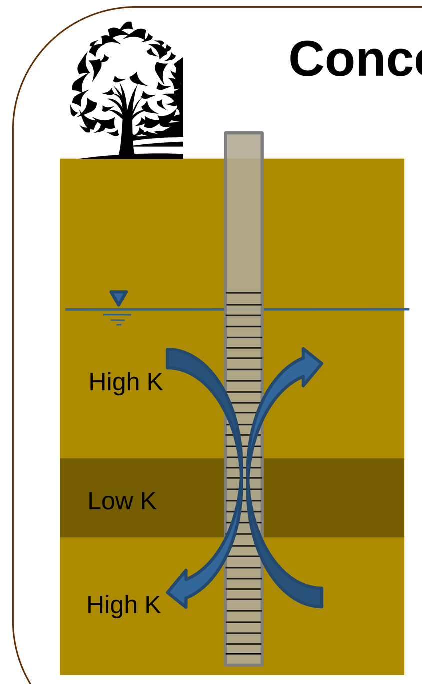
- Example of a well that is directly correlated (399-2-10)



- Water-level elevations in the adjacent multi-level well cluster were used to calculate head differences between the upper and lower high K zones, which were plotted along with wellbore flow (399-2-21)
  - As expected, Δh and flow are highly correlated
  - Δh of ~2 cm resulted in wellbore flow of ~ 4 LPM



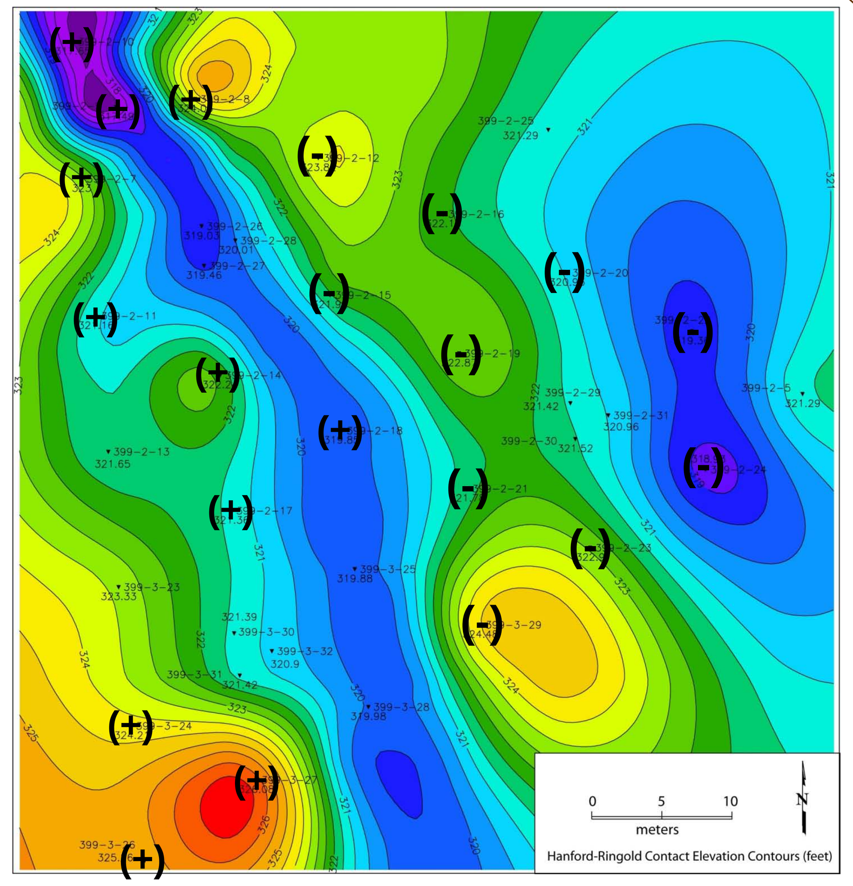
Conceptual Model



- Wellbore flow in long-screen wells at the IFRC site is related to:
  - Geohydrologic conditions – upper and lower high K zones separated by lower K zone
  - River hydrodynamics
  - Well construction – long-screen wells allow intercommunication between high K zones
  - Differing degrees of connectivity between the upper and lower high K zones and the river, resulting in head differences that drive flows upward or downward
- Temporally variable – fluctuating river boundary
- Spatially variable – can be used to infer river connectivity and geologic structure between wellfield and river (see Spatial Distribution panel)
- See **Poster 10** for a discussion of wellbore flow modeling efforts

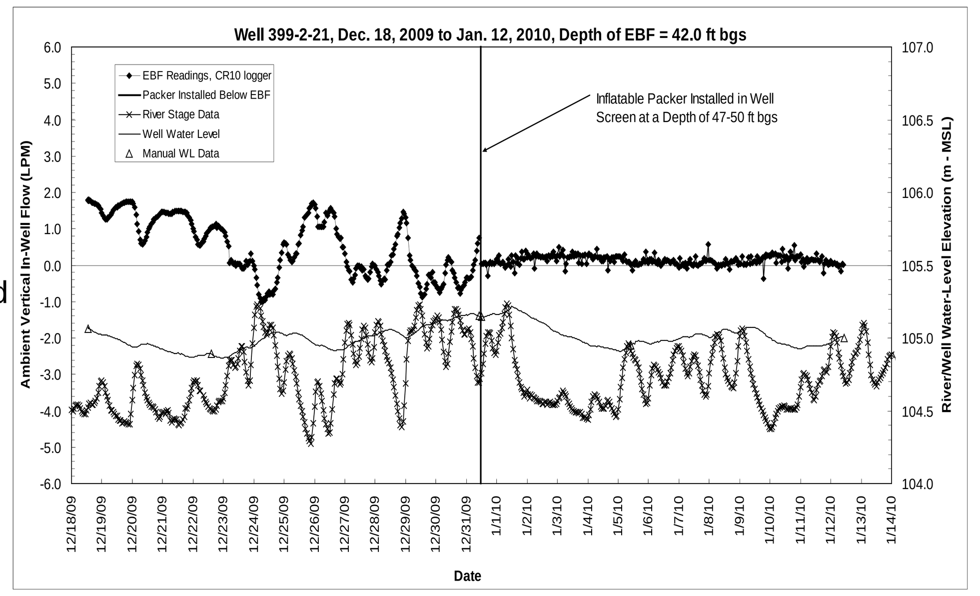
Spatial Distribution of Wellbore Flow

- Ambient wellbore flows measured at multiple locations across the IFRC site
  - Both direct and inverse correlations observed
  - (-) Inverse correlation indicated
  - (+) Direct correlation indicated
- Generally consistent with spatial distribution of observed concentration variability during U desorption experiment (see implications panel)
- Manuscript submitted to *GWMR* postulating one plausible CM for observed spatial variability is associated with geologic controls and their impact on hydraulic connection to the river
  - Western wells – lower zone predominantly connected to river through paleochannel
  - Eastern wells – lower zone less connected due to a high in the H/R contact (not shown)



Mitigation

- Mitigation approach tested
  - Install inflatable packer to increase hydraulic resistance within wellbore
  - Minimize intercommunication between upper and lower high K zones
  - Wellbore flows were effectively reduced by approximately 80%
  - Efforts are ongoing to identify the best approach for cost effectively mitigating wellbore flow effects in Hanford IFRC fully screened wells

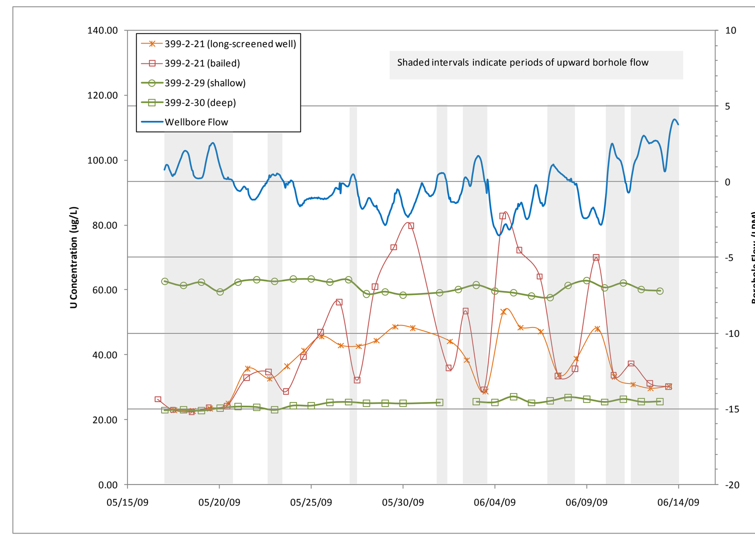


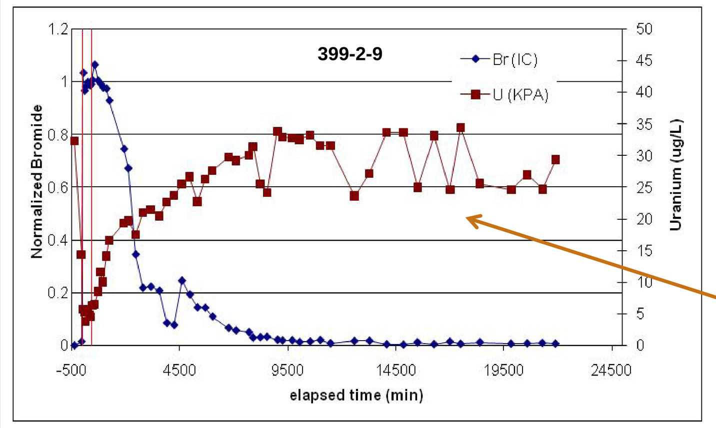
Conclusions

- Continuous EBF monitoring can be used to effectively identify and quantify wellbore flow dynamics
- Relatively large wellbore flows (up to 4 LPM) can result from a fluctuating river boundary located approximately 250 m from the test well, even for wells with relatively short (7.6 m) well screens
- River-induced wellbore flows can result in significant temporal variability in measured groundwater concentrations in long-screen wells and thus impact aqueous sampling results
- Increasing hydraulic resistance within the wellbore by installing an inflatable packer can act to reduce vertical wellbore flows and their impact on aqueous sampling results
- Spatial variability in wellbore flow response may provide some insight into local-scale geologic controls that influence hydraulic connectivity with the river
- Observed wellbore flows and their impact on measure aqueous concentrations in long-screen wells may have significant implications of the 300 Area groundwater monitoring program
  - Current plume delineations are based on semiannual (and in select cases quarterly) monitoring
  - Higher frequency variability in U concentrations may bias interpretation of monitoring results
  - Peak U concentrations would tend to be biased low during periods of upward wellbore flow because measured concentrations would be dominated by lower concentration waters from deeper in the aquifer

Implications

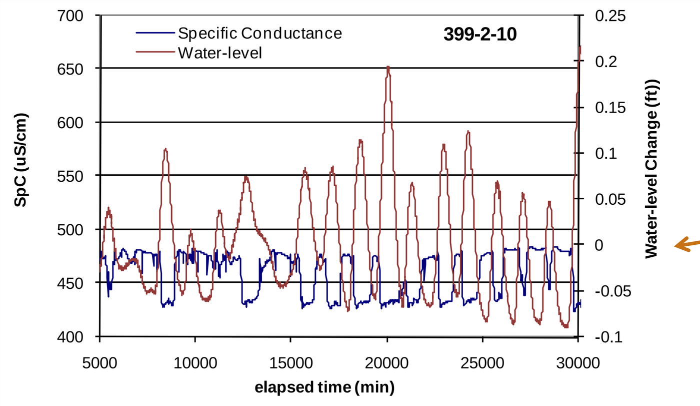
- Direct measurement of wellbore flows and their impact on aqueous U concentrations during passive U desorption experiment
  - See **Poster 7** for experiment details
  - Decreases in U concentration associated with periods of upward wellbore flow
  - Magnitude of variability observed in long-screen well consistent with depth discrete concentrations





- Indirect evidence of wellbore flow based on observed aqueous concentrations during active U desorption experiment (no wellbore flow measurements available)

Late-time variability in U concentrations most likely associated with wellbore flow and difference in groundwater U concentration with depth



Late-time increases in SpC likely associated with transport of slower moving Br tracer through the upper zone

Water-level drop results in downward wellbore flow and associated increase in SpC

Water-level change computed as WL minus average WL over previous 10 hr period

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