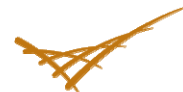


# Hydrologic Characterization and Results from the First Tracer Experiment at the Hanford 300 Area IFRC Site

Mark Rockhold, Vince Vermeul, Chris Murray,  
and John Zachara

4<sup>th</sup> Annual DOE-ERSP PI Meeting  
April 20-23, 2009, Lansdowne, Virginia



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# Outline

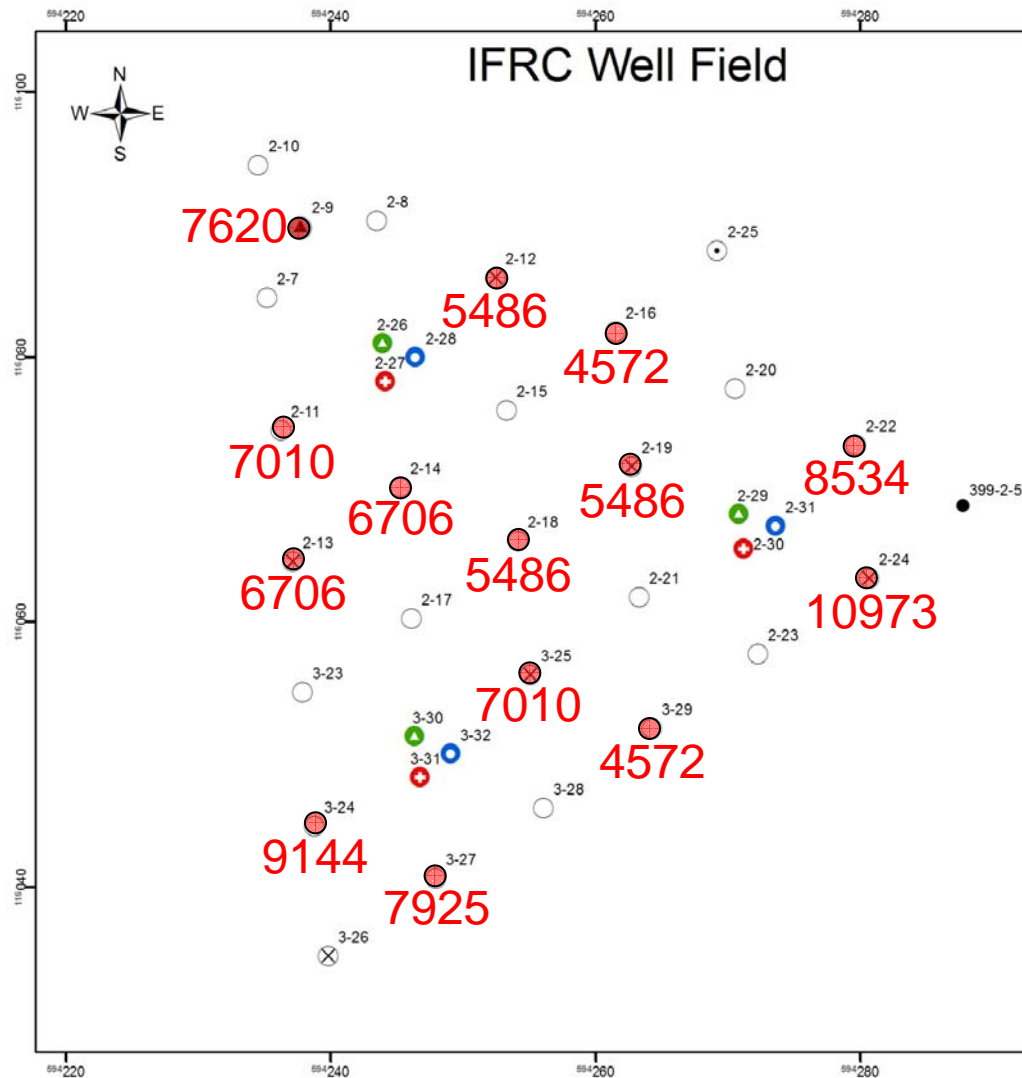
- ▶ Hydraulic property characterization
- ▶ Tracer test (Nov. 2008 field experiment)
- ▶ Preliminary flow and transport modeling

# Hydraulic Property Characterization

- ▶ Constant rate injection tests (field)
- ▶ Electromagnetic borehole flow meter (EBF) testing (field)
- ▶ Multi-step outflow experiments (lab)



# Constant Rate Injection Tests



- ▶ Number wells tested: 14
- ▶ Injection rate: 316 gpm
- ▶ Test duration: 20 min
- ▶ Typical displacement:
  - < 0.1 ft (2-3 cm)
- ▶ Methods of analysis:
  - Neuman (1975)
  - Theis (1935)
- ▶ **Average K = 6945 m/d**

# EBF Testing

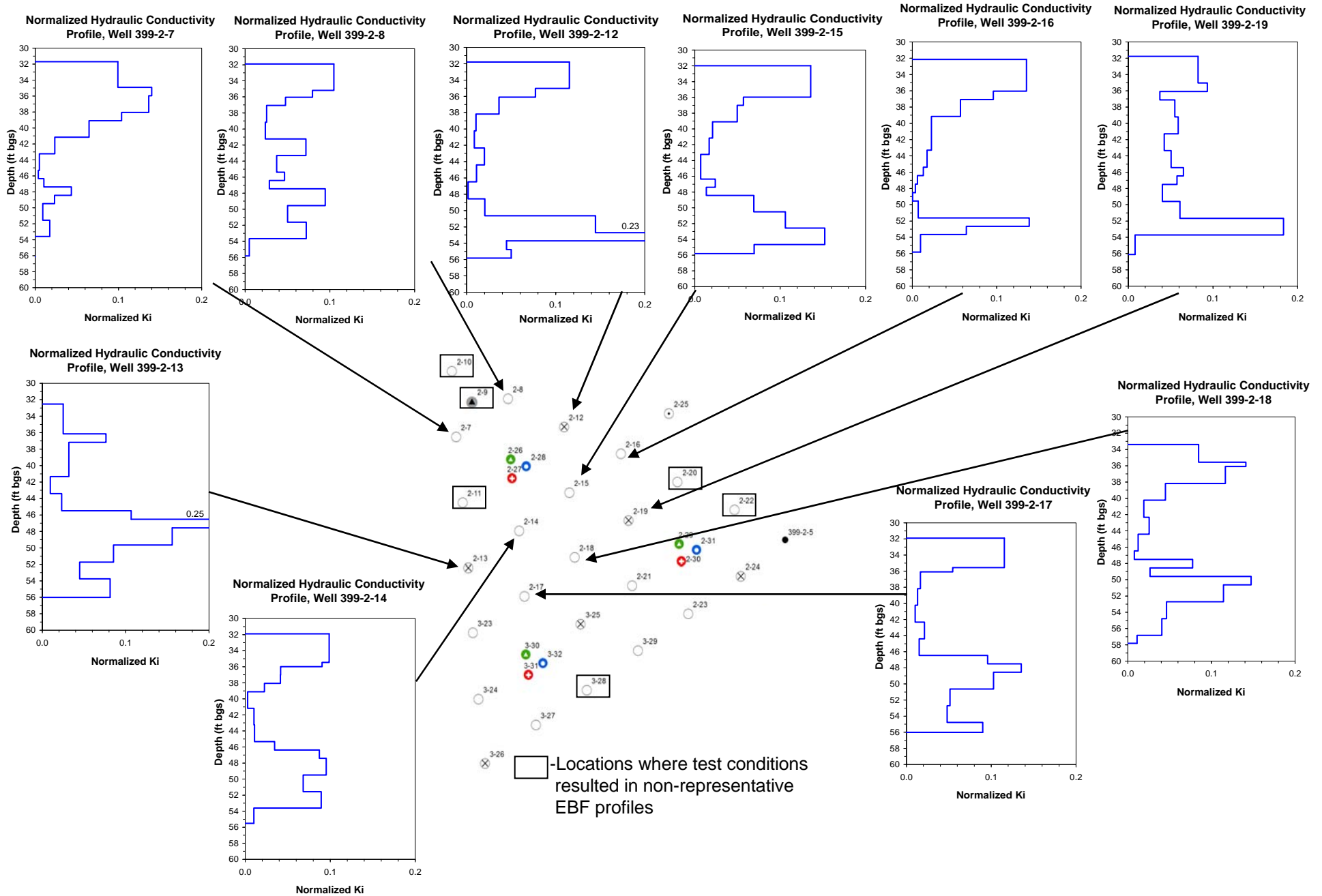
- ▶ Number of wells tested: 26
- ▶ Extraction rate: 1.04 - 1.55 gpm
- ▶ Measurement interval: 1 - 2 ft (~0.3 - 0.6 m)
- ▶ Method of analysis:
  - Molz et al. (1994)
- ▶ Absolute K estimated from

$$\bar{K} = \frac{\sum_i K_i dz_i}{b}$$

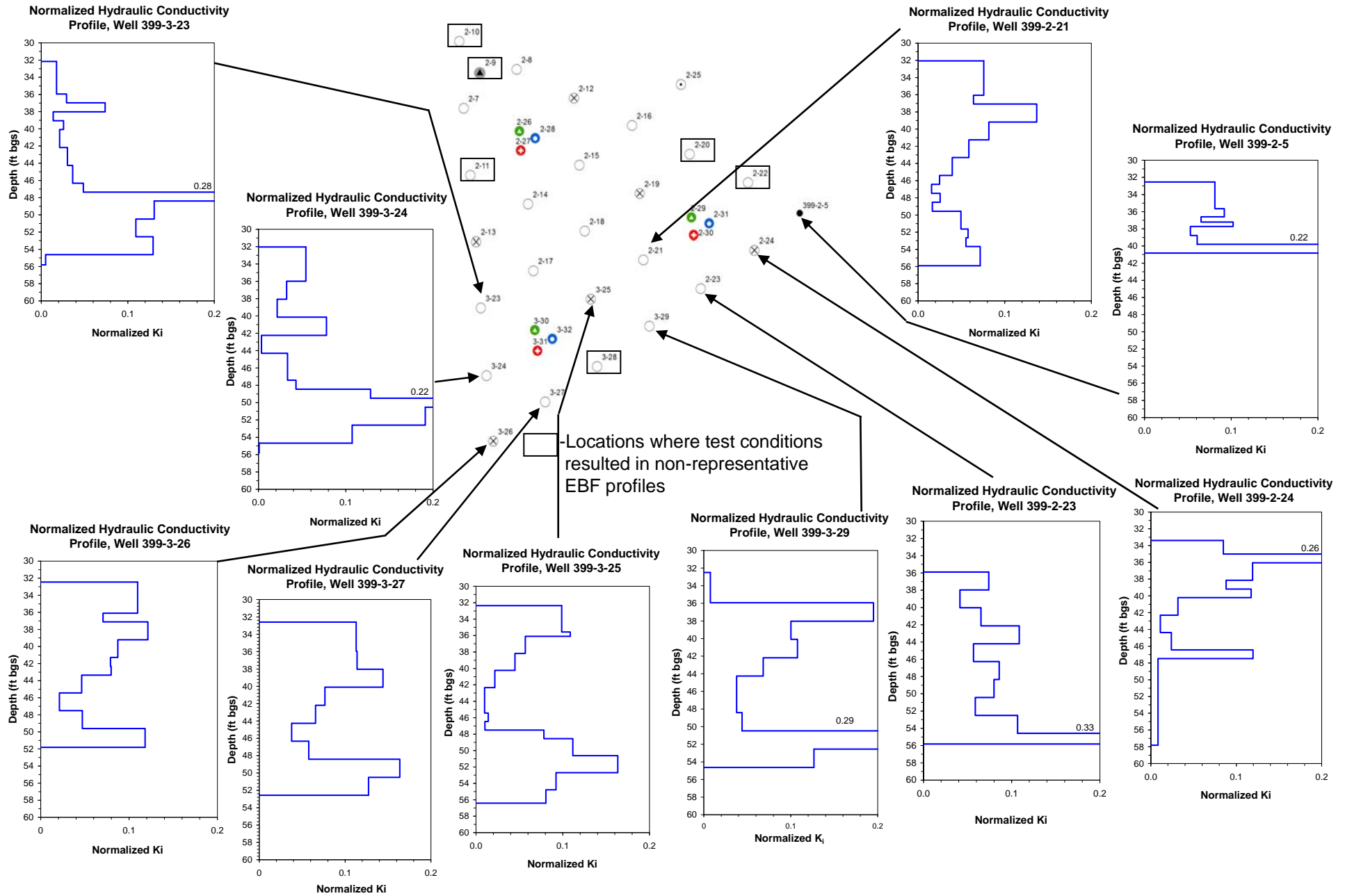
$$b = \sum_i dz_i$$



# Normalized EBF - K Profiles



# Normalized EBF - K Profiles

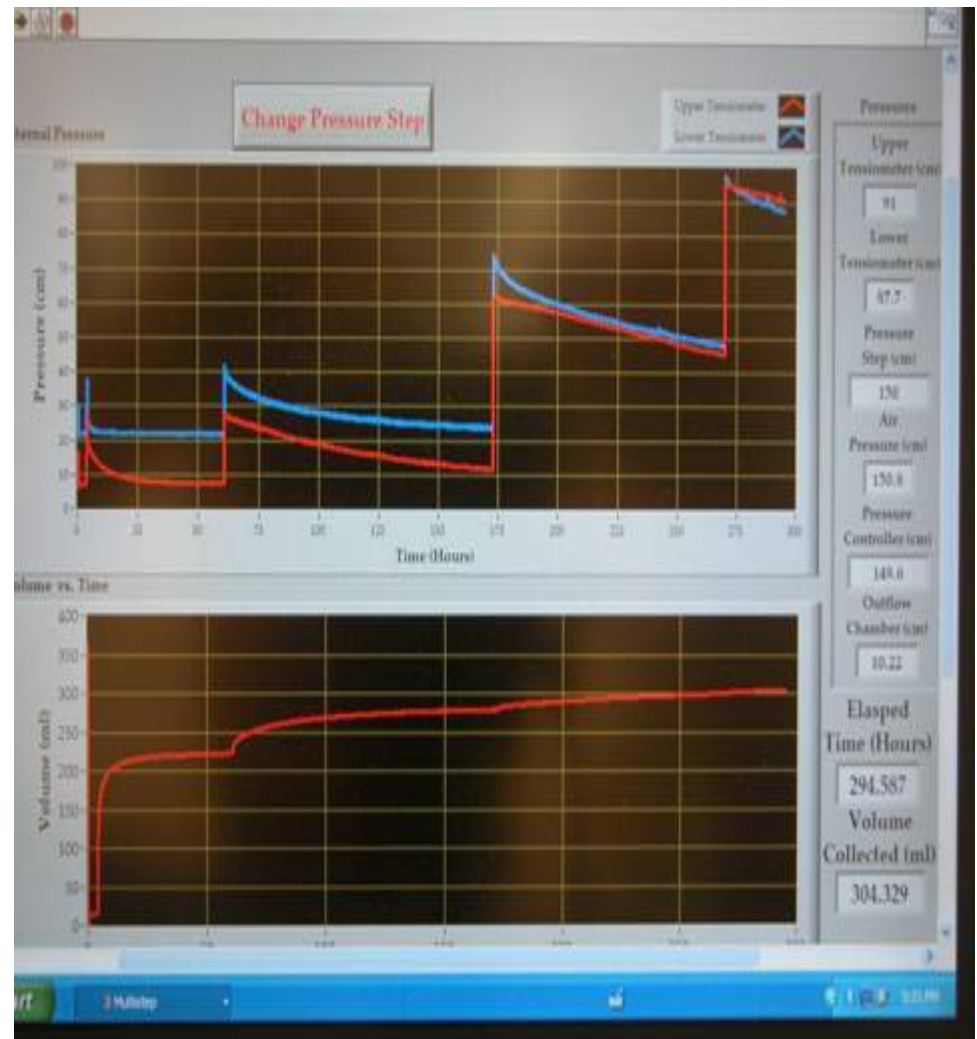


# Multi-Step Outflow Experiments (40 cores)

Intact cores



Automated measurement system



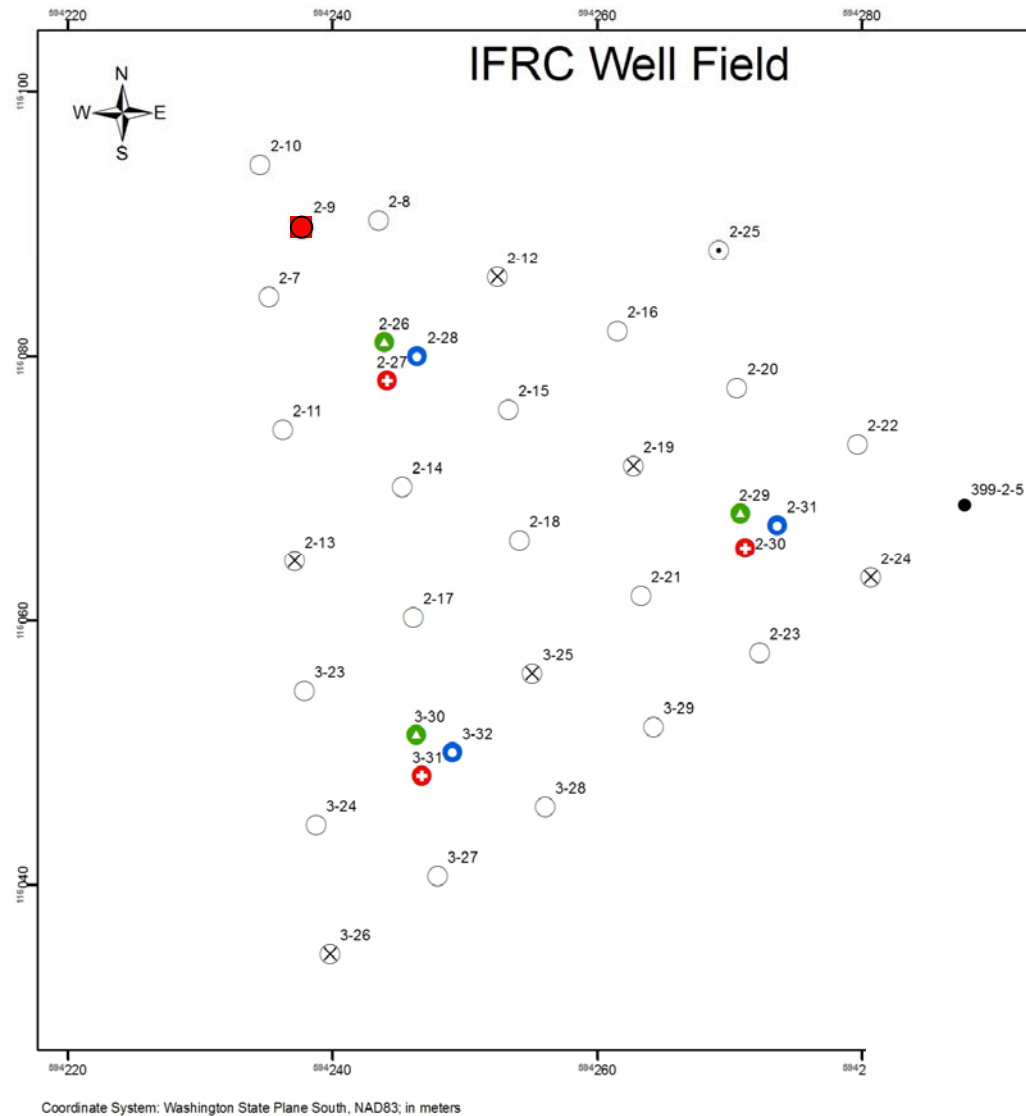


# Additional lab characterization

- ▶ Ksat
- ▶ Bulk and particle densities
- ▶ Whole sediment grain-size distributions
- ▶ Geochemical properties (Zachara)
- ▶ GEA (Ward)
- ▶ Electrical properties (Ward and Versteeg)

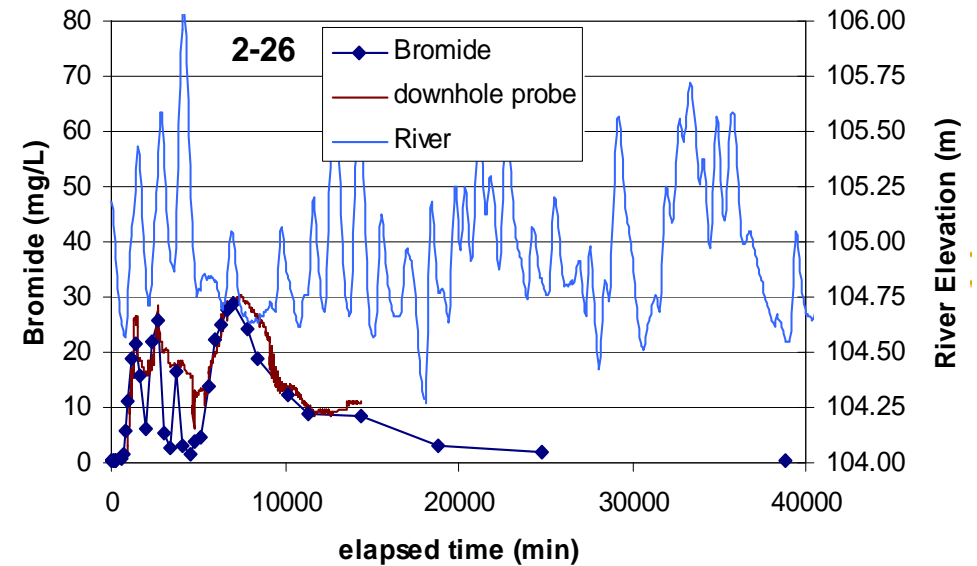
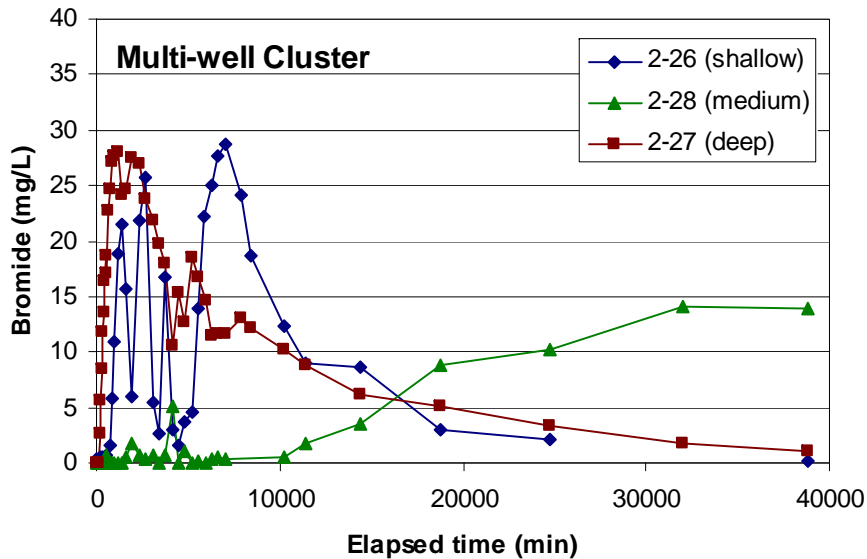
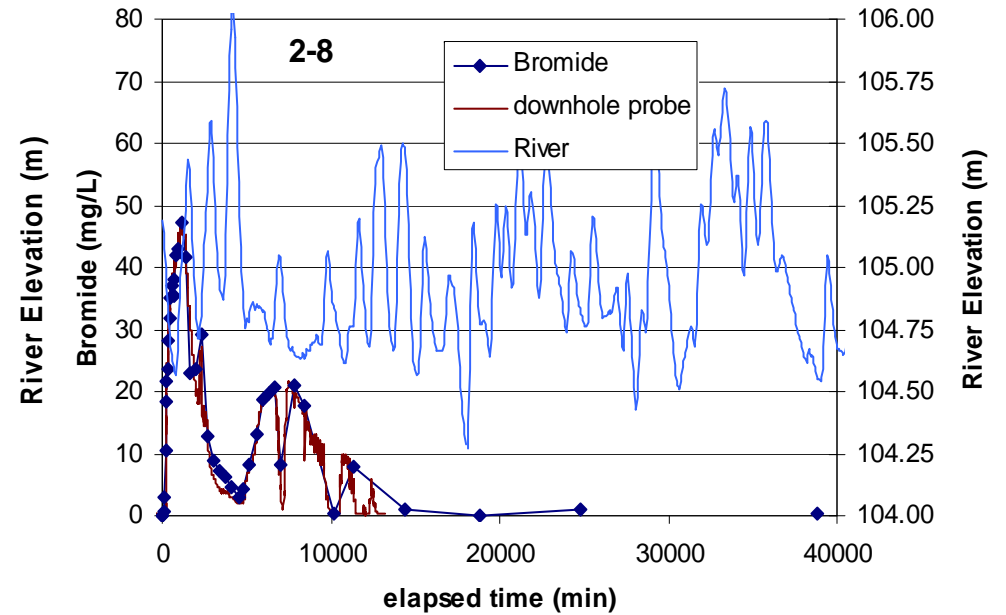
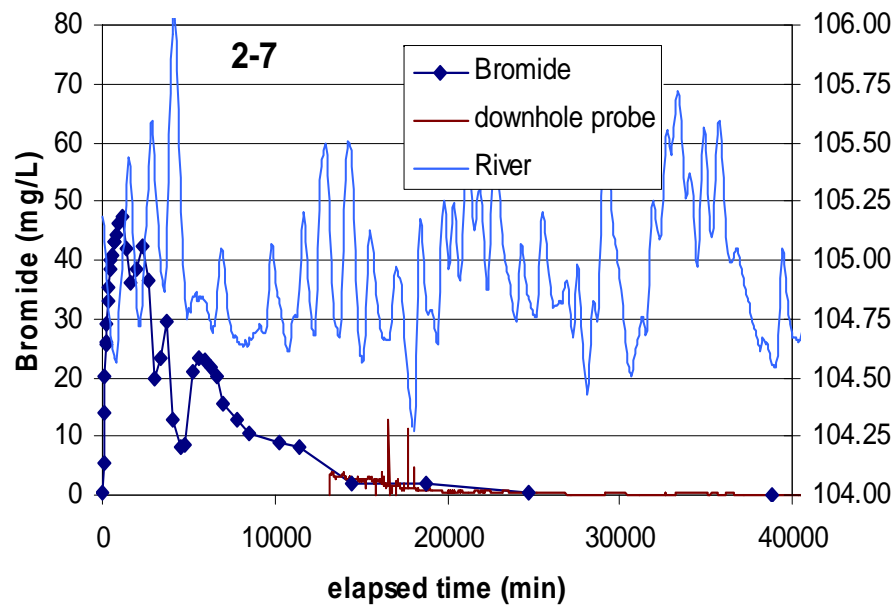


# Tracer test (Nov. 2008 experiment)

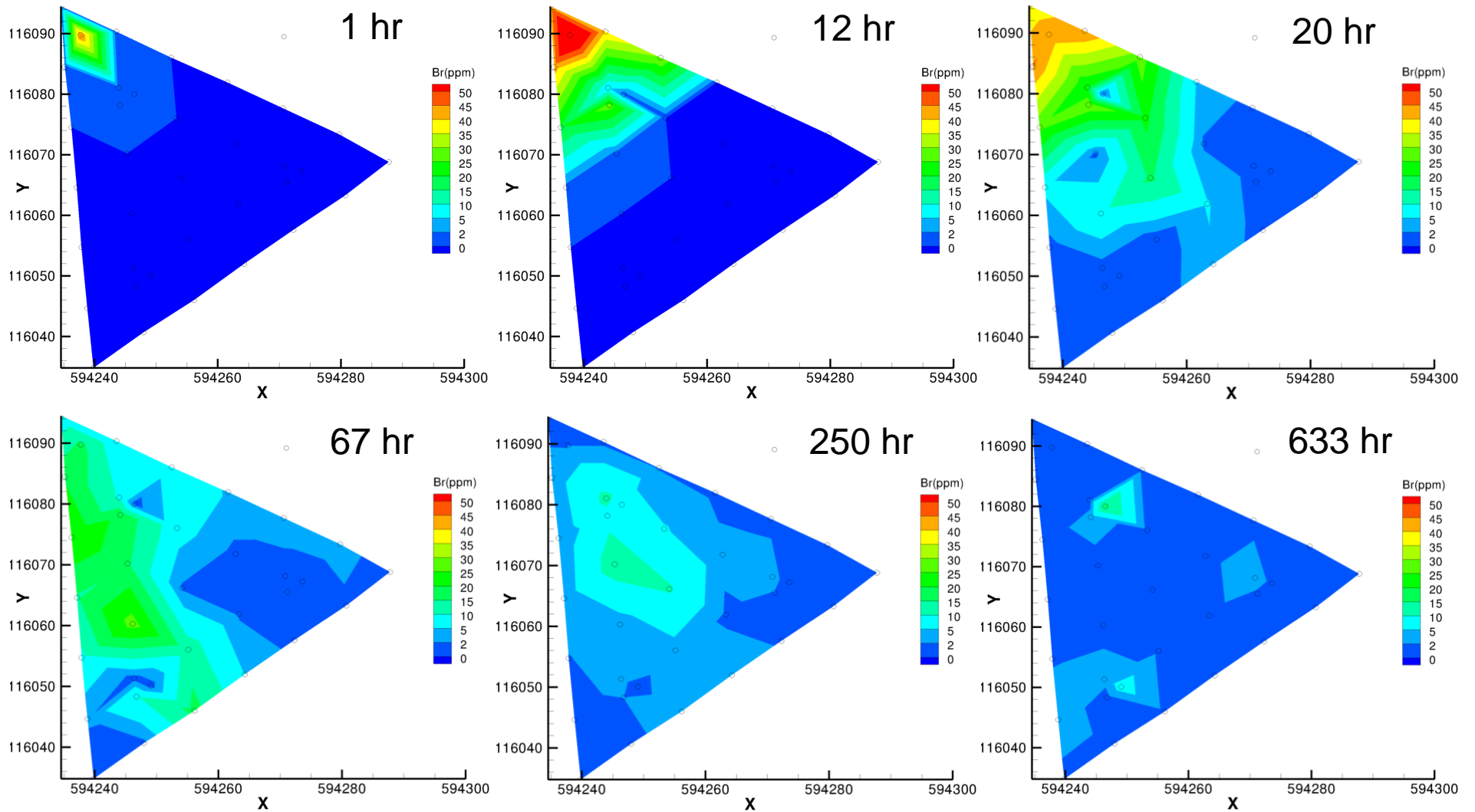


- ▶ Injection well: 399-2-9
- ▶ Injection volume: ~160,000 gal
- ▶ Injection rate: 180 gpm
- ▶ Injection duration: ~900 min (15 hr)
- ▶ Avg. Br- concentration: 56 mg/L
- ▶ Experimental duration: Nov. 11 – Dec. 8, 2008

# Tracer test (Nov. 2008 experiment)



# Tracer test (Nov. 2008 experiment)



# Flow and Transport Modeling (STOMP)

## ► Grid specifications

### ■ Coarse grid<sup>†</sup>

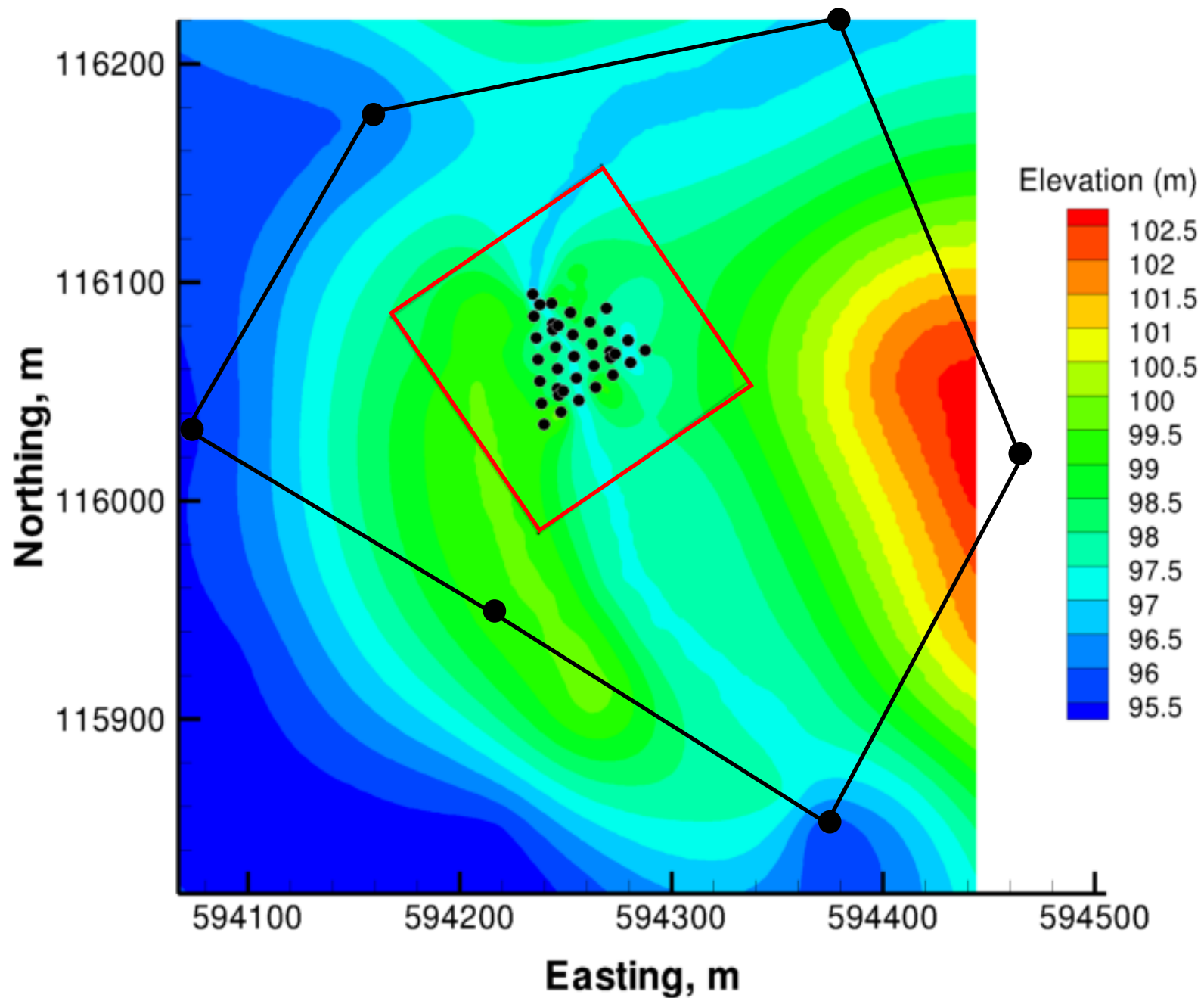
- 91 x 91 x 20 grid blocks (165,620 total)
- Uniform 1-m spacing in x-y, uniform 0.5-m spacing in z

### ■ Fine grid

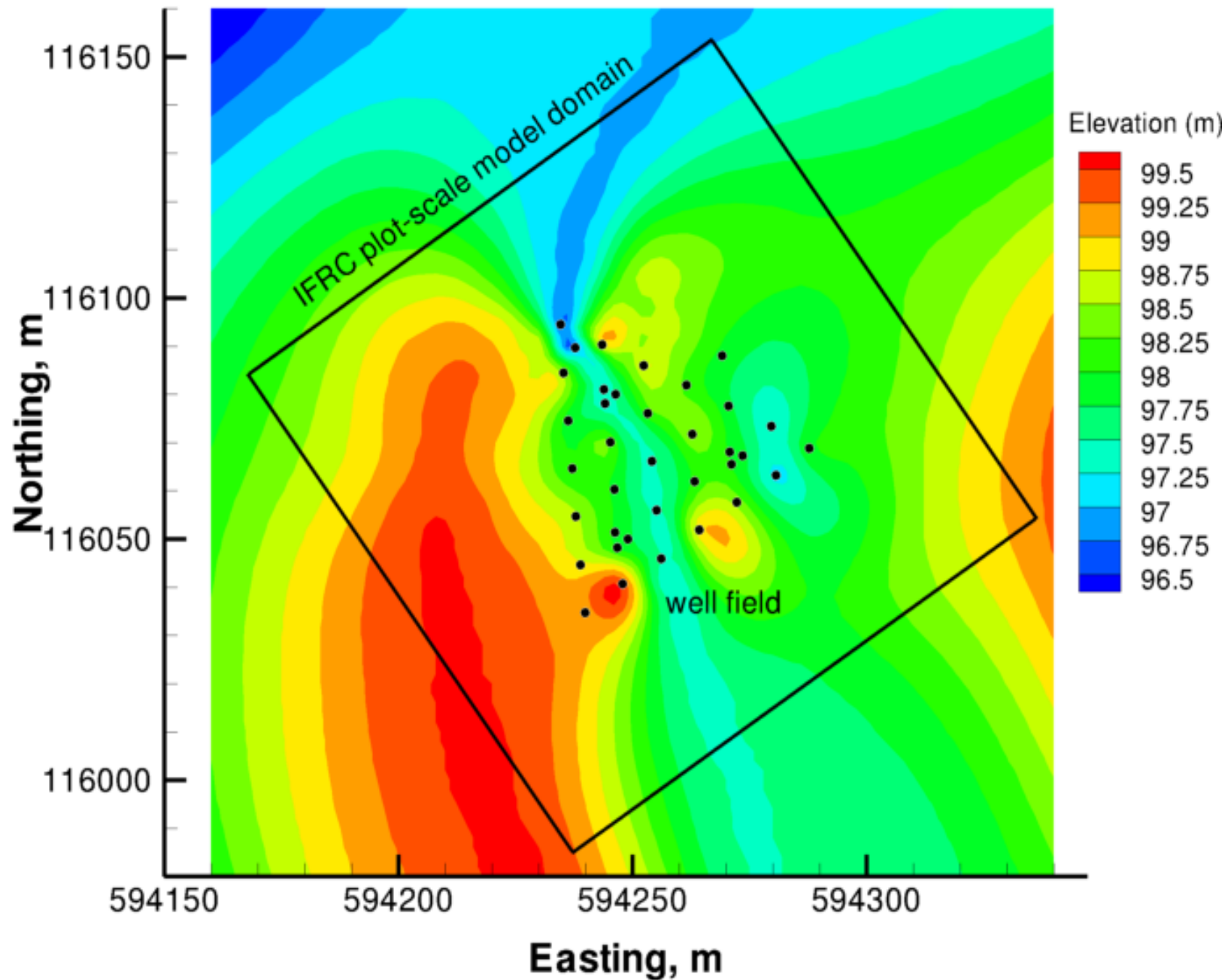
- 121 x 121 x 110 grid blocks (1,610,510 total)
- Uniform 1-m spacing in x-y, uniform 0.1-m spacing in z

<sup>†</sup>A coarse grid STOMP model has been provided to INL and to two SFA projects.

# Interpreted Elevation of Hanford-Ringold Fm Contact



# Interpreted Elevation of the Hanford - Ringold Fm Contact

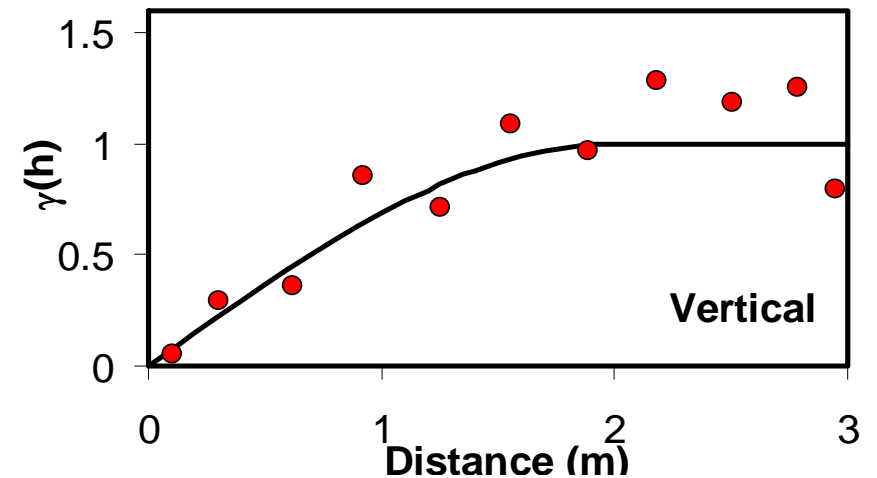
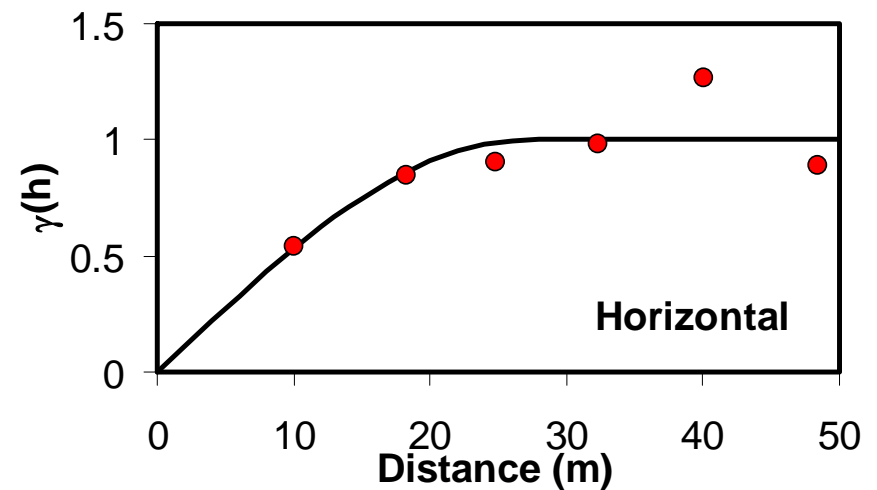


# Flow and Transport Modeling

## ► Variography

- Hydraulic conductivity
  - Single-structure spherical model
  - Nugget = 0
  - Sill = 1 (standardized)
  - Horizontal range = 27 m
  - Vertical range = 2 m

**Hydraulic Conductivity  
Normal Scores Variograms**





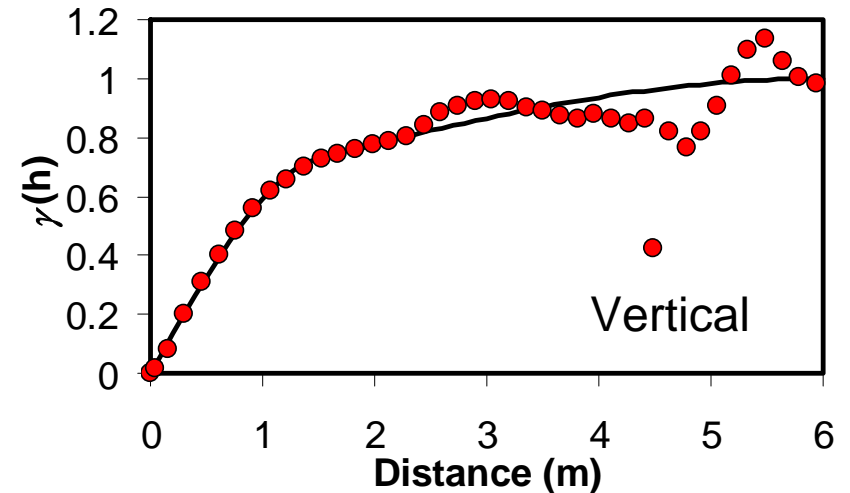
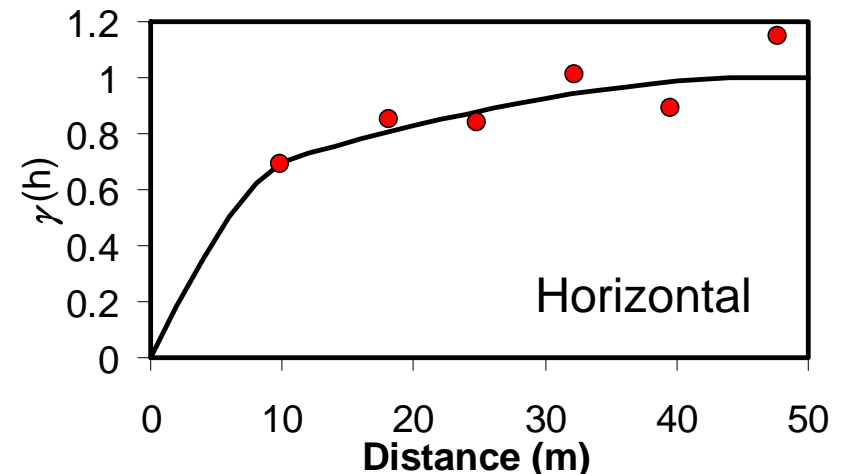
# Flow and Transport Modeling

## ► Variography

### ■ Gamma log data

- Nested spherical model (2 structures)
- Nugget = 0
- Sill 1 = 0.57
- Sill 2 = 0.43
- Horizontal range 1 = 11 m
- Horizontal range 2 = 47 m
- Vertical range 1 = 1.5 m
- Vertical range 2 = 6 m

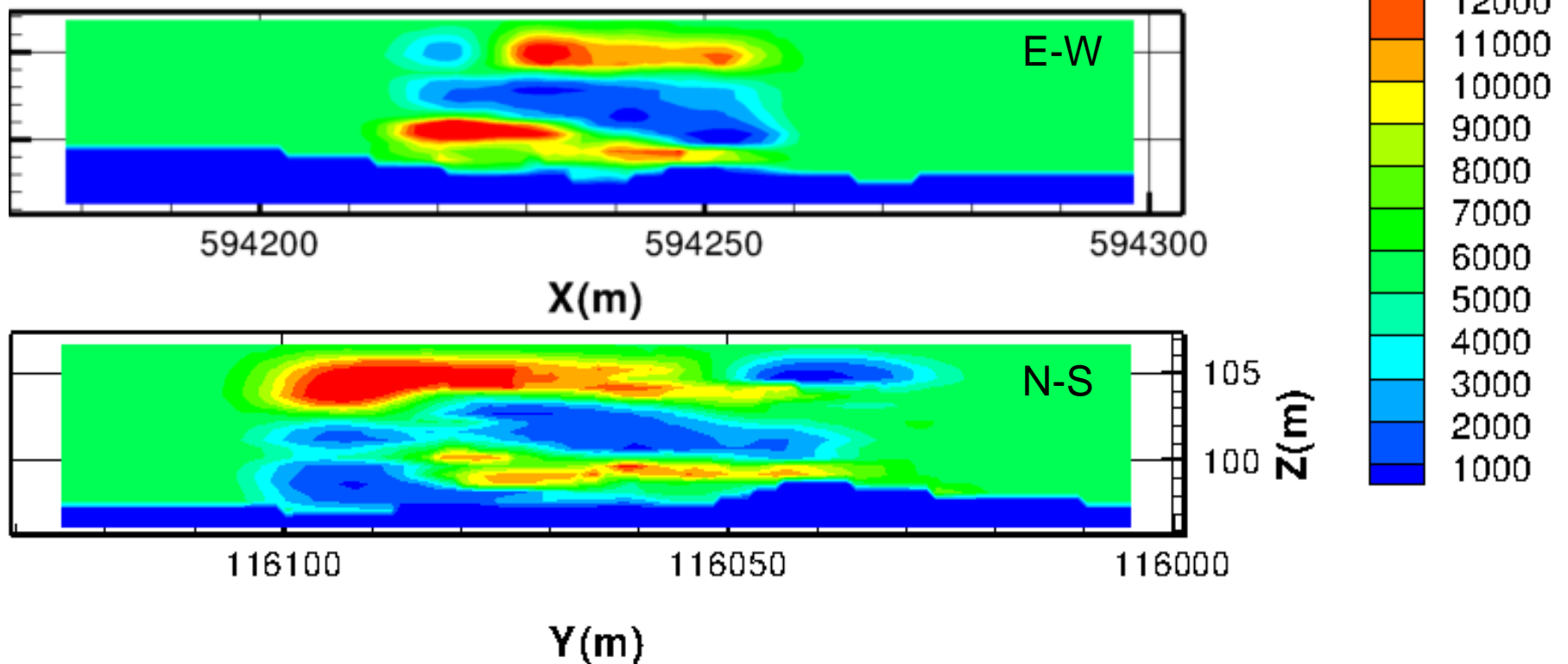
**Total Gamma  
Normal Scores Variograms**



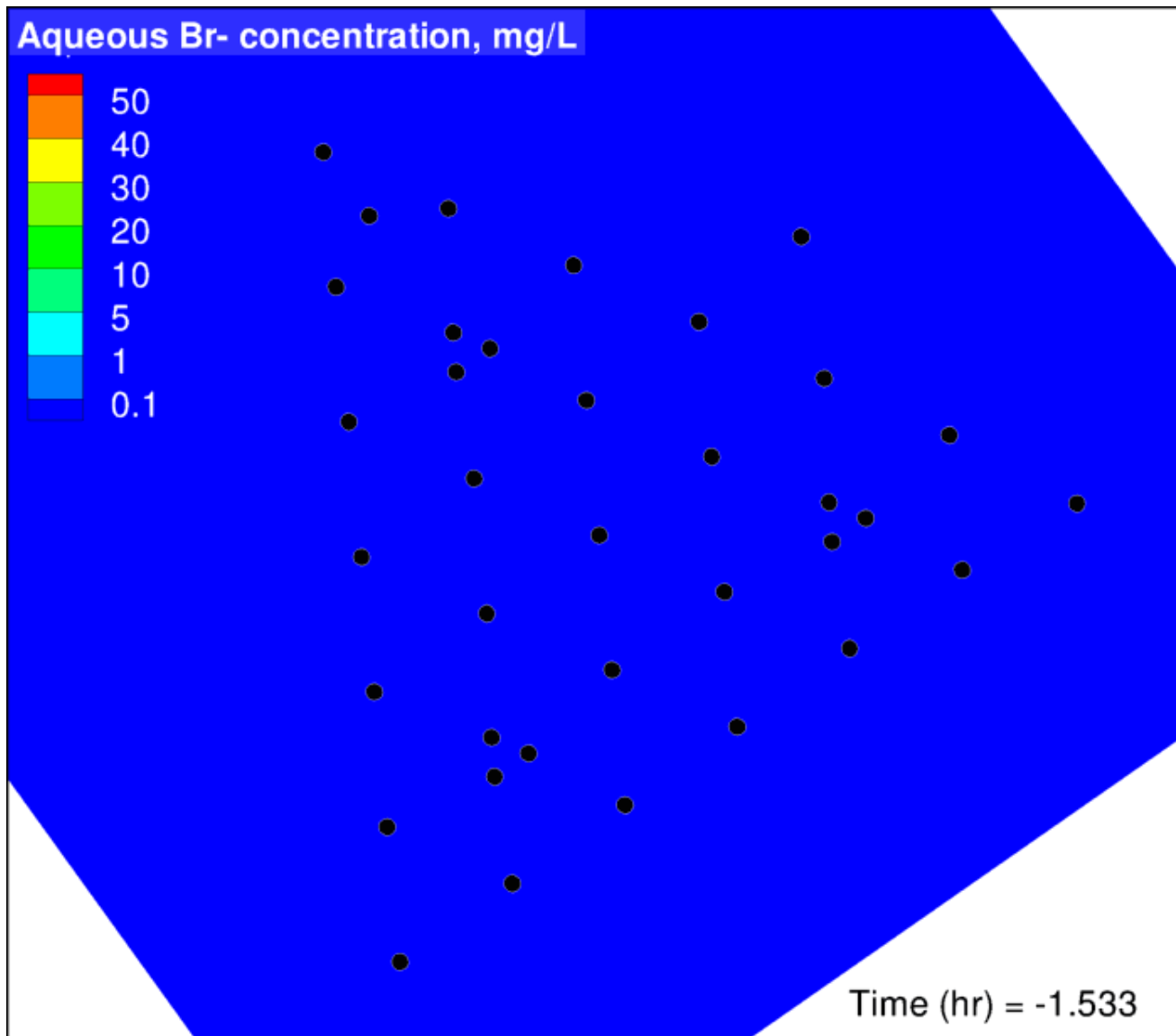
# Flow and Transport Modeling

## ► Property field generation

- Simple kriging
- Co-kriging
- Simulated annealing

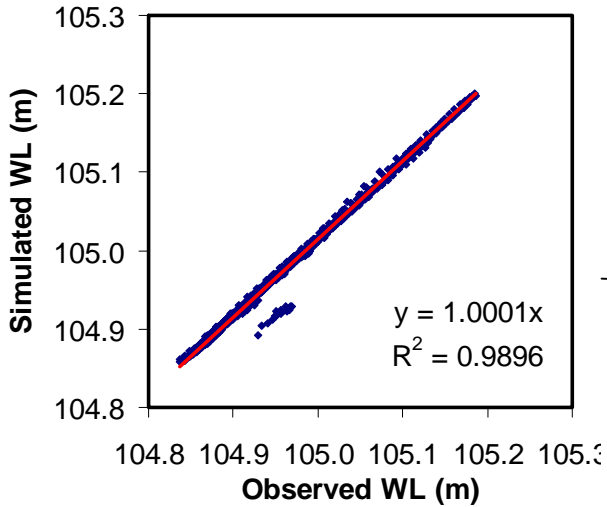


# Flow and Transport Modeling

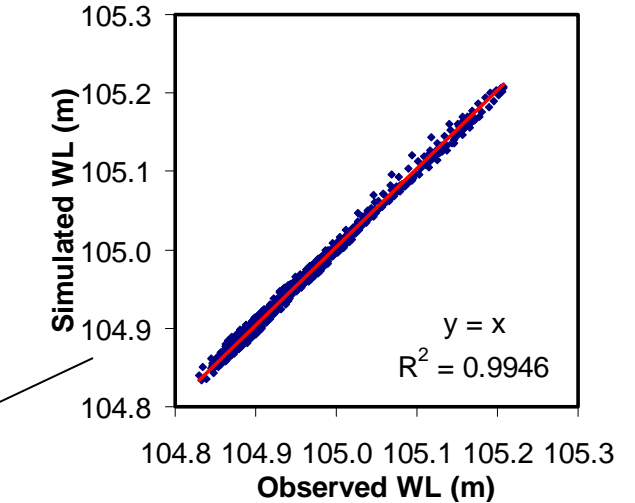


# Observed versus simulated water levels

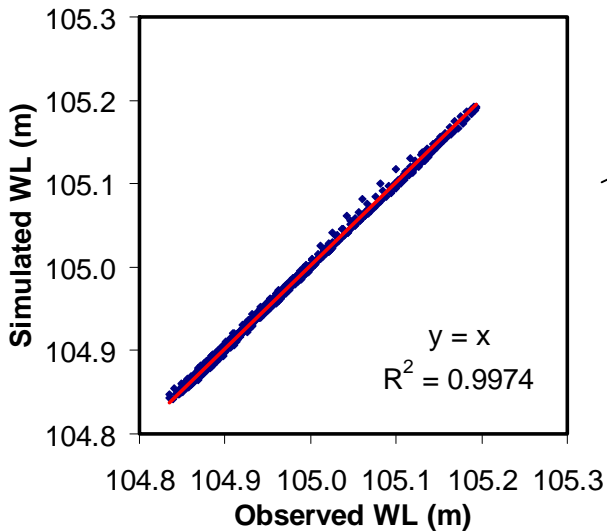
Well 399-2-9



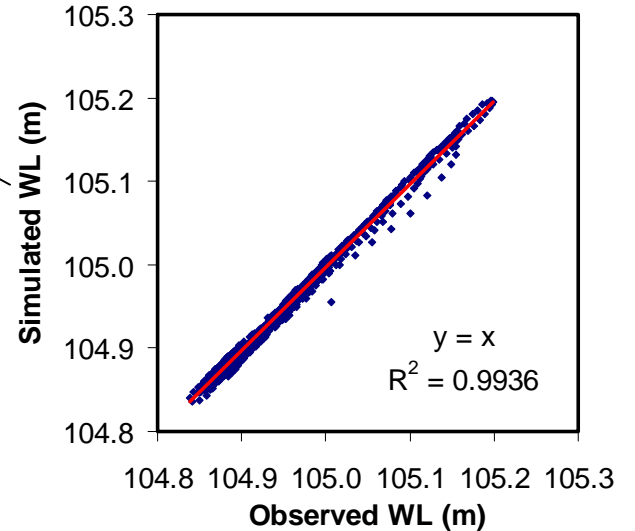
Well 399-2-5



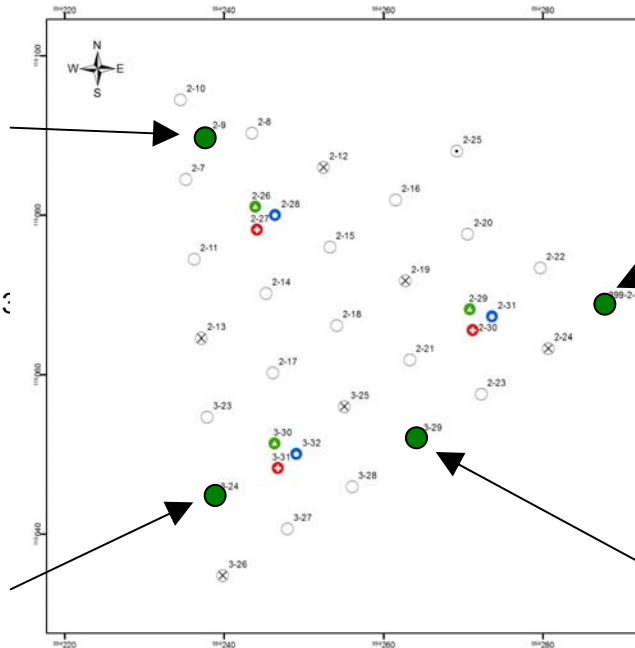
Well 399-3-24



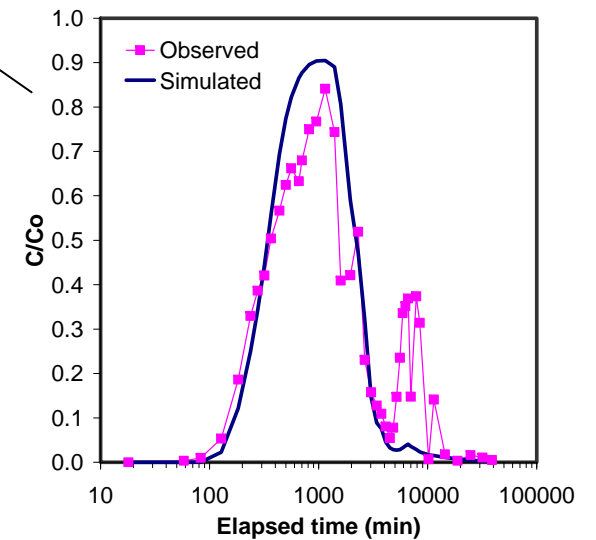
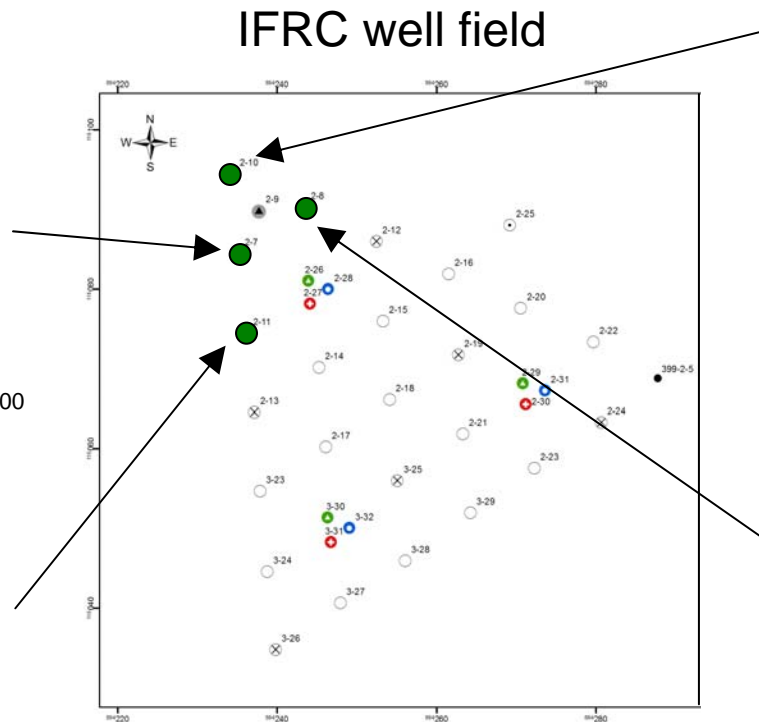
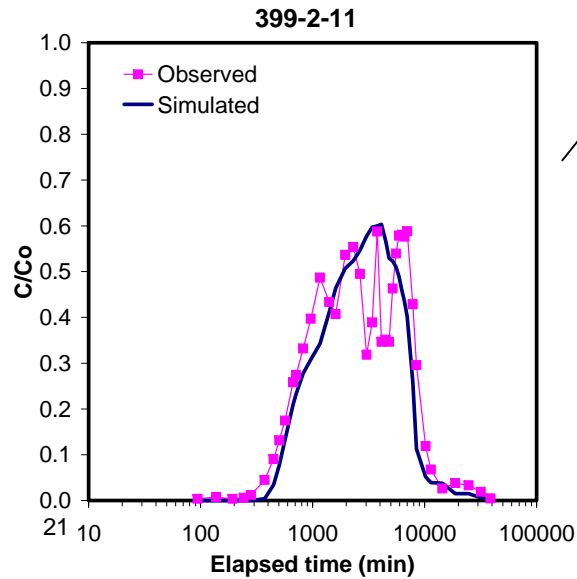
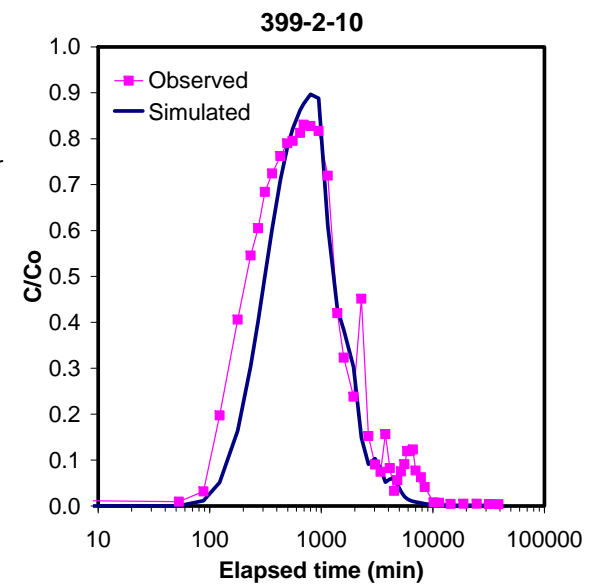
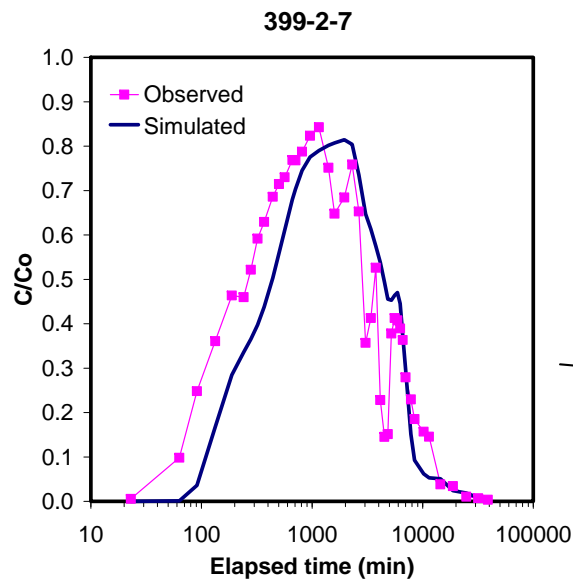
Well 399-3-29



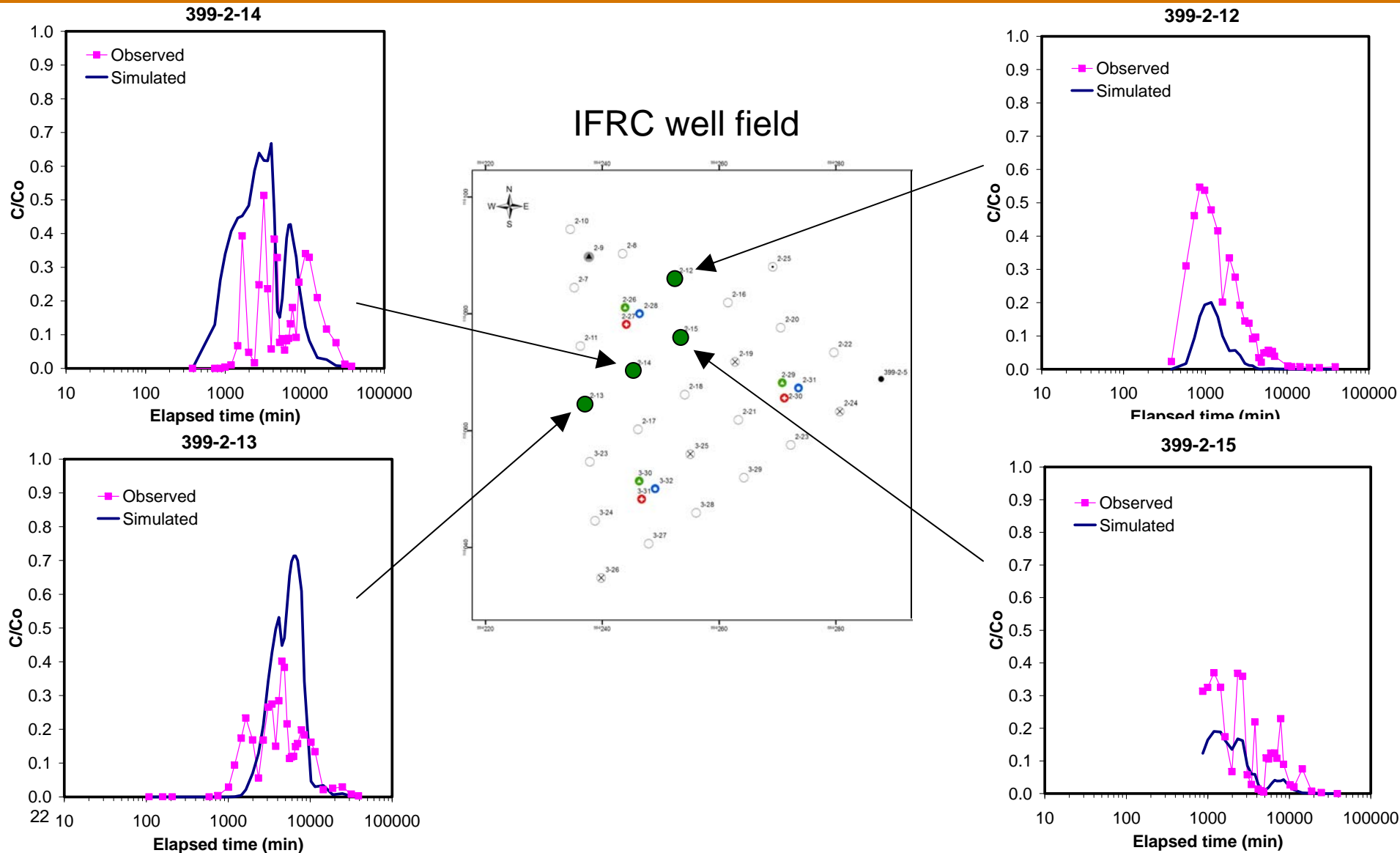
IFRC well field



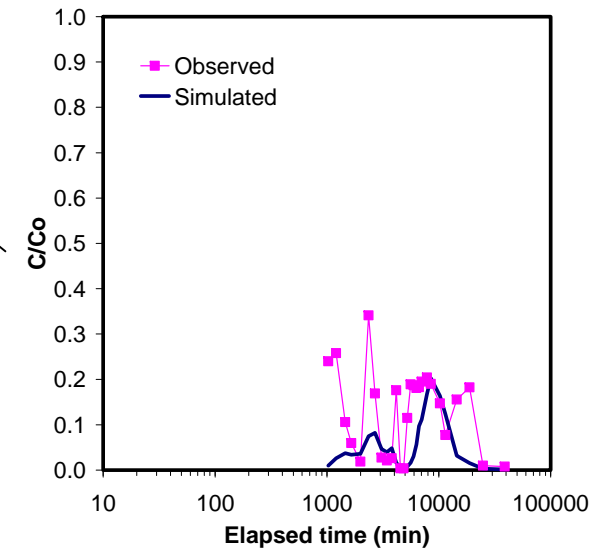
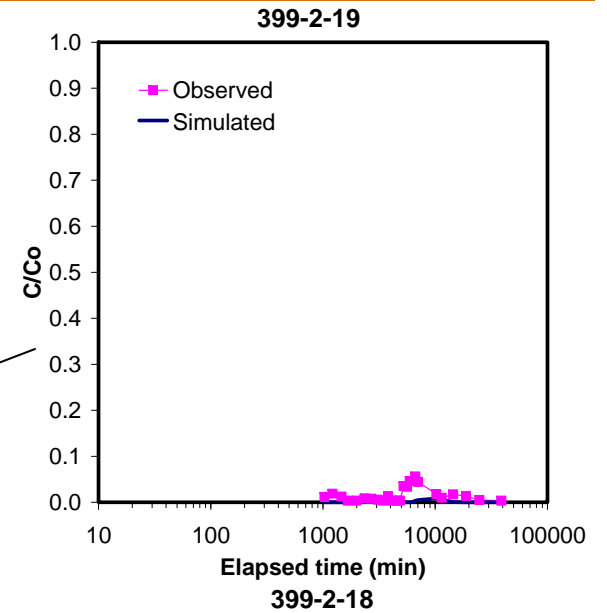
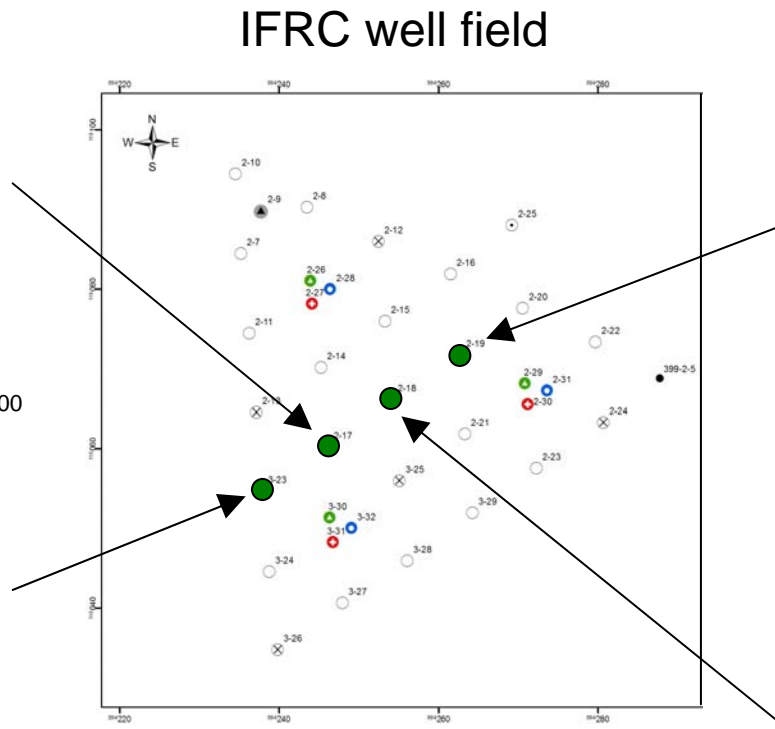
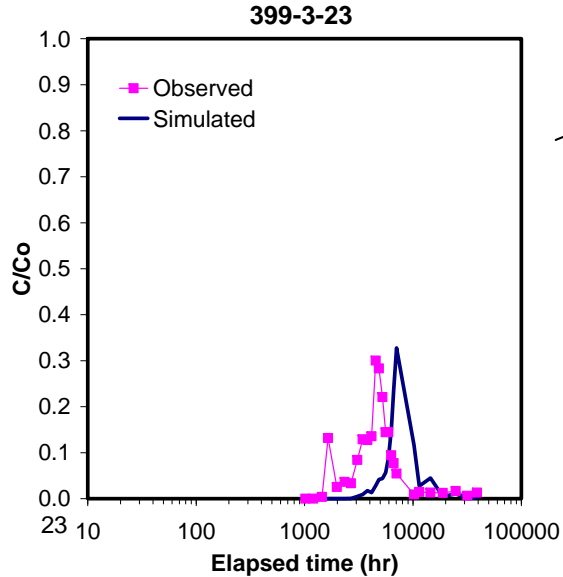
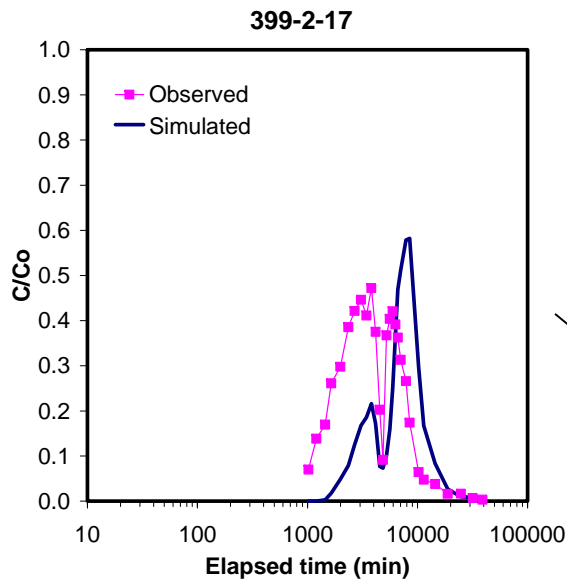
# Observed and simulated tracer BTCs



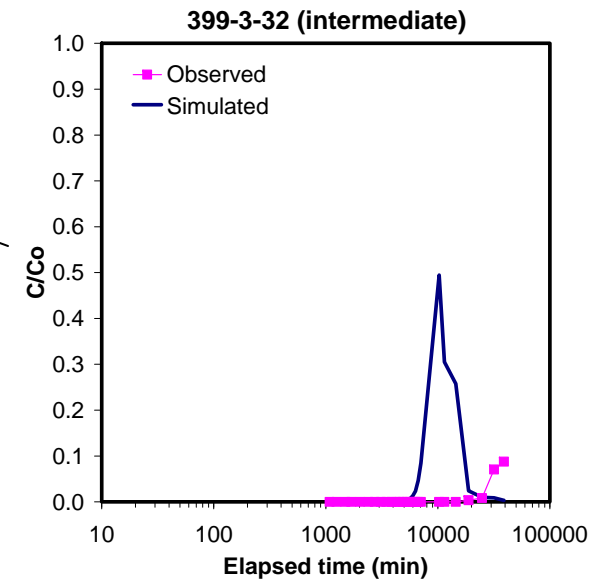
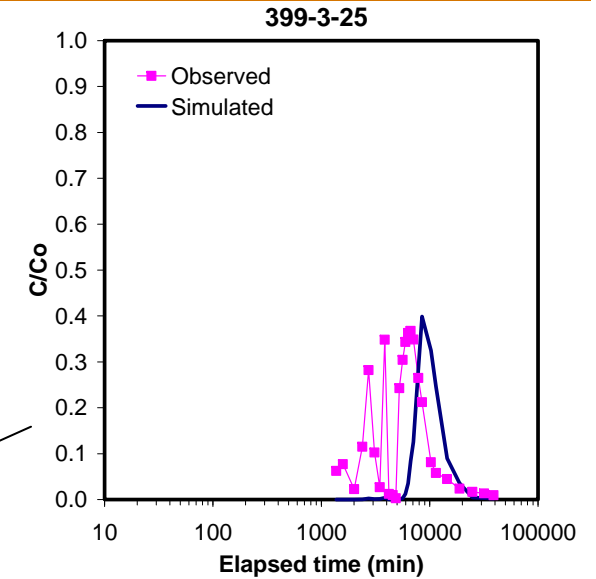
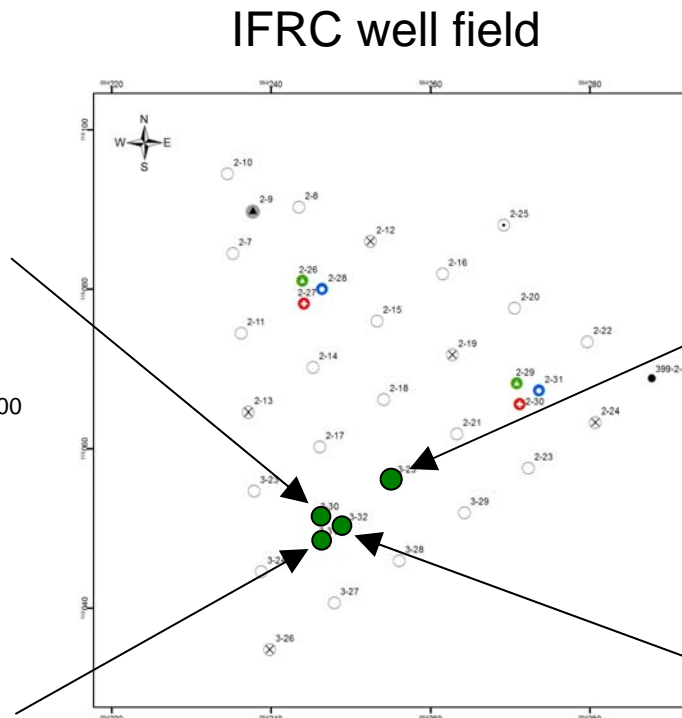
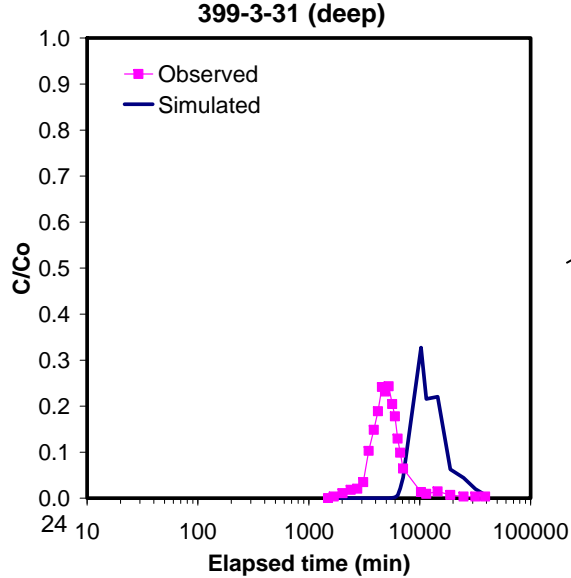
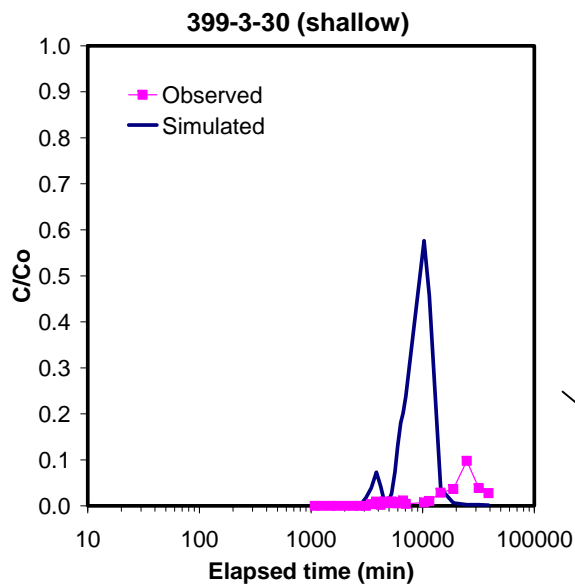
# Observed and simulated tracer BTCs



# Observed and simulated tracer BTCs

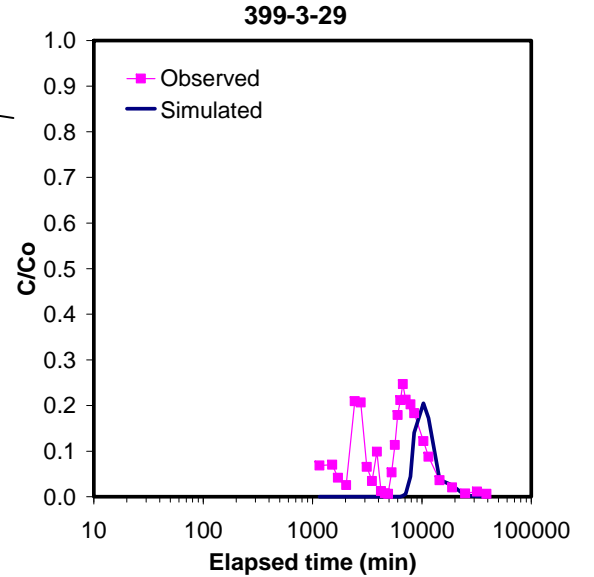
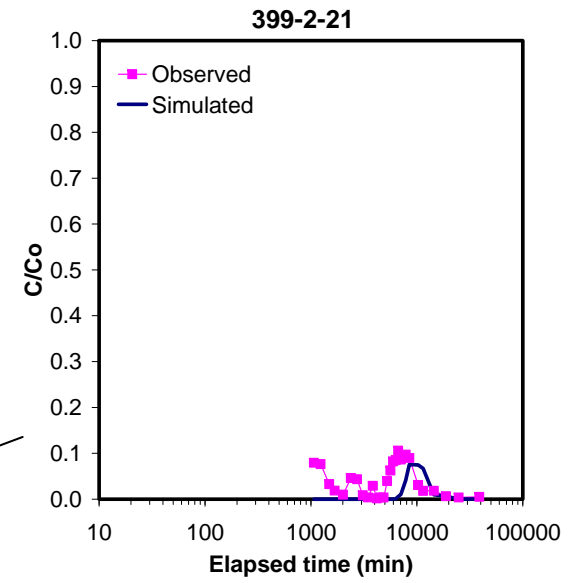
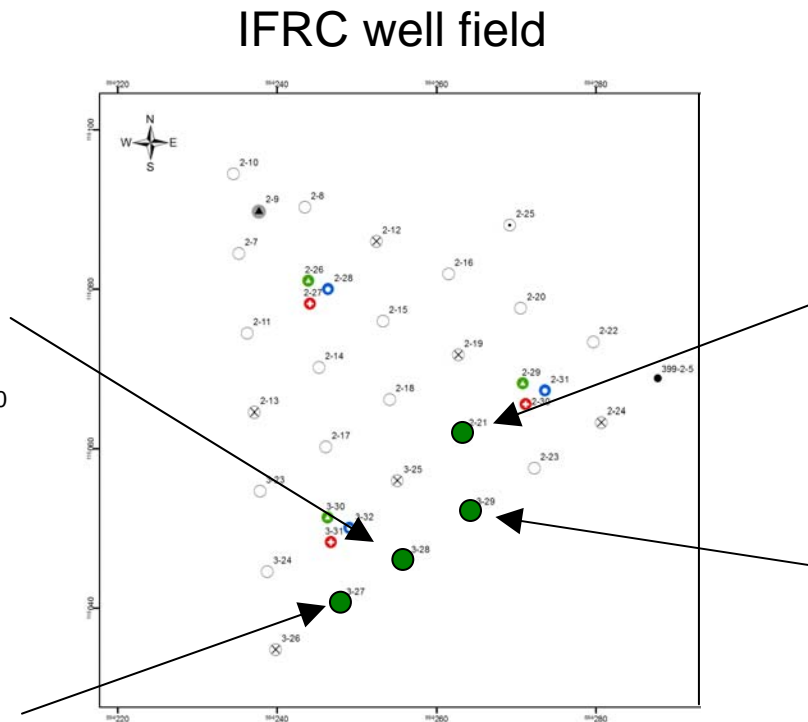
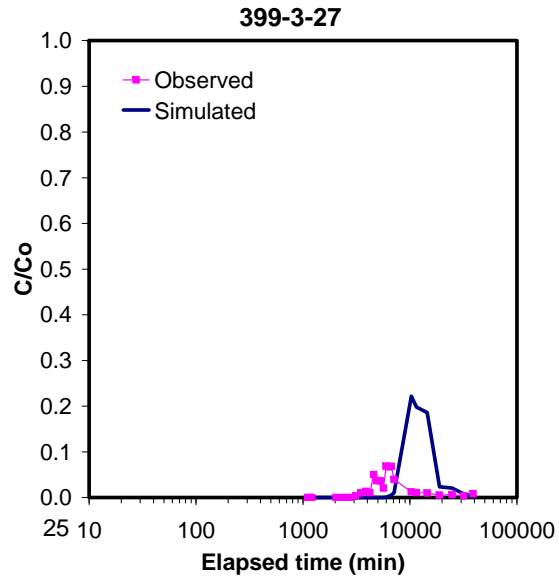
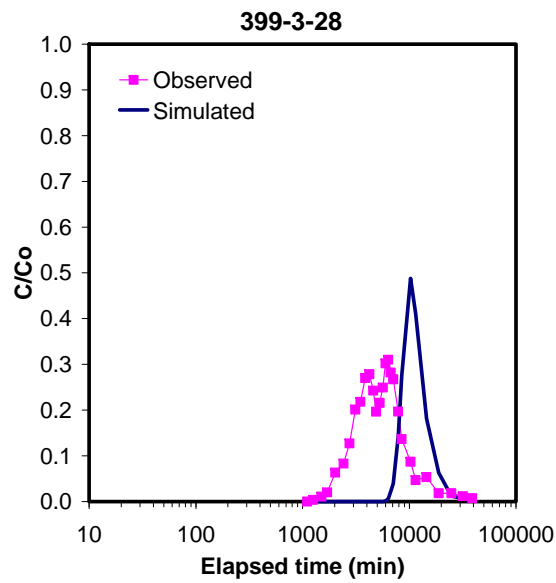


# Observed and simulated tracer BTCs

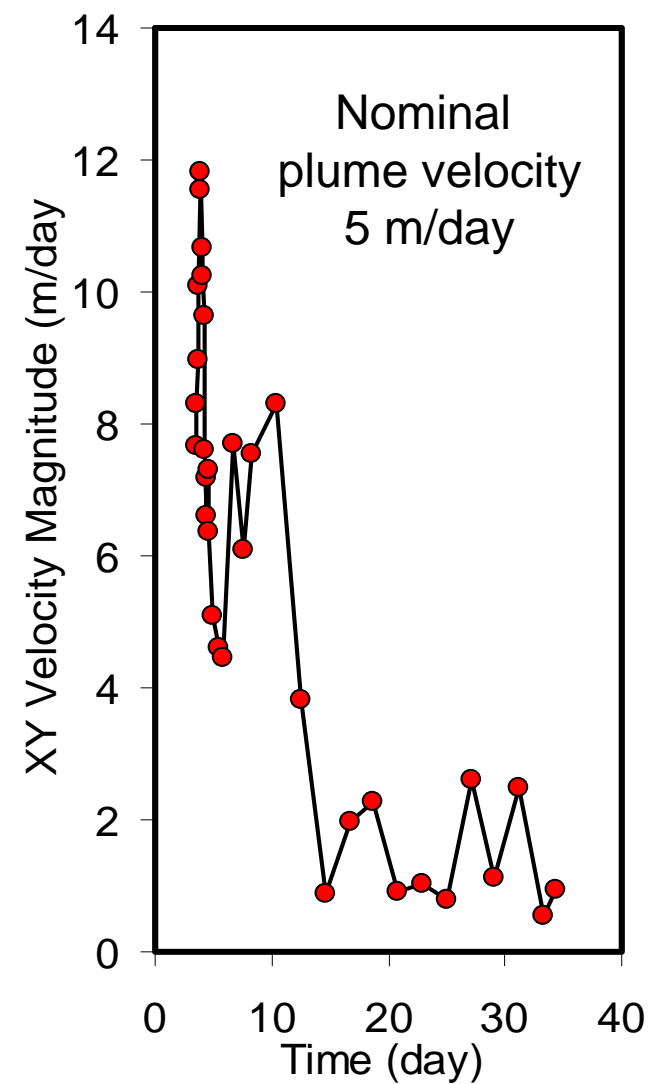
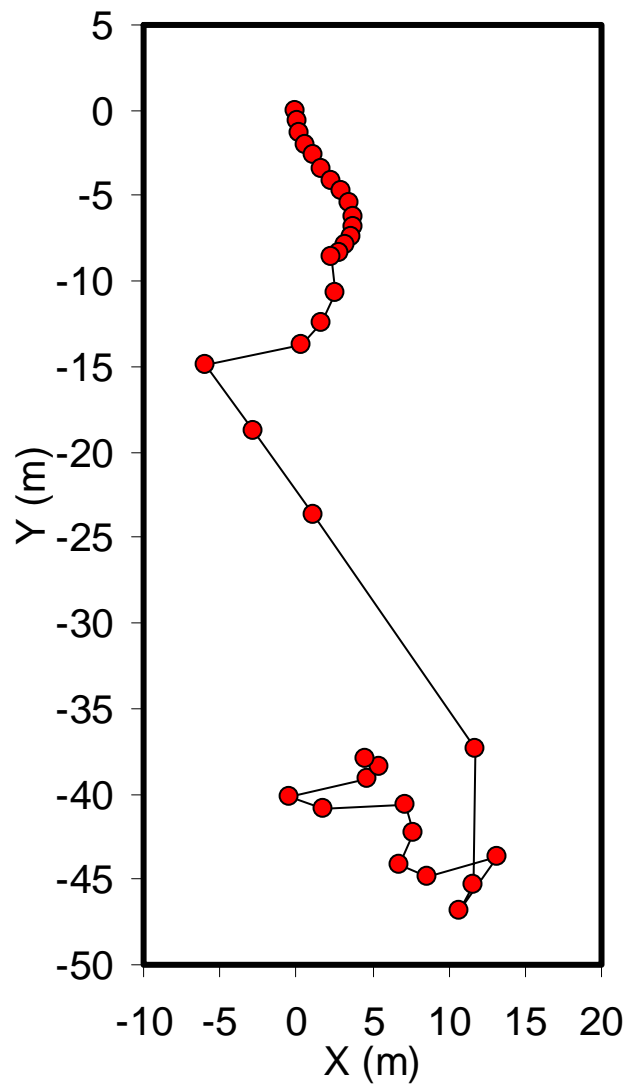
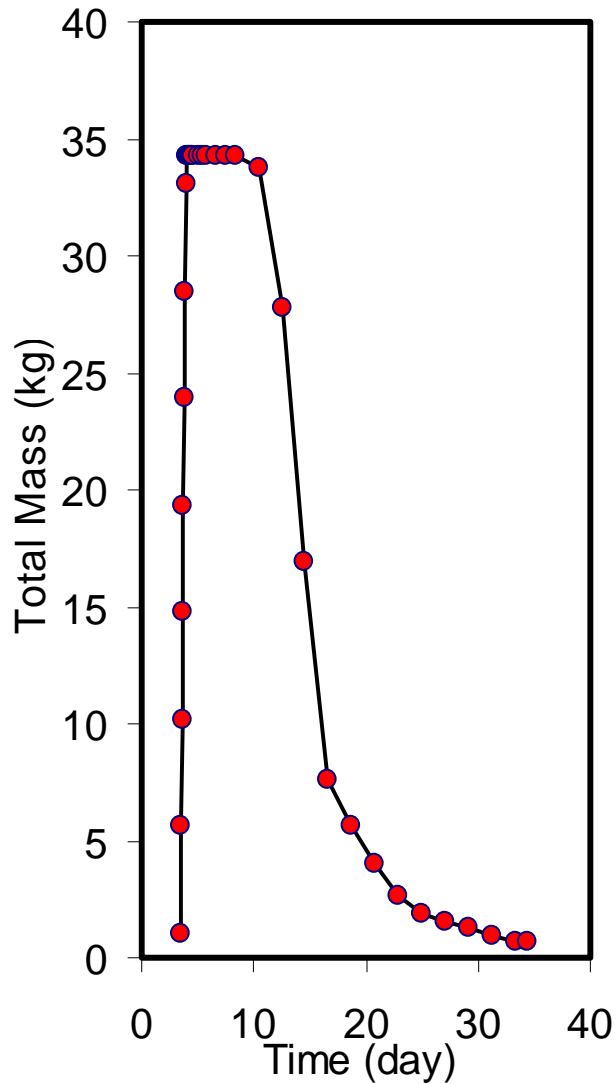




# Observed and simulated tracer BTCs



# Spatial moments of simulated tracer plume



# Summary

- ▶ Field hydraulic characterization appears to have been relatively effective
  - Constant rate injection tests and EBF results could be reinterpreted using alternative methods (e.g. inverse modeling)
  - Measurements in additional wells could be made
  - Additional constraints on elevation of Hanford-Ringold Fm contact beyond the footprint of the IFRC well field would be useful (incorporate recent interpretation based on surface geophysics)
- ▶ First tracer experiment was successful, but some refinements could lead to improved results
  - Smaller injection volume
  - Slower injection rate
  - More stable river conditions
- ▶ Very good matches between simulated and observed water levels can be obtained
- ▶ Fair matches between simulated and observed Br- tracer concentrations – no formal calibration yet

# Acknowledgments

- ▶ Brad Fritz, Rob Mackley, Darrell Newcomer, Donny Mendoza, Ray Clayton, and Kyle Parker (PNNL) for field characterization, monitoring, and experimental support
- ▶ Mart Oostrom, Tom Wiestma, Matt Covert, Teresa Queen, Tom Resch (PNNL) for laboratory experimental support
- ▶ Yi-Ju Bott, Mark Williams, Mark Freshley (PNNL) for geostatistical analyses, modeling support, field site management
- ▶ David Lesmes (DOE) for project oversight and guidance
- ▶ DOE-ERSP for financial support



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