2003 AFCEE Technology Transfer Workshop

Collection of Design Data: Site Characterization for Permeable Reactive Barriers

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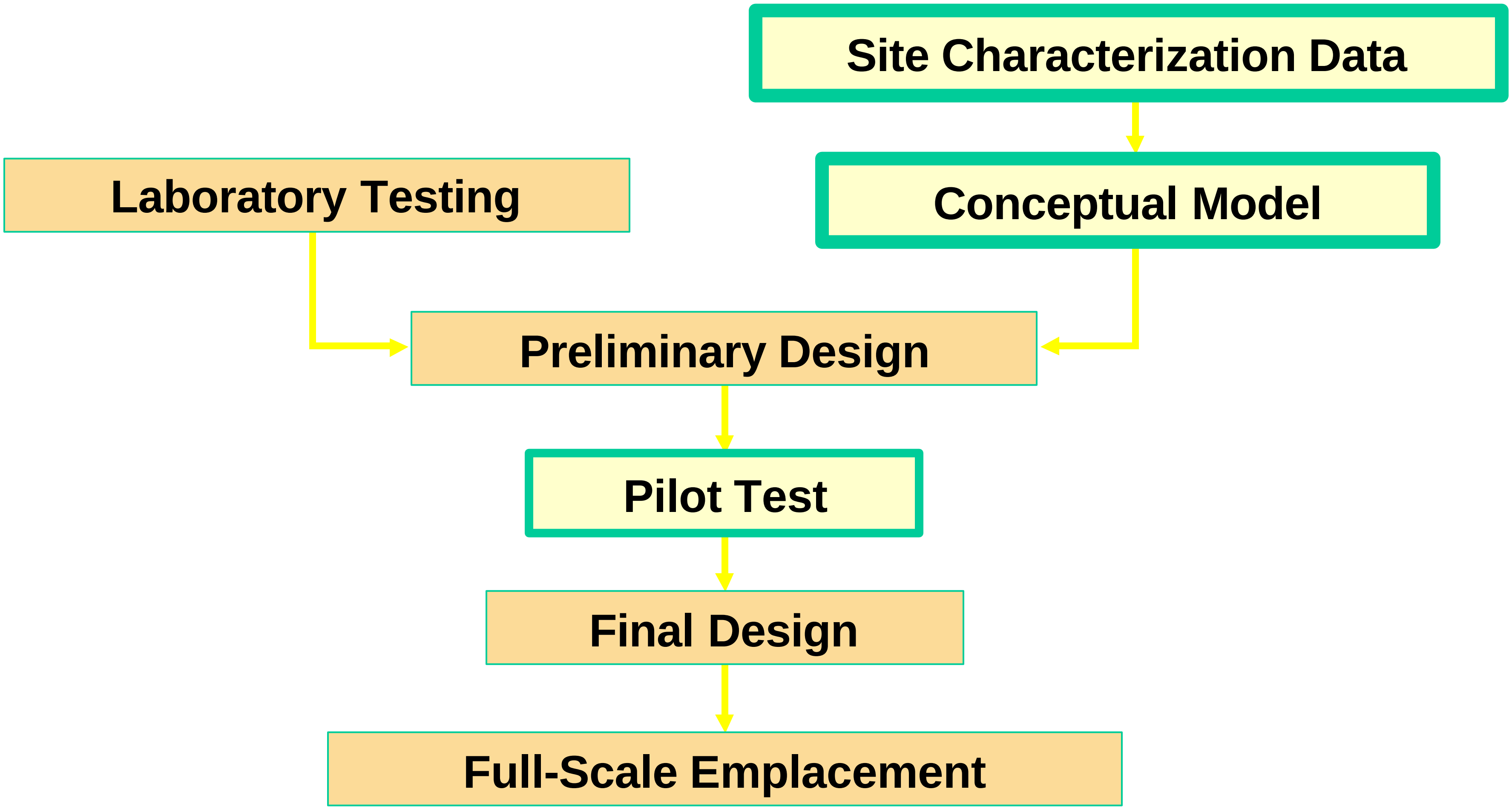
Path to PRB Design and Emplacement



Purpose

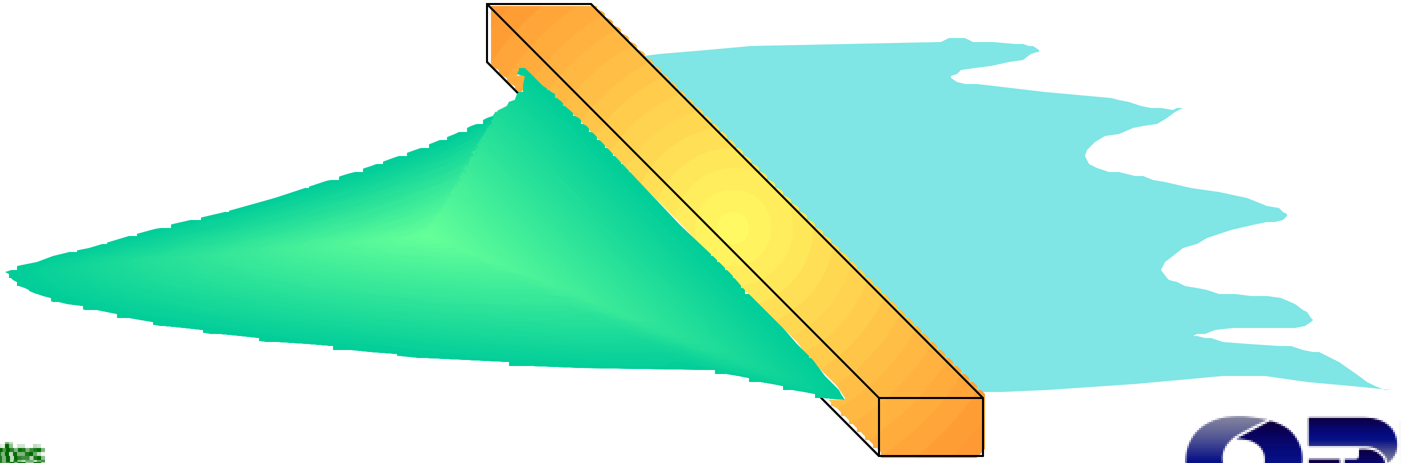
– To address the importance of characterizing a site before reactive barrier installation
– To identify the critical aspects and data needs of site characterization
– To discuss ways to get this information

Topics

- Goals, potential problems with PRBs
- Site characterization issues
- Conceptual model development
- Site characterization methods and tools

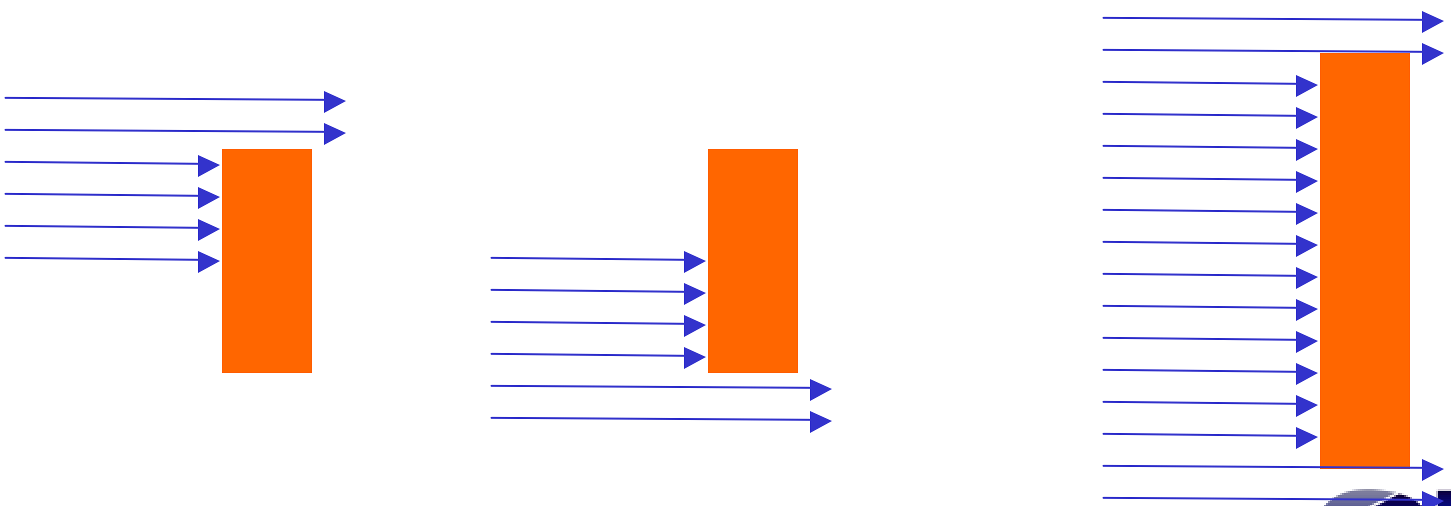
Goal = Passive Remediation System

– The plume enters under the natural gradient
– The entire plume is captured by the system
– Remedial goals are achieved at point of compliance



Potential Problems

- The plume could pass over, under, or around the barrier
- The groundwater flow direction or velocity might change
- Incomplete remediation as higher concentrations reach the barrier
- Loss of surface reactivity—precipitate coatings, etc.
- Barrier plugging, decreased permeability



Side Views

Site Characterization Issues to Address to Achieve Goal

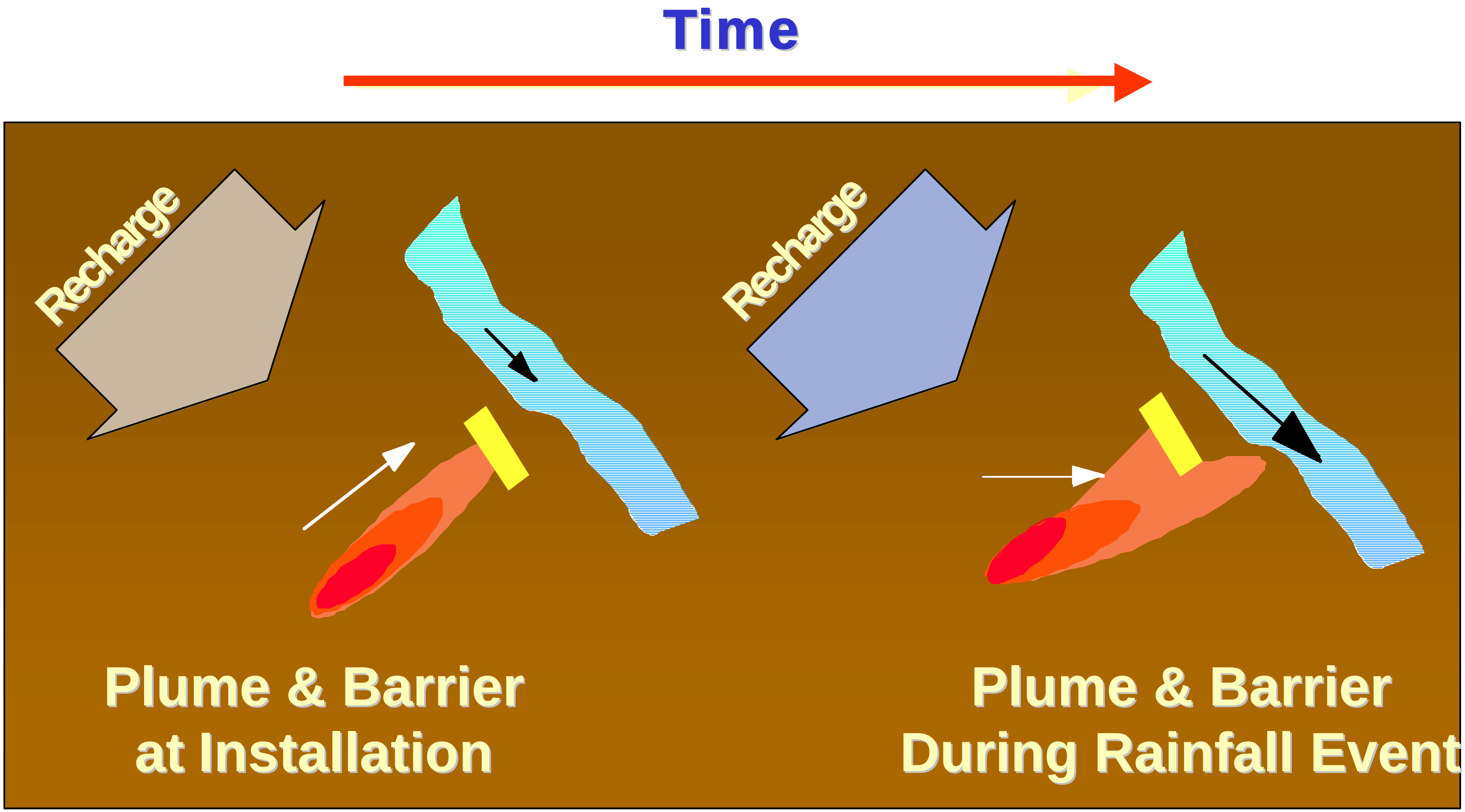
– Hydrology
– Geology
– Contaminant distribution within the aquifer
– Geochemistry
– Microbiology

These parameters are not discrete, but highly interactive.

Hydrology

- Groundwater flow
  - direction
  - velocity
  - flux
- Seasonal changes in groundwater flow velocity, direction (e.g. due to recharge events)
- Effects of nearby intermittent pumping
- Provide data for construction of groundwater flow model

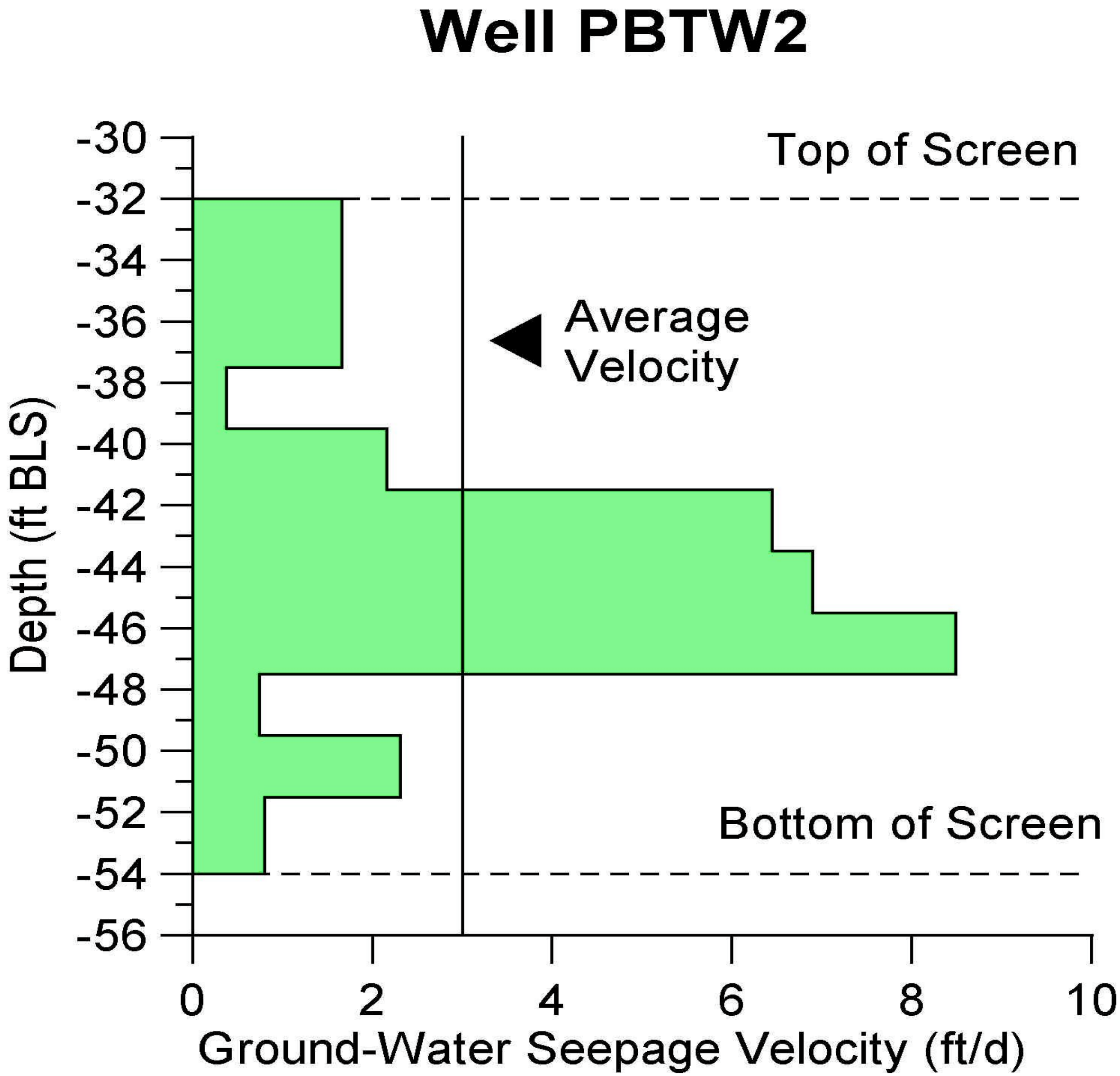
Plume / Hydrologic Characterization



Hydraulic Conductivity Distribution

- Controls flux
- May vary by several orders of magnitude
- Knowledge of variations in flow velocity field important for optimized PRB design

Seepage Velocity



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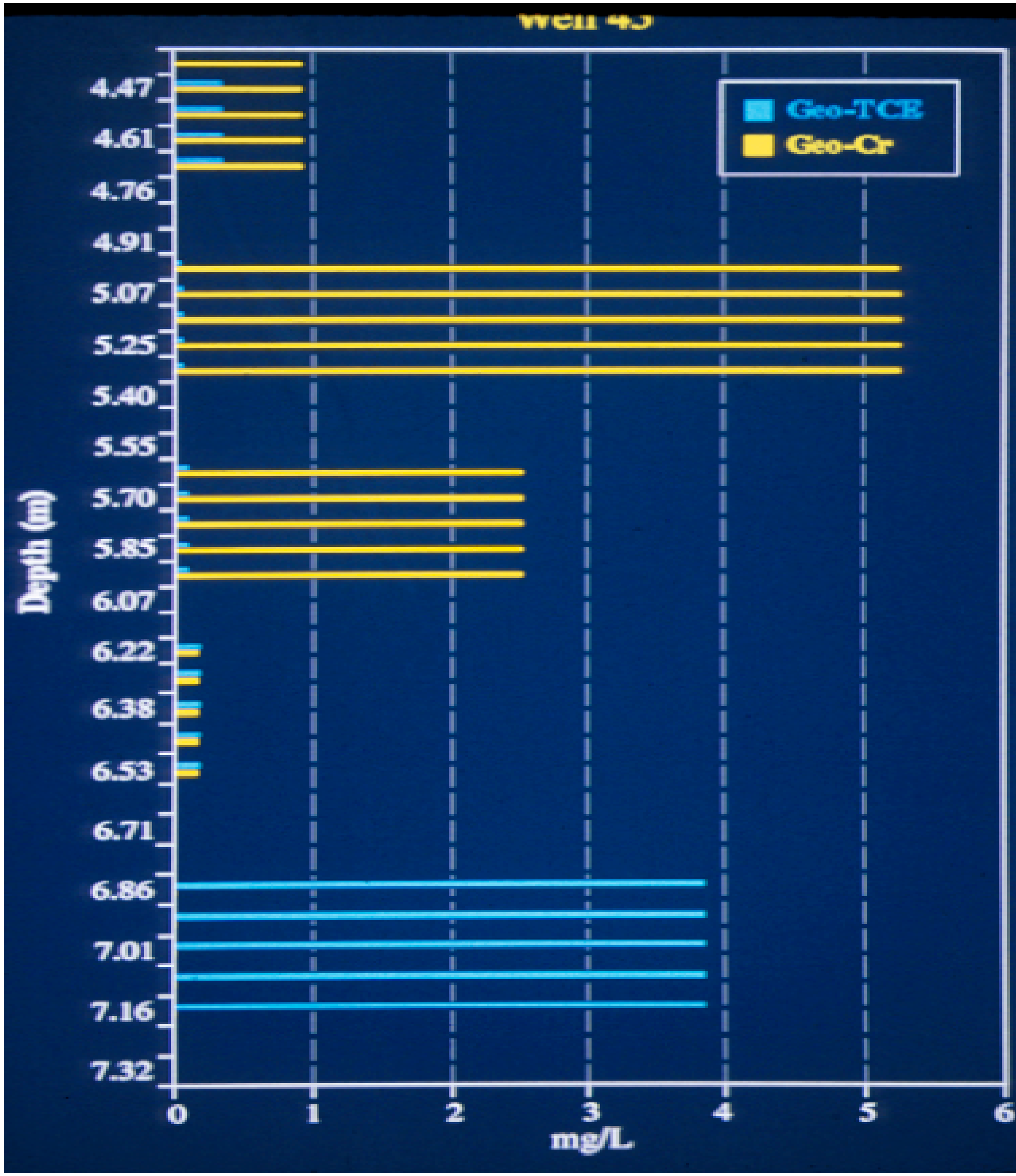
Geologic Setting

- Depositional environment & hydrochemistry
  - Red flags: fine textured strata, high TOC, high NO_3, high SO_4, high CO_3
- Stratigraphy
  - depths and continuity of sand layers, clay layers, bedrock
    - keyed barrier or hanging wall
    - zones of water/contaminant movement
    - degree of fracturing

Contaminant Distribution

- Identify contaminants and degradation products
- Plume location in all dimensions
  - x, y, z, concentrations and time
  - Is natural attenuation occurring?
    - Has steady state been reached?
    - Are the high concentration zones moving?
    - What concentrations will reach the wall?
- Identification of ALL sources?

Geoprobe
Cr and TCE Data



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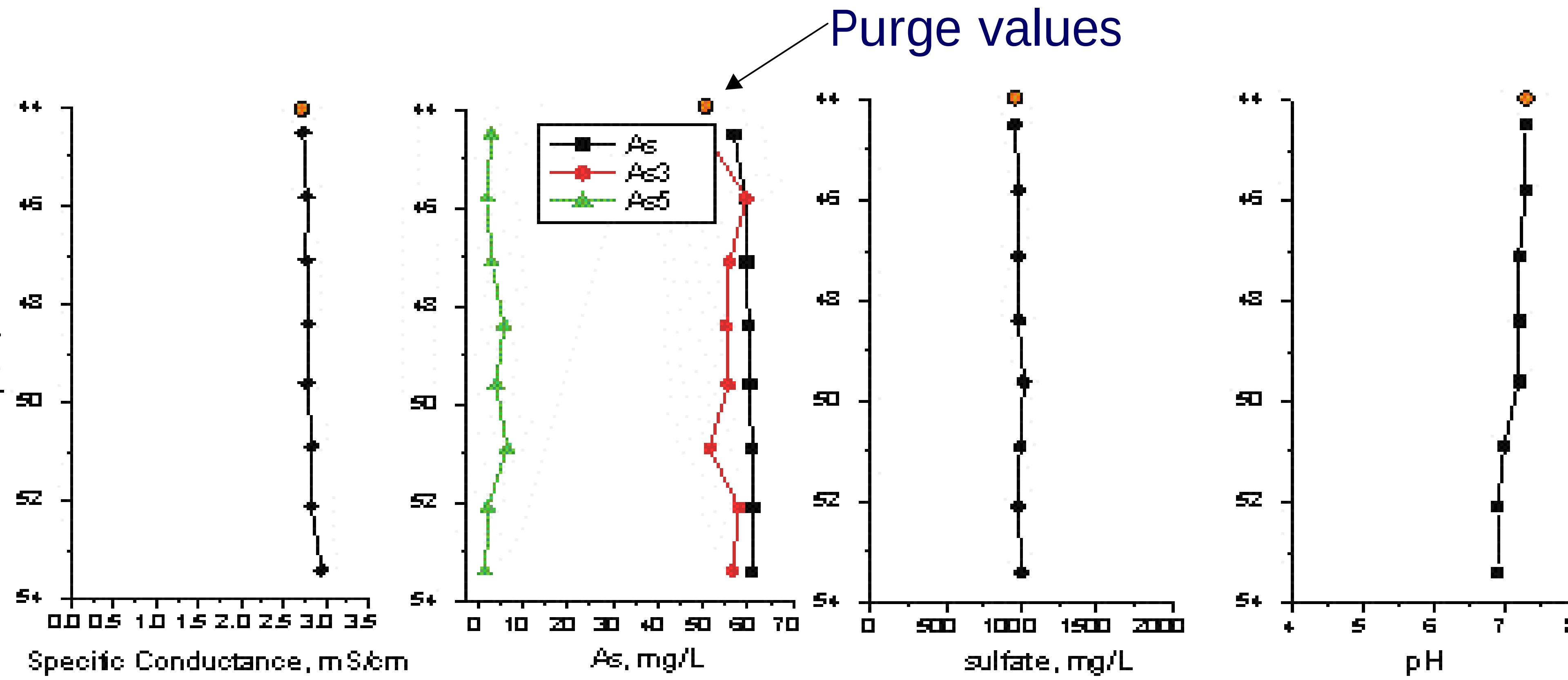
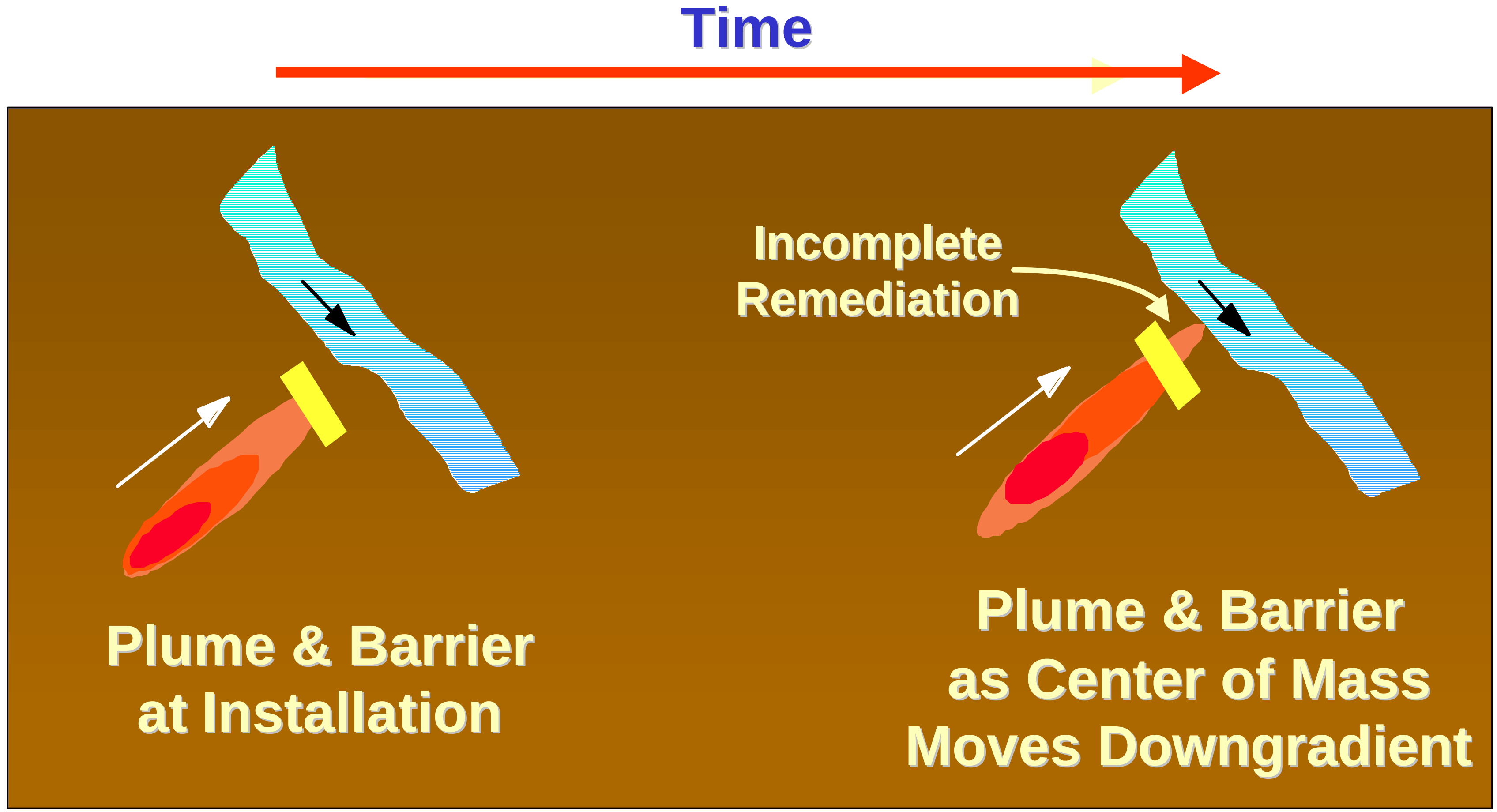
Discrete multi-level sampling well PBTW2



Plume Stability, Steady State



Geochemistry Considerations

- Oxygen concentration
  - O_2 is preferred electron acceptor
  - high O_2, increased $Fe(OH)_3$ precipitation
- Carbonate alkalinity
  - precipitation of $Ca(CO)_3$ (calcite) and other carbonate minerals
- Sulfate concentration
  - possible sulfide formation
  - possible microbial fouling
- Nitrate concentration
  - decreased reactivity for chlorinated compounds, chromate, others

Water Quality Parameters

- Major ions (Na, Ca, Mg, K, SO_4, Cl, HCO_3)
- Dissolved oxygen distribution
- Redox potential (Eh)
- pH
- Specific conductance
- Needed input parameters for geochemical modeling

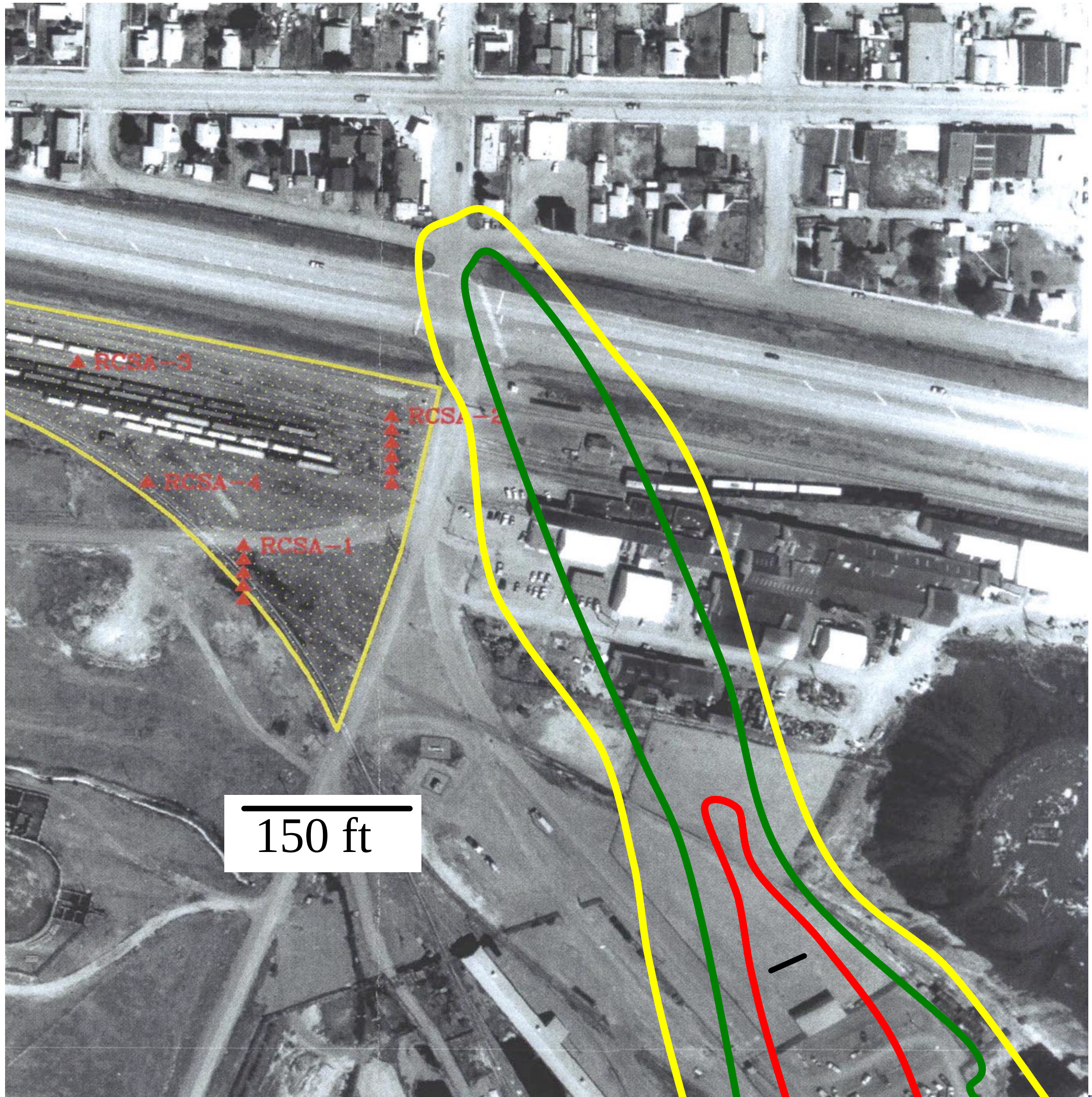
Microbiology

- Beneficial effects, i.e., enhanced remediation
  - upgradient natural attenuation of plume
  - degradation products?
  - increased degradation in vicinity of wall
- Detrimental effects
  - biofouling and loss of permeability

Conceptual Model

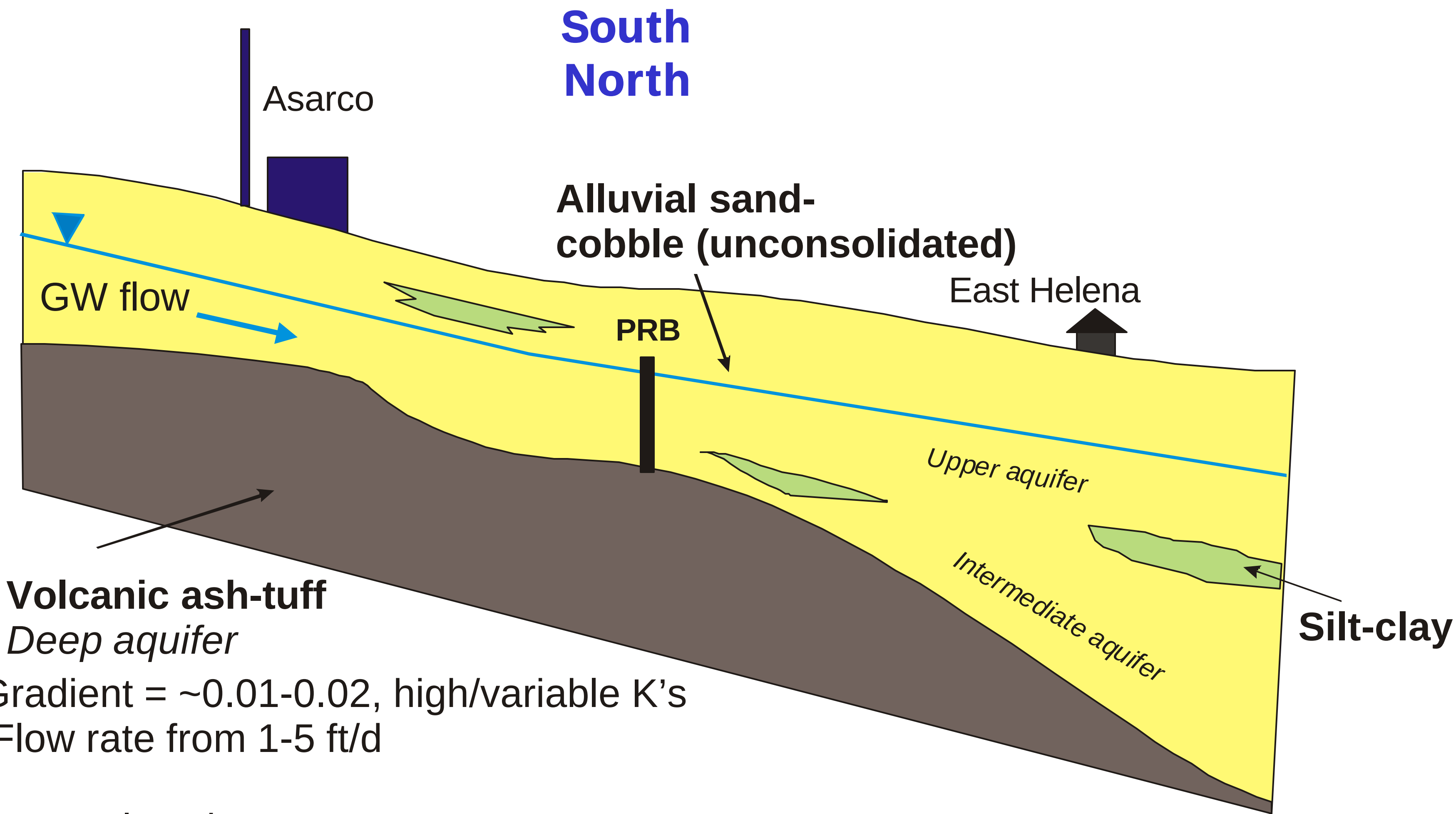
- Develop conceptual model based on site characterization
- Iterative process as more data is collected
- Does the conceptual model coincide with increased observations

rsenic in
hallow
quifer



5 ppm
10 ppm
50 ppm

Site Conceptual Model



Gradient = ~0.01-0.02, high/variable K's
Flow rate from 1-5 ft/d

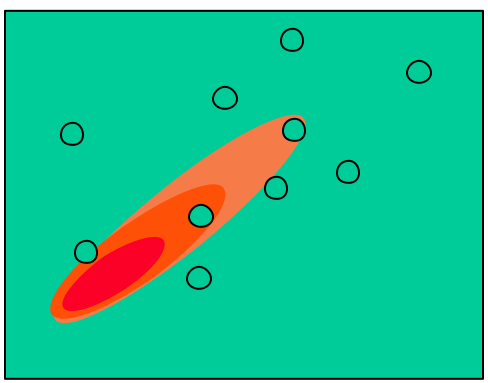
At PRB location:
40-55 ft to ash
15-25 ft saturated thickness

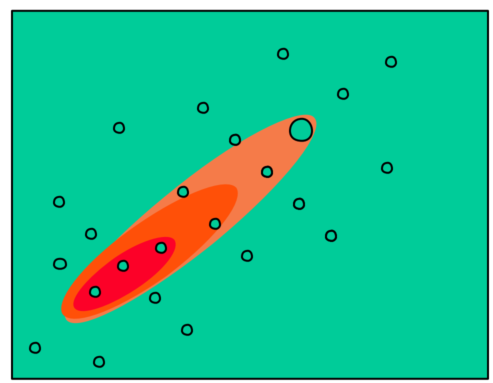
Characterization Methods

- Use push tool technologies
  - Geoprobe® and Hydropunch®
  - cone penetrometers
- Examine K variability
  - Flowmeters
  - Mini slug tests
- Map and model the results
  - hydrologic
  - geochemical

Push Tool Technologies

- Driven rapidly and inexpensively
  - more samples can be collected, allowing:
    - denser coverage of the area
    - evaluation of a larger area
- Can collect water, soil, and soil-gas samples





Geoprobe® Model 5400

Geoprobe® Model 4220

Geoprobe® Model 540B

Photos courtesy of Geoprobe Systems

Push Tool Technologies

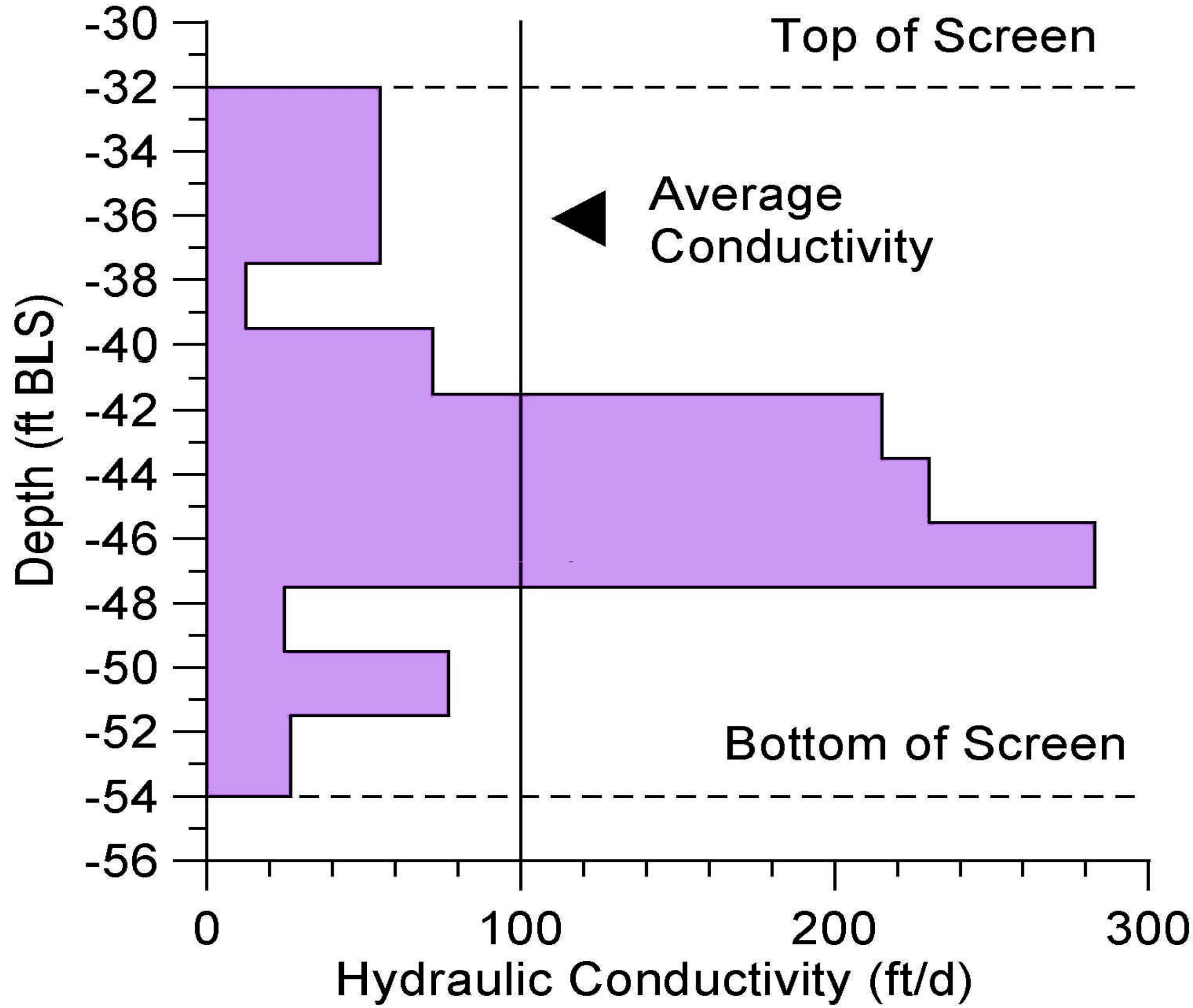
- Discrete vertical delineation of aquifer
  - better data on stratigraphic continuity
  - depending on the tools, you can get:
    - soil resistance to penetration
    - soil saturation
    - hydraulic conductivity
    - electrical conductivity
    - NAPLs using laser-induced fluorescence, etc.

Hydrologic Characterization Tools

– Pumping tests
– Mini-Slug tests
– Borehole flowmeters
– Borehole dilution tests
– Tracer tests
– Potentiometric information

Well PBTW2

EM Borehole Flowmeter



Groundwater Flow Modeling Studies

- Determine design velocity through treatment zone
- Determine length of system required to capture plume
- Assess potential for bypass/underflow

Groundwater Flow Modeling Studies

- Combine aquifer characteristics and reactive material properties
- Effects of reactive material variability
- Effects of changing material properties over time
- Permeable barrier configuration
- Identification of monitoring well locations

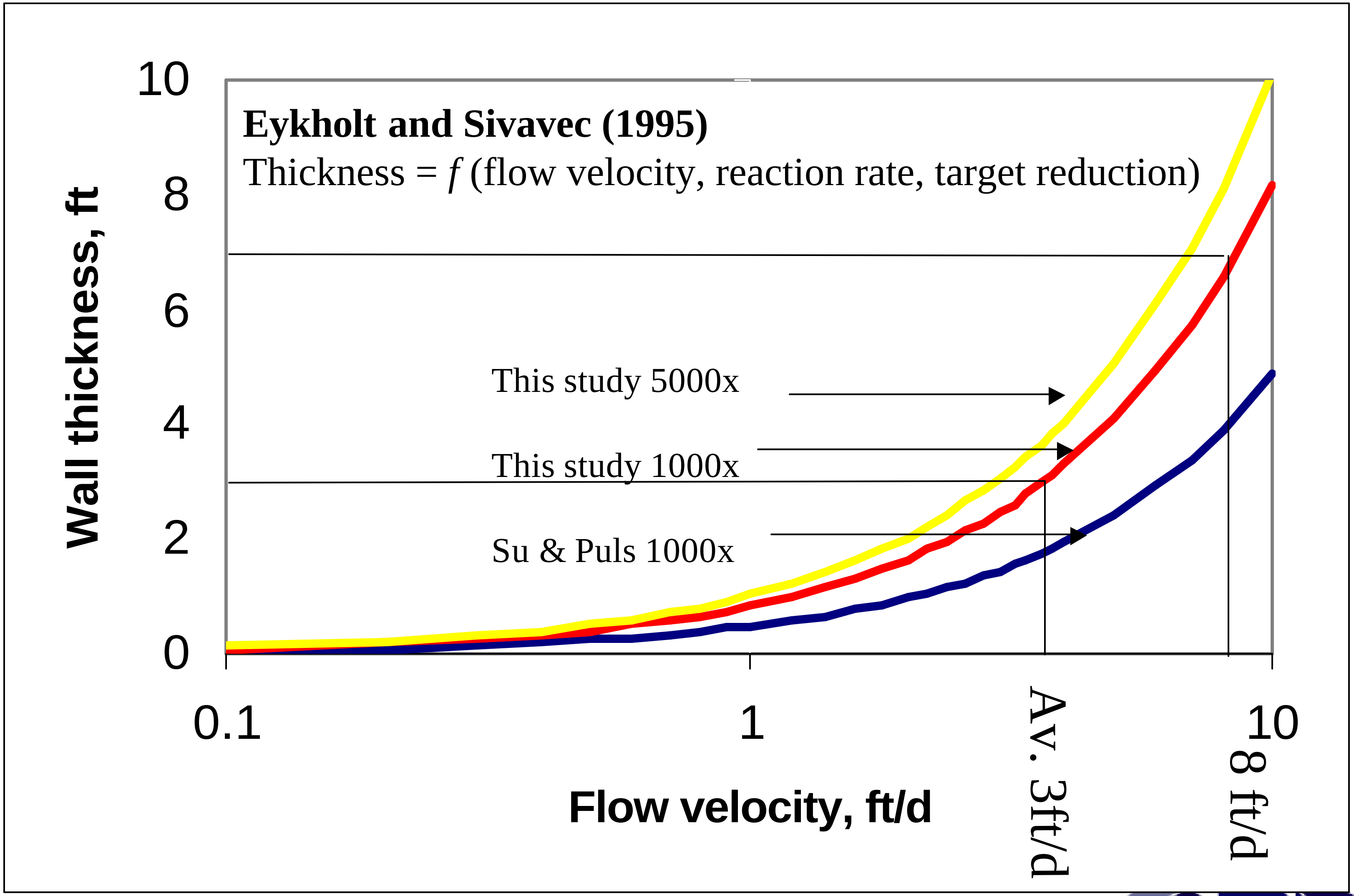
Groundwater Velocity through a PRB

- For a continuous wall, ground water flow velocity can be approximated using:
  - $V = Ki / n$, where
    - V = ground water velocity
    - K = hydraulic conductivity
    - i – gradient
    - n = porosity

Dimensions of PRB

- Residence time requirement (bench scale studies/database)
- Treatment zone flow velocity (model results)
- Thickness = residence time x groundwater velocity
- Determine length and depth of system required to capture plume, prevent underflow etc.

PRB Thickness



Why do a Pilot?

- Proof of concept
  - Contaminant(s)
  - Reactive media
- Challenging site characteristics
- New design
  - Construction
- NO substitute for field testing

Pilot Installation—Moffett Field

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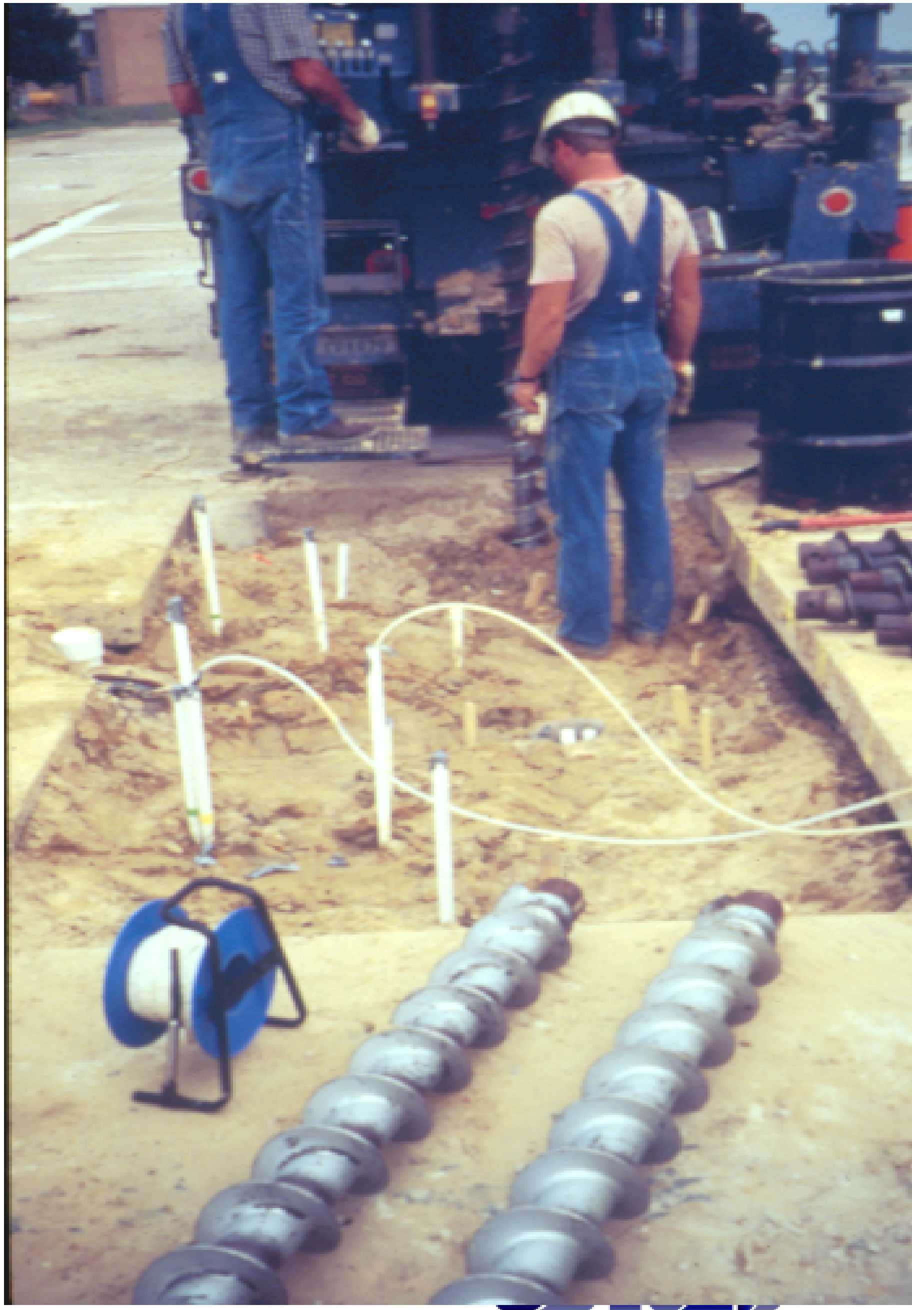
Elizabeth City Pilot Test Site Sep 1994



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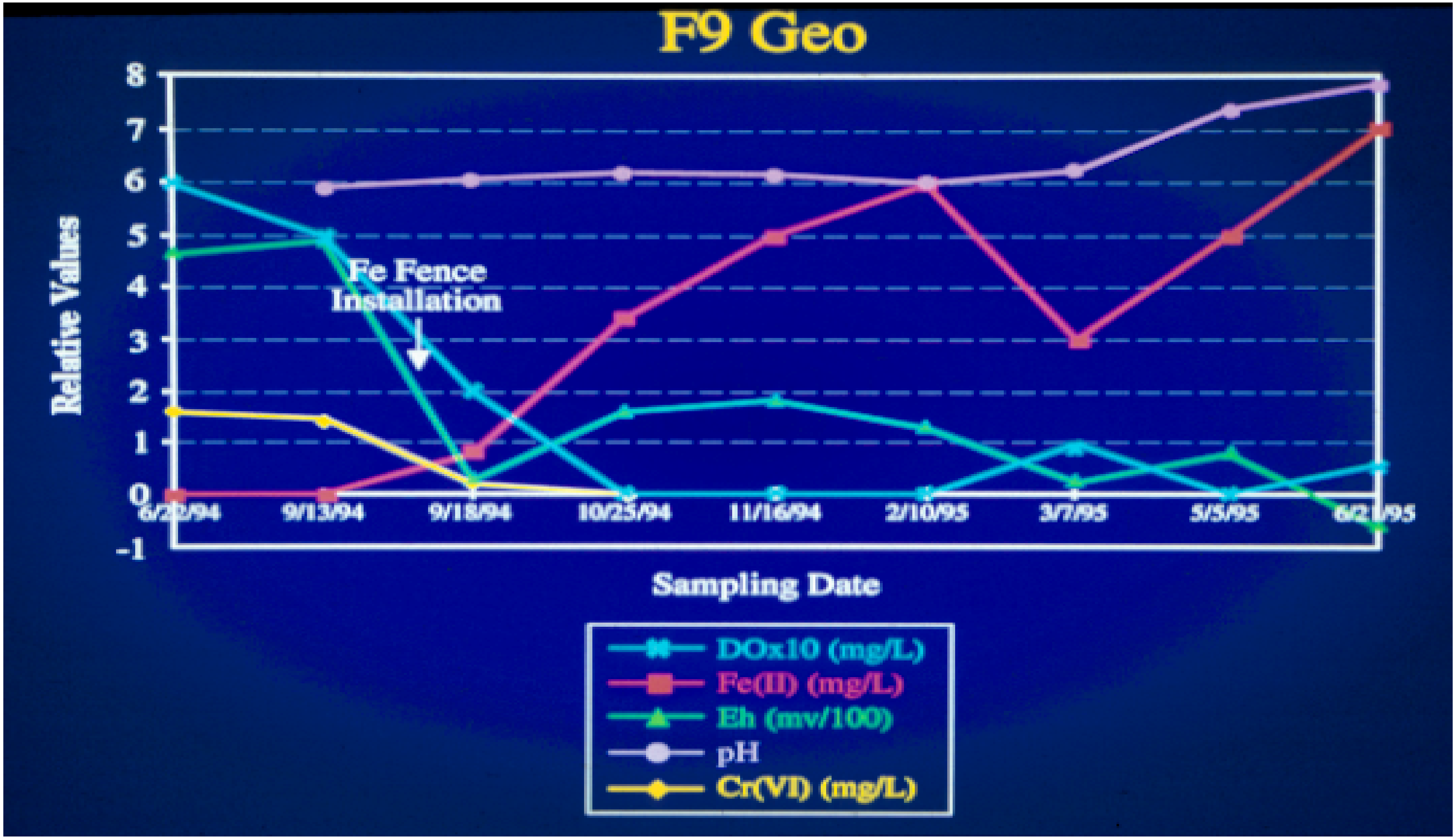
Geochemistry Data
PRB Pilot Test, 1994



Conclusions

- A thorough site characterization is needed for the immediate and continued success of a reactive barrier installation
- The "passive" nature of the technology makes this critical
- Good hydrologic characterization essential to remedial effectiveness

Conclusions (continued)

– Current conditions must be known and future conditions predicted
– Push technologies offer rapid, economical ways to get the needed data

Summary List of Field Design Data

- Groundwater flow, direction, velocity, temporal and spatial variability
- Aqueous geochemistry (pH, Eh, DO, alkalinity, sulfate, nitrate, other cations-anions, TOC)
- Microbiology (natural attenuation?, biofouling)
- Stratigraphy (esp. confining layers)
- Contaminant distribution, flux (3D and time)

Acknowledgments

- R. Wilkin, S. Acree , C. Paul, F. Beck, M. McNeil, P. Clark, of USEPA/NRMRL
- EPA-RTDF / ITRC PRB training course 1999