Understanding Uranium Plume Persistence Processes at a Former Uranium Mill Tailings Area Through the Use of Laboratory and Field Methods

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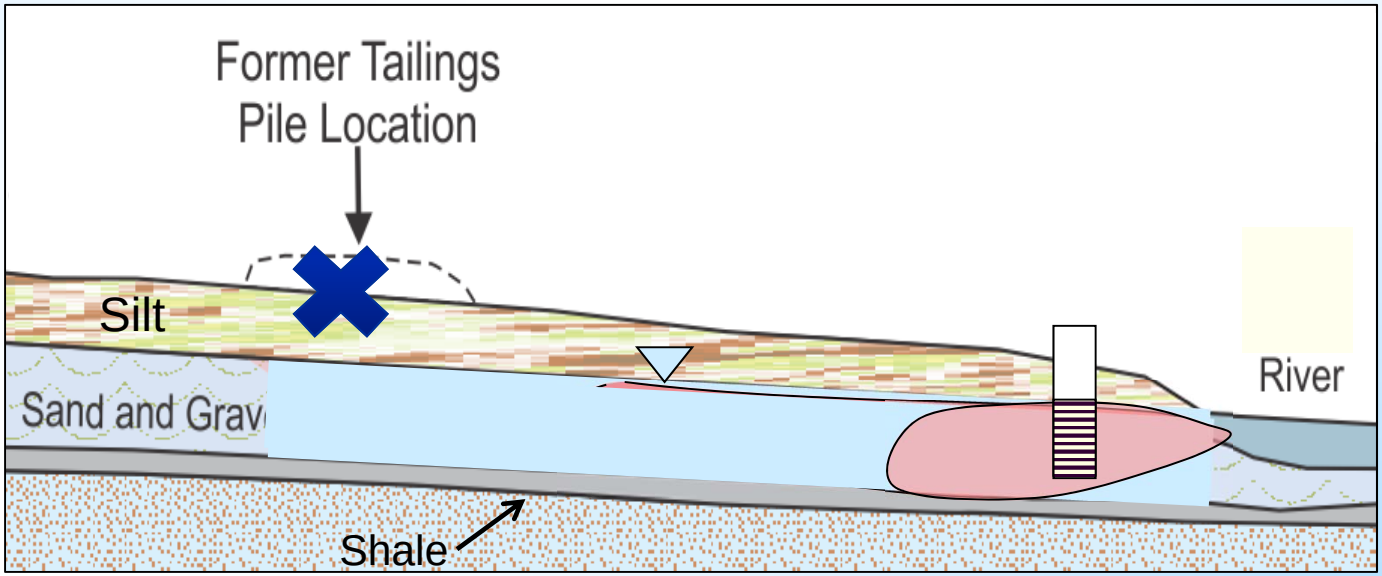
Plume Persistence

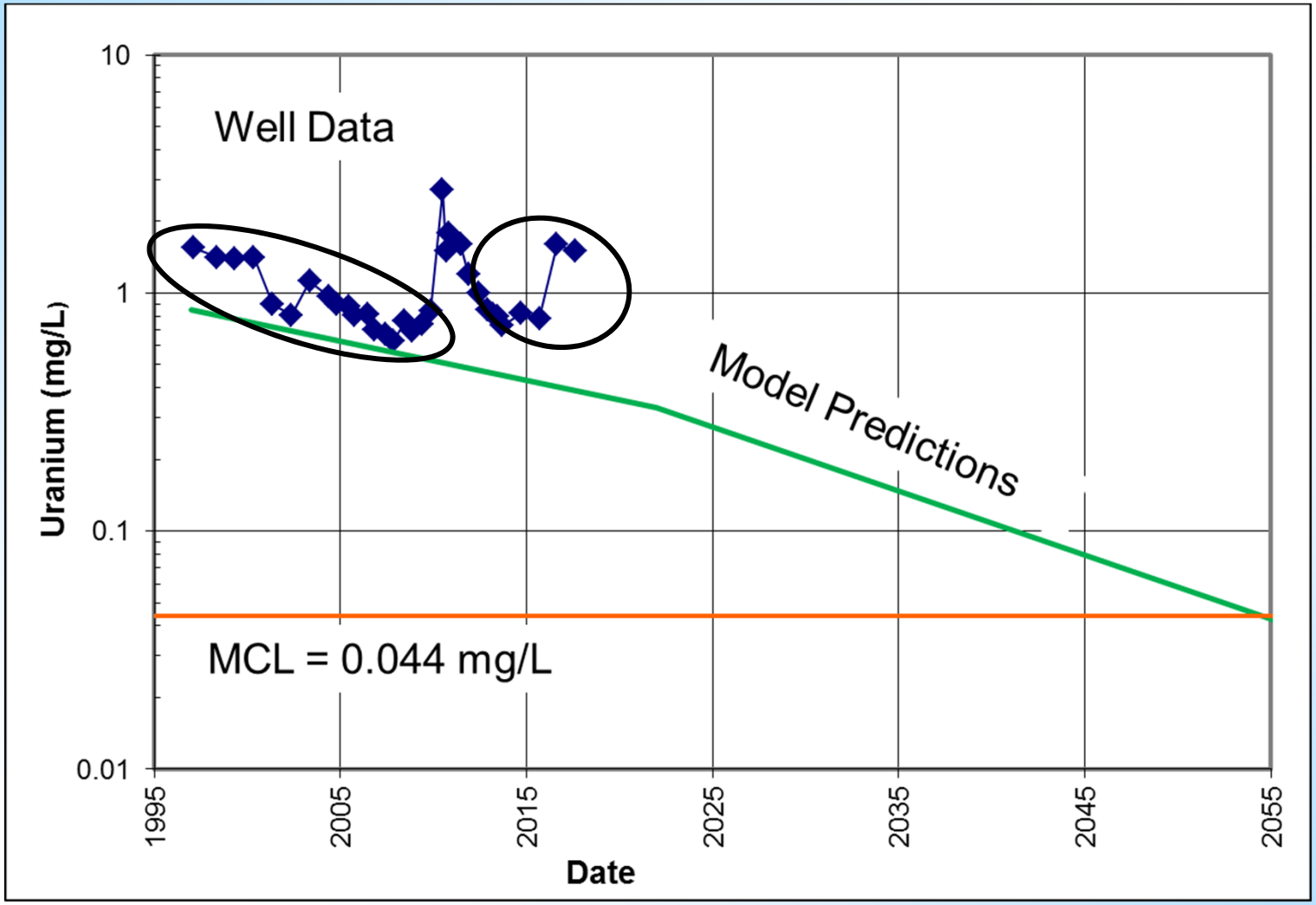
- Uranium does not degrade like organic chemicals; thus, decreasing uranium concentrations in groundwater to below standards relies on:
  - Active remediation
    - Extraction and treatment
    - Permanently fix on the solid phase
  - Natural flushing (monitored natural attenuation)
- Past decisions relied on transport modeling to provide predictions of uranium concentrations through space and time
- Plume persistence
  - Initial estimates predicted lower groundwater uranium concentrations than what are occurring

Uranium Ore-Processing Sites
Past Estimates of Natural Flushing

- Tailings have been removed, assumed source removed
- Uranium plume in alluvial sands and gravels, assumed limited attenuation – Kd approach
- Rifle, Grand Junction, and Naturita, CO; Riverton, WY; etc.



Actual Data Compared to Model Predictions



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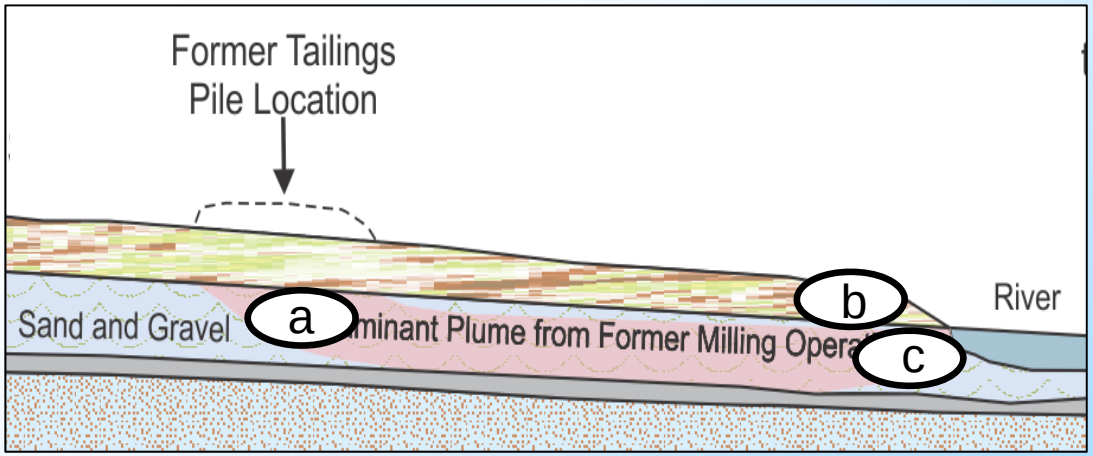
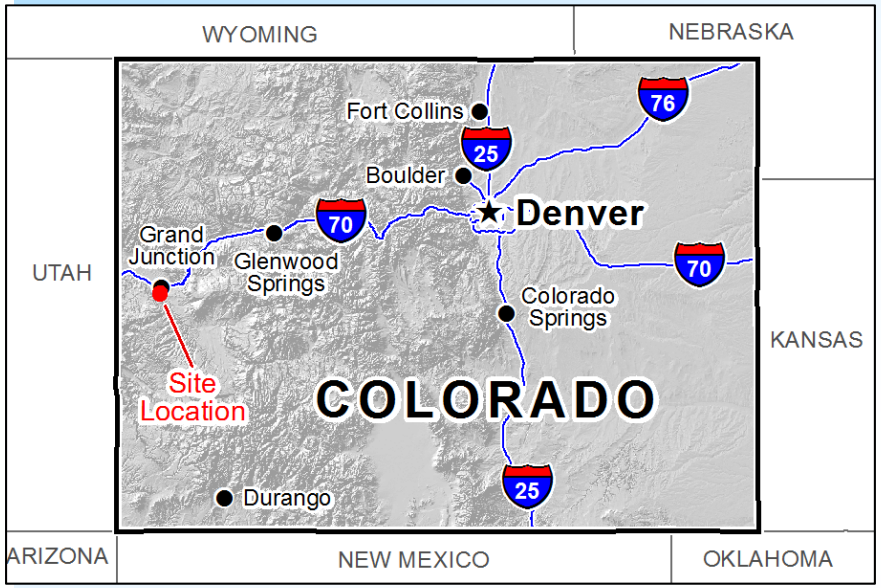
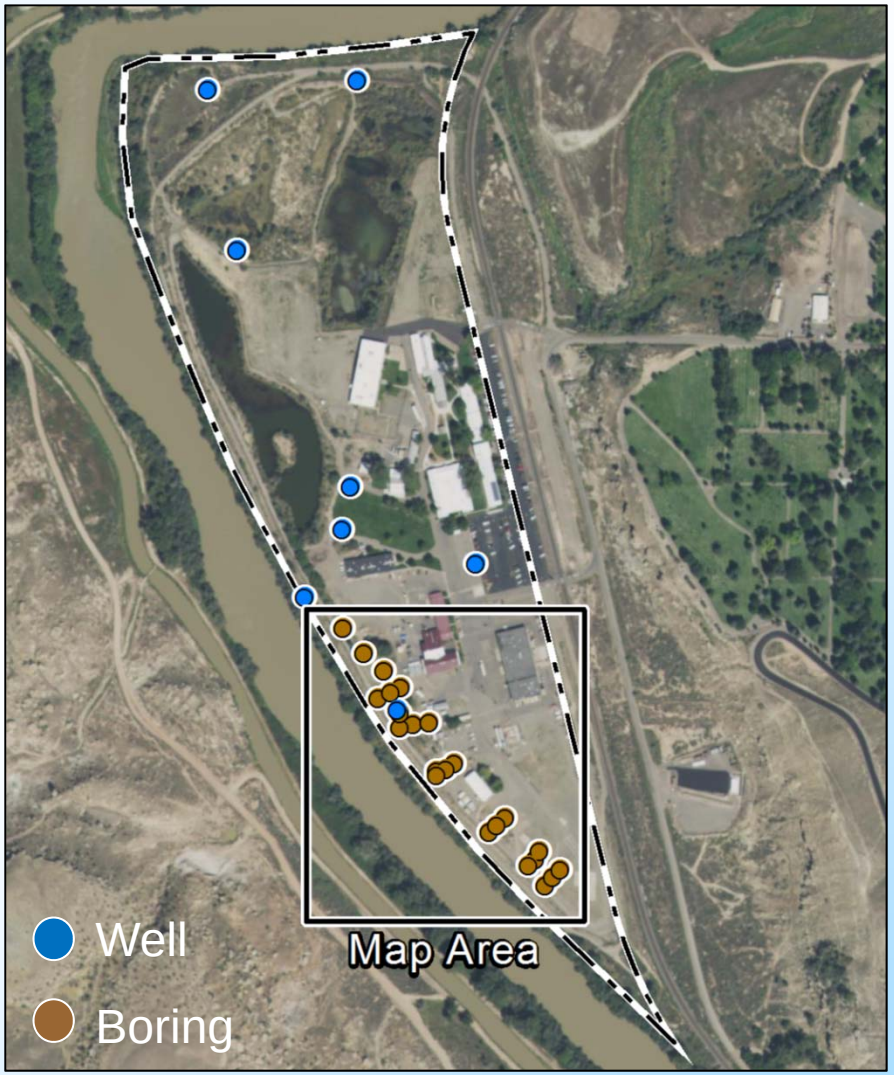
New Data (20+ Years of Hindsight)

- Natural flushing not occurring as previously modeled
  - Persistent secondary sources
- Solid-phase uranium sources not accounted for in prior modeling:
  a) Precipitates with associated uranium below the former tailings
  b) Evaporites above the water table due to plume wicking
  c) Organic zones near the river



Grand Junction, Colorado, Site



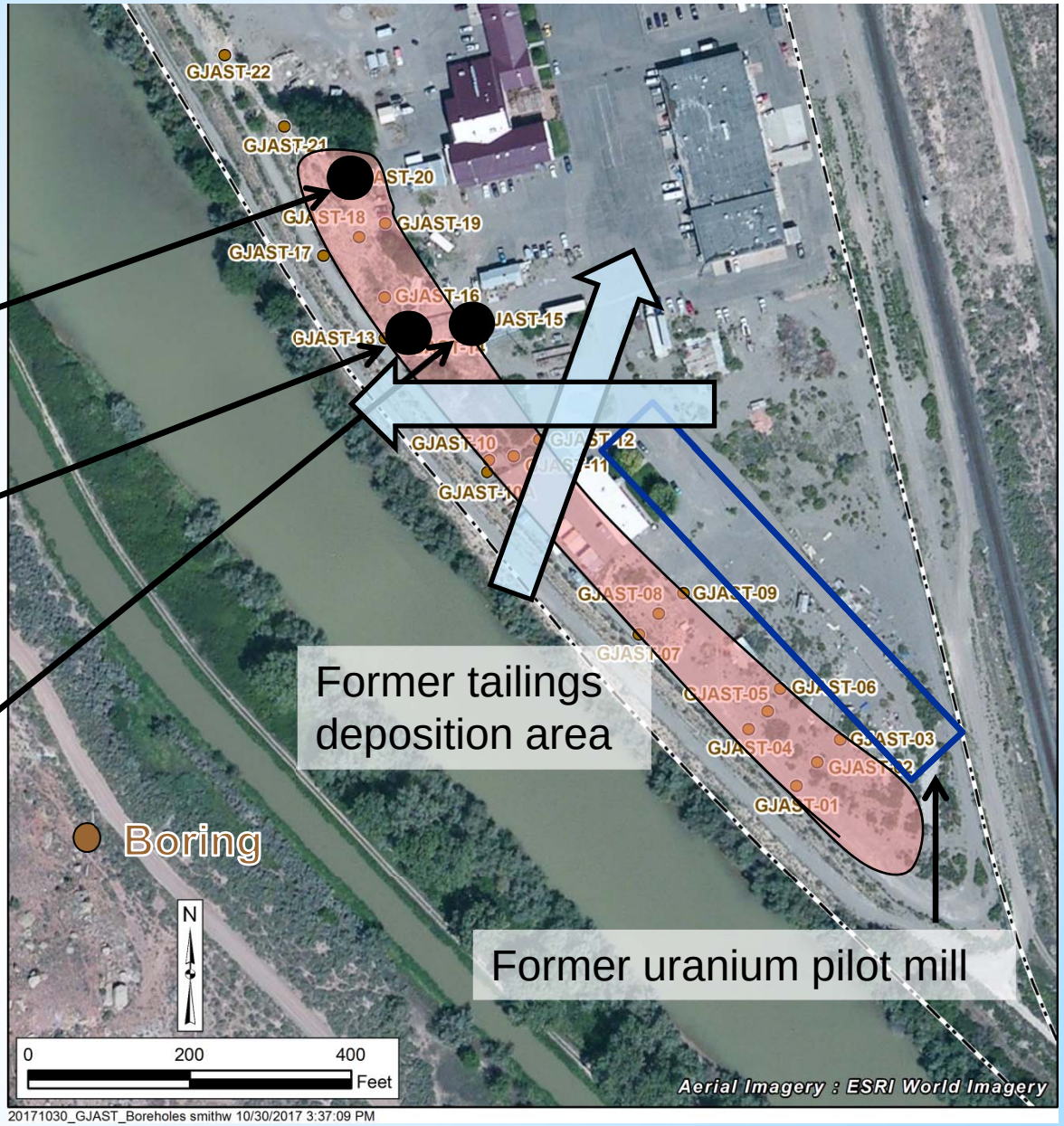


Three Focus Areas for Tracer Testing

Gypsum below water table (column test from here)

Evaporites in the unsaturated zone

Naturally reduced zone (NRZ) with organics



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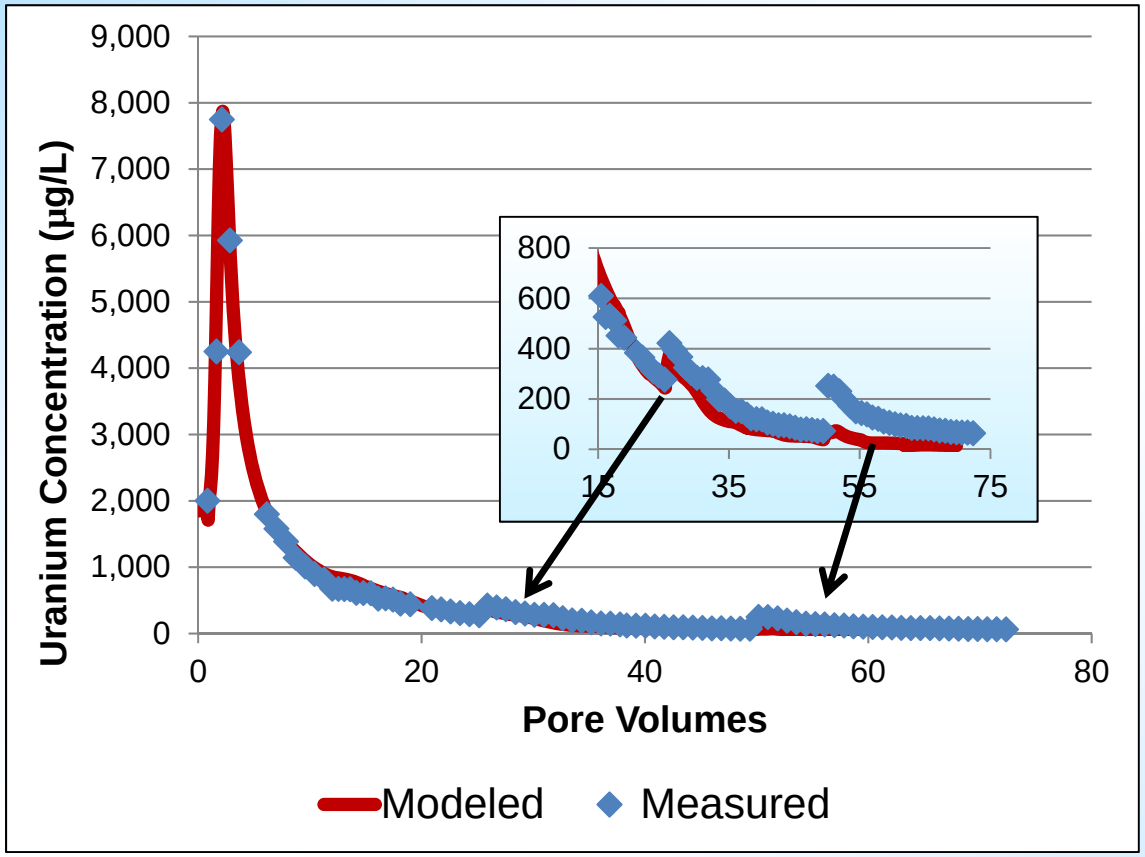
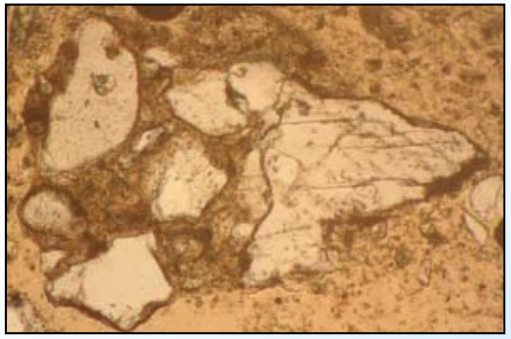
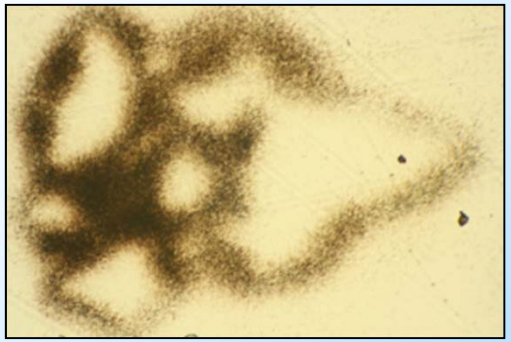
Column Test Results and Modeling

- Key processes: dual porosity, desorption, and mineral dissolution





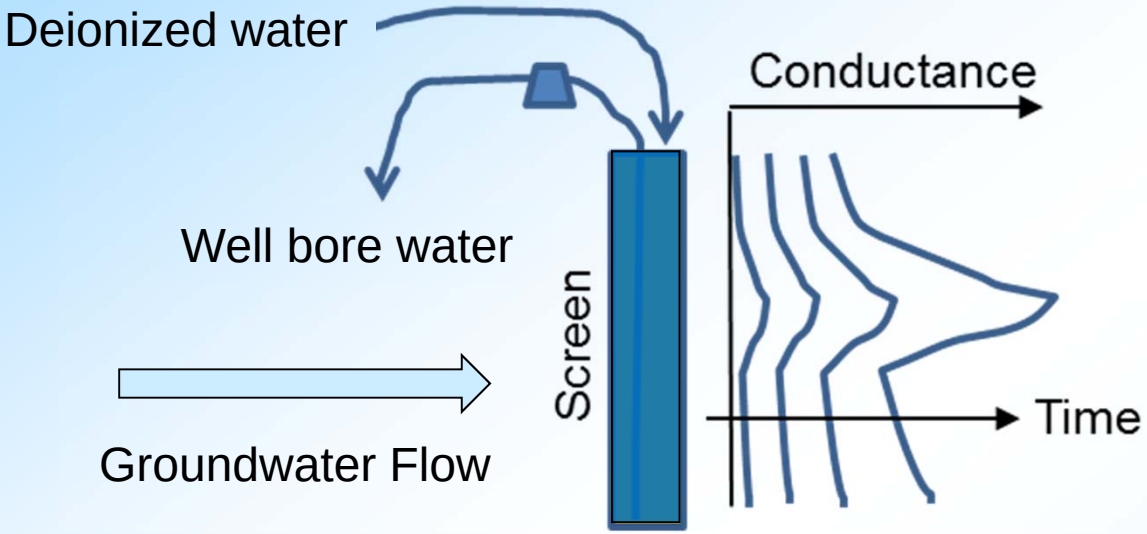


Stop-flow U increase and fission-track radiography indicates the need to consider dual porosity

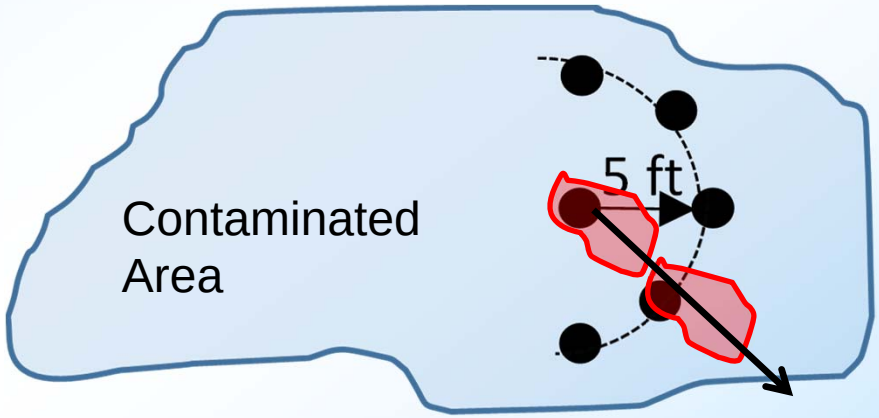
Tracer Testing Objectives

- Evaluation of tracer testing methods to better understand uranium release and transport processes at the field scale
  - Groundwater flow direction and velocity
  - Vertical stratification
  - Mineral precipitation/dissolution
  - Dispersion and dual porosity
  - Adsorption/desorption
  - Unsaturated zone influence
- Compare field-scale uranium release and transport parameters with those derived from column tests for use in updating site conceptual models and transport models

Borehole Dilution

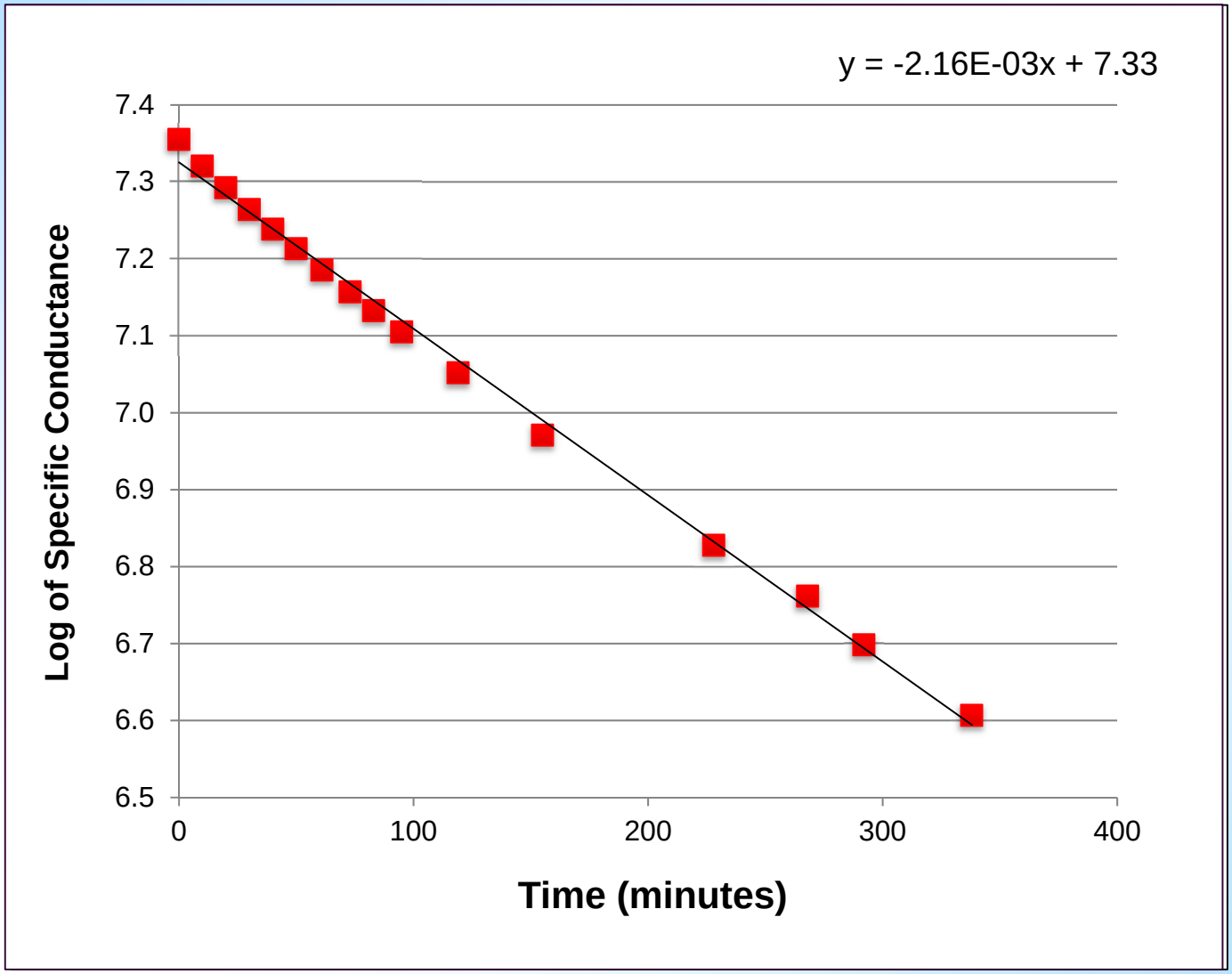


Replace well bore water with deionized water and then track conductance change through time



Fluorescein Dye

Borehole Dilution Results



1.5 ft/day linear velocity
Flow direction directly west

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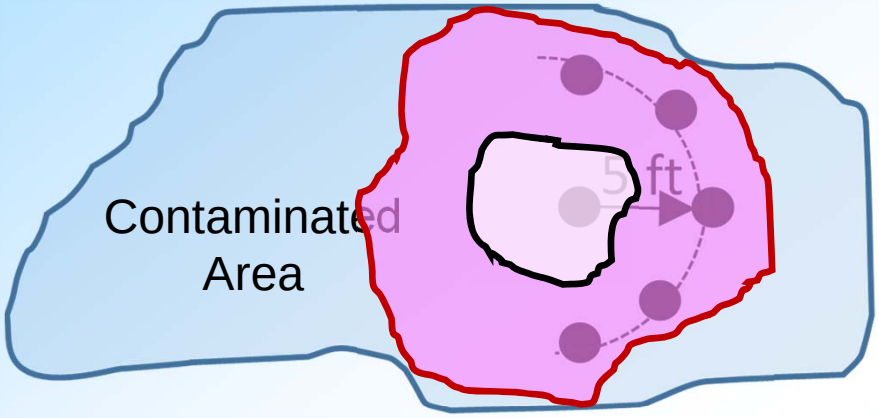
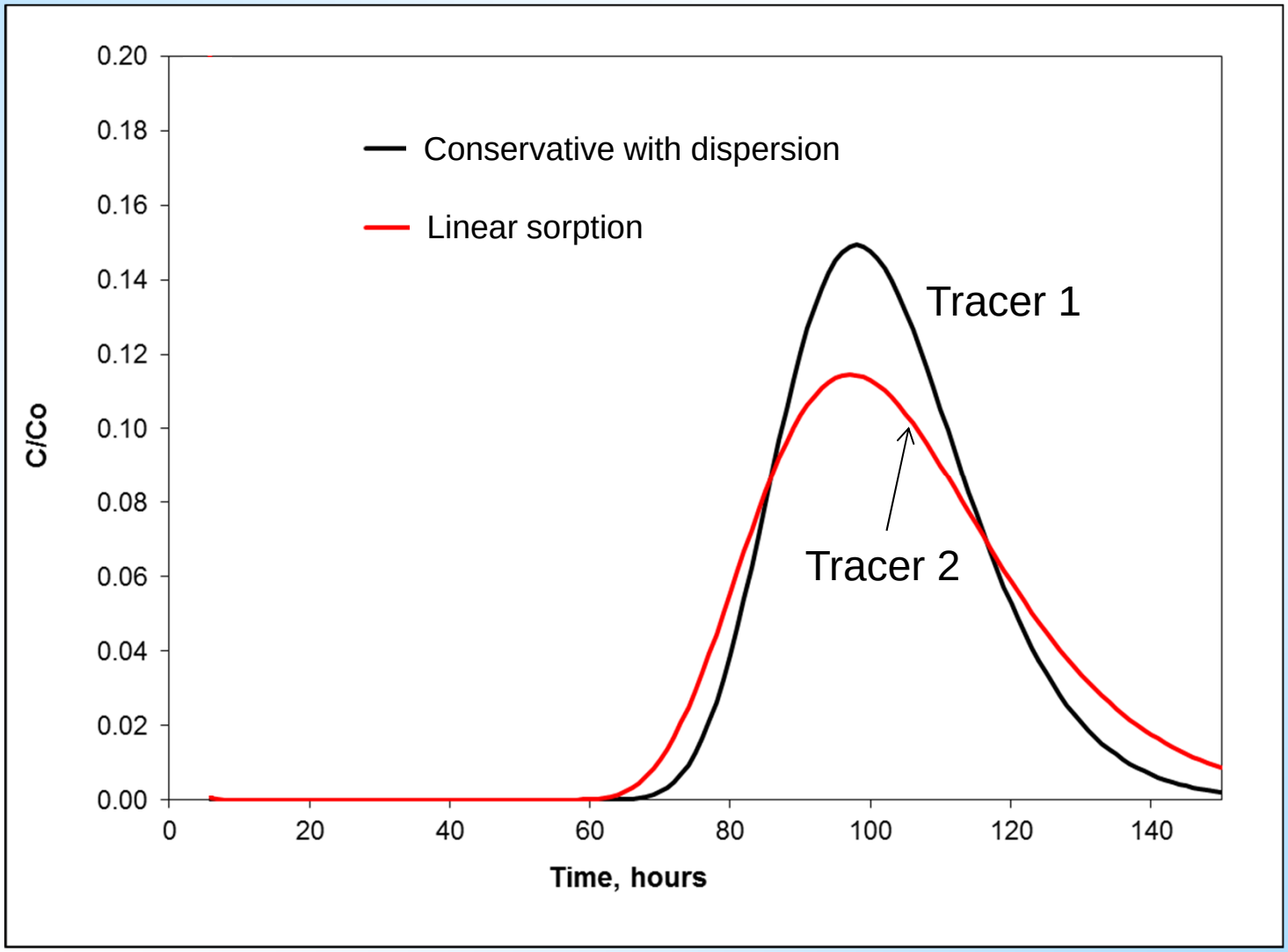
Push-Pull (single well injection and extraction)



"Push" river water with tracers, followed by river water without tracers, let injected water move with the natural gradient. Then "pull" the injected water back.

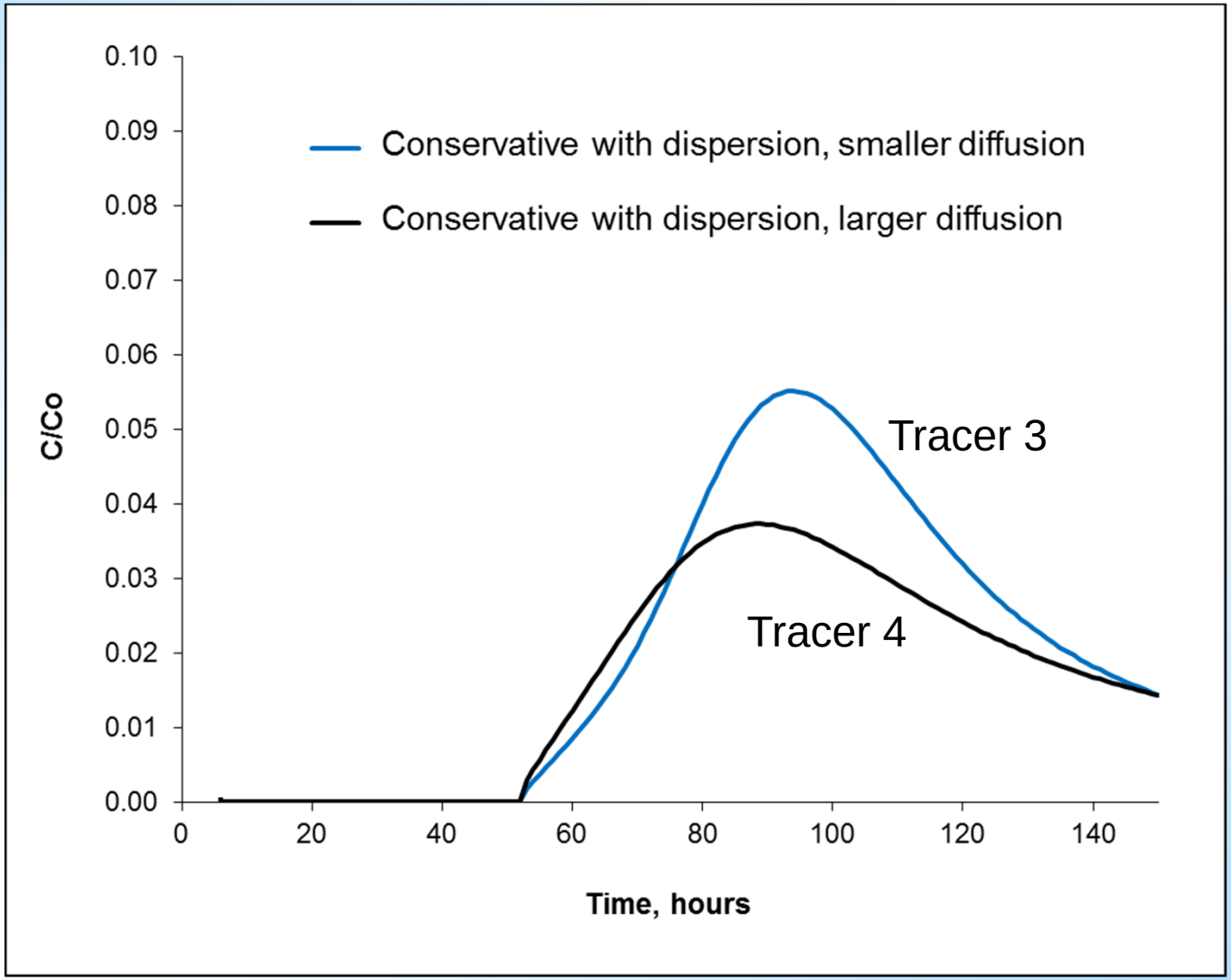
Dispersion and Sorption Influence

- Five-hour injection, 45-hour chase, two-hour drift

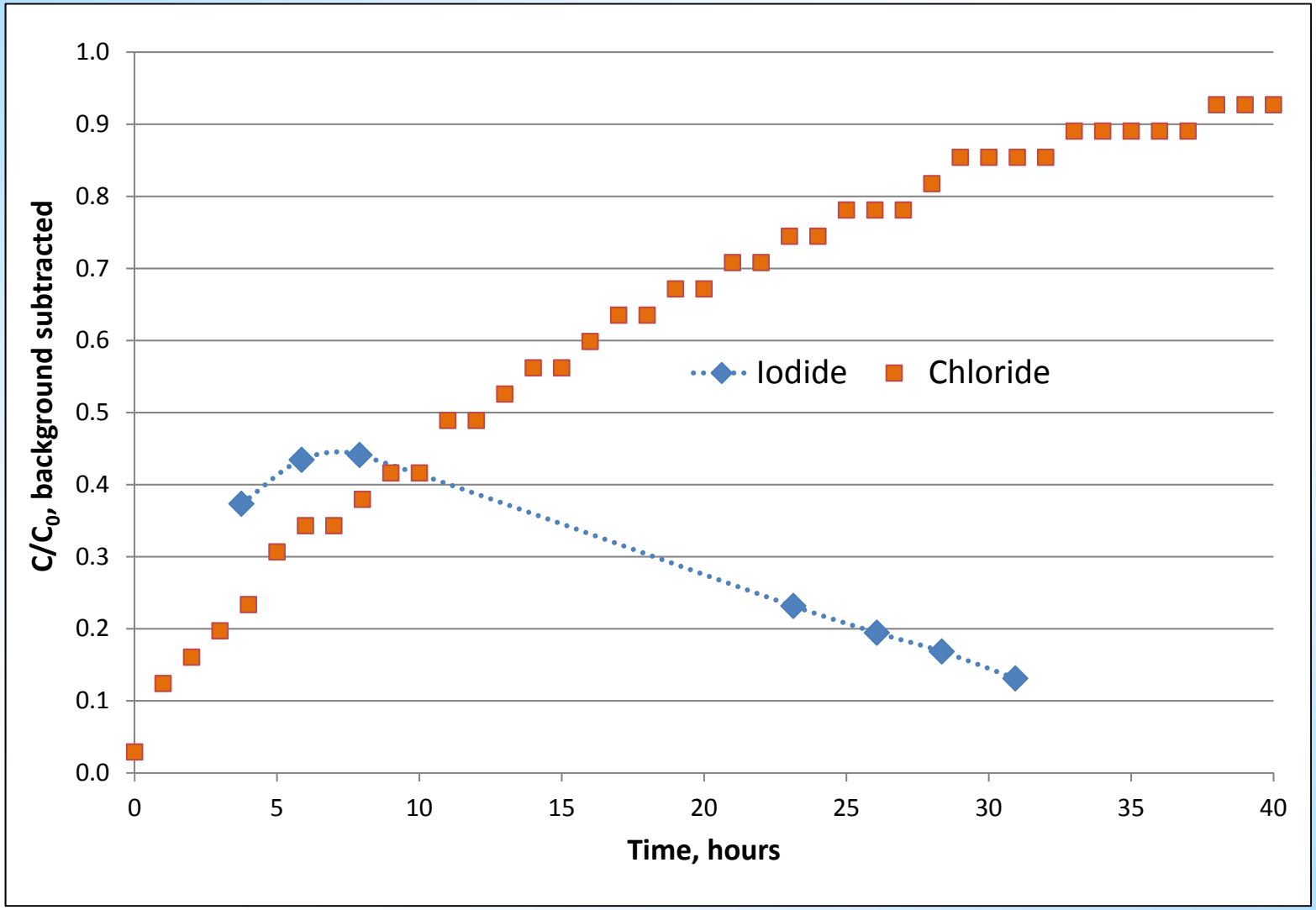


Dual Porosity Influence

- Five-hour injection, 45-hour chase, two-hour drift



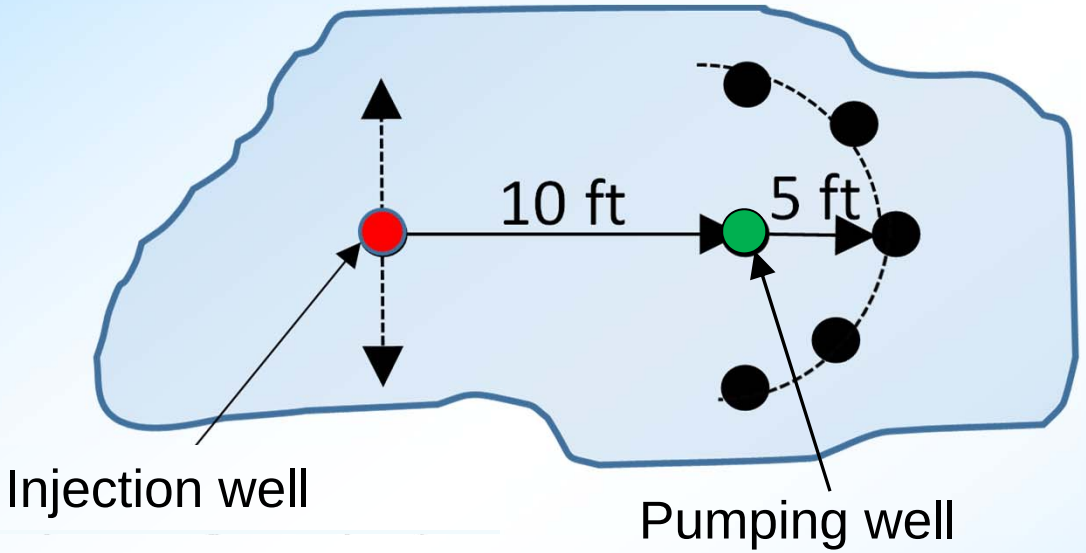
Push-Pull Results



Time from start of pumping back ("pull" phase)

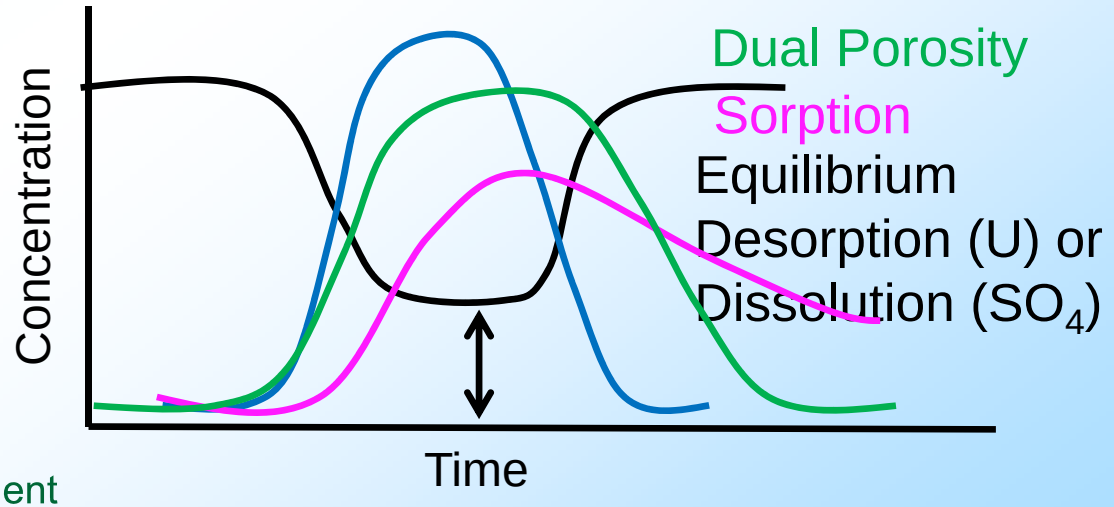
Cross Hole

Use borehole dilution results to align injection well with groundwater flow direction

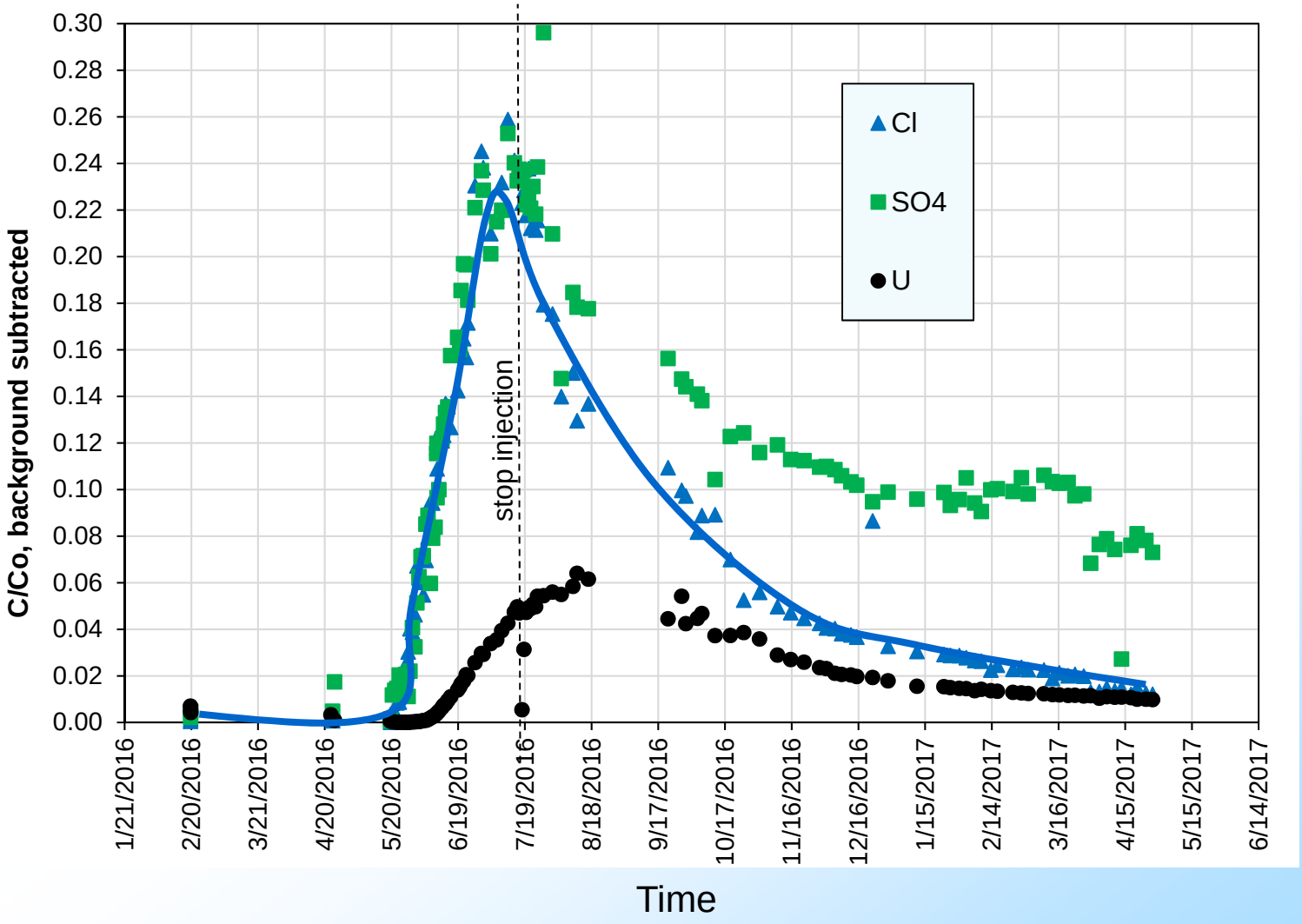


Theoretical Results

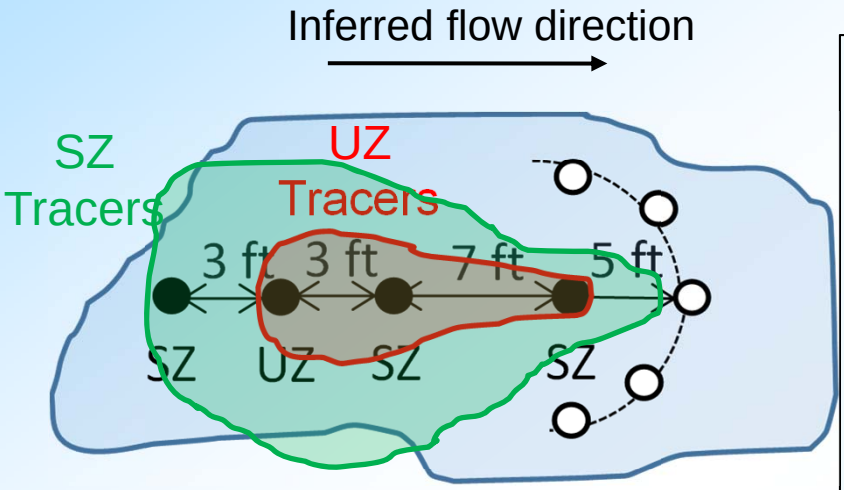
With pumping longer than injection

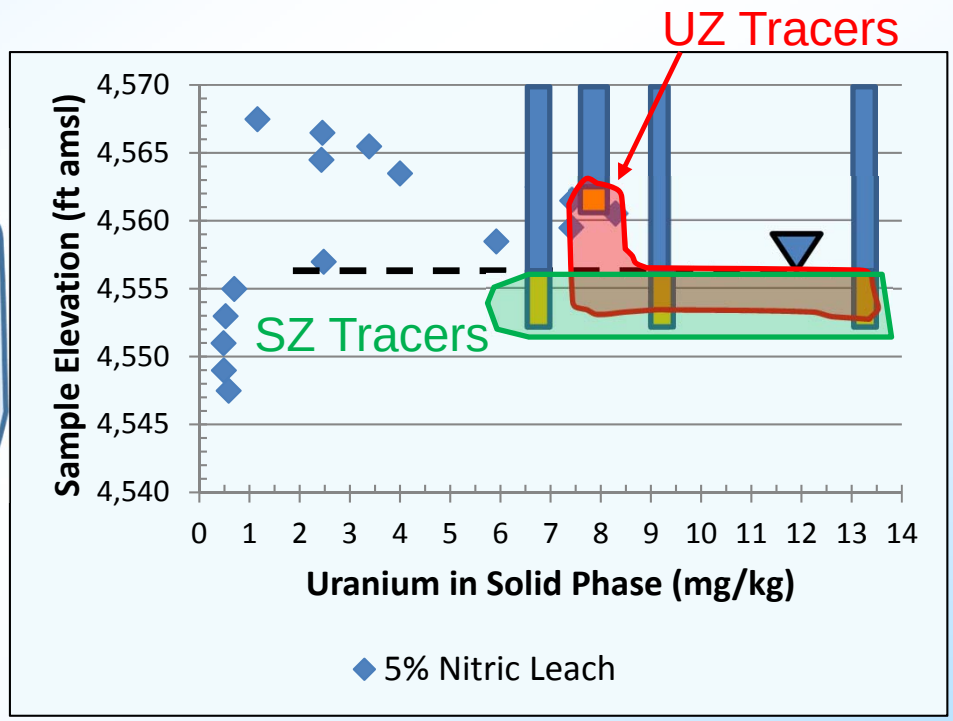


Example Data (Injecting Cl, SO_4, and U) Smith-Ranch Highland In Situ Recovery Site



Evaporite Site with Unsaturated Zone (UZ) and Saturated Zone (SZ) Tracer Test





Test dissolution (infiltration event) of evaporites that have greater uranium concentration

Summary and Conclusions

- Goal: improved predictions of uranium fate and transport
- Column testing and modeling indicate need for dual porosity, sorption, and mineral dissolution processes
- Multiple tracer testing approaches are being used to test multiple processes at the field scale
- Still need to compare laboratory and field-scale results
- Result: revised conceptual and numerical models with new predictions of uranium fate and transport for updated decision making on site management
- Approach is applicable at other sites, but first demonstrate use of techniques at the Grand Junction site