# PNNL/Alabama/ORNL Project Activities and Results

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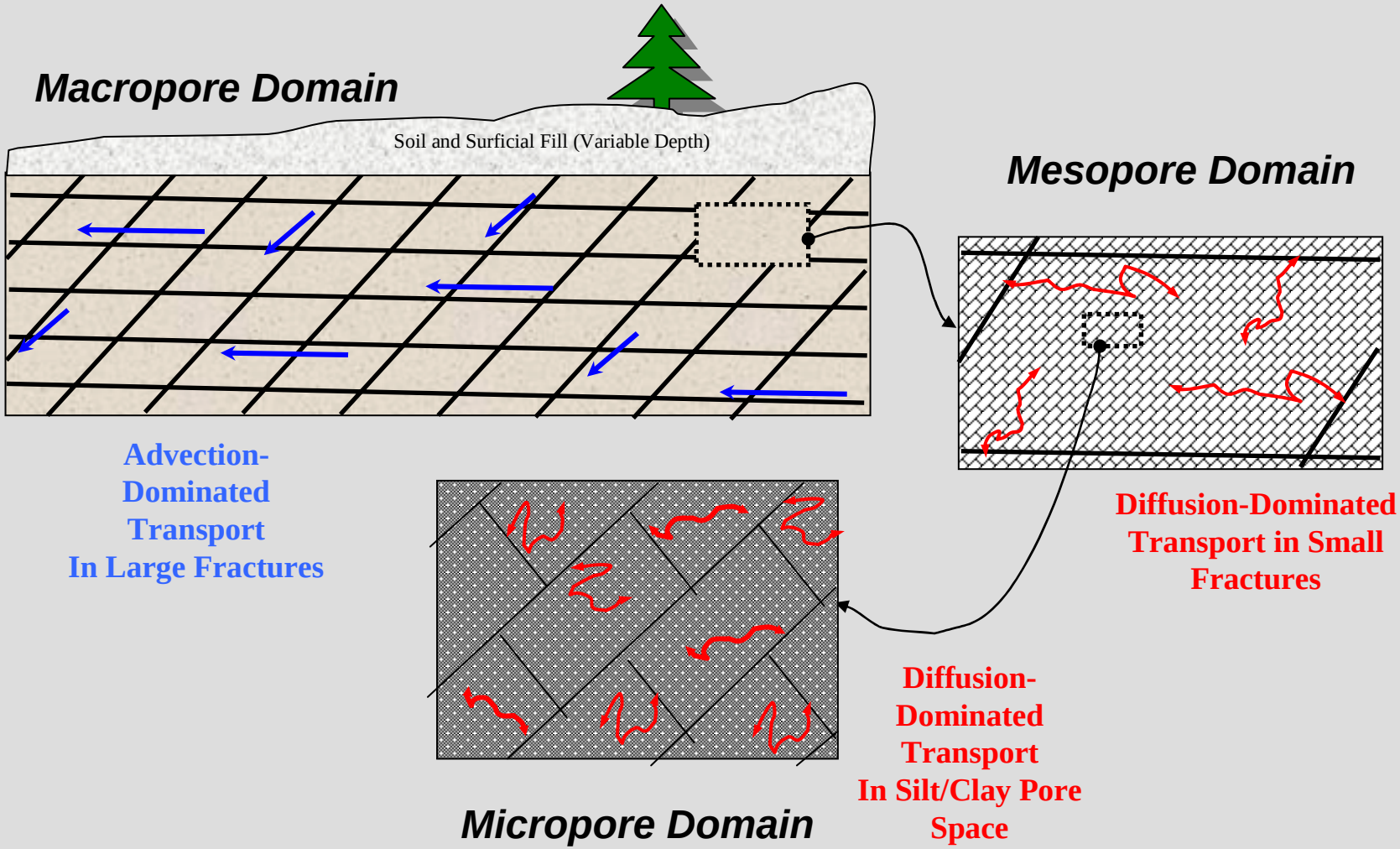
# Outline

- Overview of Project Concept and Goals
- FY2003 Activities and Results
- Plans for Future Activities
- Collaborative Opportunities

# Structured Porous Media



# Fractured Saprolite

# Problem

- 10-20% of porosity is accessible by active pumping
- 10-20% of porosity will respond to pumping on intermediate time scales
- 60-80% of porosity (and associated contamination) is hydraulically inaccessible (controlled by slow diffusive mass transfer)

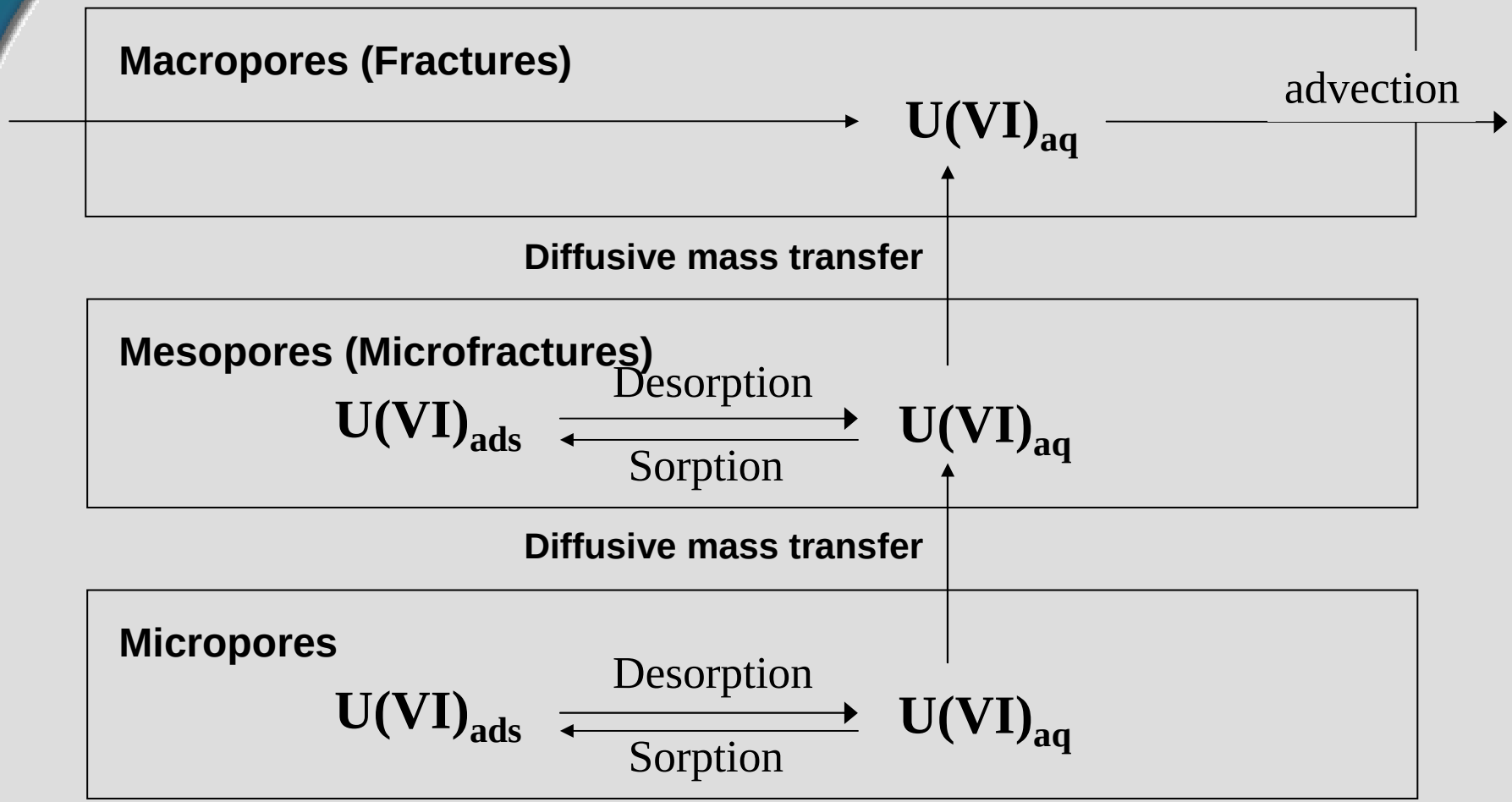
# Hypothesis

- **Mobile radionuclides in low-permeability porous matrix regions of fractured saprolite can be effectively isolated and immobilized by stimulating localized in-situ biological activity in highly-permeable fractured and microfractured zones within the saprolite.**

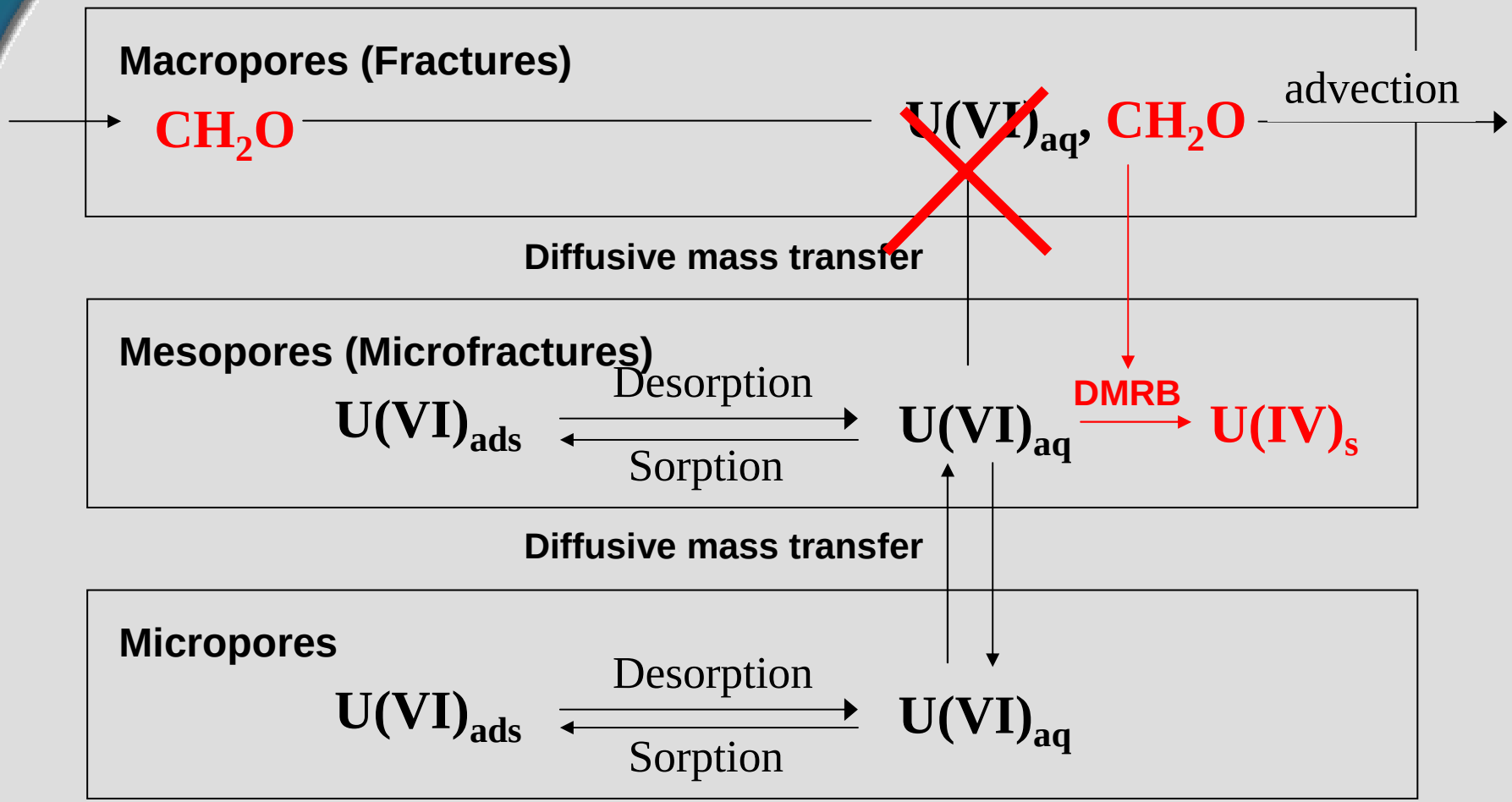
# Strategic Approach

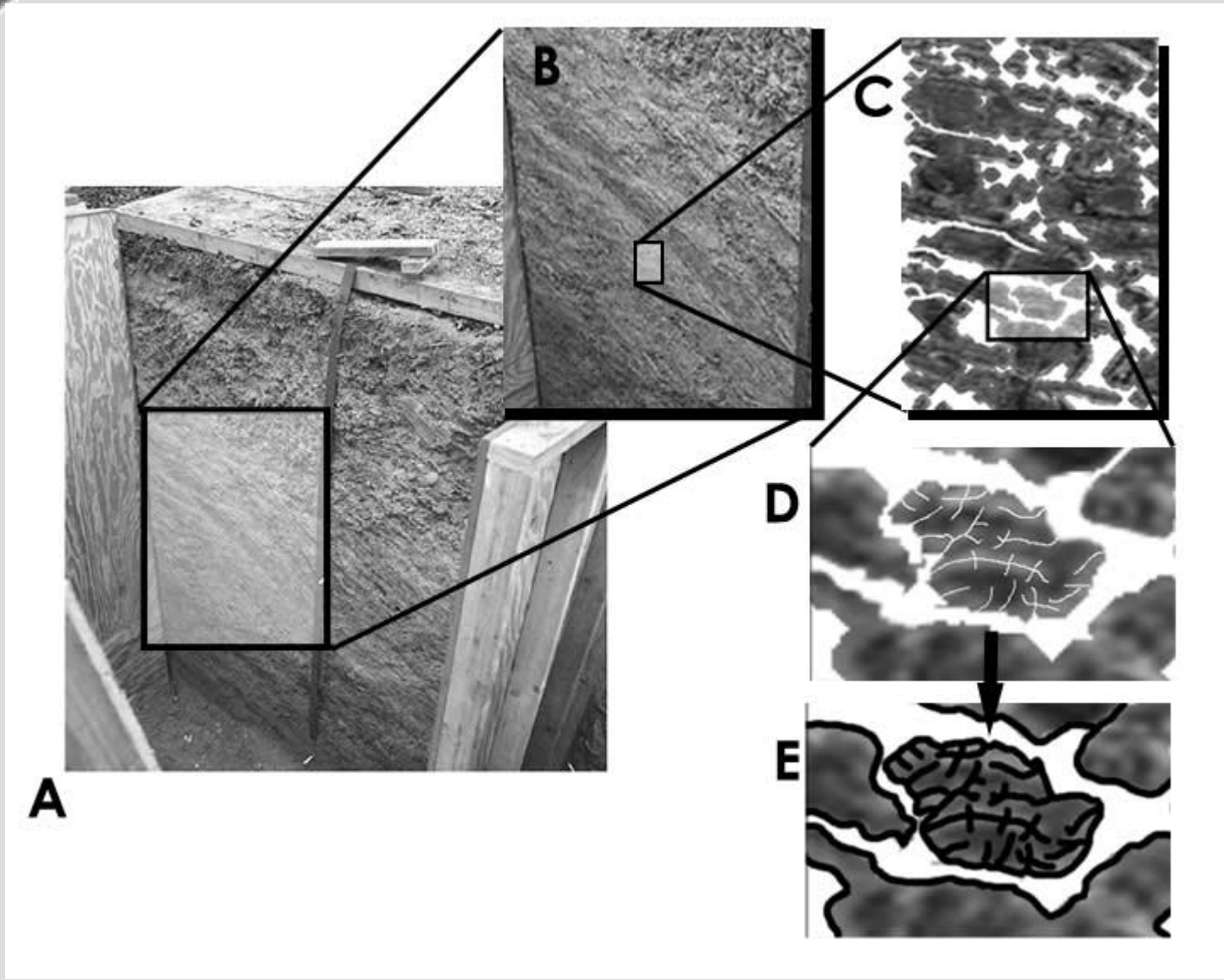
- Use the media structure to advantage
- Isolate radionuclide contaminants in micropore region from free-moving water (macropore) by stimulating biological activity in mesopores
- Effectively create localized distributed reactive barriers around microporous blocks

# 1-D Multiple Pore Region Model of Bacterial U(VI) Reduction



# 1-D Multiple Pore Region Model of Bacterial U(VI) Reduction




A
B
C
D
E

# Research Elements

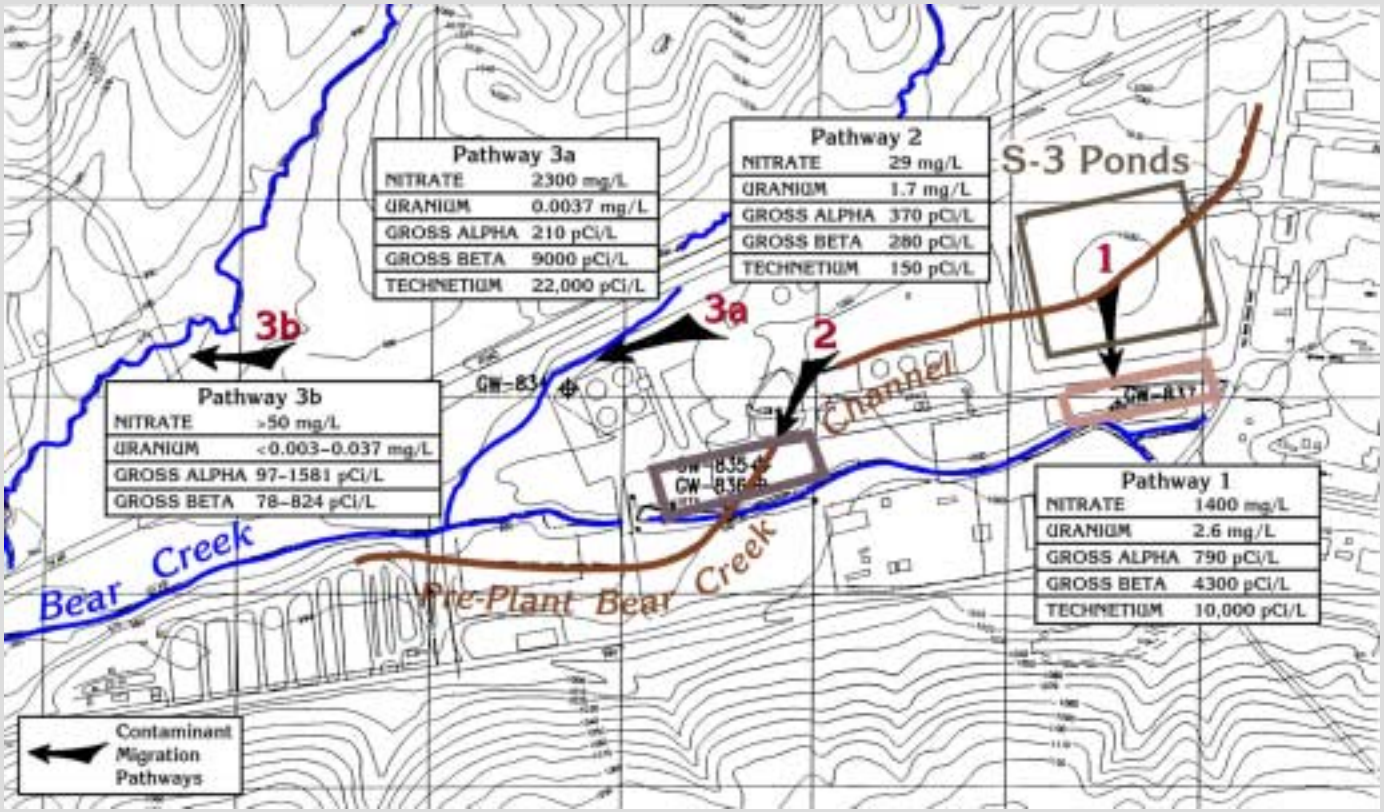
- Preliminary Field Studies
- Laboratory Fe/U Reduction Potential Analyses
- Bench-Scale Testing
- Microscopic Biogeochemical Analyses
- Numerical Model Application
- **Field-Scale Biostimulation Experiment**

# Element 1: Preliminary Field Experiments

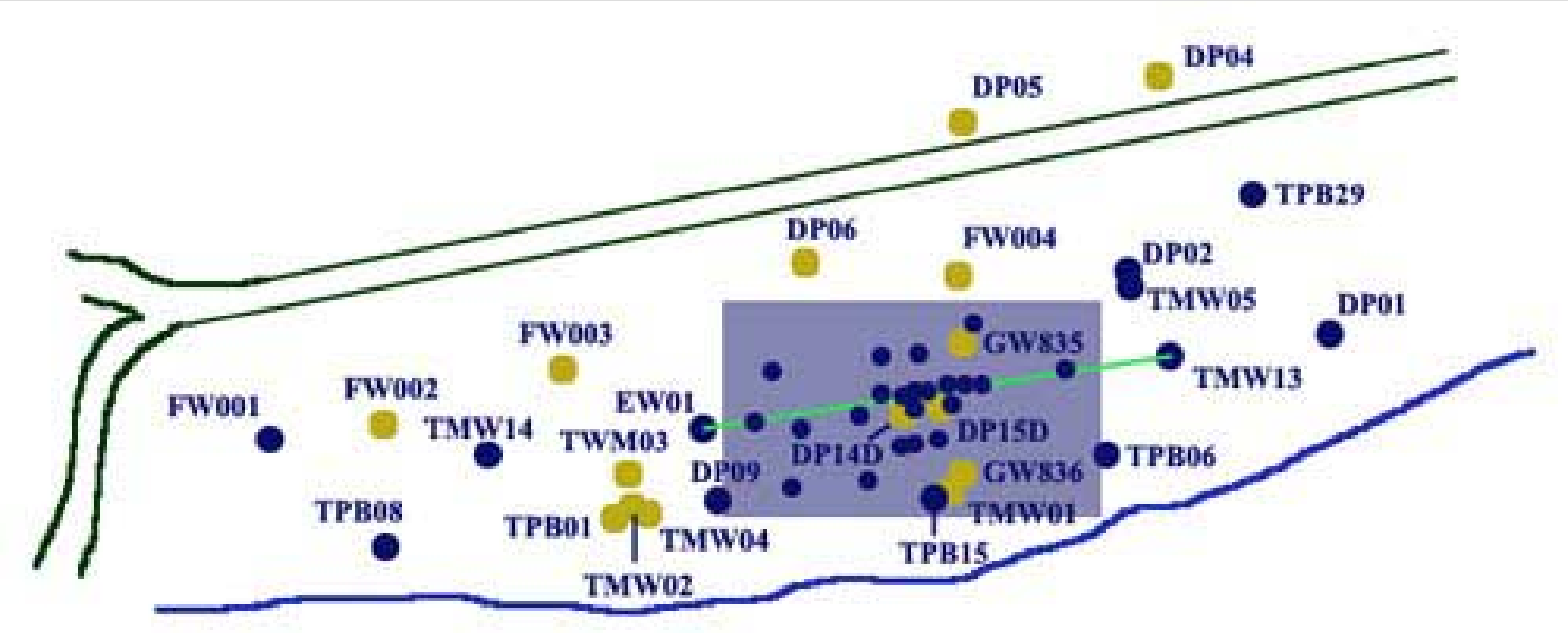
- Site selection and local characterization
  - Well installation and testing
  - Sediment sample collection
  - Field-scale tracer tests  (flow directions and rates, transfer rates)
  - Geophysical surveys (fracture geometry, contaminant distribution)

# Site Selection and Characterization

- Conceptual model of contaminant source at FRC Area 2

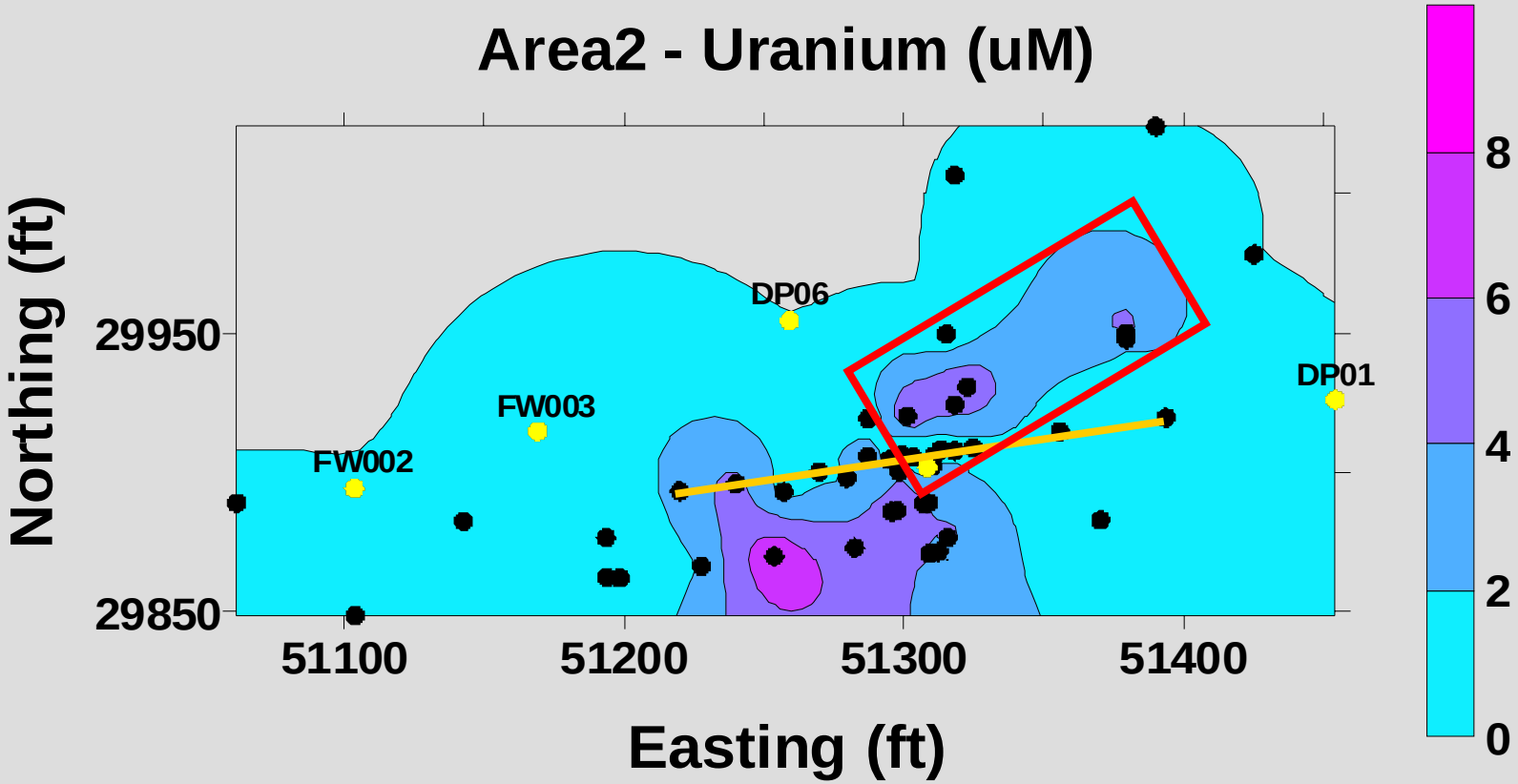


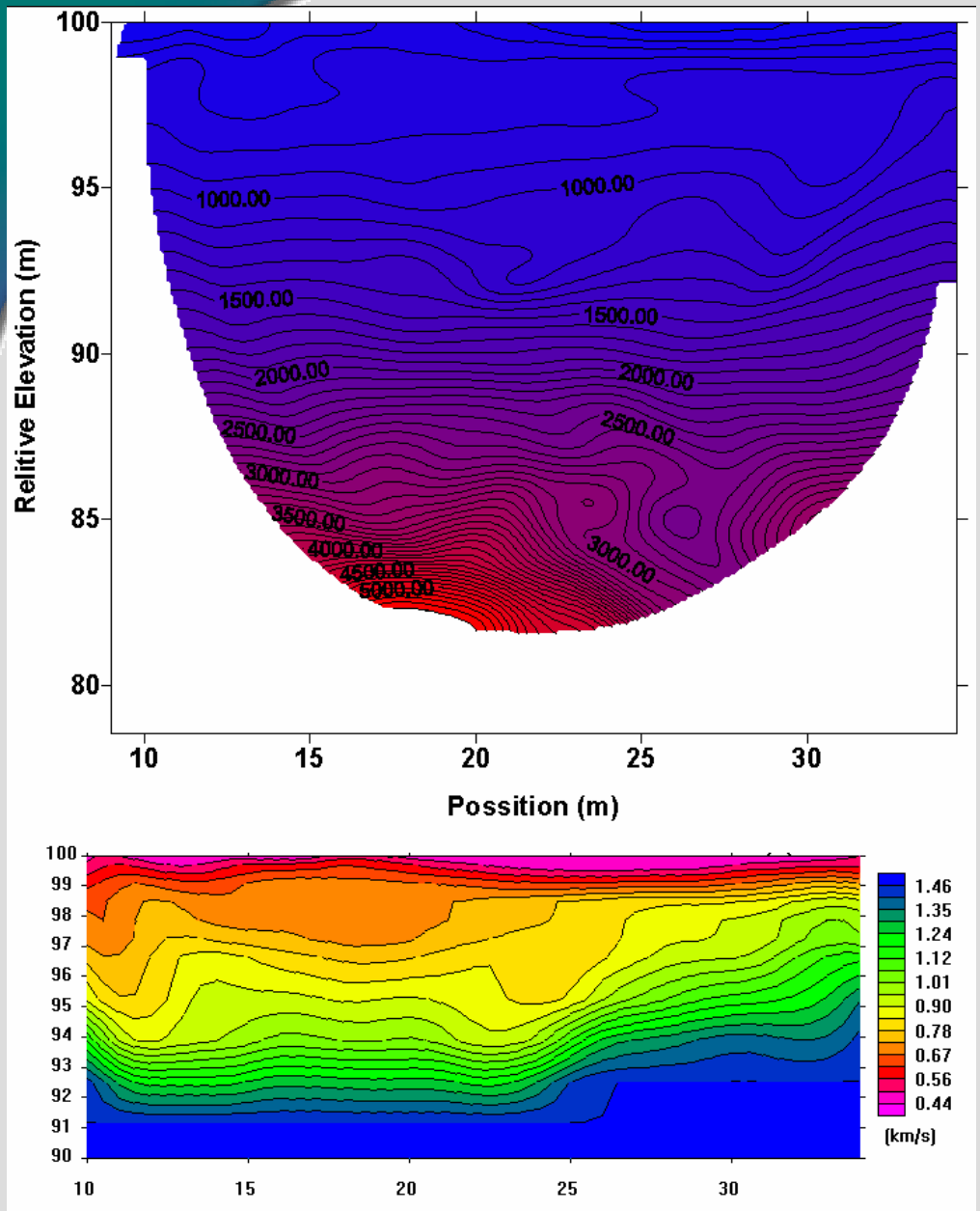
# Area 2

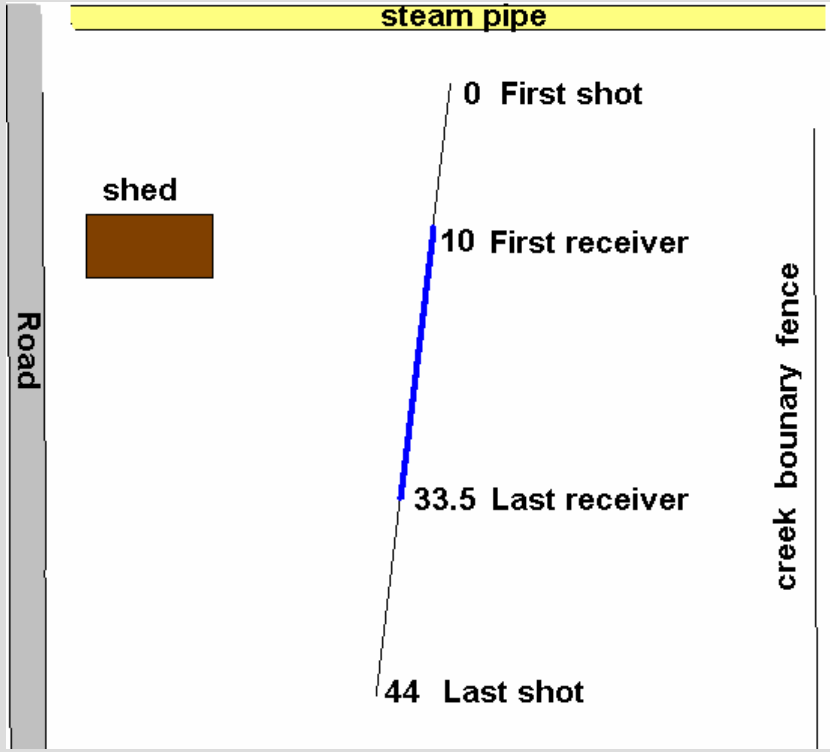

DP04
DP05
TPB29
DP06
FW004
DP02
TMW05
DP01
FW003
GW835
TMW13
FW001
FW002
EW01
TMW14
TWM03
DP15D
DP14D
DP09
GW836
TPB06
TPB08
TPB01
TMW04
TMW01
TPB15
TMW02

# Contaminant Survey

- Conducted by Istok group Sept. 2002



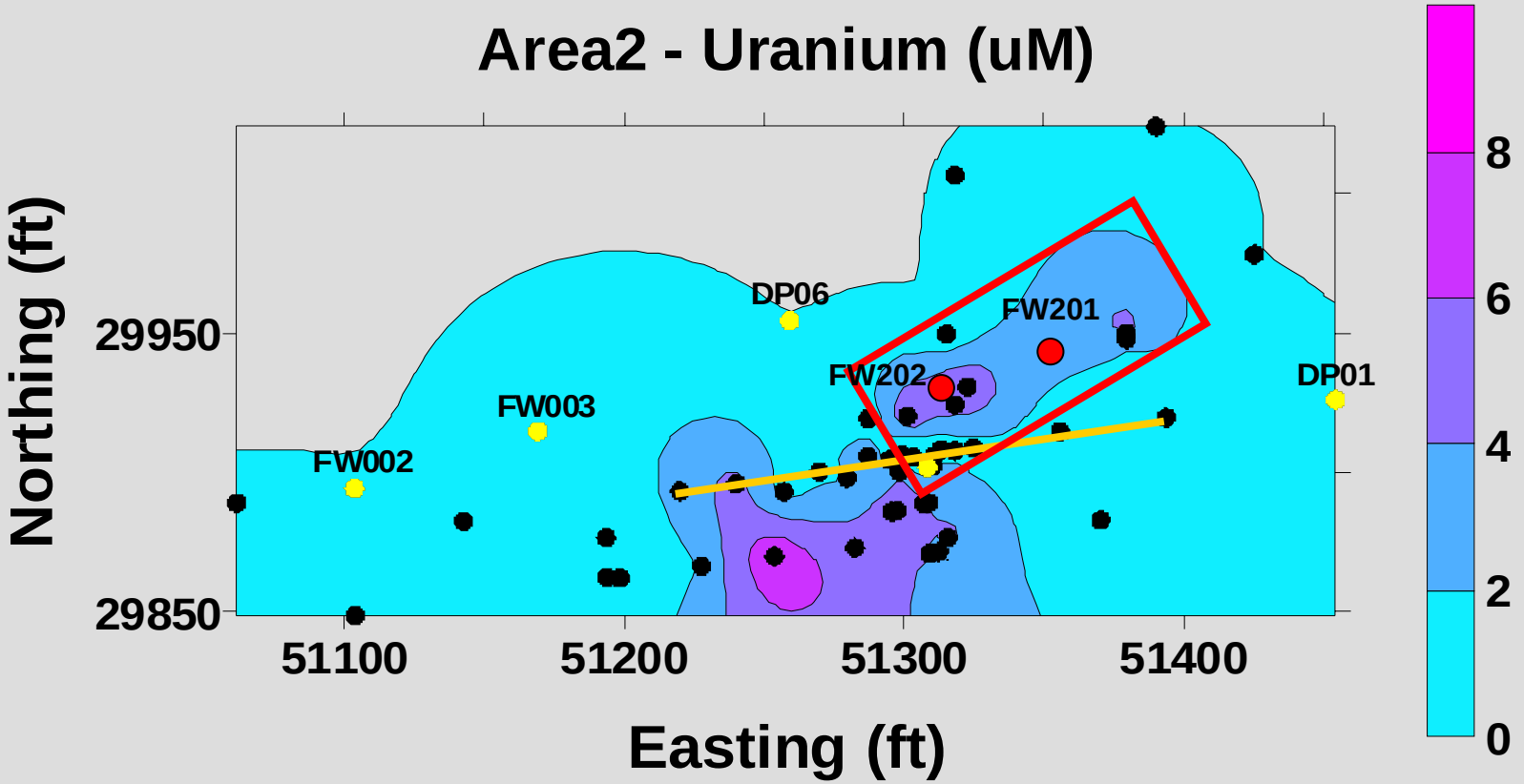

Relitive Elevation (m)
Possition (m)
1000.00
1500.00
2000.00
2500.00
3000.00
3500.00
4000.00
4500.00
5000.00
1.46
1.35
1.24
1.12
1.01
0.90
0.78
0.67
0.56
0.44
(km/s)


steam pipe
0 First shot
shed
10 First receiver
Road
creek bounary fence
33.5 Last receiver
44 Last shot

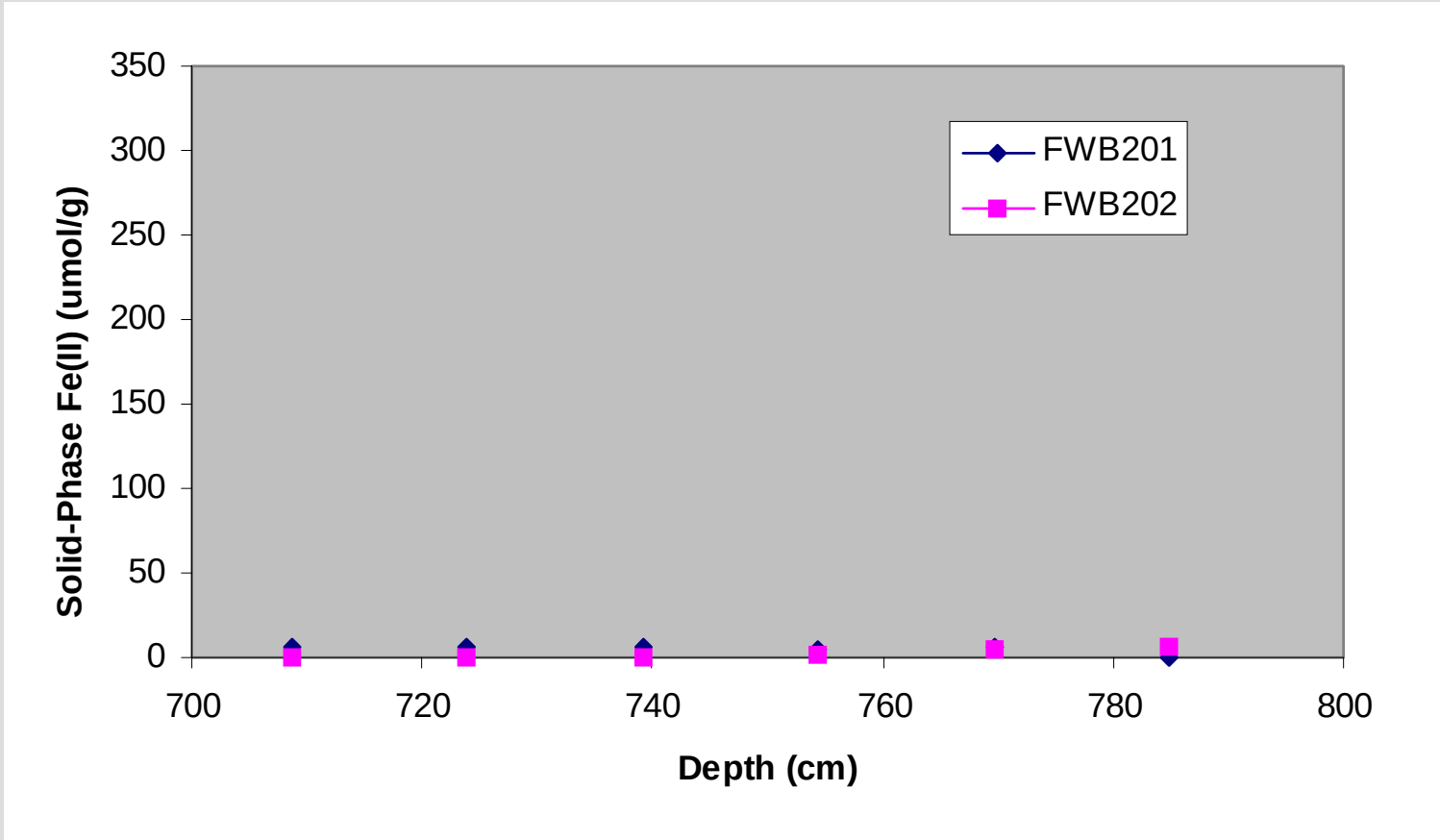
# Well Installation – Round 1

# Exploratory Wells FW201, FW202

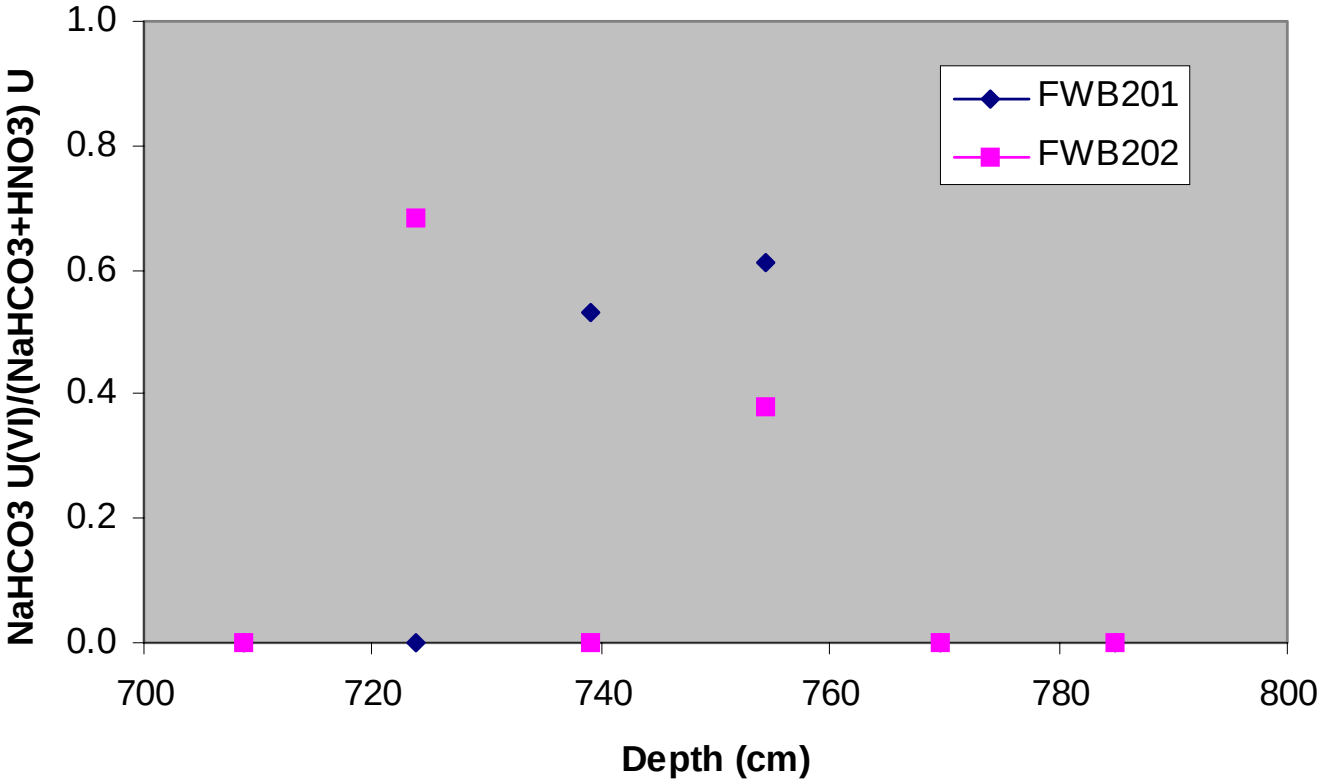
- May 2003



# Sediment-Associated Iron



# Sediment-Associated Uranium



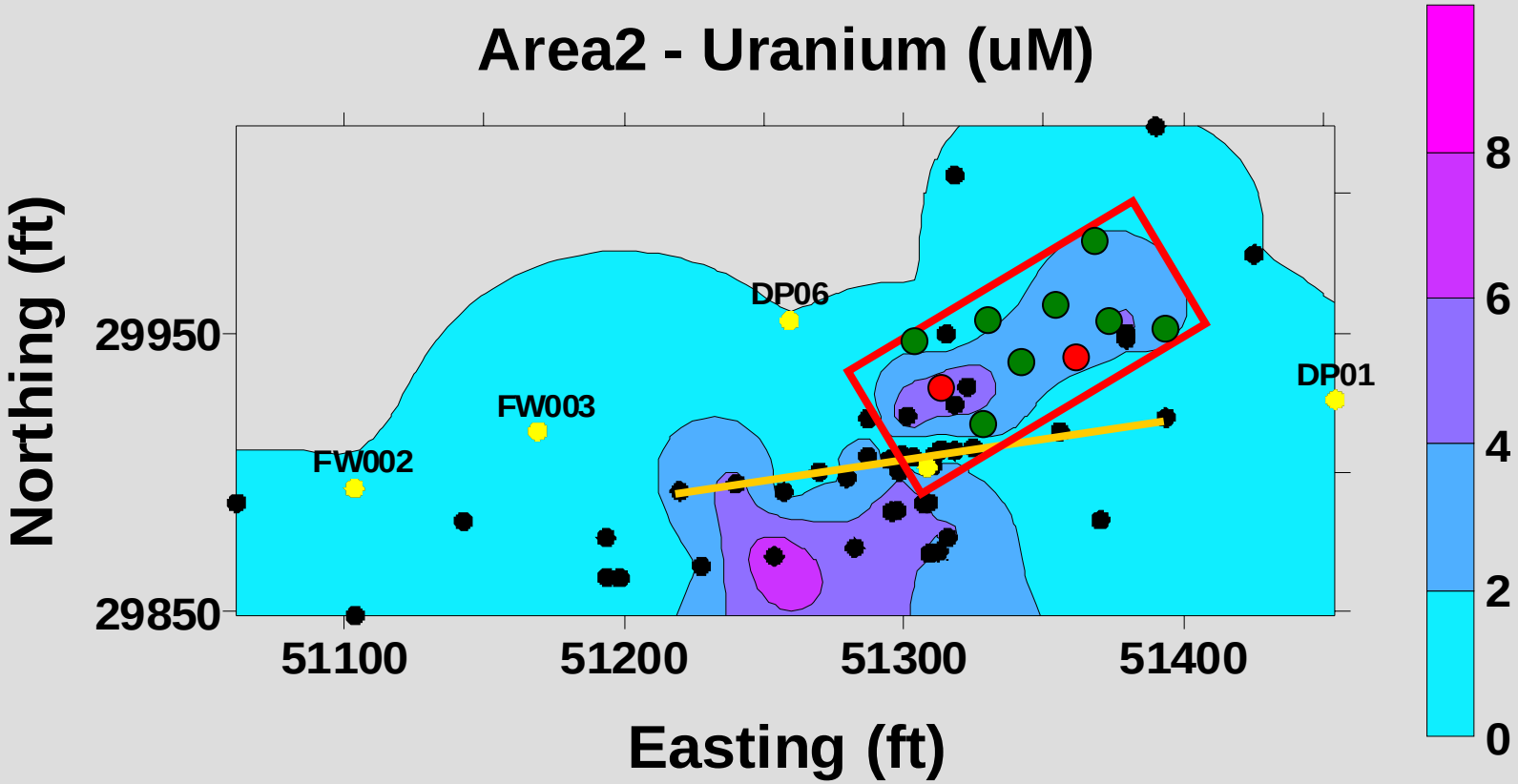
# Aqueous Constituents

| | | pH | Conc (ppm) | | |
|---|---|---|---|---|---|
| | U (ppb) | | Cl- | NO3- | SO4= |
| FW201-1-000892 | 264.194 | 6.47 | 144.977 | 328.657 | 88.601 |
| FW201-2-000895 | 1401.456 | 6.80 | 32.256 | 205.18 | 123.01 |
| FW202-1-000898 | 938.33 | 6.13 | 95.134 | 1274.934 | 75.669 |
| FW202-2-000902 | 1719.041 | 6.83 | 23.02 | 42.068 | 101.589 |

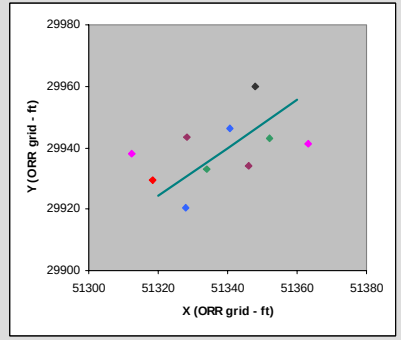
| | WT Elev (ft |
|---|---|
| FW201-1 | 986.36 |
| FW201-2 | 986.12 |
| FW202-1 | 986.22 |
| FW202-2 | 986.08 |

# Round 2 Well Installation
# Detailed Characterization Wells

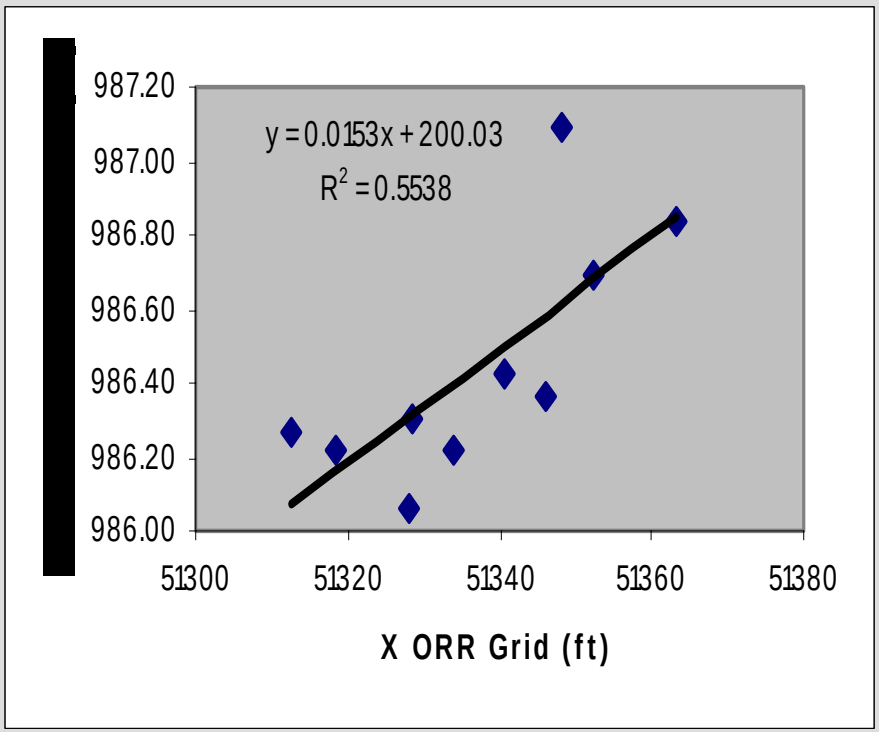
- August 2003

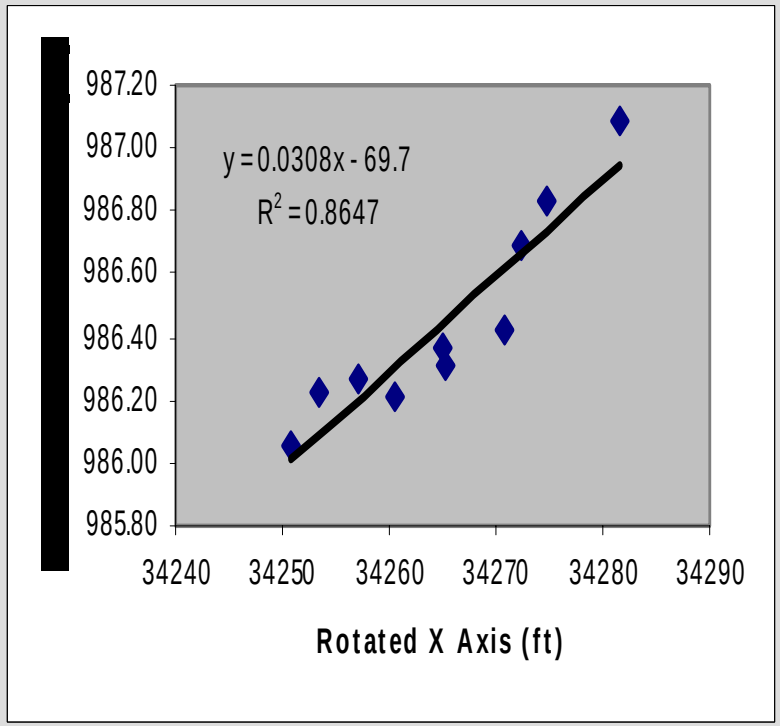


# Aqueous Data



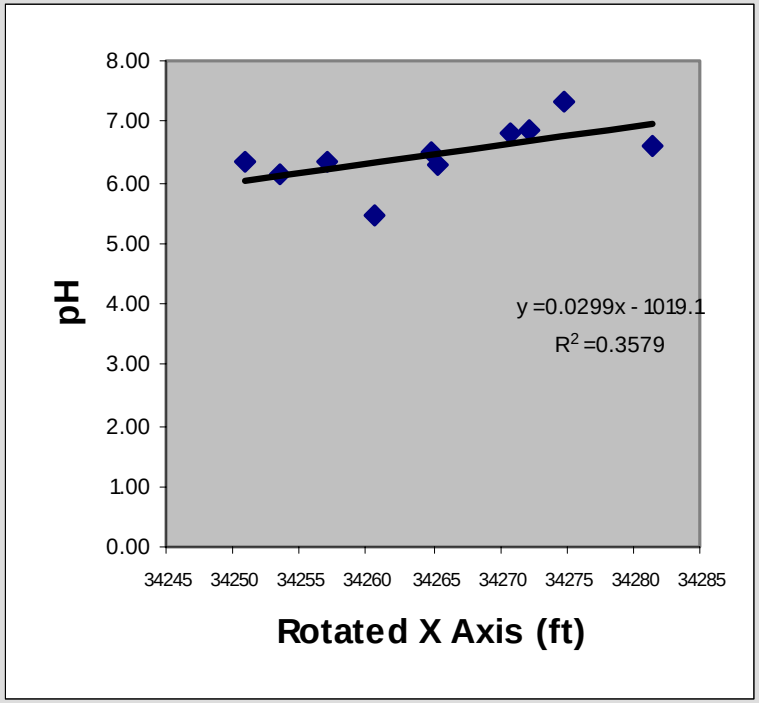

- Eric will be performing U and Fe extractions on core material from the target zone.

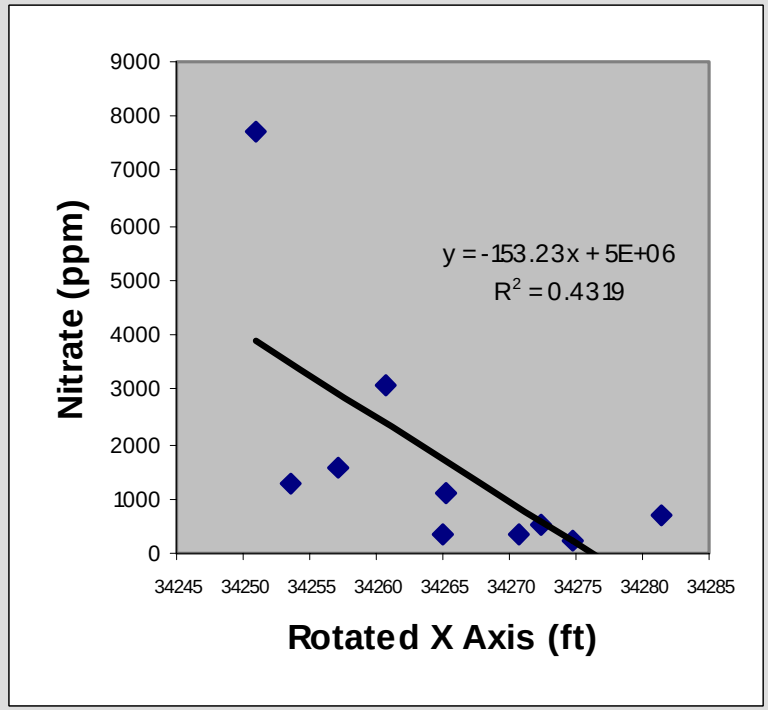


# Aqueous Data

- Rotated axis plots:



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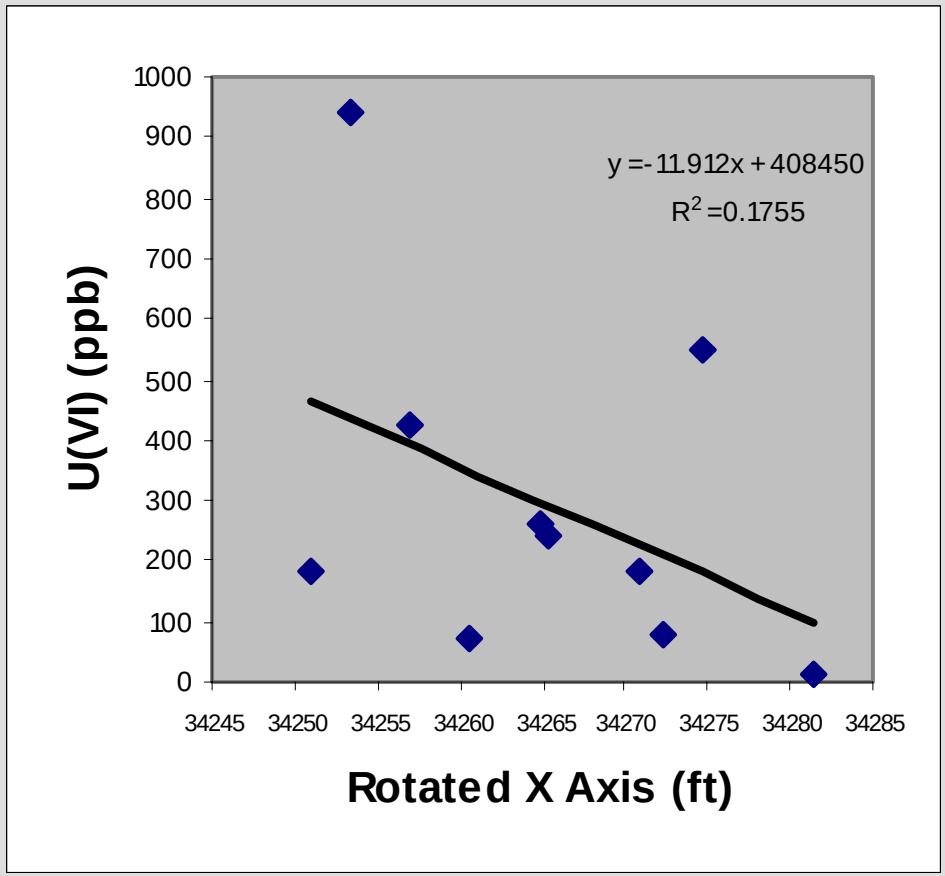


# Element 2: Fe/U Reduction Potential

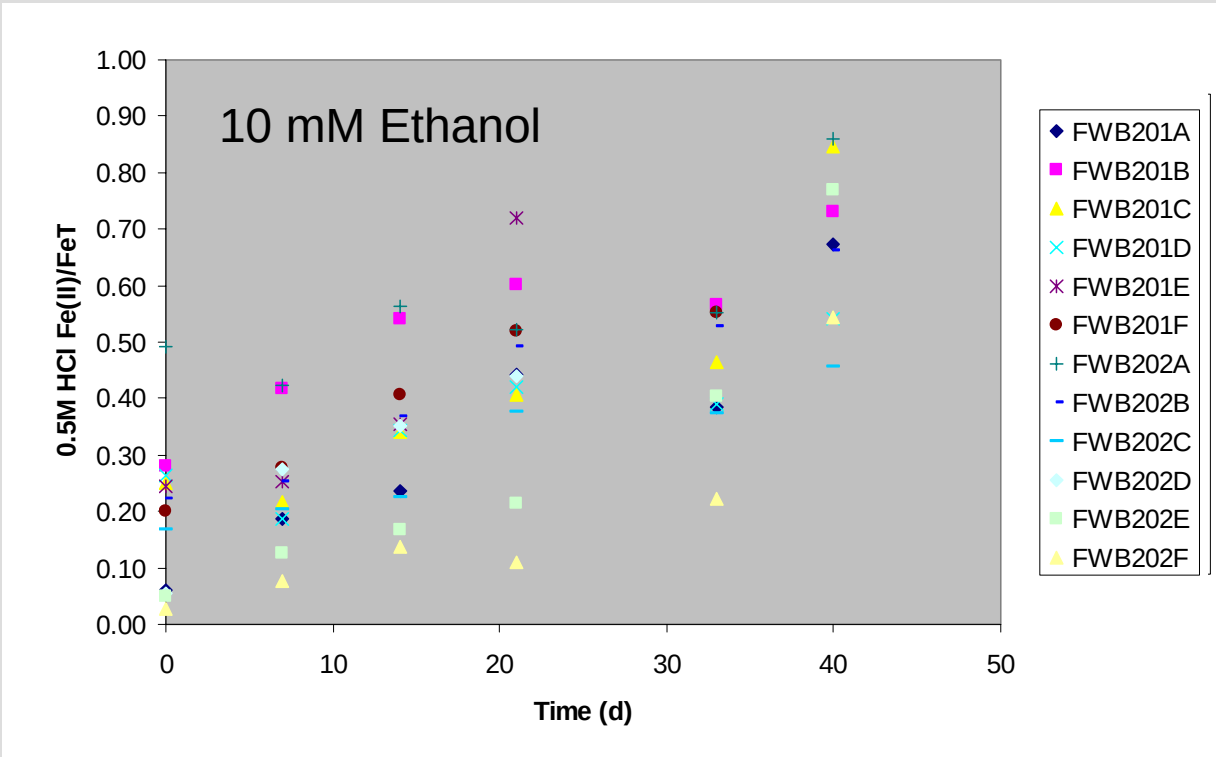
- Sediment laboratory wet-chemical analysis and molecular analysis of sediment and groundwater samples

**• Measure concentrations of U(VI) and other constituents in Area 2**
**• Identify abundance and spatial distribution of DMRB before and during in situ biostimulation**
**• Define bacterial Fe(III)/U(VI) reduction rates and biomass development during biostimulation in batch sediment slurry experiments**

Oxidized Reduced

# Fe Reduction Data

- Evaluation of transformation of endogenous and/or added U(VI) is underway.
- Early results on Fe reduction:



# Element 3: Bench-scale testing of hypothesized process

- Undisturbed column studies

  - **Perform proof-of-principle experiment at bench scale.**
  - **Derive rate constants for use in upscaling studies.**
  - **Identify reaction network and examine solid phase reaction products.**

# Intact Column Studies

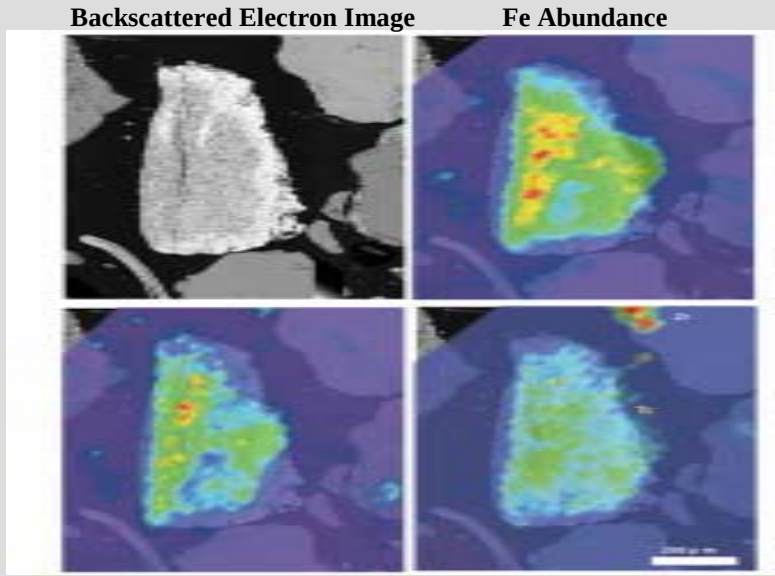

Amorphous Fe (ammonium oxalate extraction) 11.0 ± 0.2 mmole/kg
Total Fe (citrate-dithionate-bicarbonate) 320 ± 10 mmole/kg
Total Mn (acidic hydroxylamine hydrochloride) 3.1 ± 0.1 mmole/kg

# Element 4: Microscopic biogeochemical analyses

- **Determine the spatial distribution of U(IV/VI) and other mineral reaction products in mesopore and micropore domains before and after biostimulation**

- **Confirm and/or modify conceptual models of process association with specific pore domains**

- **Identify the chemical and physical properties of U(IV) fracture precipitates and their association with other biogenic materials.**

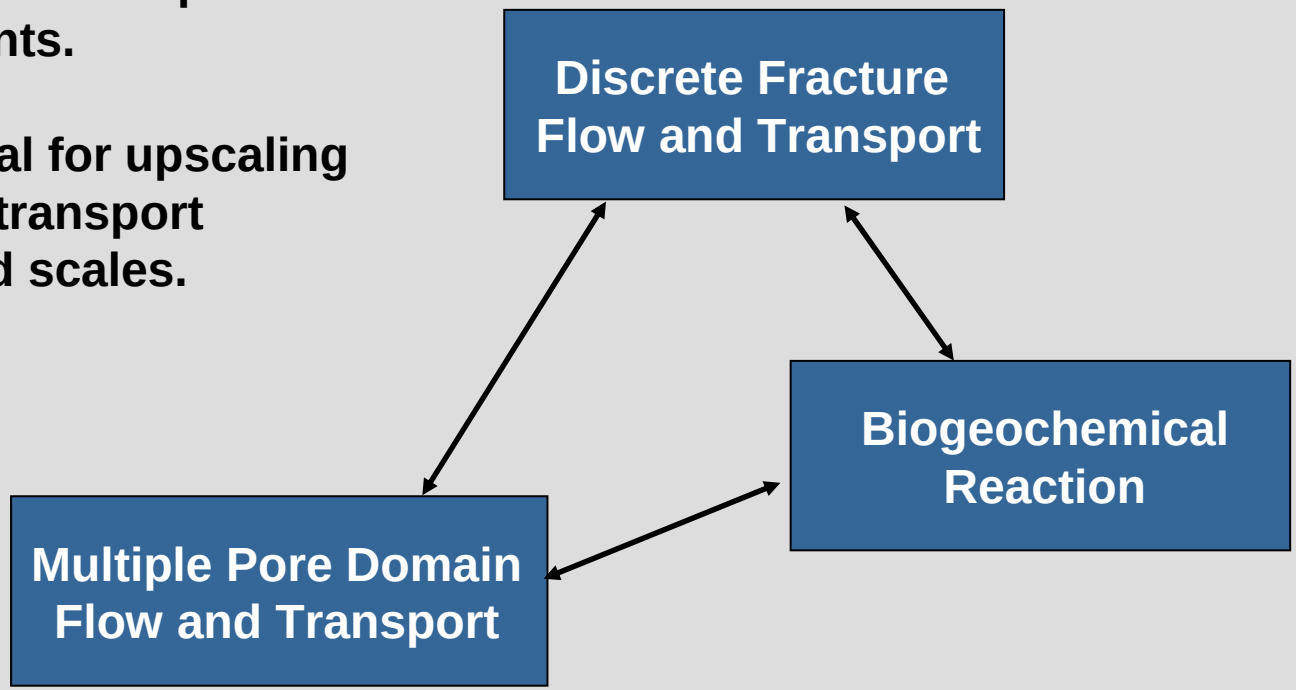



Spatial distribution of Fe, Mn, and Tc(IV) in bioreduced Hanford sediment.

# Element 5: Numerical model application

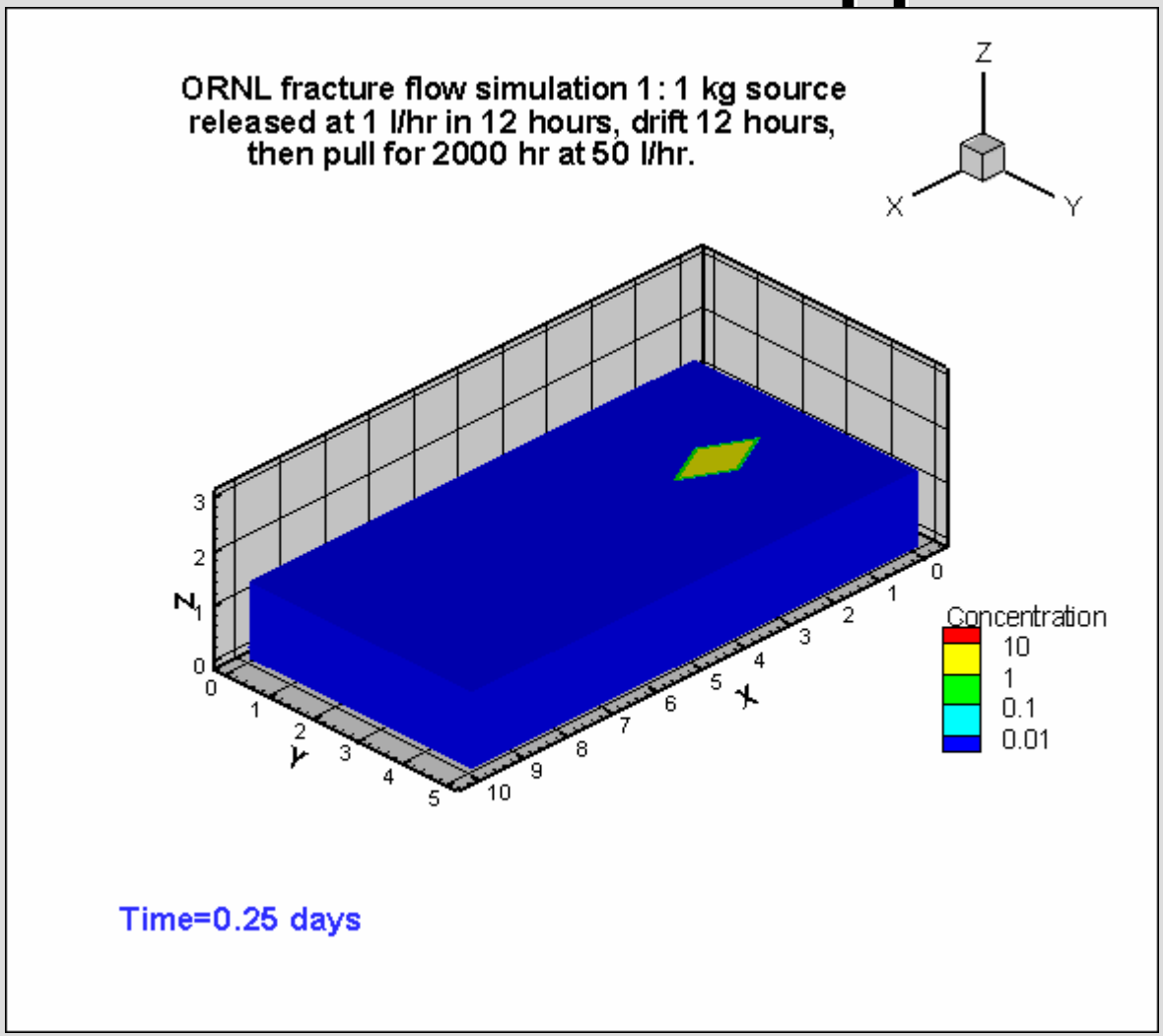
- **Provide quantitative basis for iterative design and interpretation of field experiments.**

- **Assess potential for upscaling laboratory-scale transport properties to field scales.**



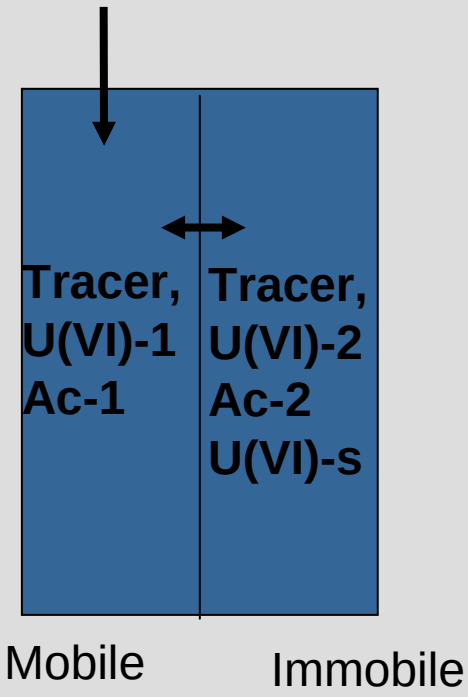
# Element 5: Numerical model application

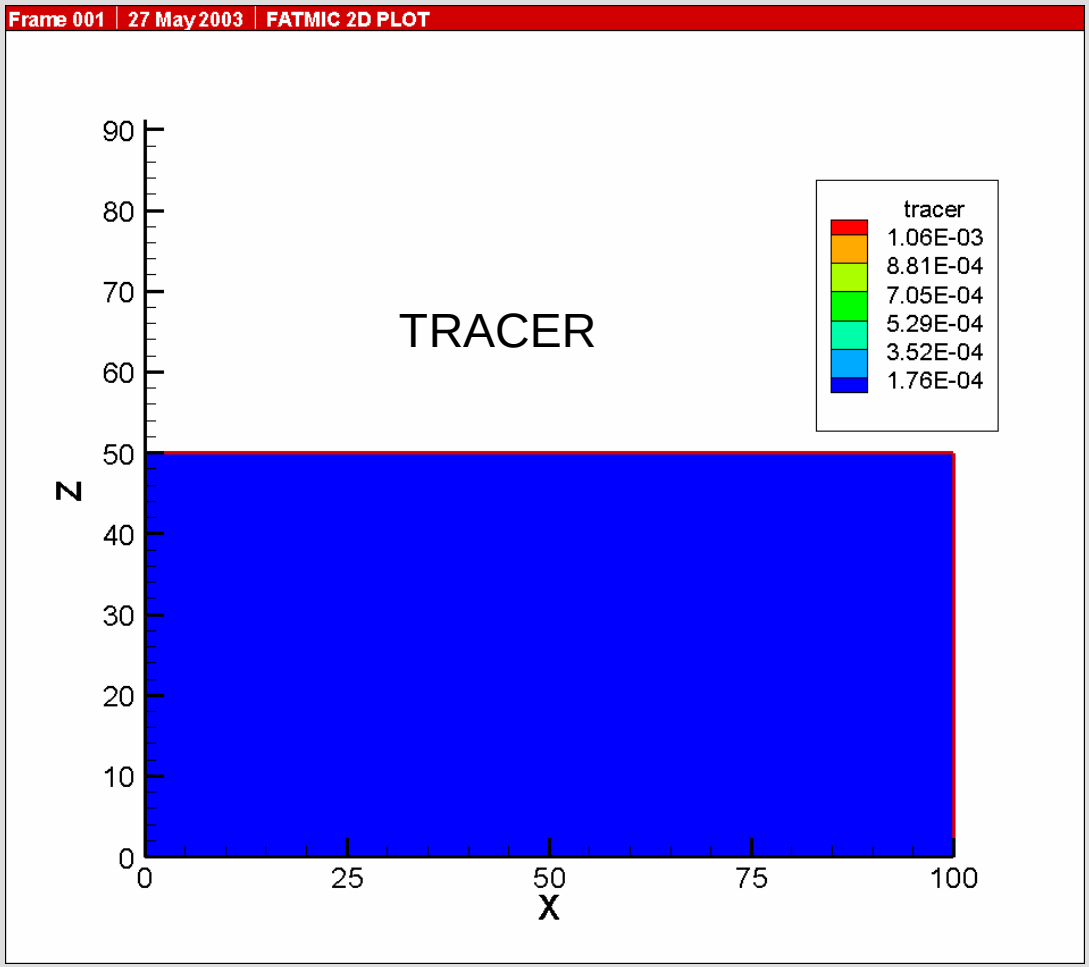
- **FRAC3DVS (Therrien and Sudicky)**



# Element 5: Numerical model application

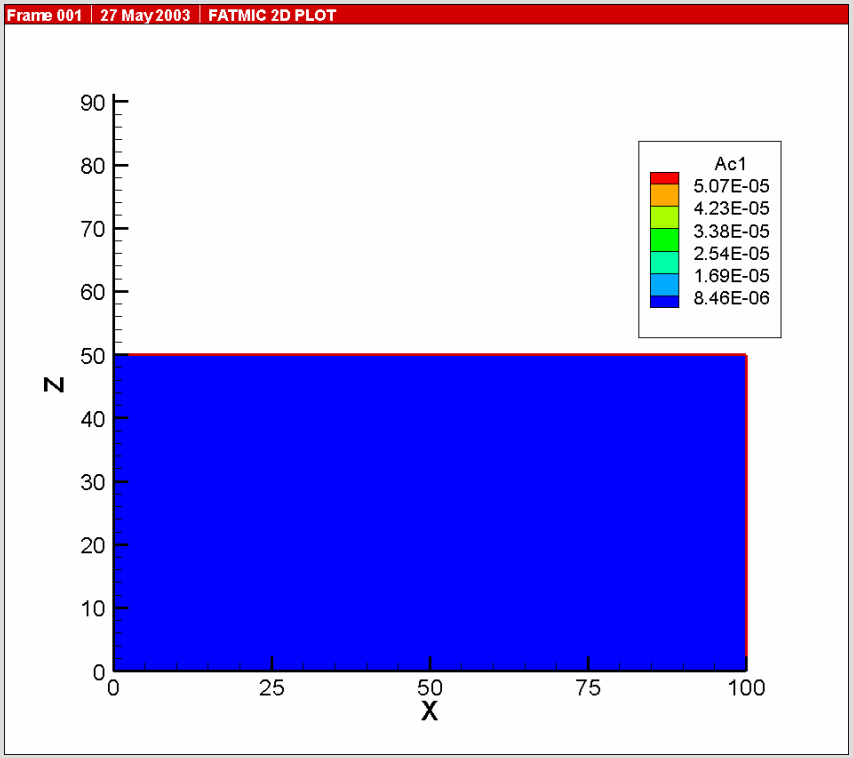
- **BioGeoChem (Fang, Yeh, Burgos))**



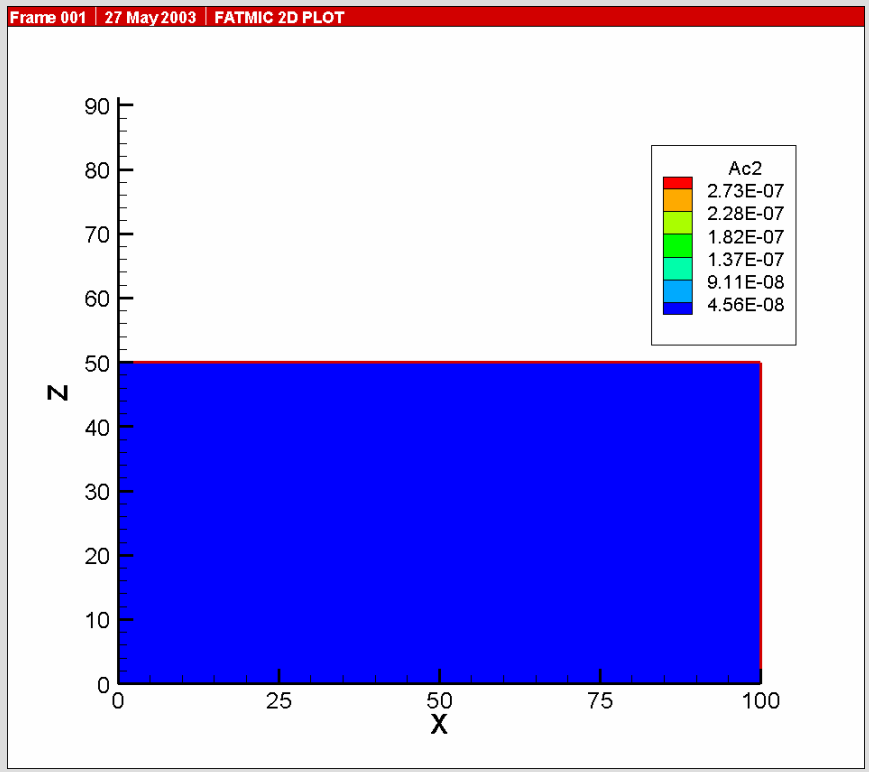



# Element 5: Numerical model application

Ac(1)

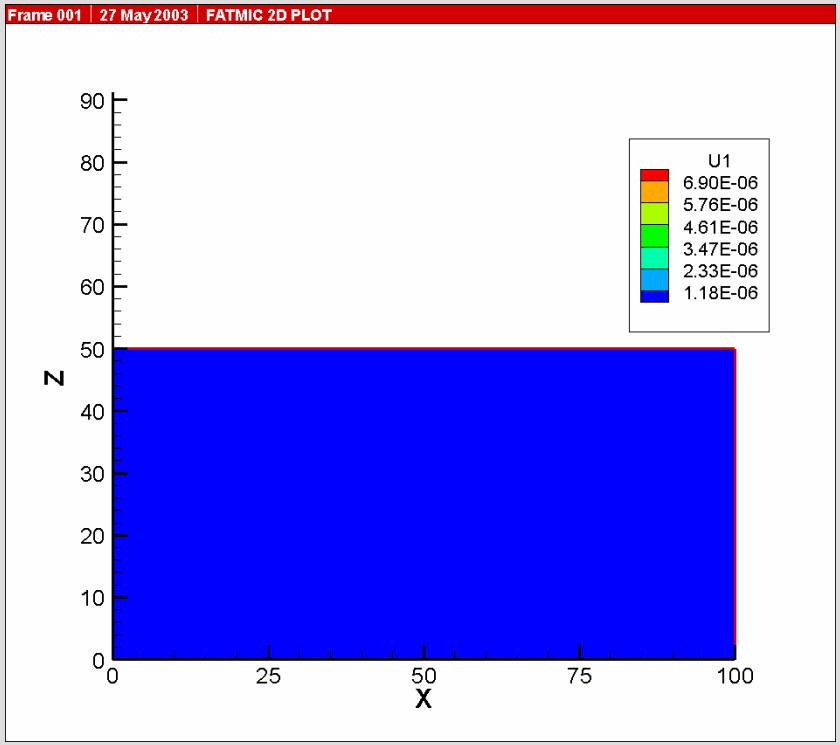



Ac(2)

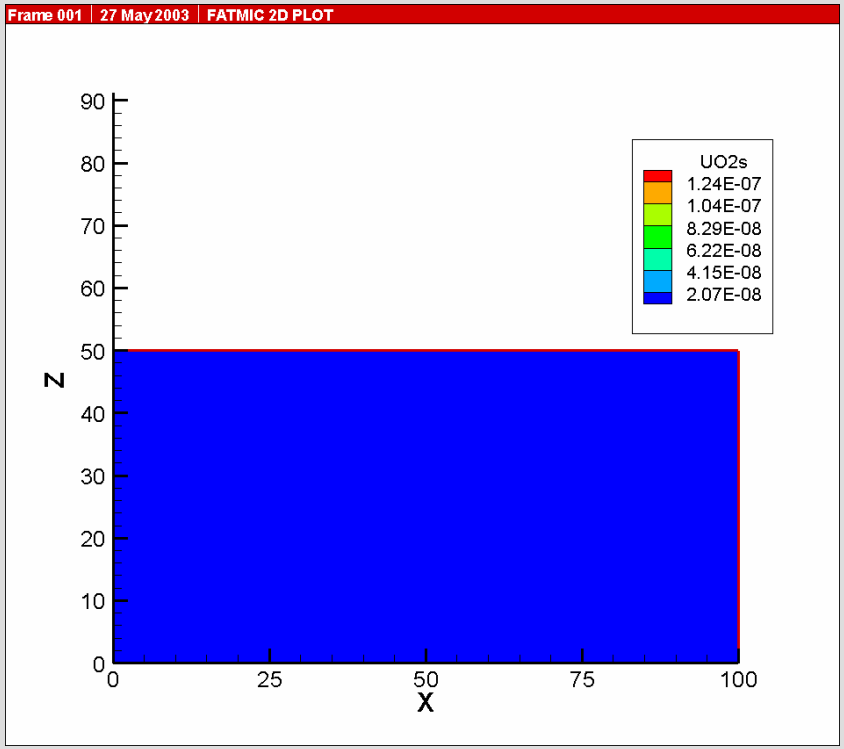


# Element 5: Numerical model application

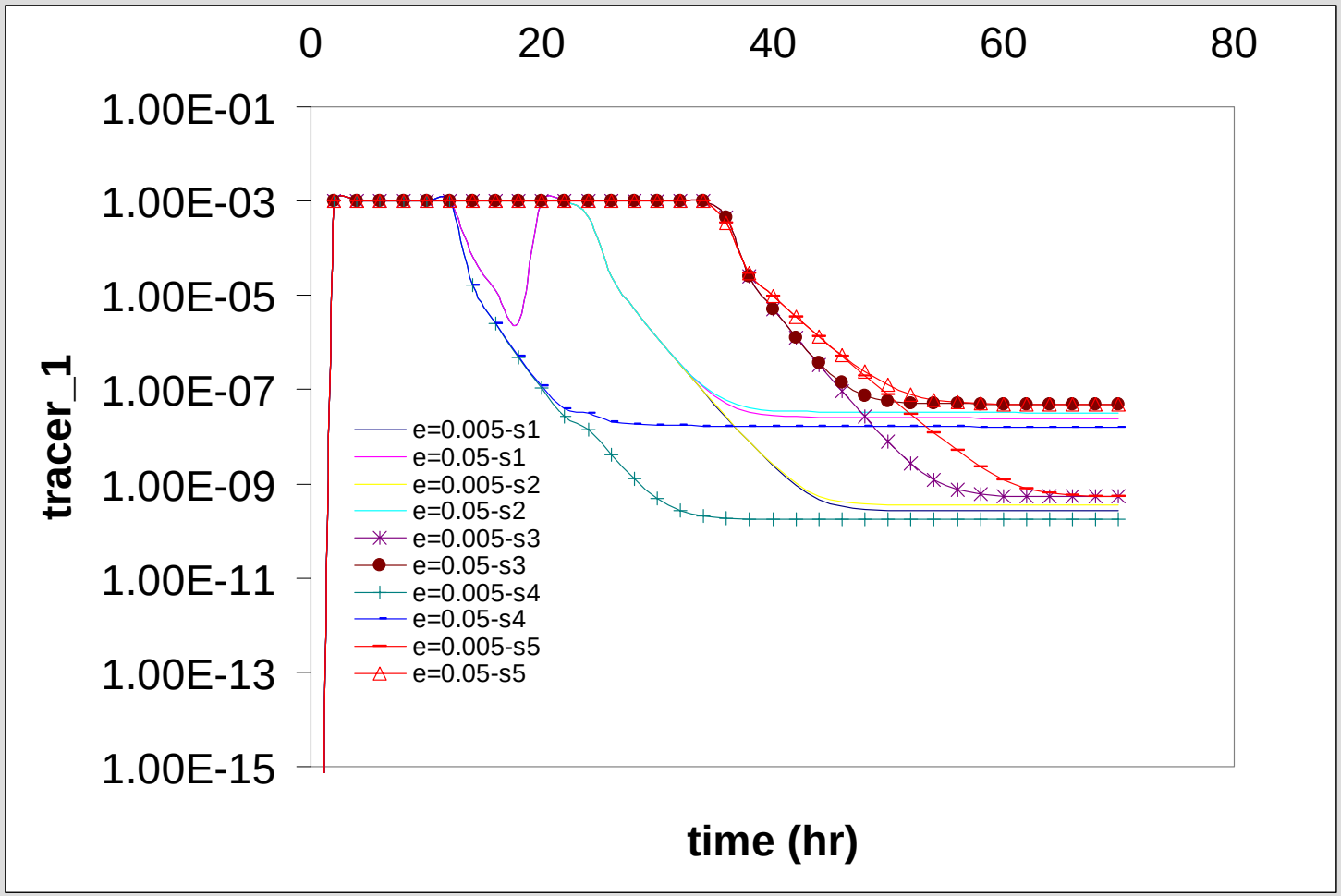
U(VI) - 1




UO2s

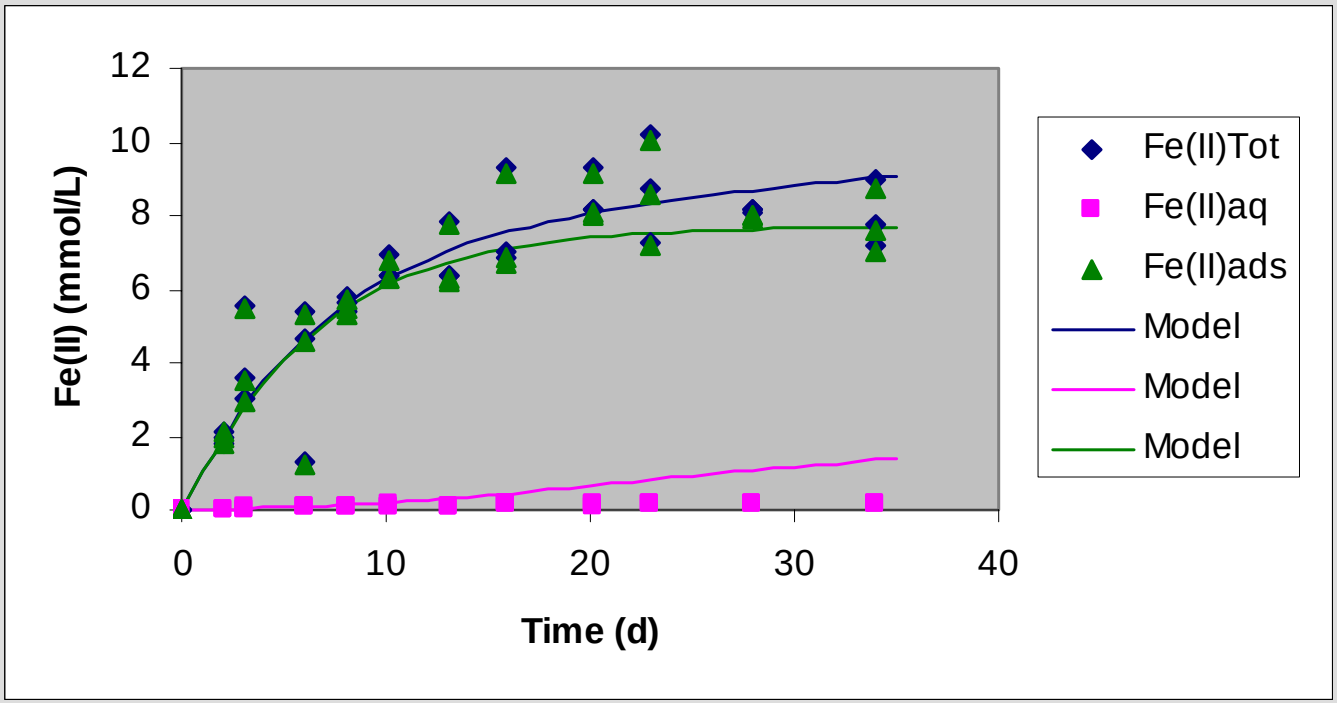


# Tracer Test Design



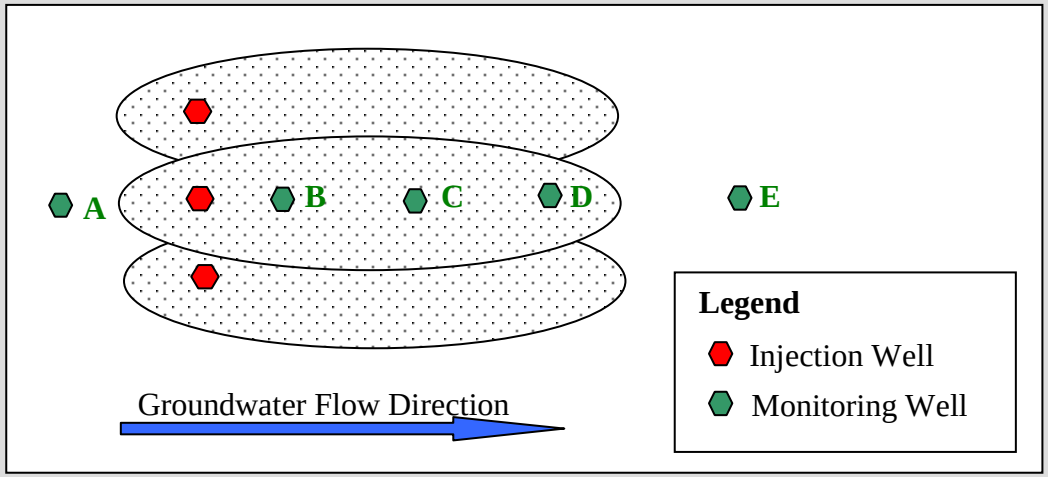
# Element 5: Numerical model application

• **Other NABIR research (Roden/Burgos) is developing reaction-based models of coupled iron(iii) oxide and U(VI) reduction kinetics including sorption Fe(II) and U(VI) and site blocking.**



# Element 6: Field biostimulation experiment at Area 2

- Experimental design – how impacted by hypothesis?
- Observe decrease of U(VI) in macropores
- Quantitative interpretation
- Post-experimental drilling



# Near-Term Field Work Plans

- **Sequential installation of well field**
  - **1: Exploratory wells (April-May 2003)**
  - **2: Detailed characterization wells (Aug-Sept 2003)**
  - **3: Complete experimental wellfield (2004)**
- **Collection of intact blocks from background area**
  - **Excavation likely in May 2003**
  - **Column preparation and loading ~6 months**

# Near-Term Field Work Plans

- **Objectives:**
  - Define hydrologic system characteristics
    - hydraulic gradient
    - flow rate
    - degree of transience
    - effective porosity
    - flow path connectedness
  - Design and implement tracer tests
    - Single well
    - Multiple well
  - Install cross-well geophysical wells
  - Perform long-term continuous monitoring

# Collaborative Opportunities

- Linkages already identified:
  - Istok et al. – Numerical modeling of push-pull tests; joint implementation of single-well methods
  - Criddle et al. – Biogeochemical modeling and geophysical characterization
  - Wan et al. / Fendorf et al. / Liu et al – Diffusive controls on bioremediation
  - Chandler et al. – Microbead analysis
  - Long et al. – UMTRA – Field experimental techniques