Water-Quality Issues Related to Uranium In Situ Recovery Sites

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Geological Society of America
Denver, Colorado • September 25–28, 2016

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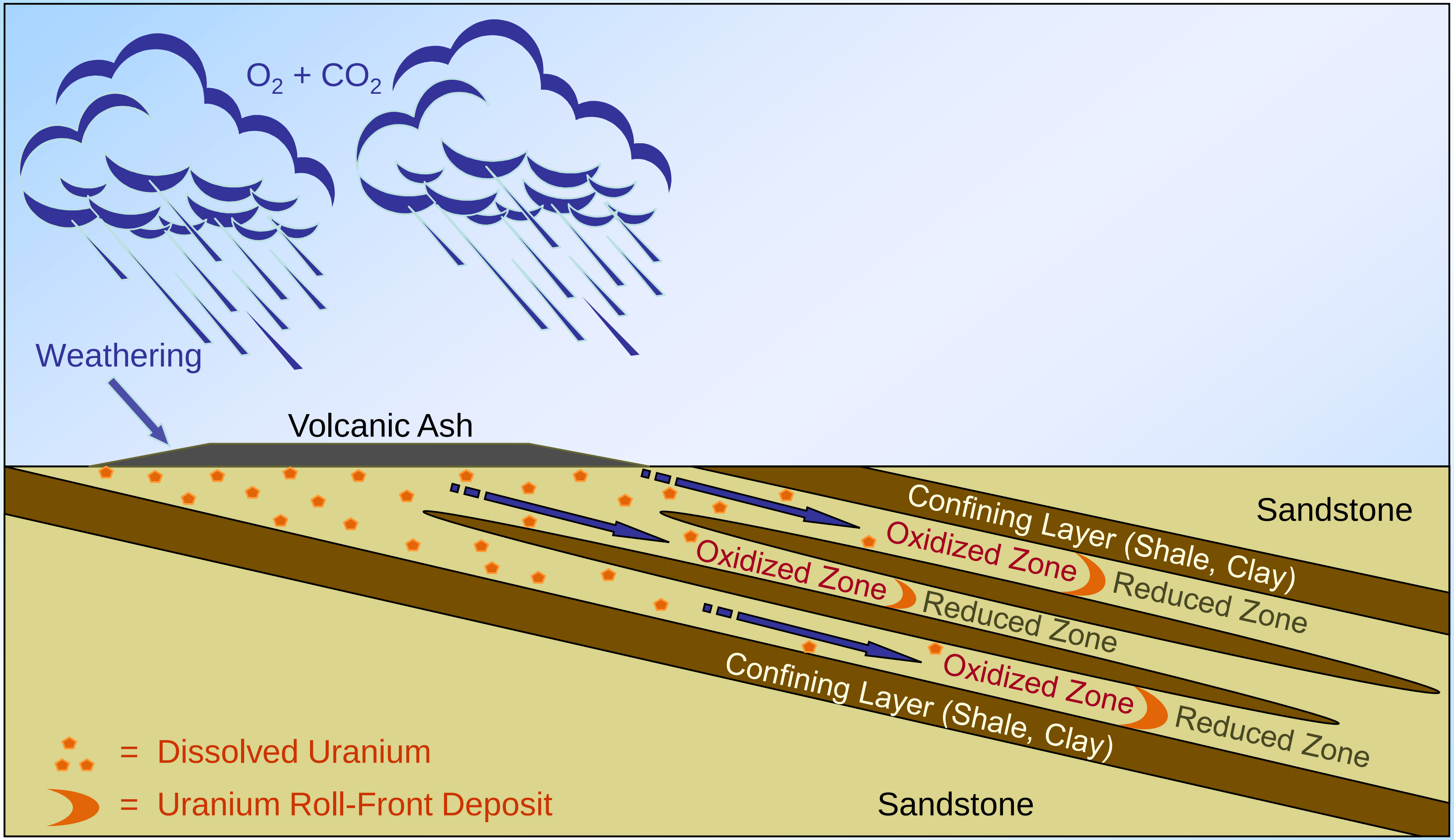
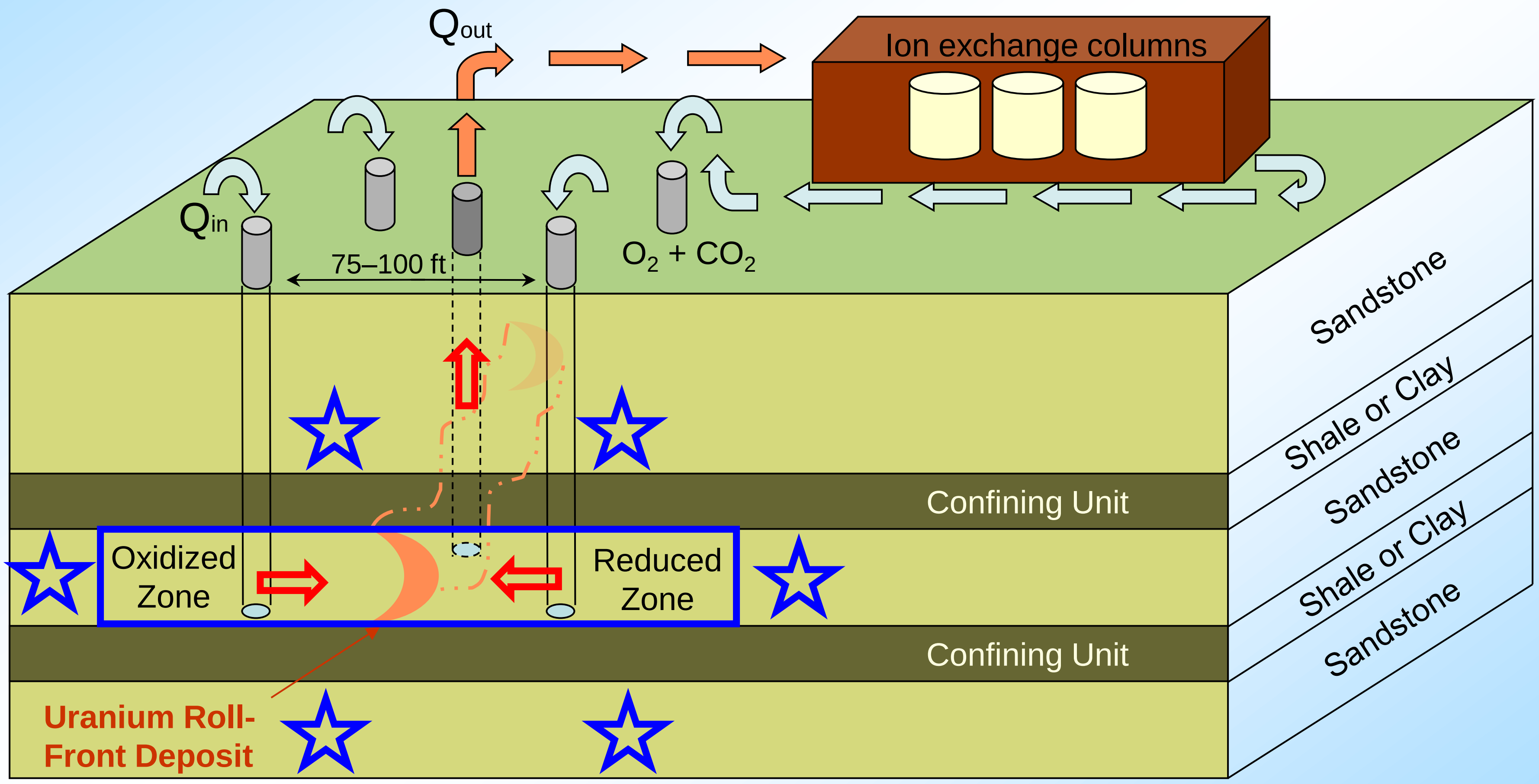
Uranium Roll Front: Formation

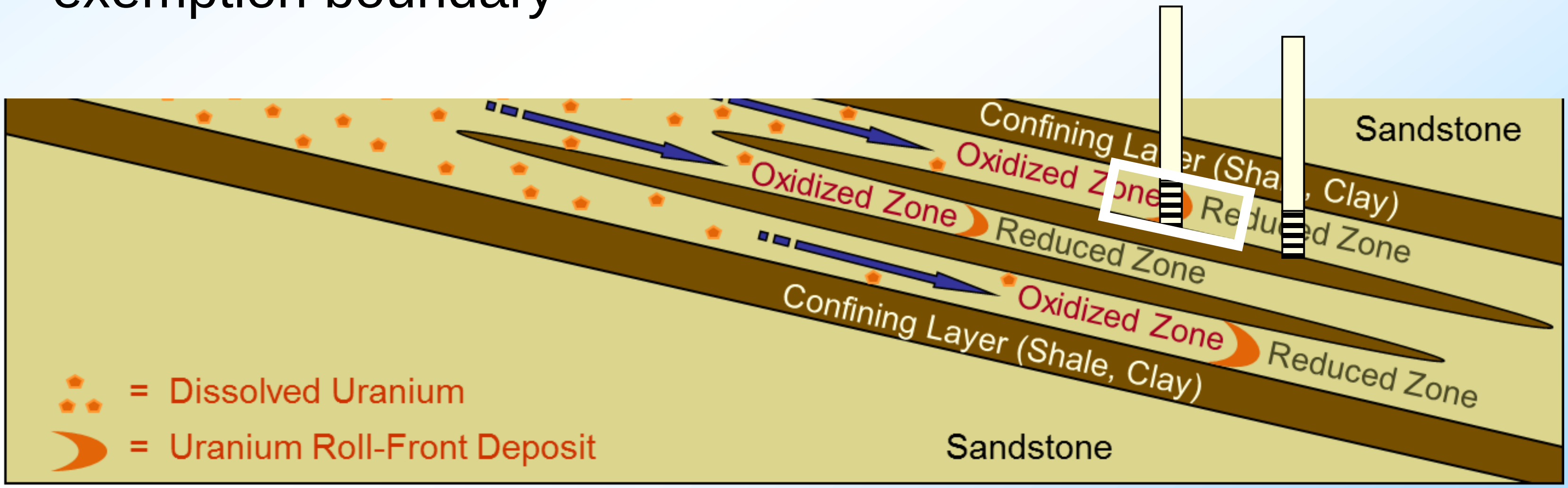


In Situ Recovery (ISR) Process



Groundwater Quality Issues

- Aquifer outside of the ISR zone could be used for:
  - Agricultural irrigation
  - Livestock water
  - Drinking water
- U.S. Environmental Protection Agency (EPA) requirement: No change in groundwater quality outside of the aquifer exemption boundary



Groundwater Quality Issues: Reality

- Restoration to full, pre-ISR water quality is difficult because:
  - The ISR process has significantly altered the solid phase
  - Aquifer heterogeneities limit restoration efficiency
- Past ISR closures
  - Some went to “class-of-use”
  - Sometimes 1 year or less of monitoring
- Proposed EPA regulations
  - 3 years of monitoring in conjunction with geochemical modeling
  - 30 years of monitoring

Stakeholder Interest and EPA regulations

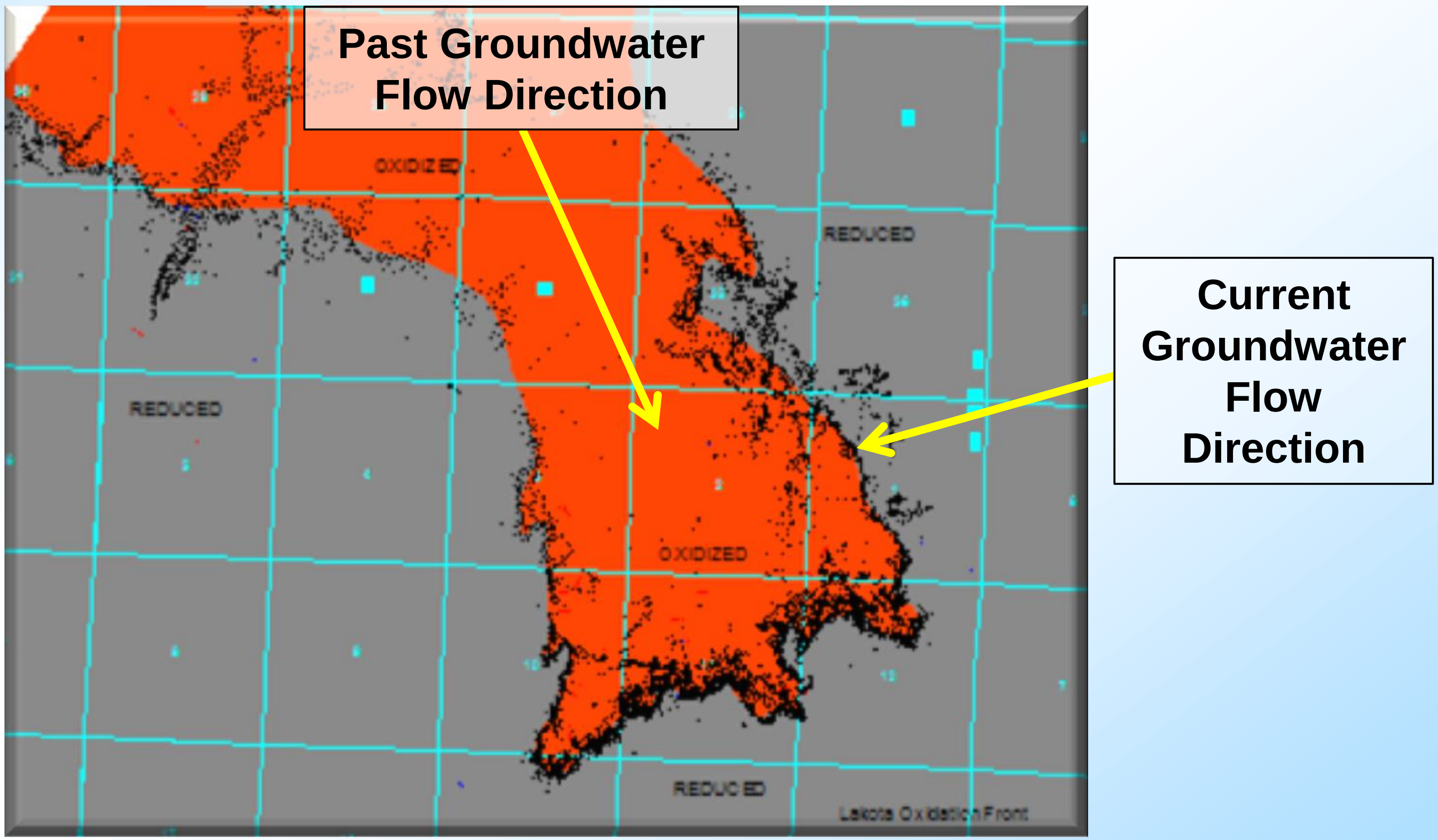
- Determine "no impact on downgradient water quality" before ISR development or closure
  - Future rock-water interaction
- Focus on downgradient water quality
  - Appropriate data collection (rock and water)
  - Applicable laboratory and field testing
  - Predictive reactive transport modeling
- Pre-ISR data
  - General site knowledge
  - Core collection
  - Batch testing
  - Column testing
  - Reactive transport modeling

Empirical Data and Parameters for Modeling

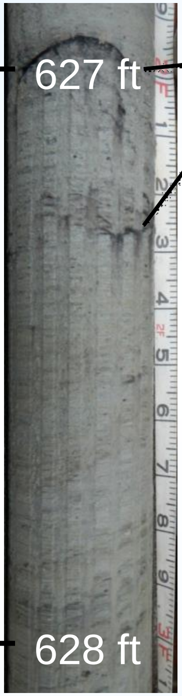
- Contaminant sorption/desorption
  - With changes in geochemistry along the groundwater-flow path due to rock-water interaction
- Contaminant precipitation/dissolution
  - With changes in geochemistry along the groundwater-flow path due to rock-water interaction
- Dual porosity mechanisms (long tailing affect)
  - Geologic layering
  - Fractured rock, or
  - Large grain size distributions

General Hydrogeology

- Geology (rock)
- Groundwater flow directions and velocity (water)



Collect Core



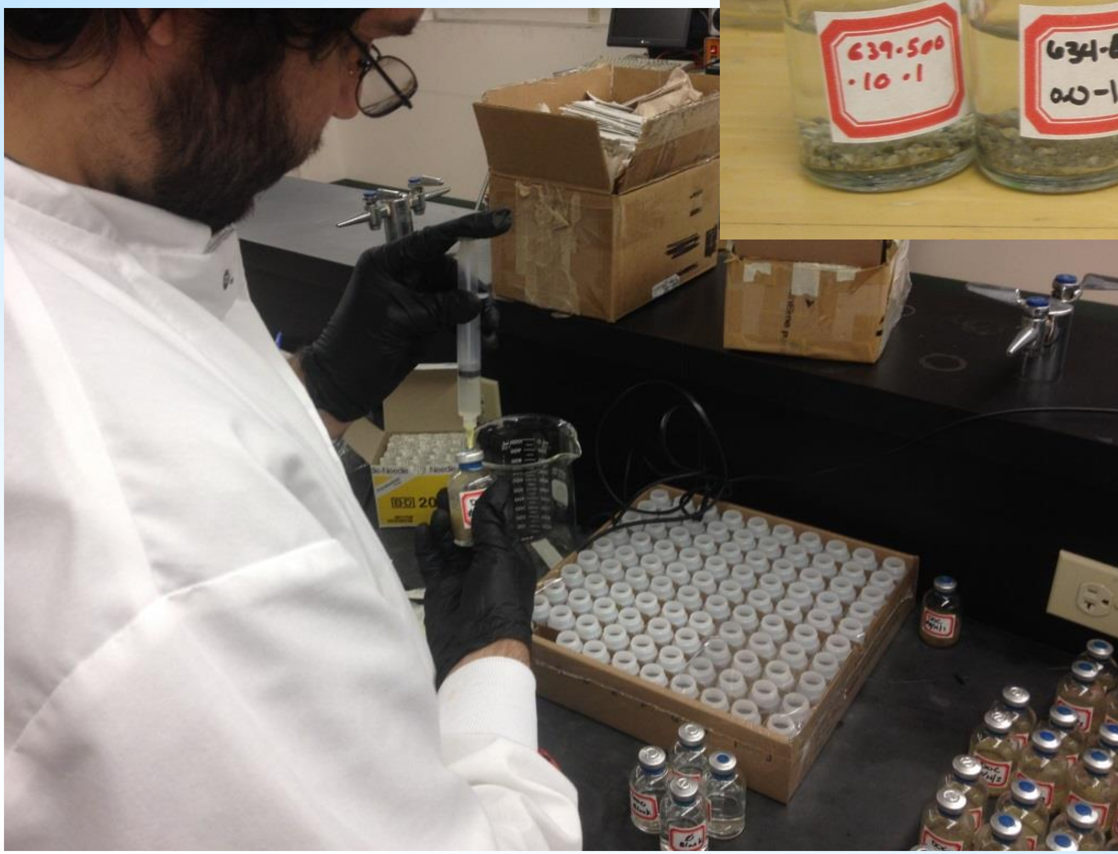
Organic bands with minor deformation

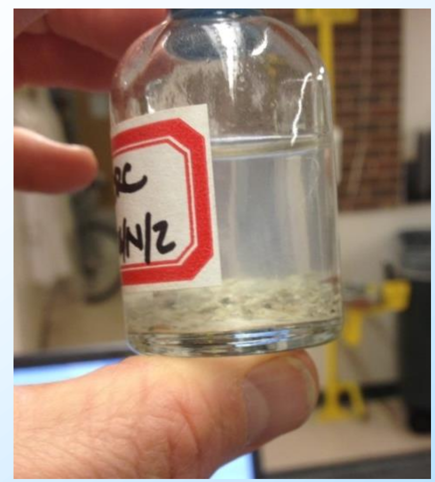
Core is mostly well-sorted, massive, medium-grained gray sandstone with localized organic zone

Characterize the mineralogy

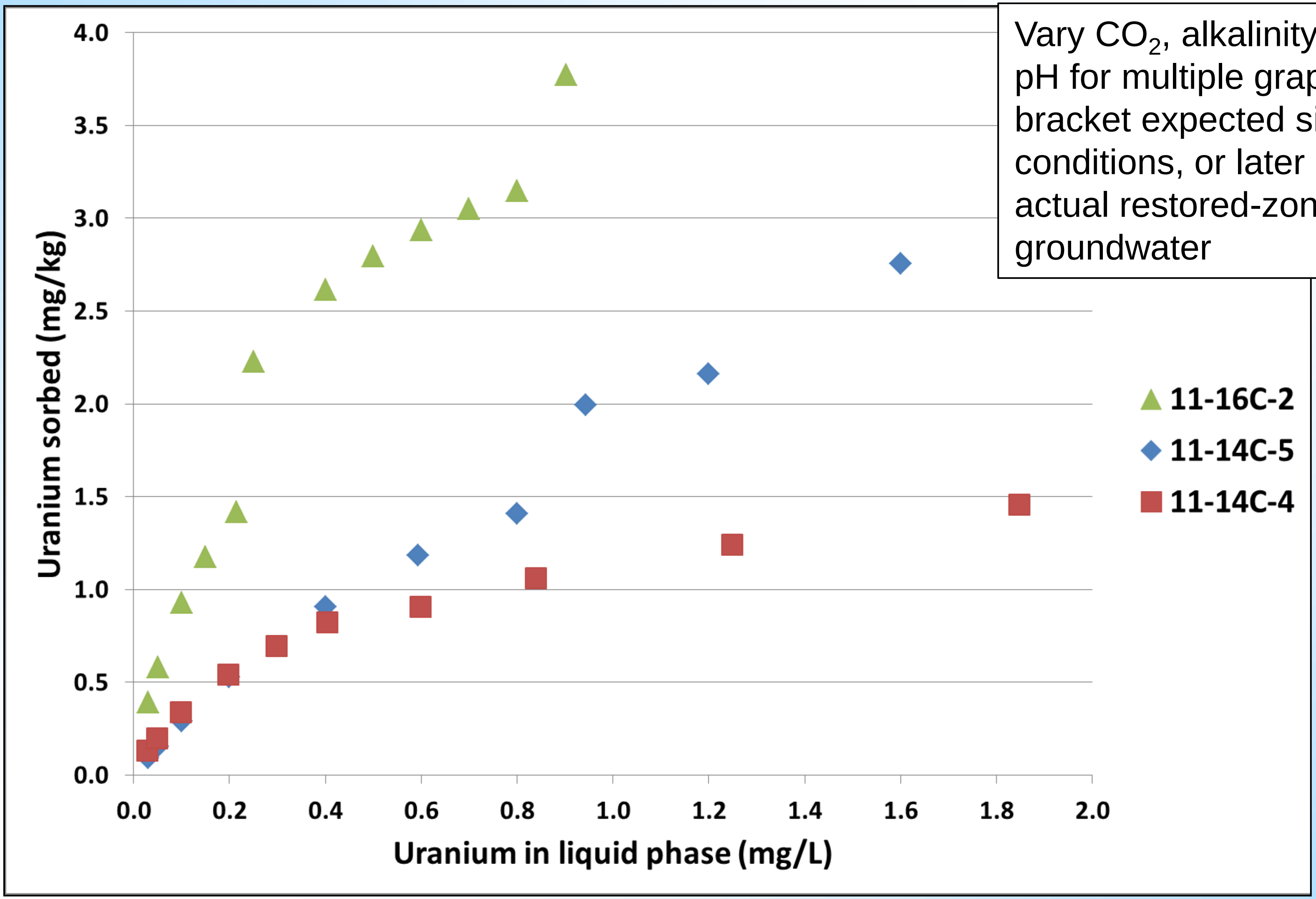
Batch Testing

Vary geochemistry to get sorption and precipitation potential



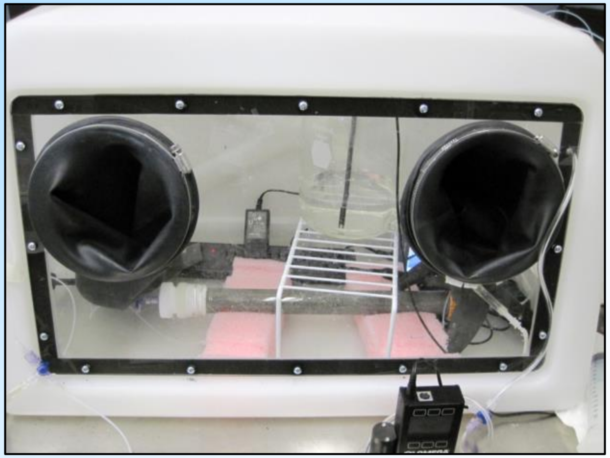


Example Batch Test Results

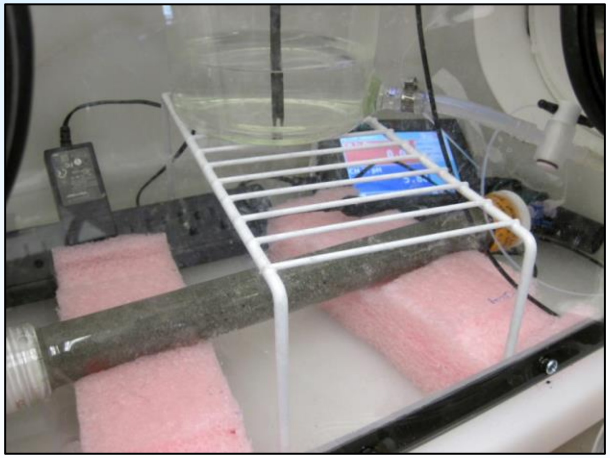


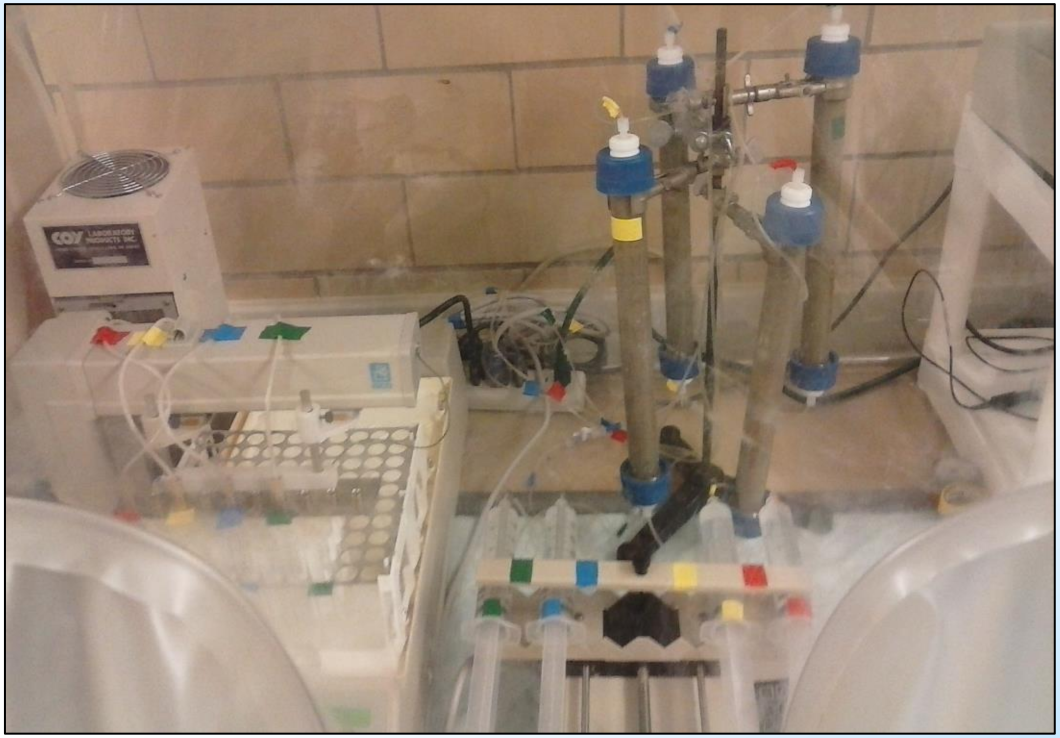
Vary CO_2, alkalinity, and pH for multiple graphs to bracket expected site conditions, or later use actual restored-zone groundwater

Column Testing



Column in a glove box at Los Alamos National Lab

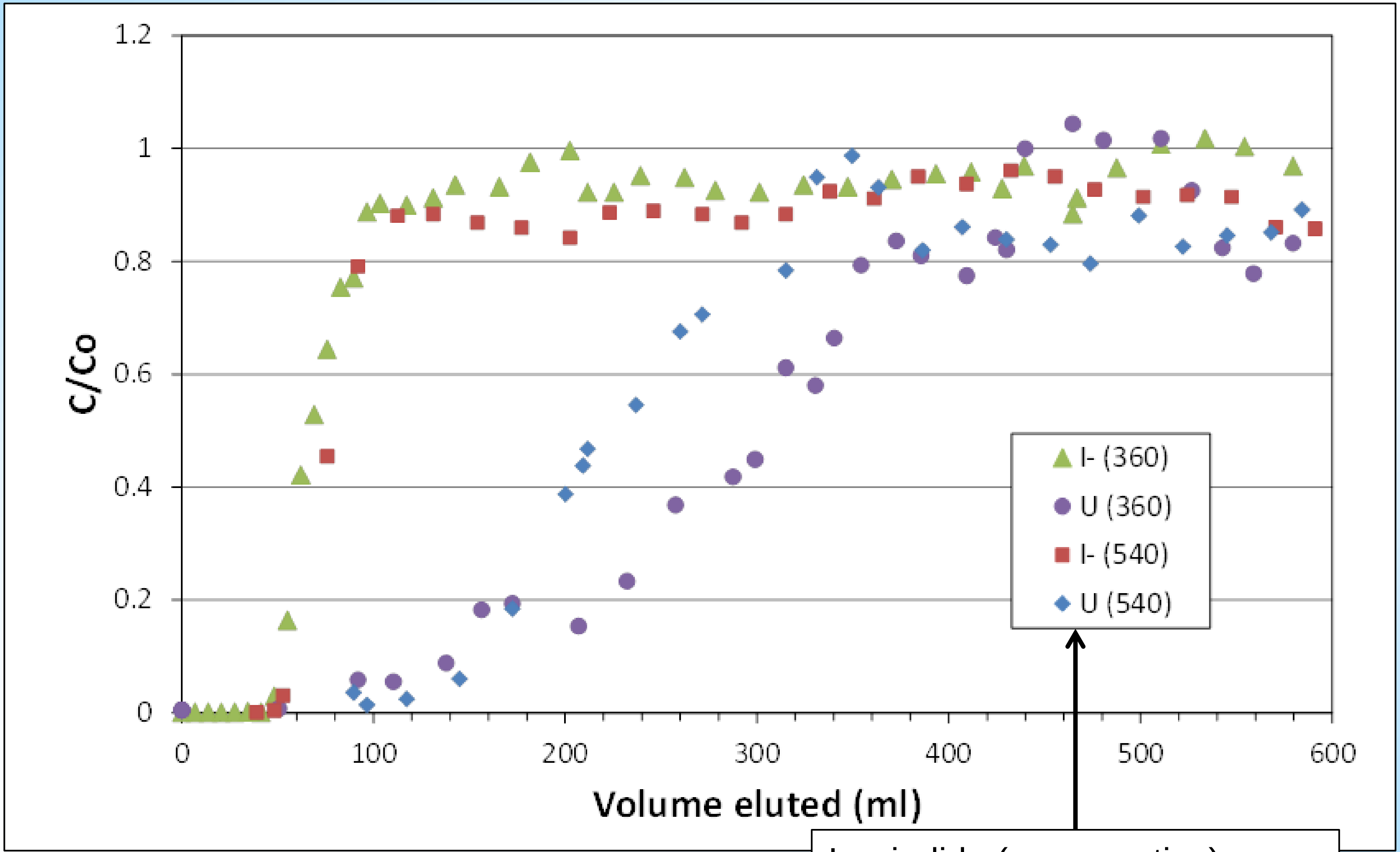




Columns in a glove box at the South Dakota School of Mines and Technology

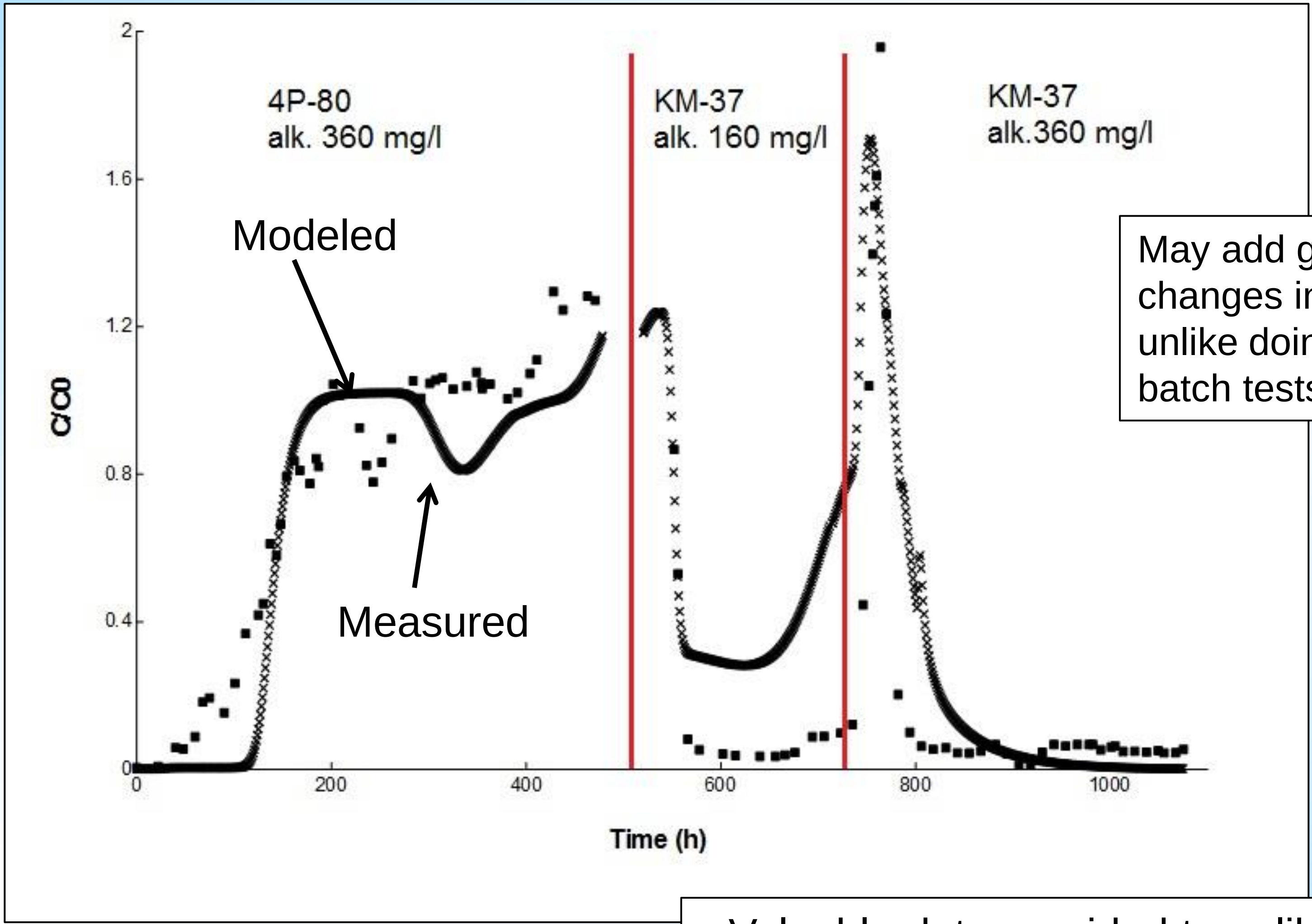
Also, vary CO_2, alkalinity, and pH to bracket expected site conditions, or later use actual restored-zone groundwater

Column Testing Example Results



I- = iodide (conservative)
U = uranium (sorptive)
Different alkalinities in mg/L

Column Testing Example Results (continued)



May add geochemical changes in one test, unlike doing separate batch tests

Valuable data provided to calibrate reactive transport models

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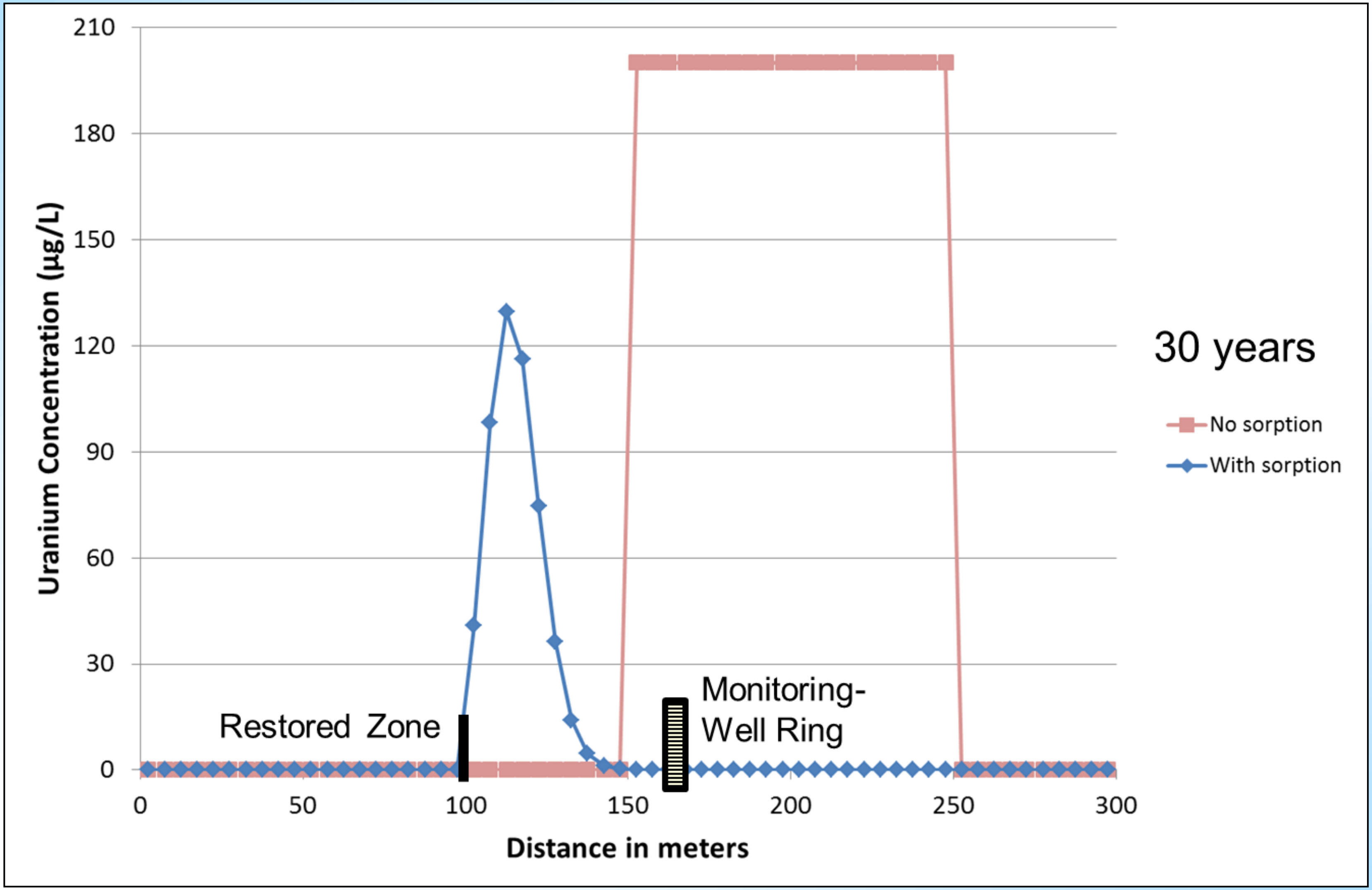
Reactive Transport Modeling

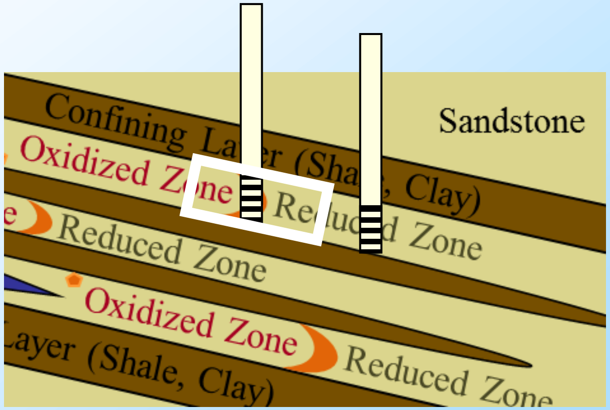


Post-Restoration Data

- Post-restoration core
- Revisit batch testing
- Revisit column testing
- Field testing
- Revisit reactive transport modeling
- Long-term monitoring data

Post-Restoration Additional Testing: Restored and Downgradient Zones

- Test restored-zone core with background groundwater to produce an evolved background groundwater (long-term groundwater from the restored zone)
- Conduct batch and column tests on the downgradient core with:
  - Unrestored groundwater (worst case)
  - Final restored groundwater (real case)
  - Evolved background groundwater (future case)
  - Background groundwater (best case)



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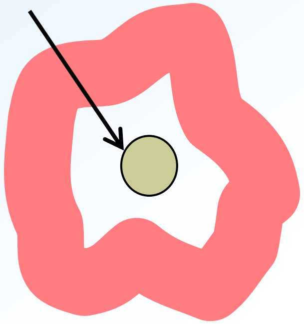
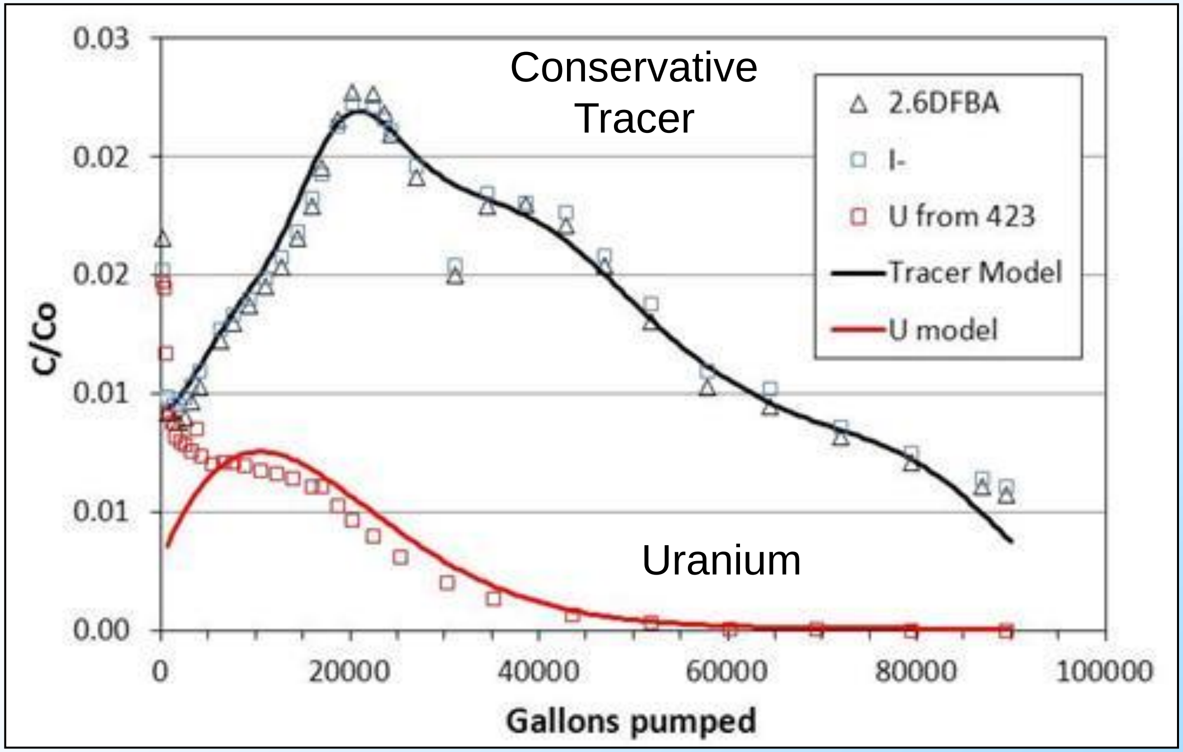
Field Pilot Tests

- Best field-scale data
- Inject and track unrestored or restored-zone water in an ore zone or downgradient zone that will be “overprinted” by future ISR



Plan View
Push-Pull Test



Conclusions

- Batch tests, column tests, and predictive reactive transport modeling can be done before ISR begins as part of the decision making/permitting process by bracketing possible post-restoration conditions
  - Help address stakeholder concerns
- The best predictions require actual restored groundwater in contact with the downgradient solid phase
- Resulting modeling provides a range of natural attenuation rates and assists with designing the best locations and time frames for continued monitoring
- Field pilot tests are the best field-scale data and can provide the best model input and calibration data