The Integrated Contaminant Elution and Tracer Test Toolkit ICET^3:

Improved Characterization of Mass Transfer, Attenuation, and Mass Removal

Mark L. Brusseau

University of Arizona

SRP Risk eLearning Webinar – Analytical Tools and Methods:

Session III – Fate and Transport of Contaminants

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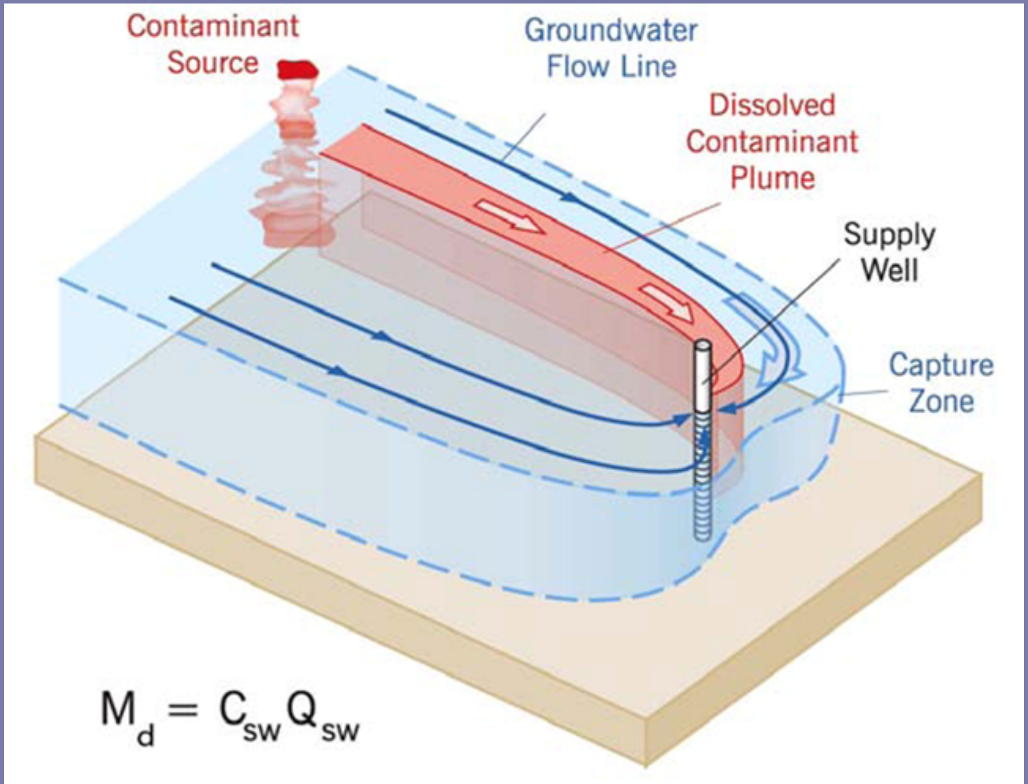
Outline

- What are contaminant elution tests (CET)
- CET advantages and applications
- Implementation
- Case study

Contaminant Elution Test

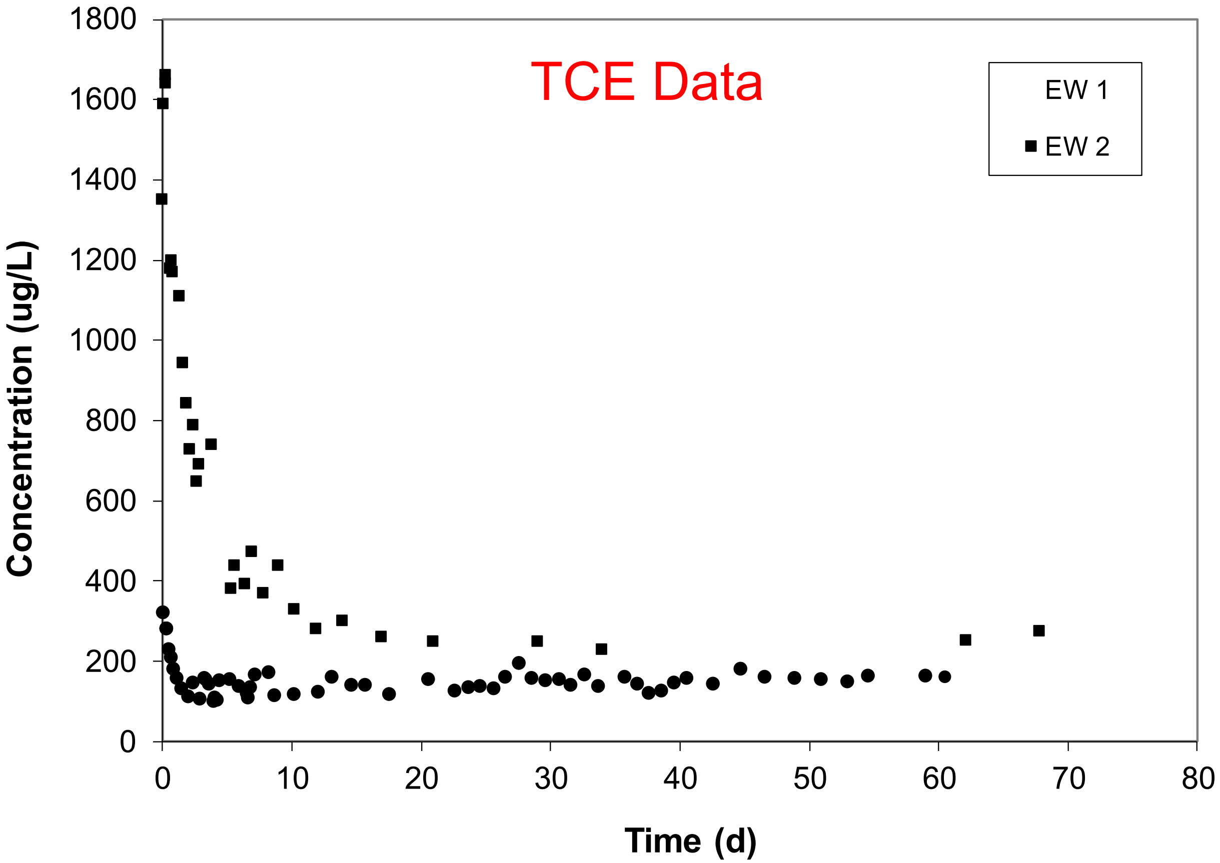
- AKA
  - induced-gradient contaminant elution test
  - contaminant pumping test
  - mass discharge test

Monitor COC concentration in fluid discharge during groundwater (or soil vapor) extraction



CET Data

- Qualitative analysis- Landmarks
- Quantitative analysis- Mathematical modeling



Data from Brusseau et al., 2007

Advantages

- Induced gradient stresses system, enhancing hydraulic and concentration gradients
  - Improved sensitivity for measuring mass transfer and attenuation
- Integrated measurement over interrogated domain
  - Reduced uncertainty from spatial variability
- Modified CET – clean water injection to displace resident solution (background plume)
  - Delineation of local fluxes and associated processes
- $ICET^3$ - tracer application
  - Characterization of specific processes and associated rates
- Rapid and relatively low cost

Outcomes

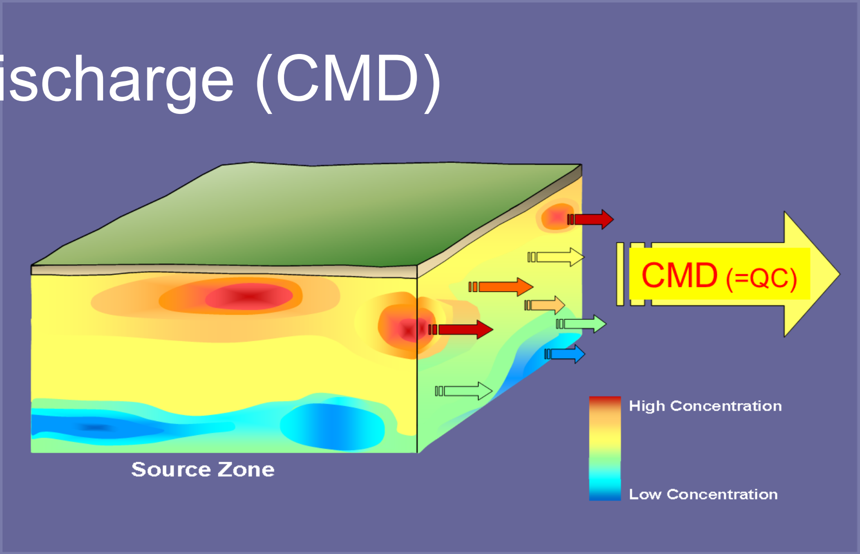
- Improved characterization of mass transfer, attenuation, and mass removal processes
  - increased accuracy of risk assessments
  - improved CSM and RI/FS
  - enhanced remedial action design
- Ultimately, improve decision making for cost-effective site management
- Integrate with other site characterization tools

Applications

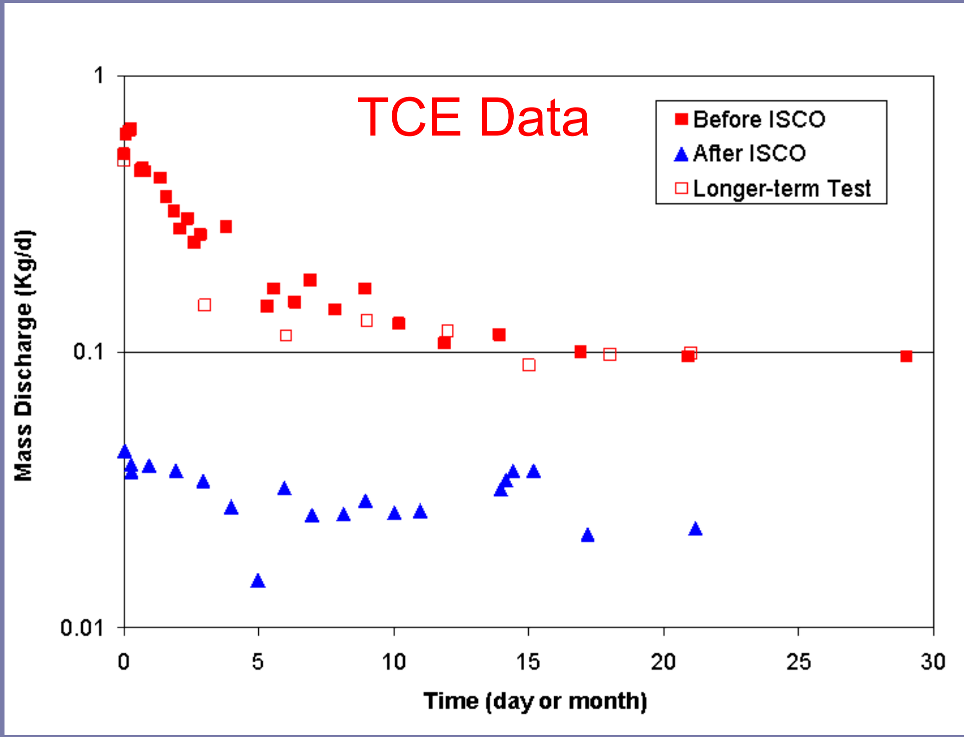
- Measure contaminant mass discharge (CMD)
- Characterize mass-removal and persistence behavior
- Delineate specific mass-transfer & attenuation processes
- Determine process-specific rate coefficients
- Estimate resident contaminant mass
- Test prospective remedial actions

Applications

- Measure contaminant mass discharge (CMD)



Data from Brusseau et al., 2011

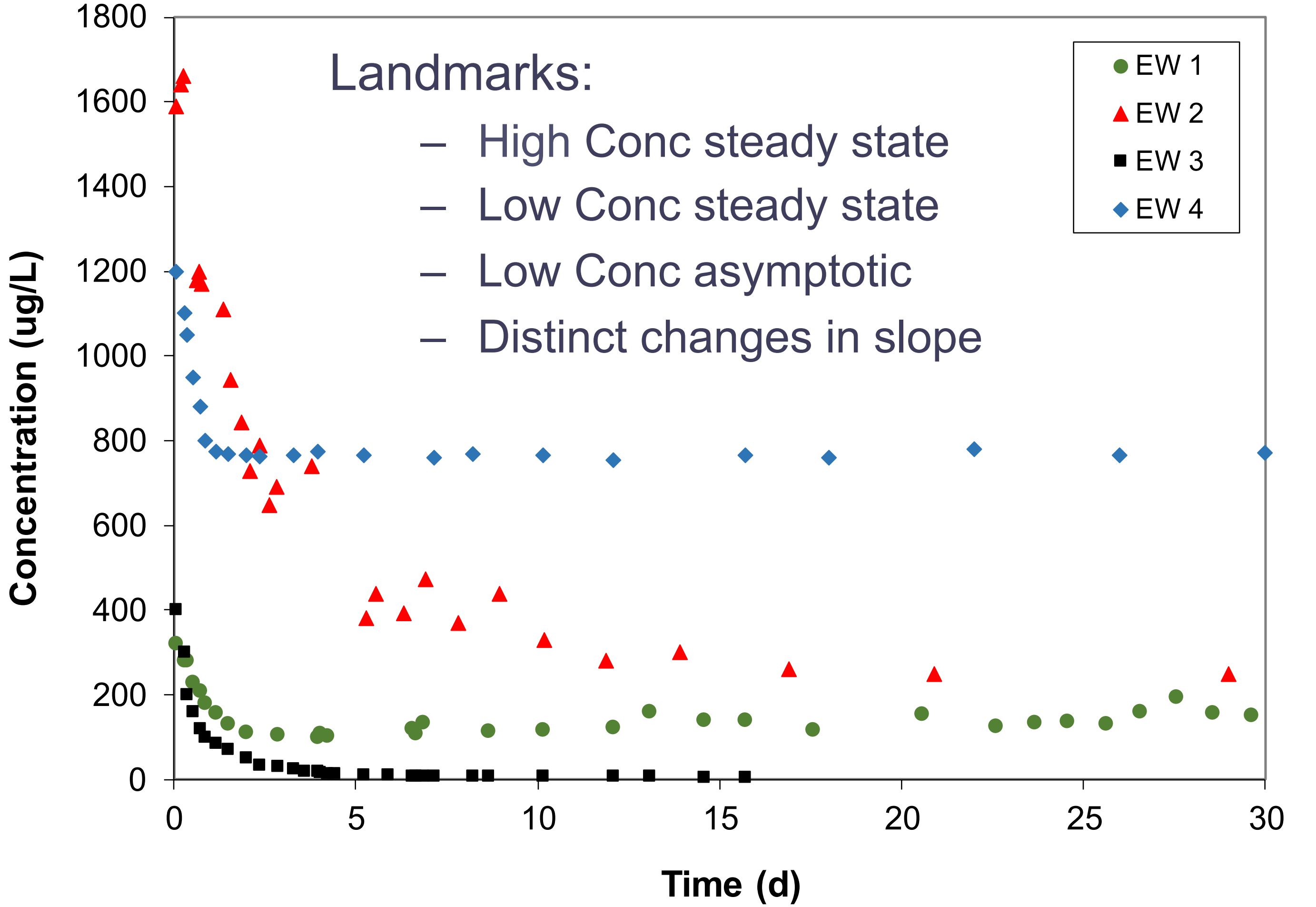


- Assess remedial action performance

Note: CMD in ROD as a RAO for Commencement Bay-South Tacoma Channel Superfund site

Applications

- Characterize mass-removal and persistence behavior

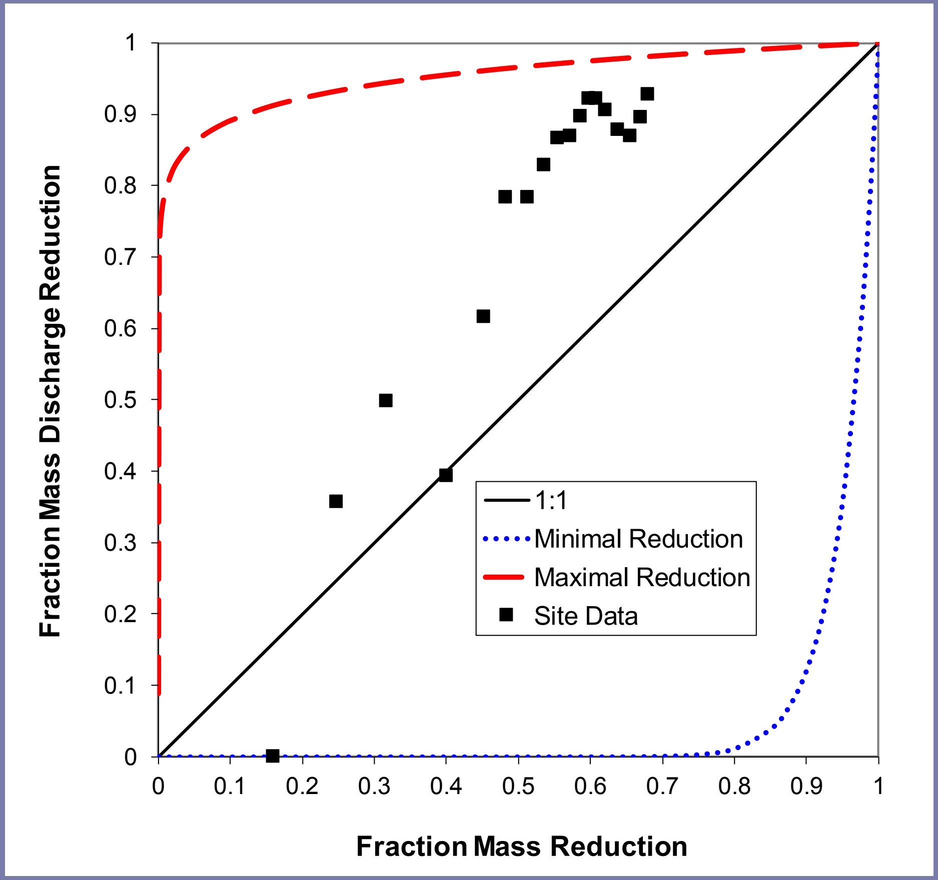


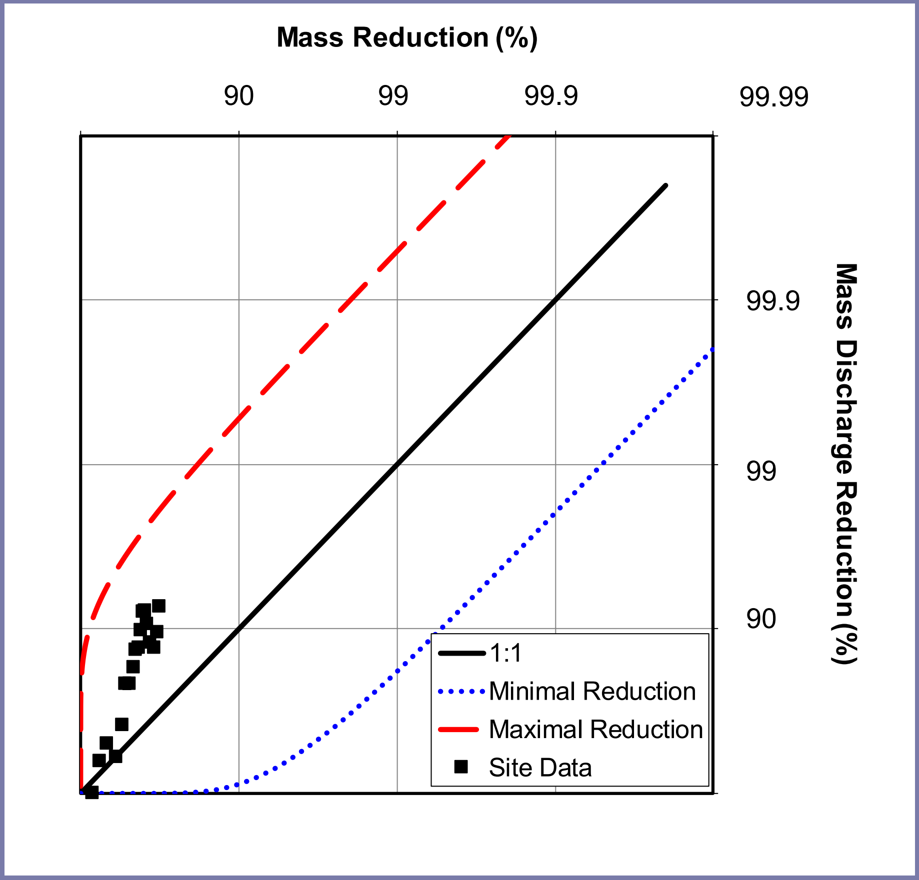
- Qualitative analysis:

Examine elution profiles to assess Type behavior

Applications

- Characterize mass-removal and persistence behavior
  - Quantitative analysis: CMDR-MR relationship



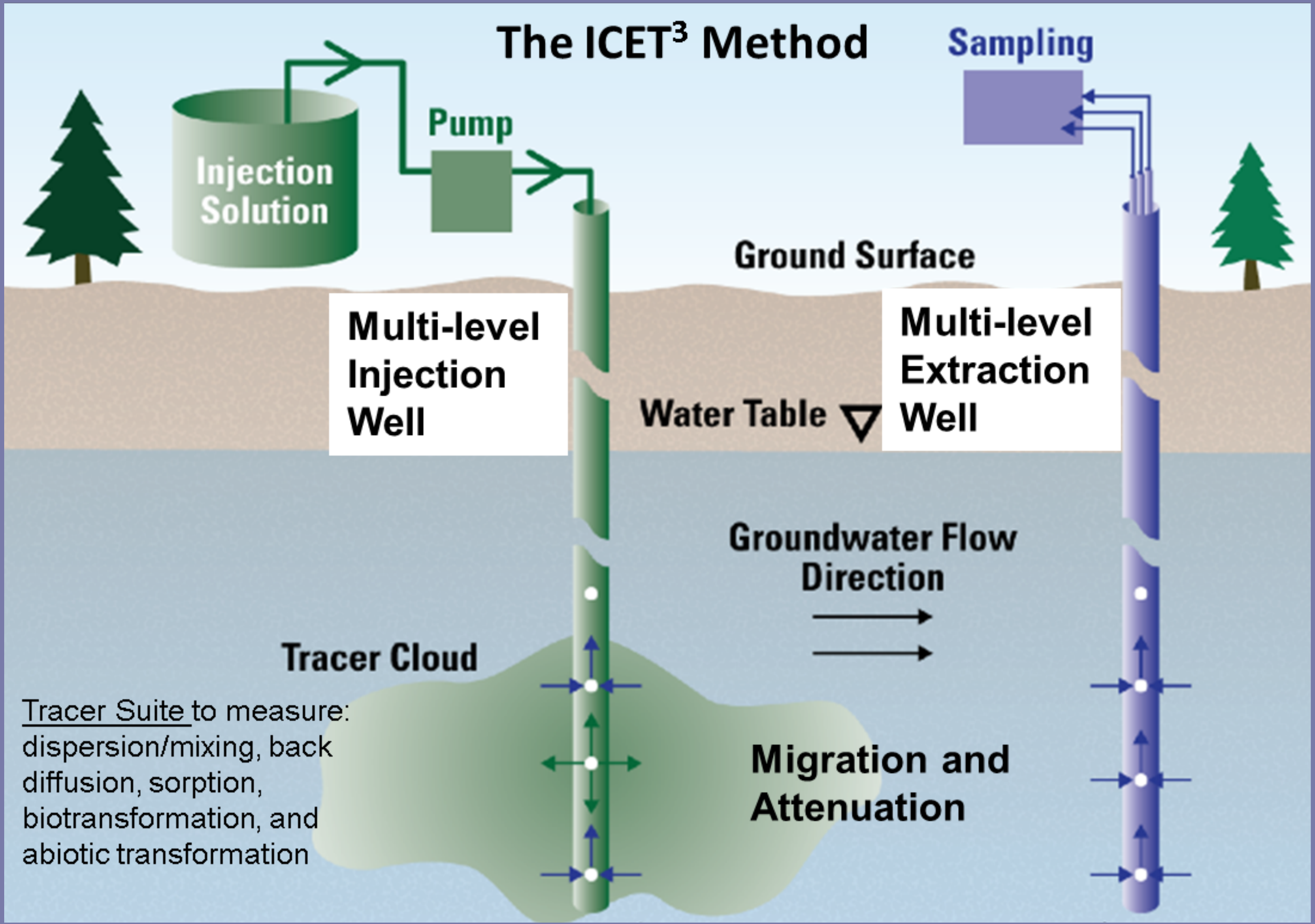


From Brusseau, 2013

Applications

- Delineate specific mass-transfer & attenuation processes

  >>>use of tracer suite



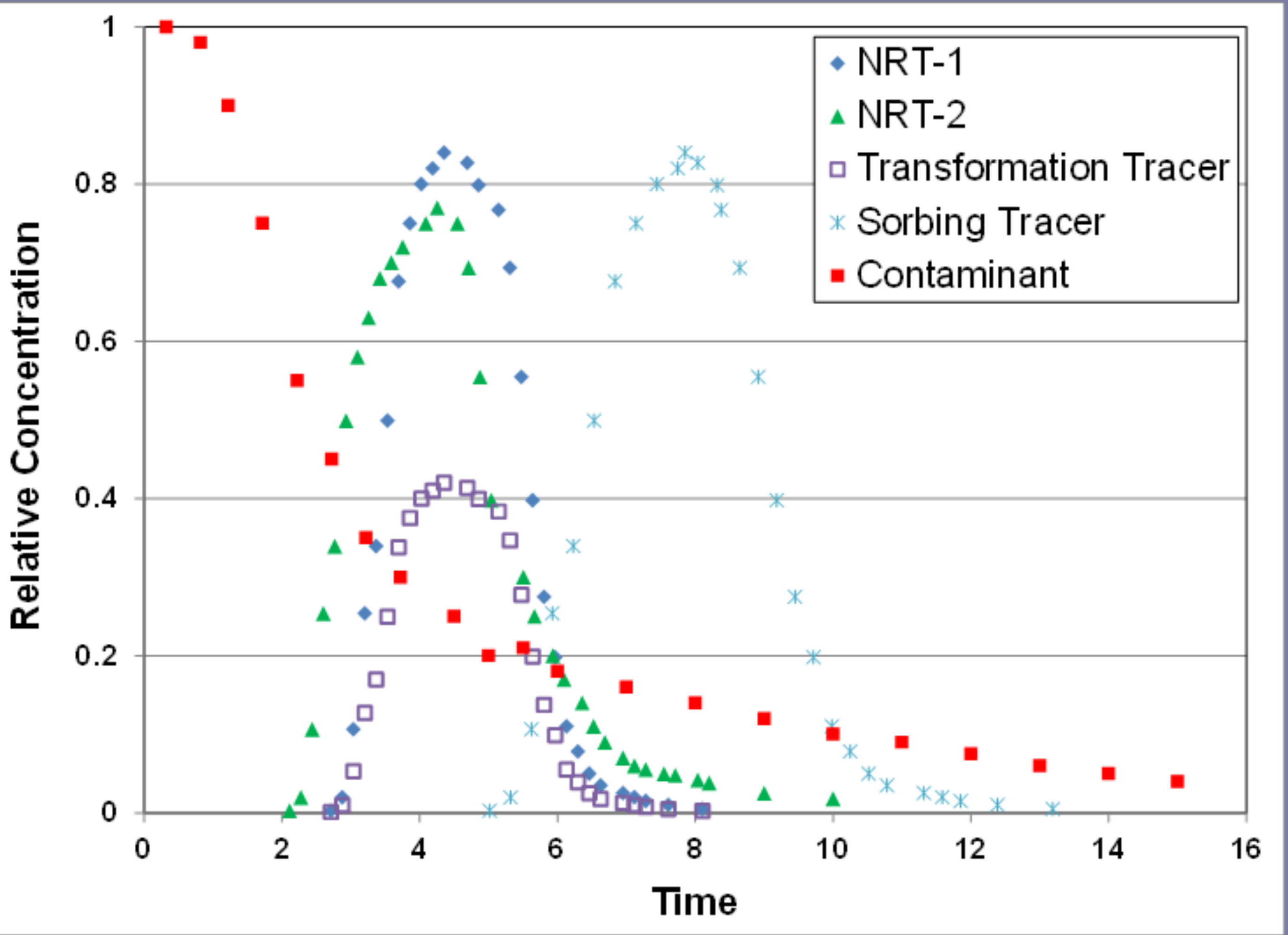
- Straightforward for systems with a single predominant mass-removal process

- Difficult for multi-process systems

•Implement tracer-test component

Applications

- Use of tracer suite to characterize specific processes and associated rate coefficients



- Multiple NRTs with different D_0 = diffusive mass transfer

- Sorbing tracer = retardation

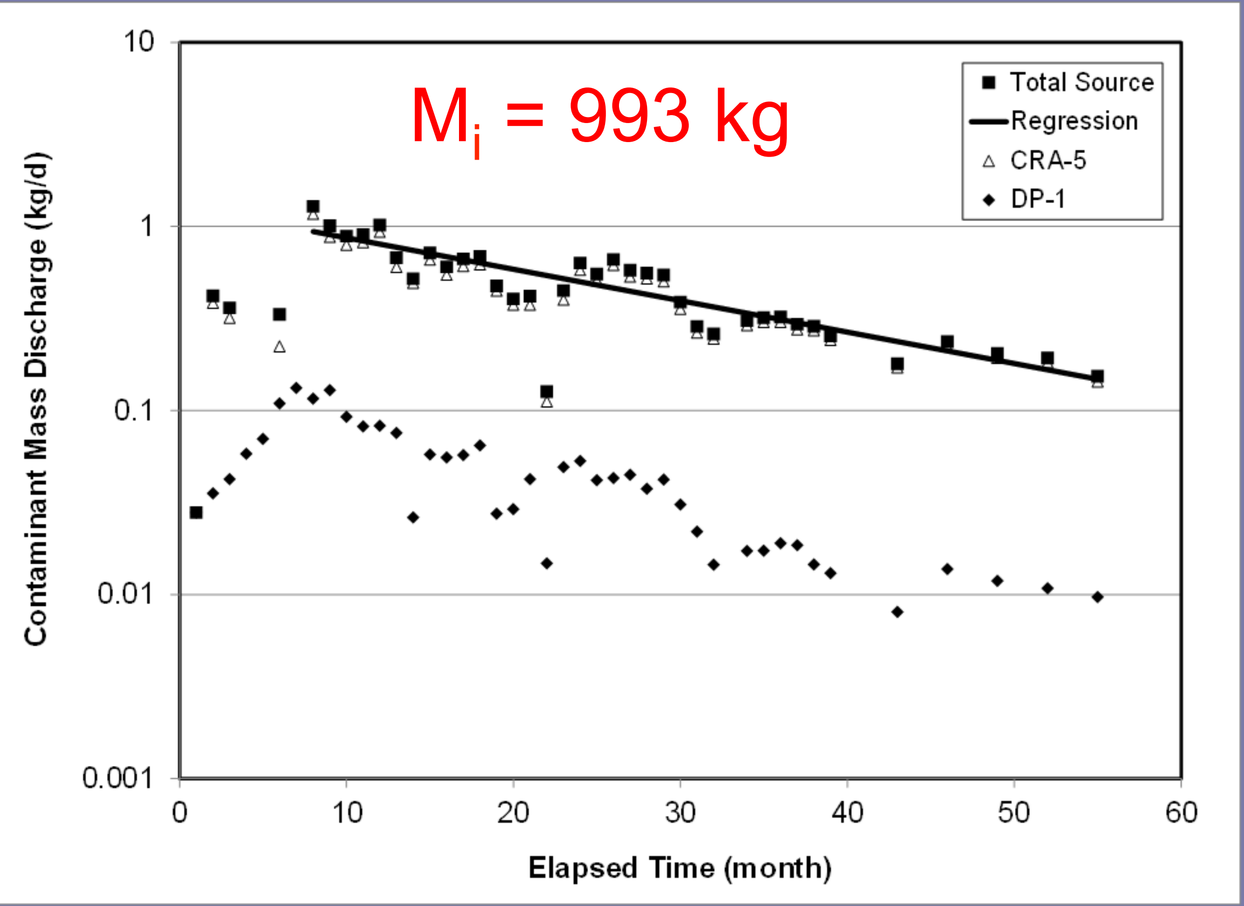
- Transformation tracers = bio/chem degradation

- NAPL partitioning tracers = NAPL characterization

Applications

- Estimate resident contaminant mass

Data from Brusseau et al., 2013



- Typically unknown and difficult to determine

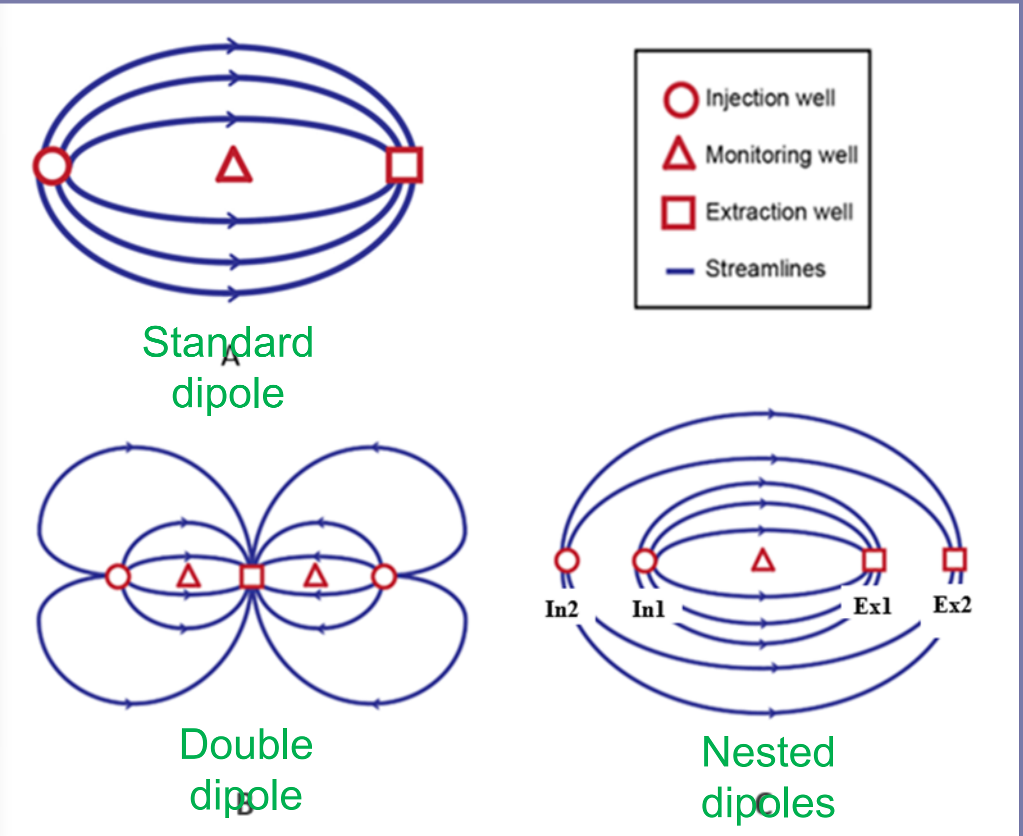
- Fit source-depletion function to temporal CMD data

Implementation

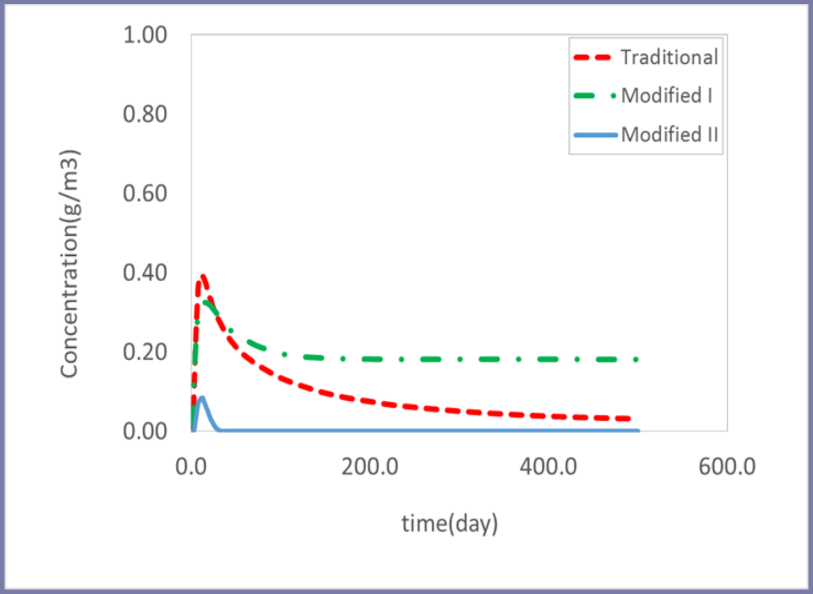
- Well-field configuration is key design factor

  - Based on test objectives

from Guo and Brusseau 2017

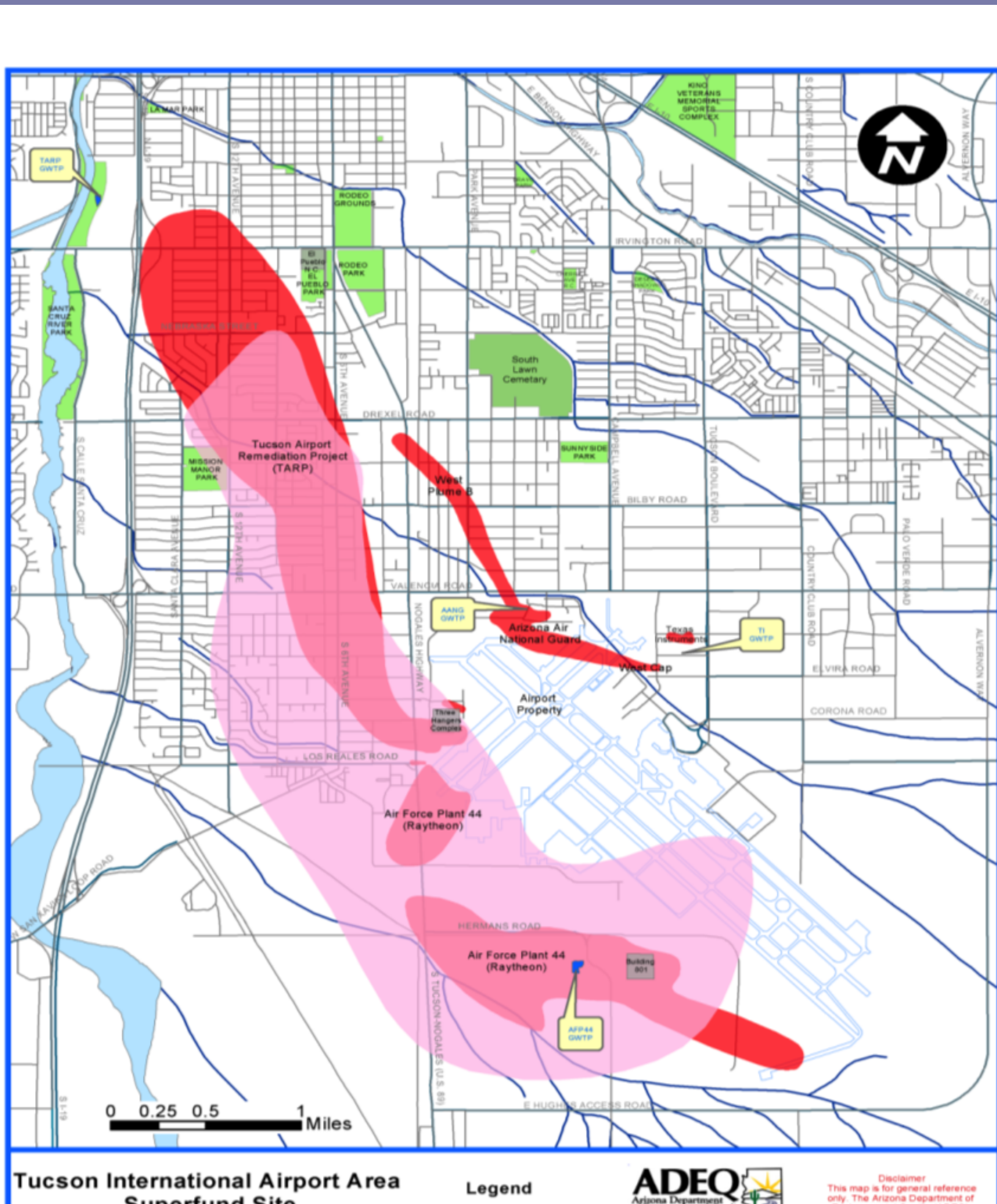


- Test of EW isolation from surrounding plume



from Guo and Brusseau 2017

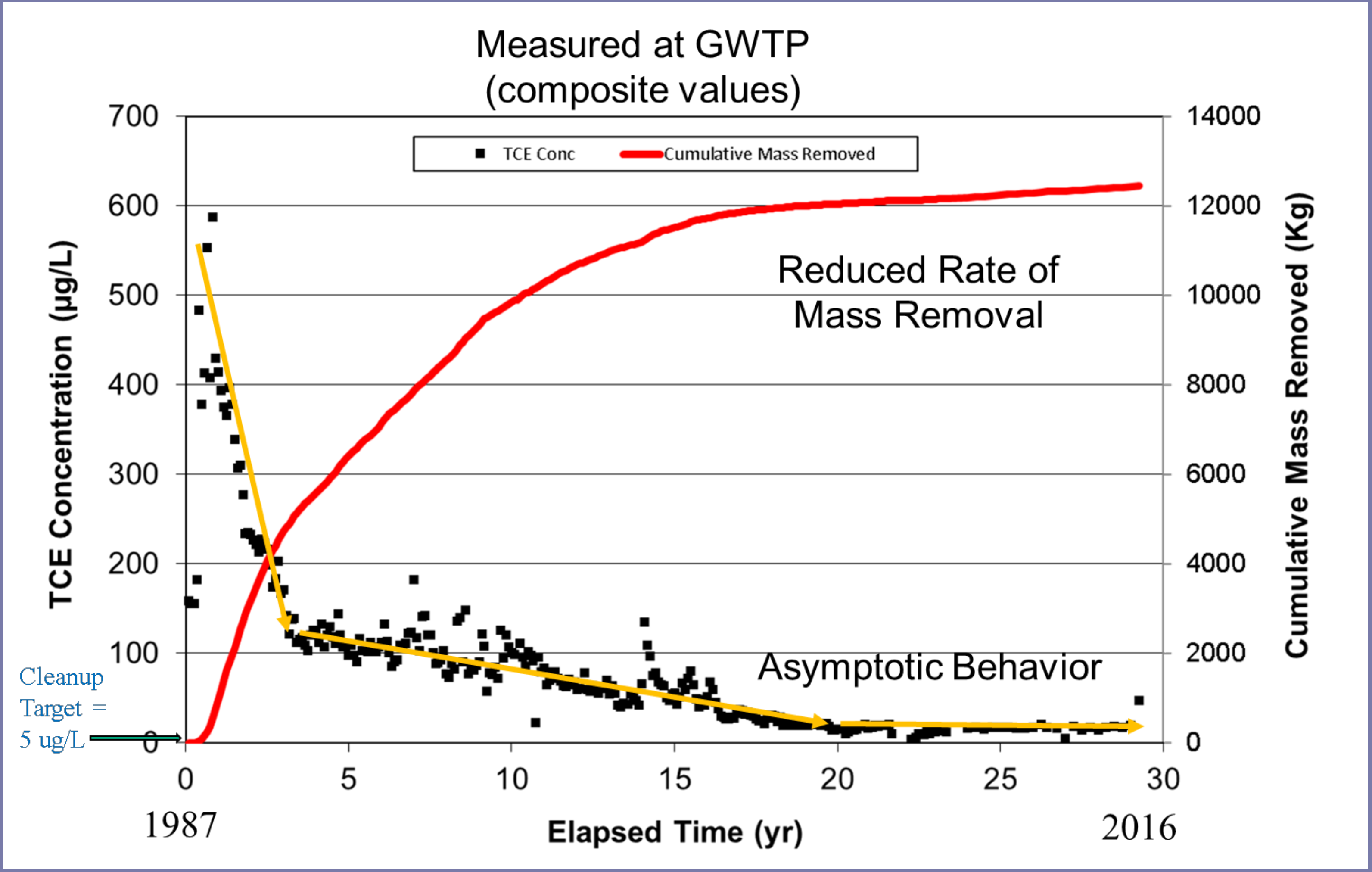
Case Study: TIAA Superfund Site



- NPL Listing in 1983
- COC = TCE
- Regional aquifer impacted
- Multiple OUs and remedial operations

GW Pump & Treat Operation

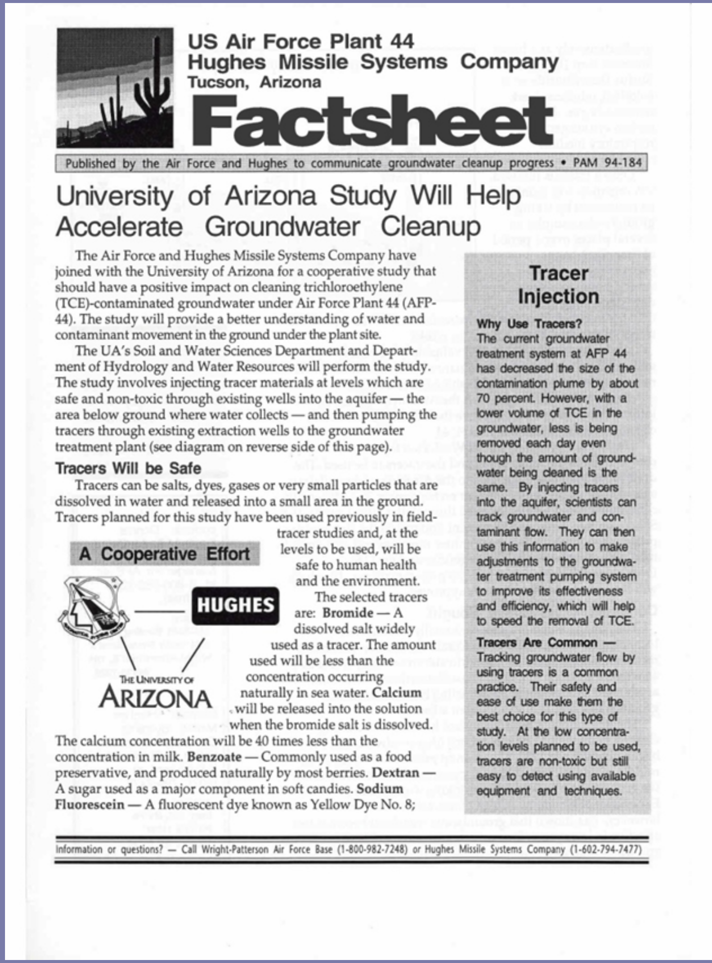
- High-resolution data set to characterize mass removal



UA- TIAA Study

Objectives: Understand T&F behavior at site and improve remediation effectiveness

- Activities
  - Characterization- ICET^3
  - Laboratory Experiments
  - Mathematical Modeling
  - Evaluate Conceptual Site Model
  - Pilot Tests of Remedial Technologies



US Air Force Plant 44
Hughes Missile Systems Company
Tucson, Arizona

Factsheet

Published by the Air Force and Hughes to communicate groundwater cleanup progress • PAM 94-184

University of Arizona Study Will Help Accelerate Groundwater Cleanup

The Air Force and Hughes Missile Systems Company have joined with the University of Arizona for a cooperative study that should have a positive impact on cleaning trichloroethylene (TCE)-contaminated groundwater under Air Force Plant 44 (AFP-44). The study will provide a better understanding of water and contaminant movement in the ground under the plant site.

The UA's Soil and Water Sciences Department and Department of Hydrology and Water Resources will perform the study. The study involves injecting tracer materials at levels which are safe and non-toxic through existing wells into the aquifer — the area below ground where water collects — and then pumping the tracers through existing extraction wells to the groundwater treatment plant (see diagram on reverse side of this page).

Tracers Will be Safe

Tracers can be salts, dyes, gases or very small particles that are dissolved in water and released into a small area in the ground. Tracers planned for this study have been used previously in field-tracer studies and, at the levels to be used, will be safe to human health and the environment.

A Cooperative Effort

HUGHES

THE UNIVERSITY OF ARIZONA

The selected tracers are: **Bromide** — A dissolved salt widely used as a tracer. The amount used will be less than the concentration occurring naturally in sea water. **Calcium** will be released into the solution when the bromide salt is dissolved. The calcium concentration will be 40 times less than the concentration in milk. **Benzoate** — Commonly used as a food preservative, and produced naturally by most berries. **Dextran** — A sugar used as a major component in soft candies. **Sodium Fluorescein** — A fluorescent dye known as Yellow Dye No. 8;

Tracer Injection

Why Use Tracers?
The current groundwater treatment system at AFP 44 has decreased the size of the contamination plume by about 70 percent. However, with a lower volume of TCE in the groundwater, less is being removed each day even though the amount of groundwater being cleaned is the same. By injecting tracers into the aquifer, scientists can track groundwater and contaminant flow. They can then use this information to make adjustments to the groundwater treatment pumping system to improve its effectiveness and efficiency, which will help to speed the removal of TCE.

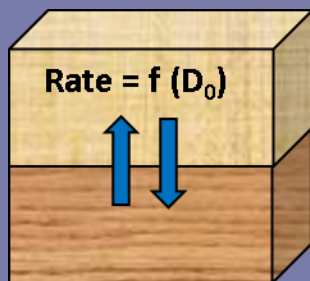
Tracers Are Common — Tracking groundwater flow by using tracers is a common practice. Their safety and ease of use make them the best choice for this type of study. At the low concentration levels planned to be used, tracers are non-toxic but still easy to detect using available equipment and techniques.

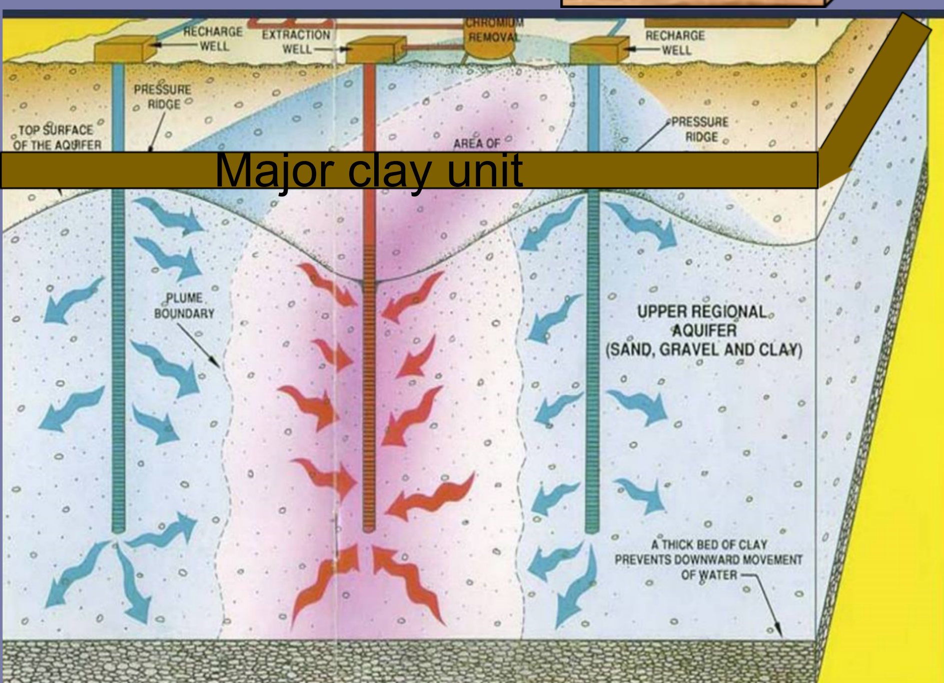
Information or questions? — Call Wright-Patterson Air Force Base (1-800-982-7248) or Hughes Missile Systems Company (1-602-794-7477)

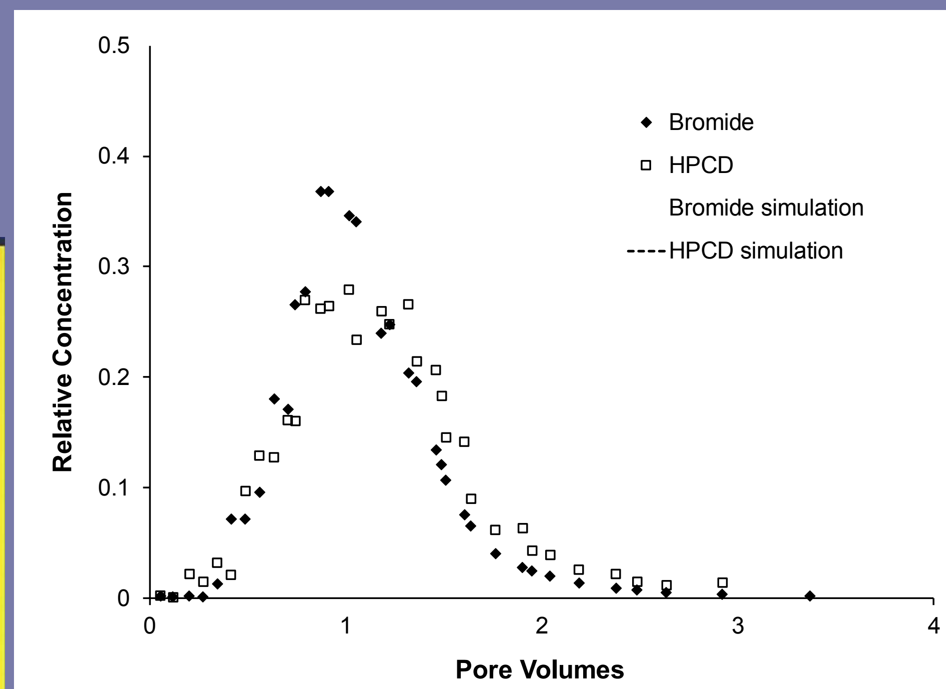
ICET^3 Application

- Presence of higher COC concs in major low-K unit
- Diffusive mass transfer (back diffusion) influencing mass removal

>>> Diffusive tracer test





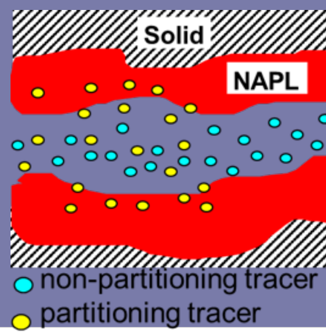


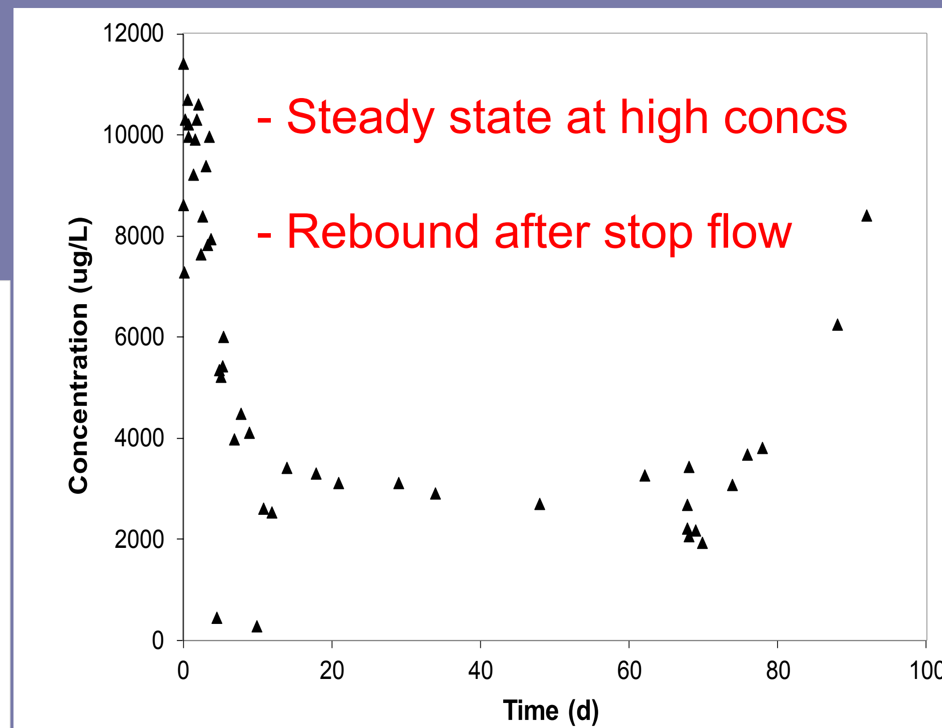
Non-reactive tracers
[HPCD D_0 < Br D_0]

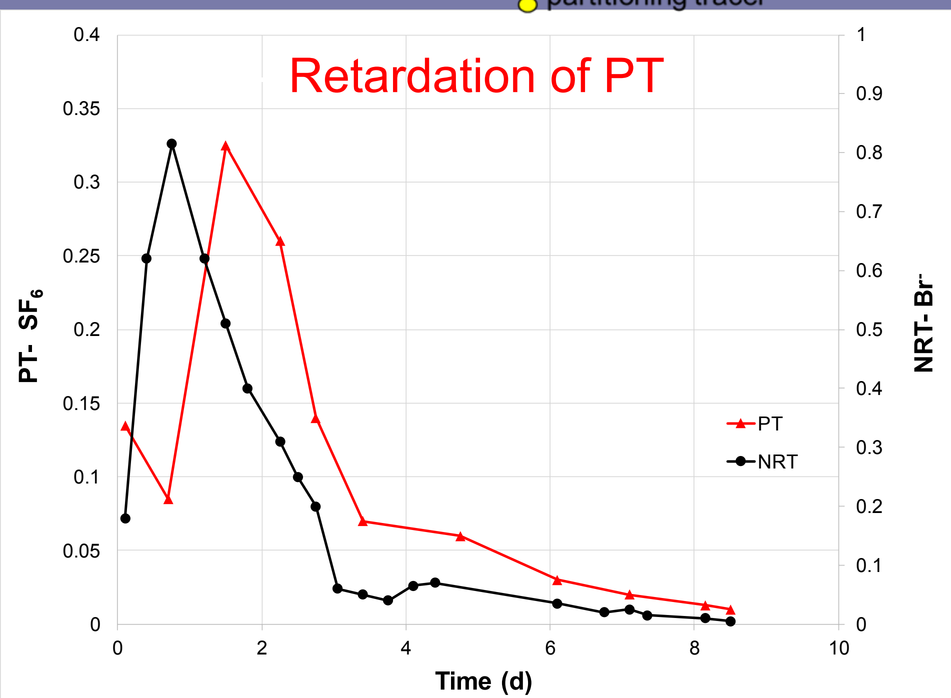
ICET^3 Application

- Presence of DNAPL in source zone

>>> NAPL Partitioning tracer test





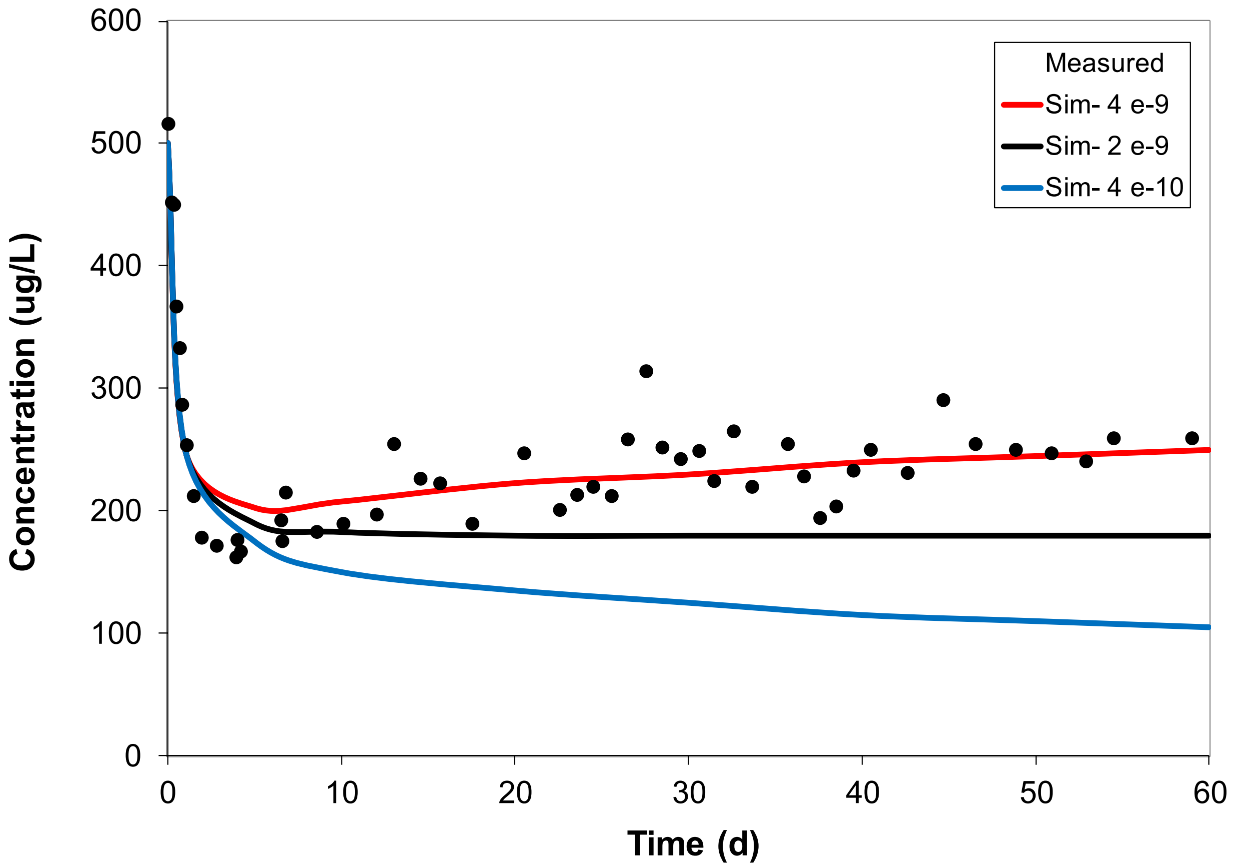


CET with Stop Flow

ICET^3 Application

- Mass removal mediated by NAPL dissolution

>>> Numerical Modeling

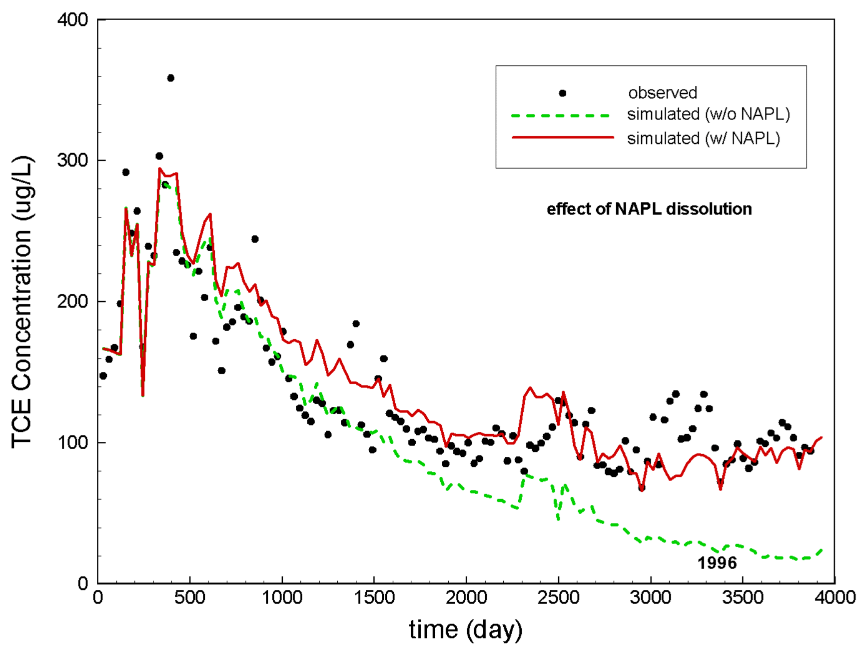


- Impact of NAPL dissolution rate coefficient

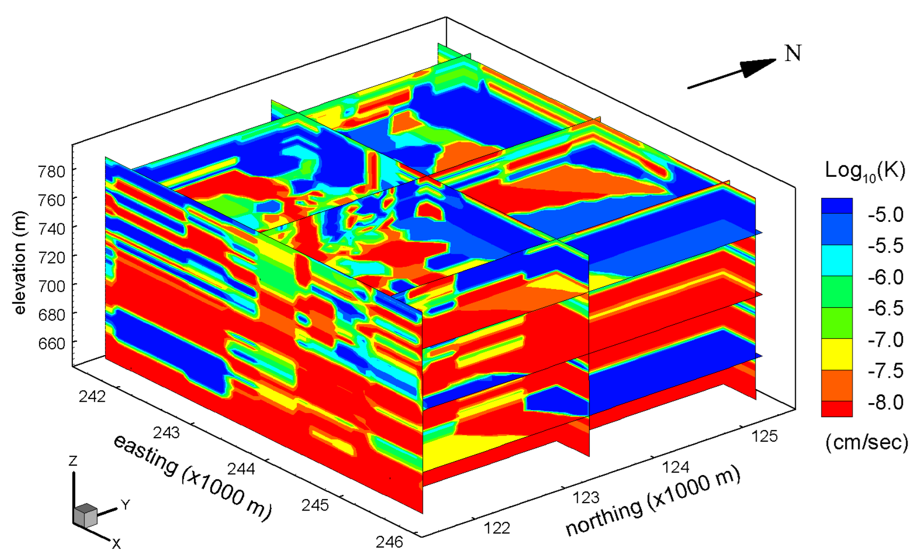
ICET³ Application

- Information obtained from ICET³ applications used to support 3-D plume-scale modeling

  - Simulation showing impact of DNAPL in source zones



Comparison of the Simulated Influent TCE Conc. at Treatment Plant with the Observed Data

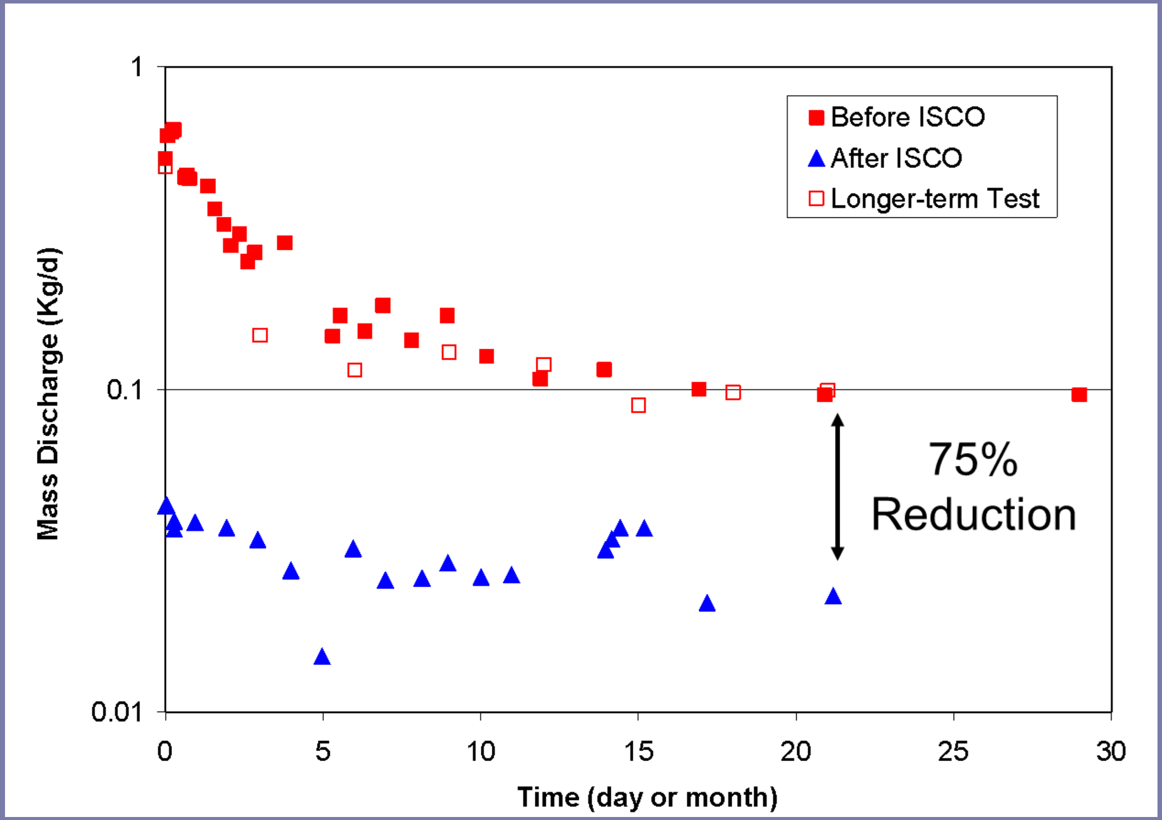


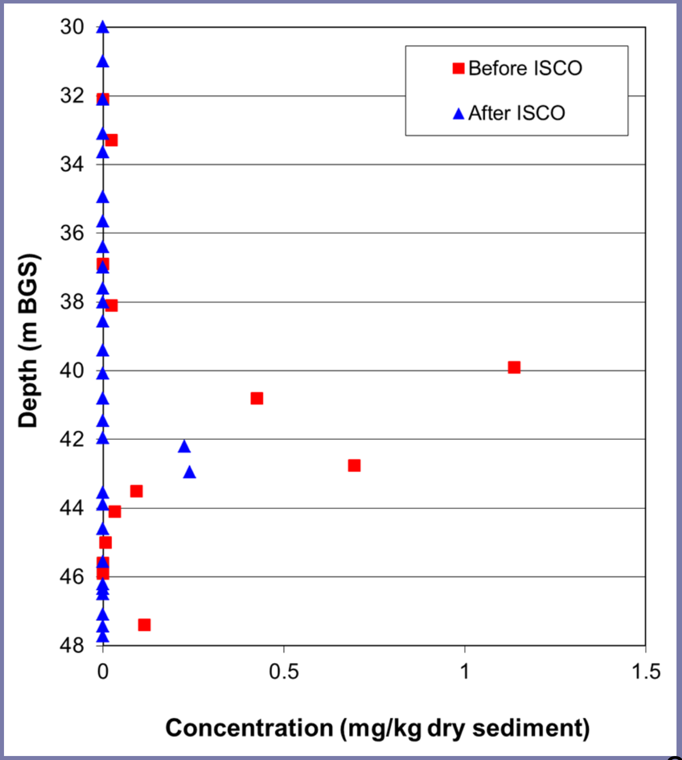
Three-Dimensional Distribution of Hydraulic Conductivities at AFP-44 Site

>>> Modeling used to predict impact of source-zone remediation

ICET^3 Application

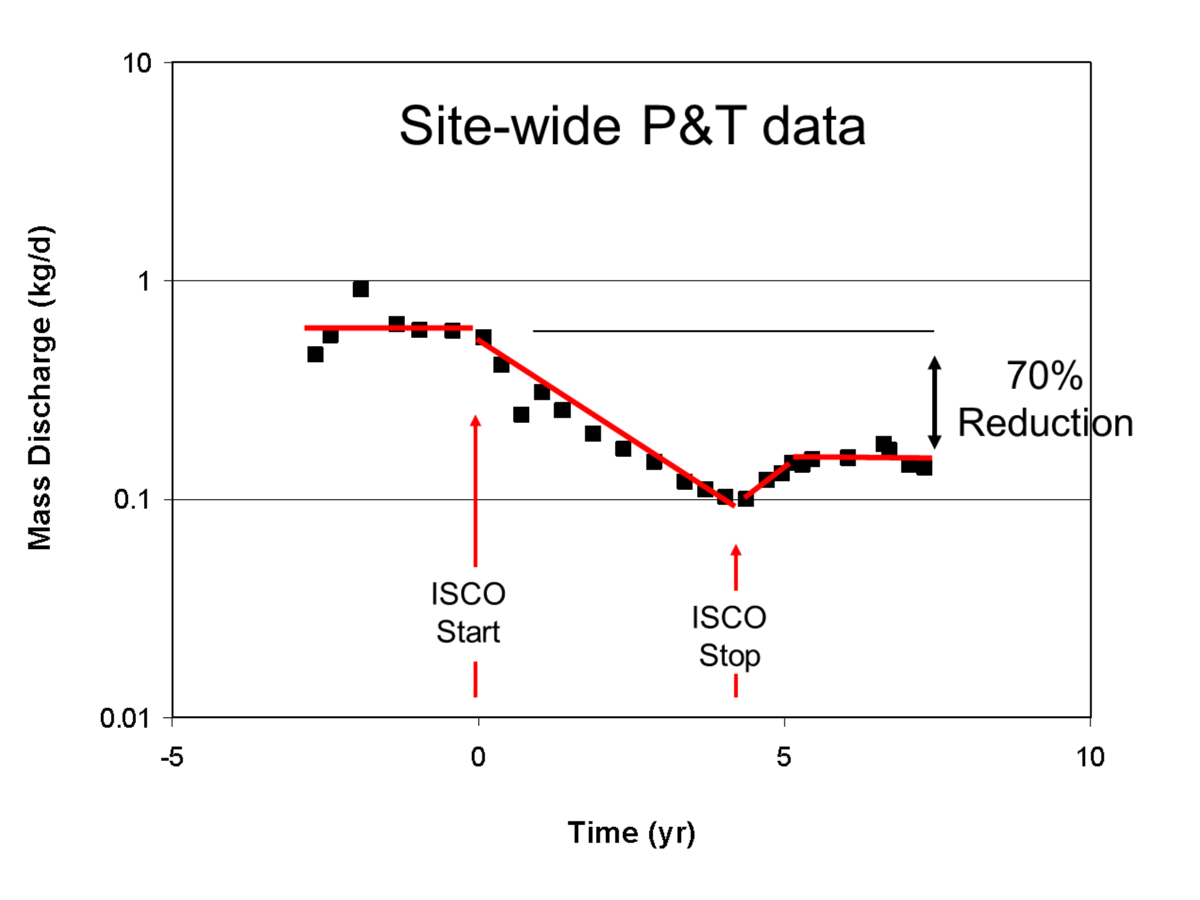
- ISCO (permanganate) implemented for source zones
- Measure CMD before and after ISCO





ICET^3 Application

- Comparison to plume-scale aggregate CMD
- Reasonable correspondence



Summary

- Utility of contaminant elution and tracer tests for site characterization

- Just one component of full site assessment

- Thank you

Acknowledgements

- NIEHS SBRP, DOD SERDP, DOD ESTCP, US Air Force, Tucson Airport Authority, US EPA
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