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POWERING THE NEW ENGINEER TO TRANSFORM THE FUTURE

Department of Environmental Engineering Sciences

Long-term DNAPL Source Zone Response to Bioaugmentation using Mass-flux Measurements and Push-pull Tracer Tests

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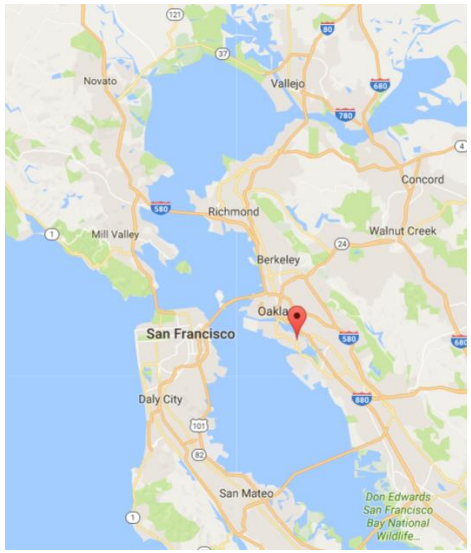
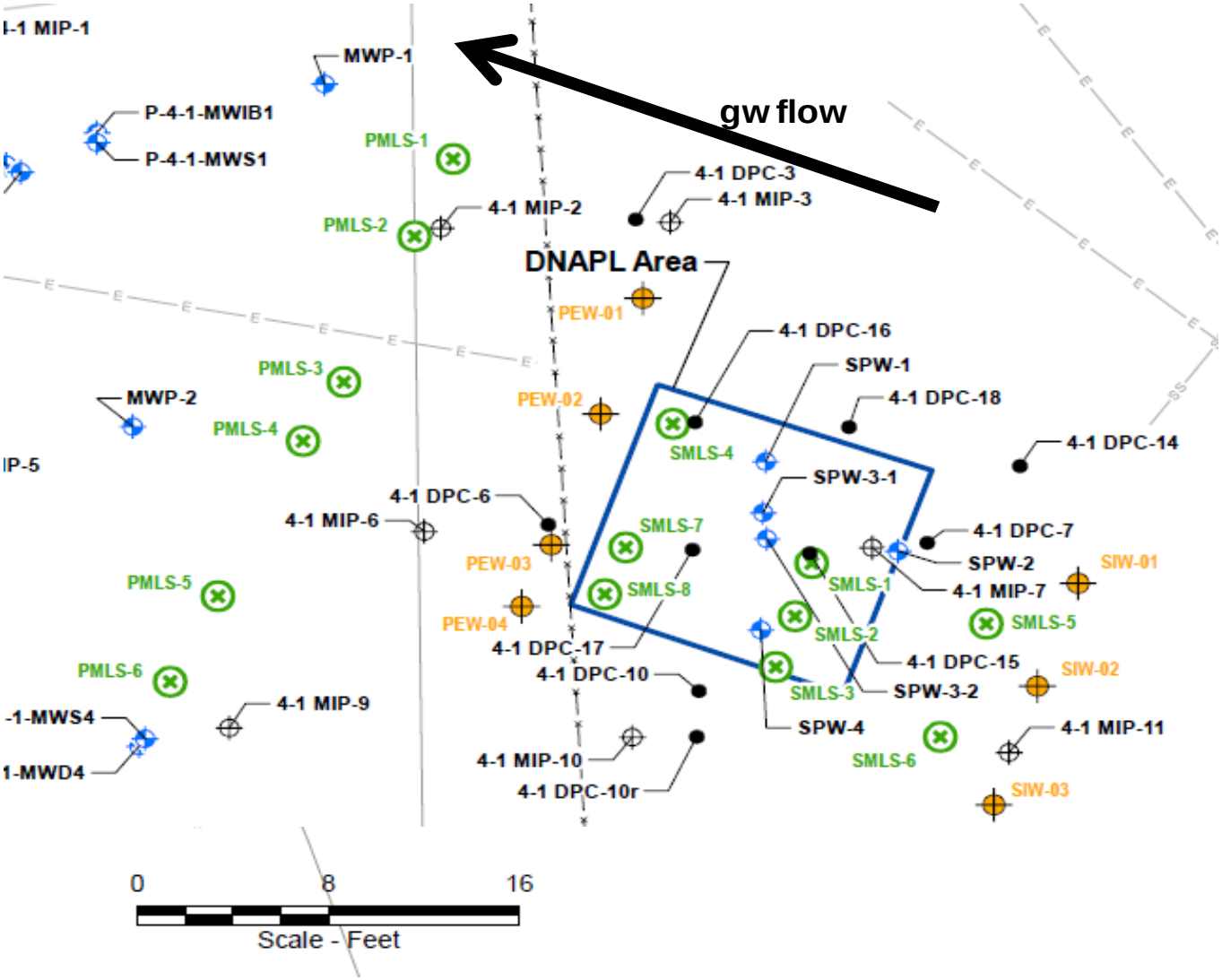
May 17, 2017

Technical Objectives

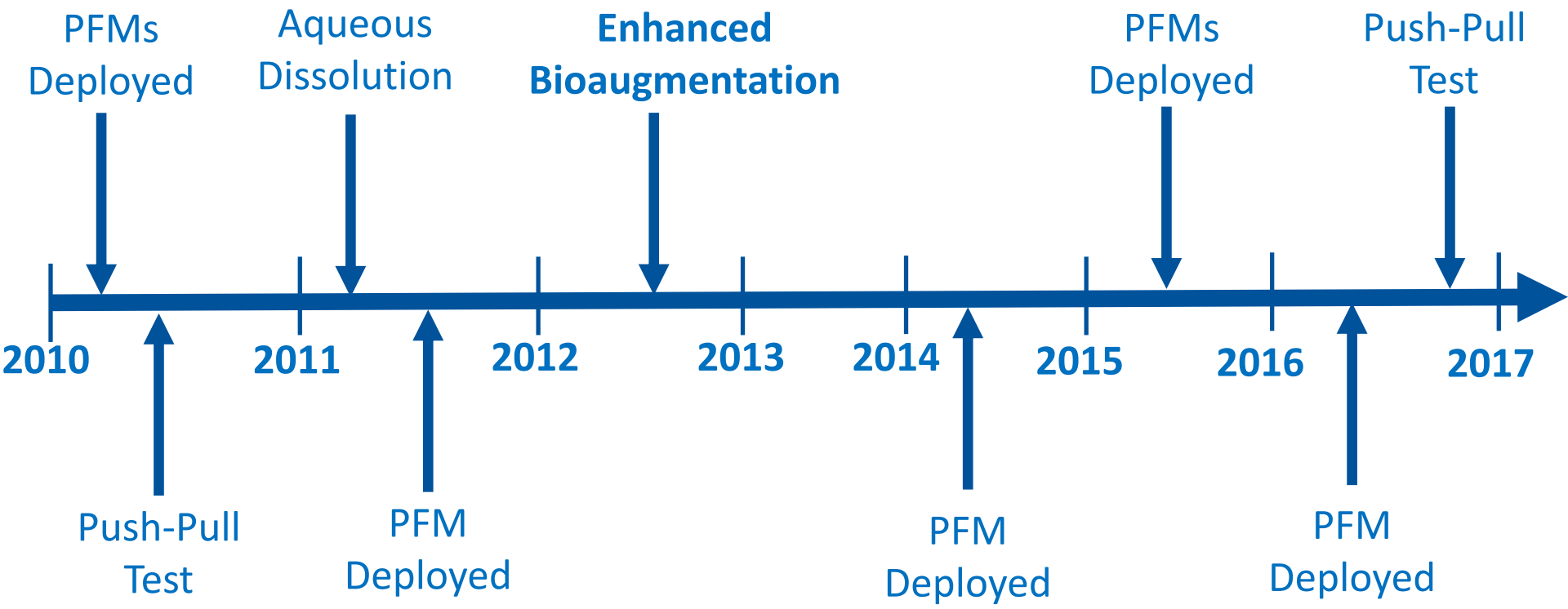
- Assess DNAPL mass quantity and composition post bioaugmentation
- Assess long-term contaminant mass flux post bioaugmentation

Alameda Point, CA



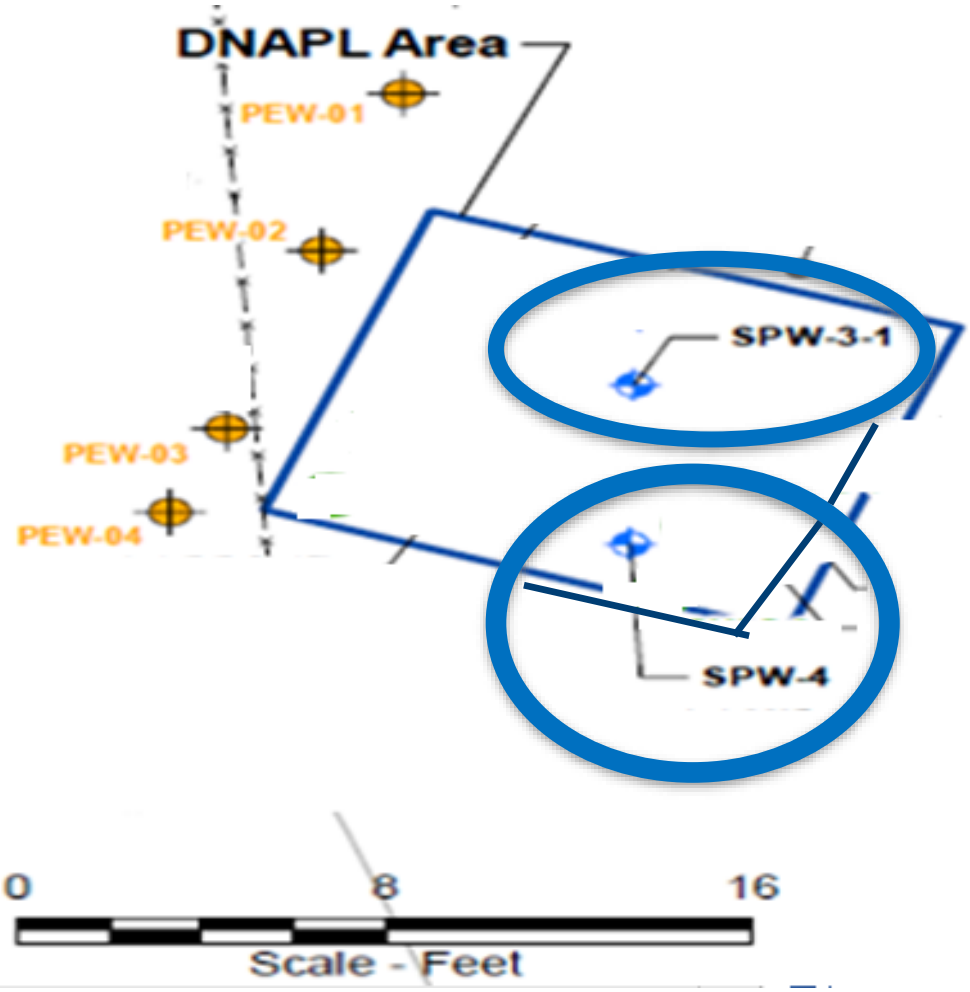


Fieldwork at Alameda, CA



Push-pull tracer analysis

- Repeated Direct Push-Pull tracer test to assess DNAPL removal
  - Nonpartitioning tracers:
    - Bromide
    - Methanol
  - Partitioning tracers:
    - e-Hexanol
    - 2-octanol
  - 3.7 L DNAPL measured 2010



Push-pull tracer analysis

Method of Moments

$$\frac{C}{C_o} = \frac{1}{2} erfc \left\{ \frac{\left(\frac{V_{ext}}{V_{inj}} - 1\right)}{\left[\frac{16}{3}\frac{\alpha_L}{\hat{r}_{max}}\left(2 - \left|1 - \frac{V_{ext}}{V_{inj}}\right|^{\frac{1}{2}} \times \left(1 - \frac{V_{ext}}{V_{inj}}\right)\right)\right]^{1/2}} \right\}$$

$$S_N = \frac{R - 1}{K_{N,2} - 1 - R(K_{N,1} - 1)}$$

Requires good separation between tracers

Equilibrium Streamtube Model

$$\bar{C}_{non-paritioning} = 1 - \frac{C_{Non-paritioning}}{C_{0-Non-paritioning}}$$

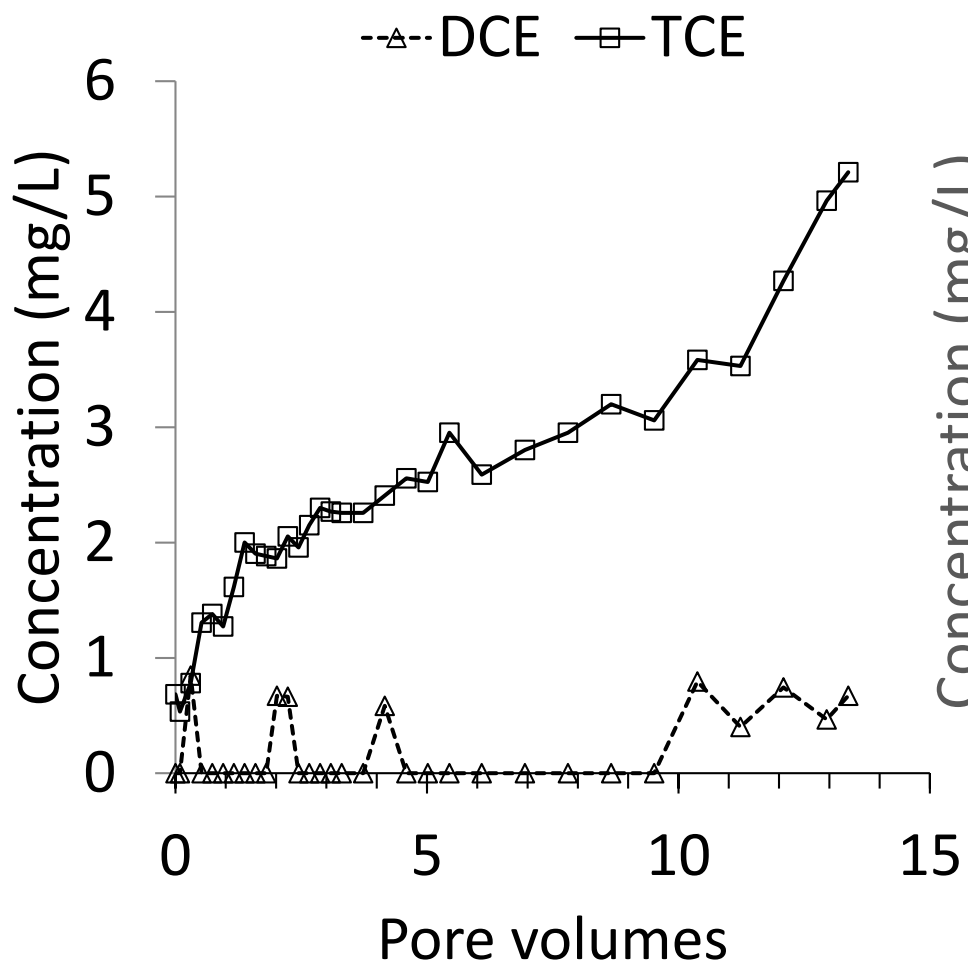
$$\bar{C}_{TCE/DCE} = \frac{C_{TCE/DCE}}{C_{\max TCE/DCE}}$$

$$\frac{C(t)}{f_c C_s} = \frac{1}{2}\left[1 - \mathrm{erf}\left(\frac{\ln t - \mu_{\ln \tau}}{\sigma_{\ln \tau}\sqrt{2}}\right)\right]$$

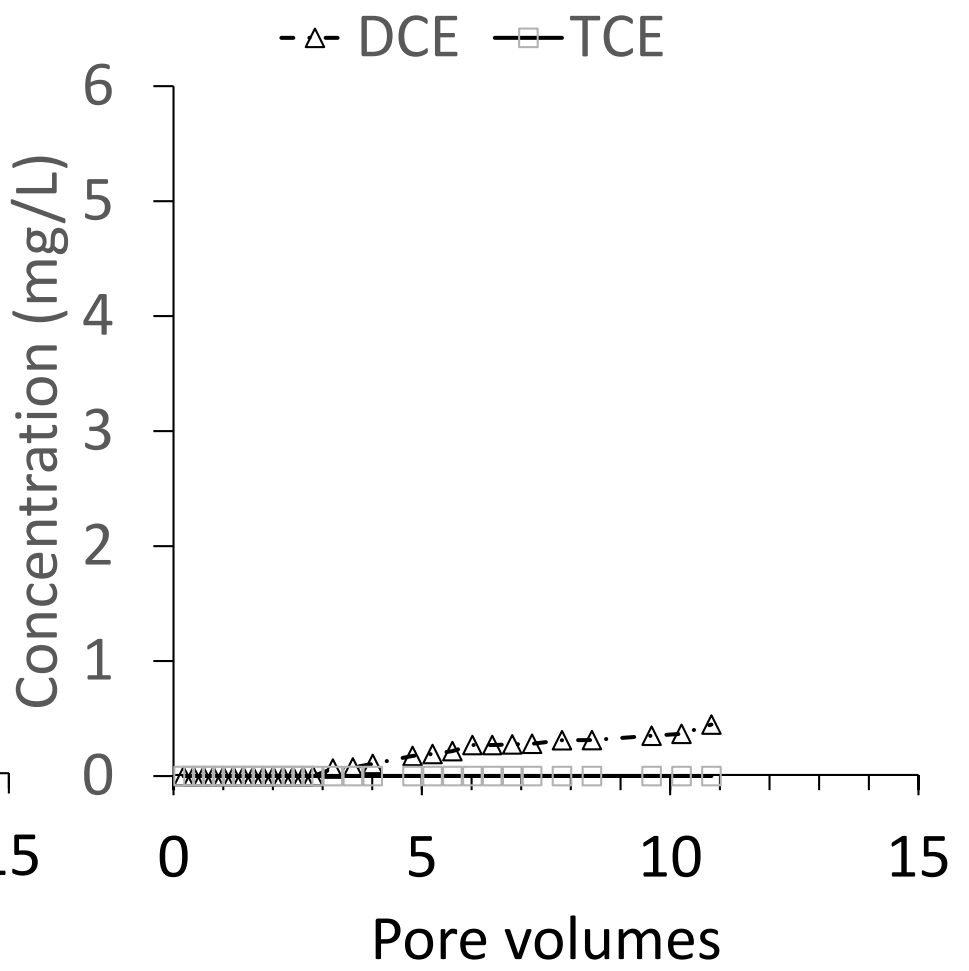
Requires immediate recovery of TCE/DCE

Push-Pull Test: SPW-4

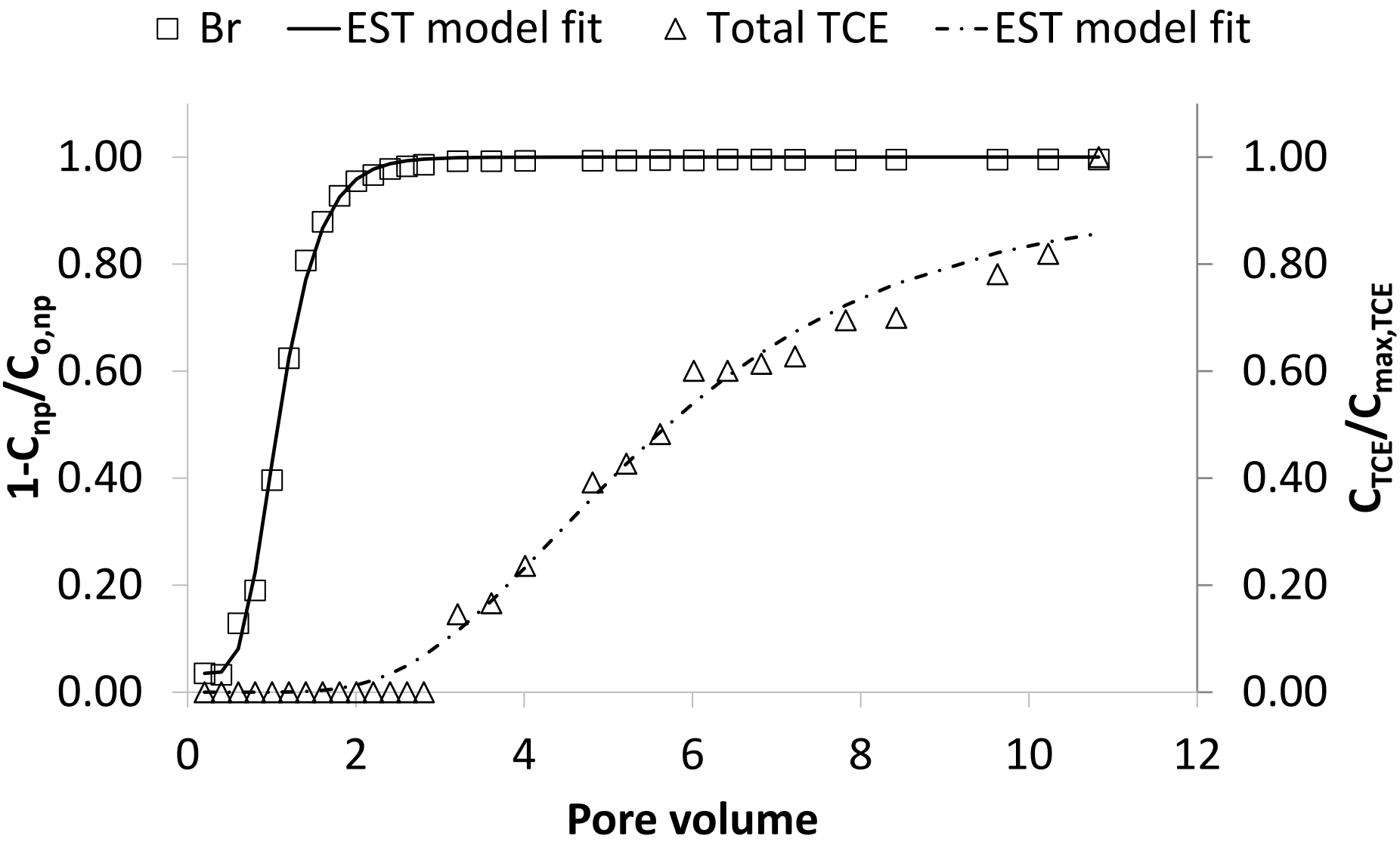
Pre-bioaugmentation



Post-bioaugmentation

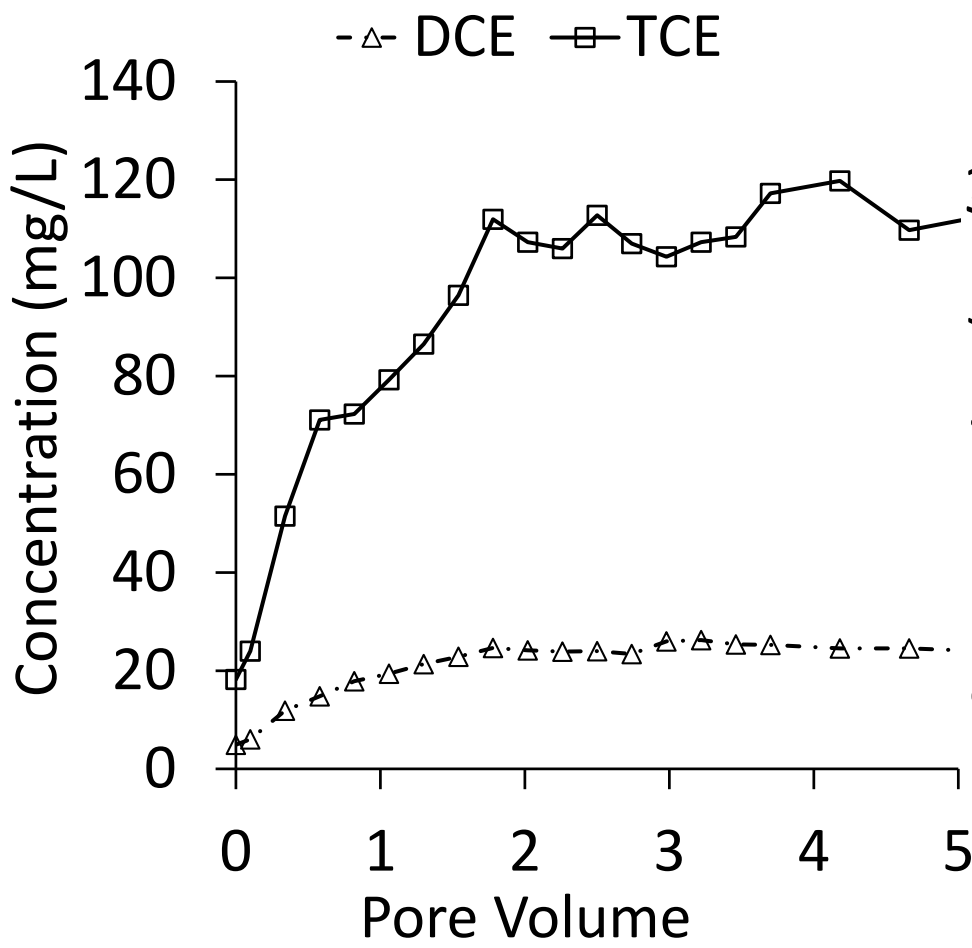


SPW-4 (No DNAPL Present)

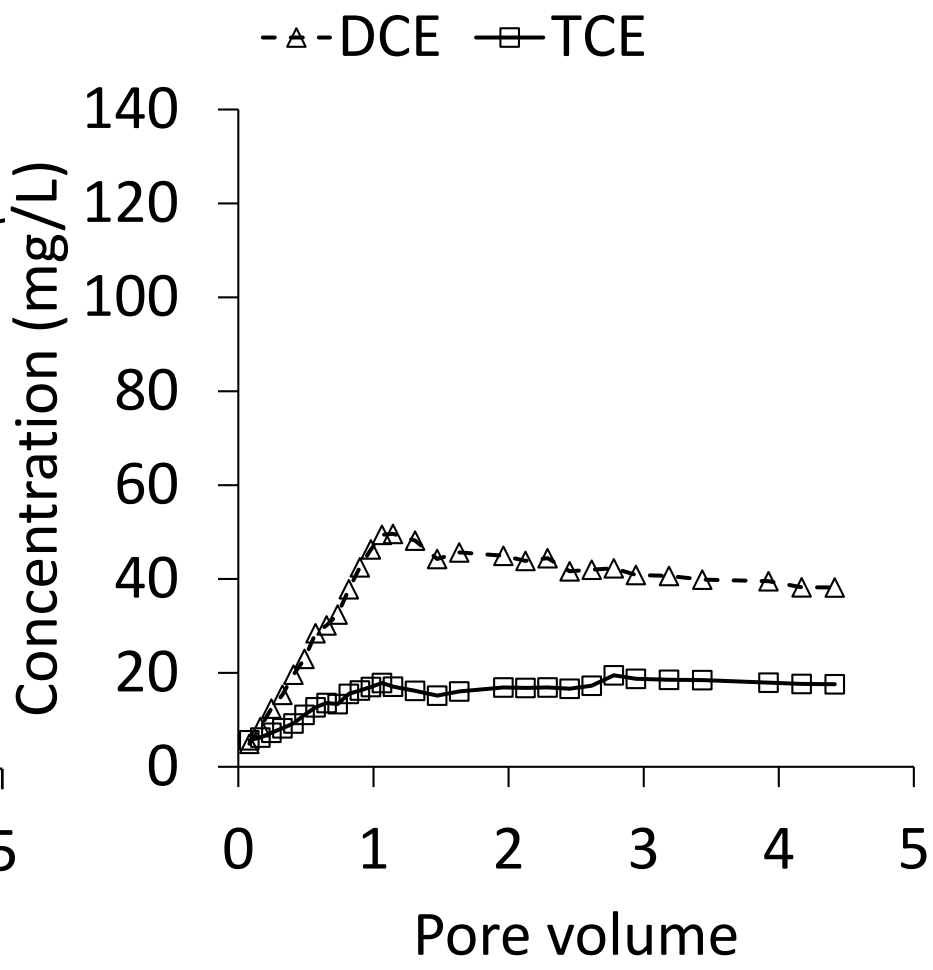


Push-Pull Test: SPW-3-1

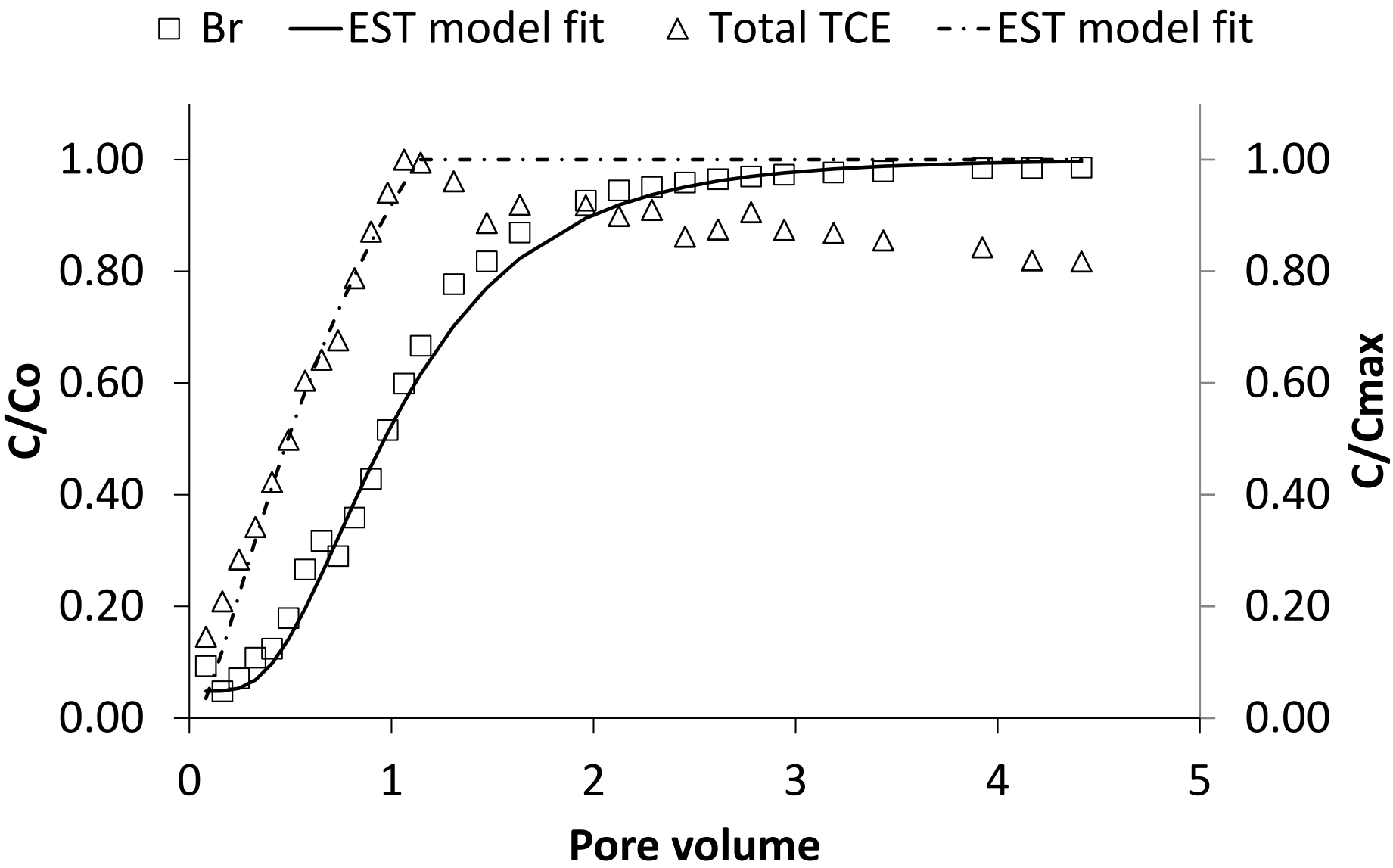
Pre-bioaugmentation



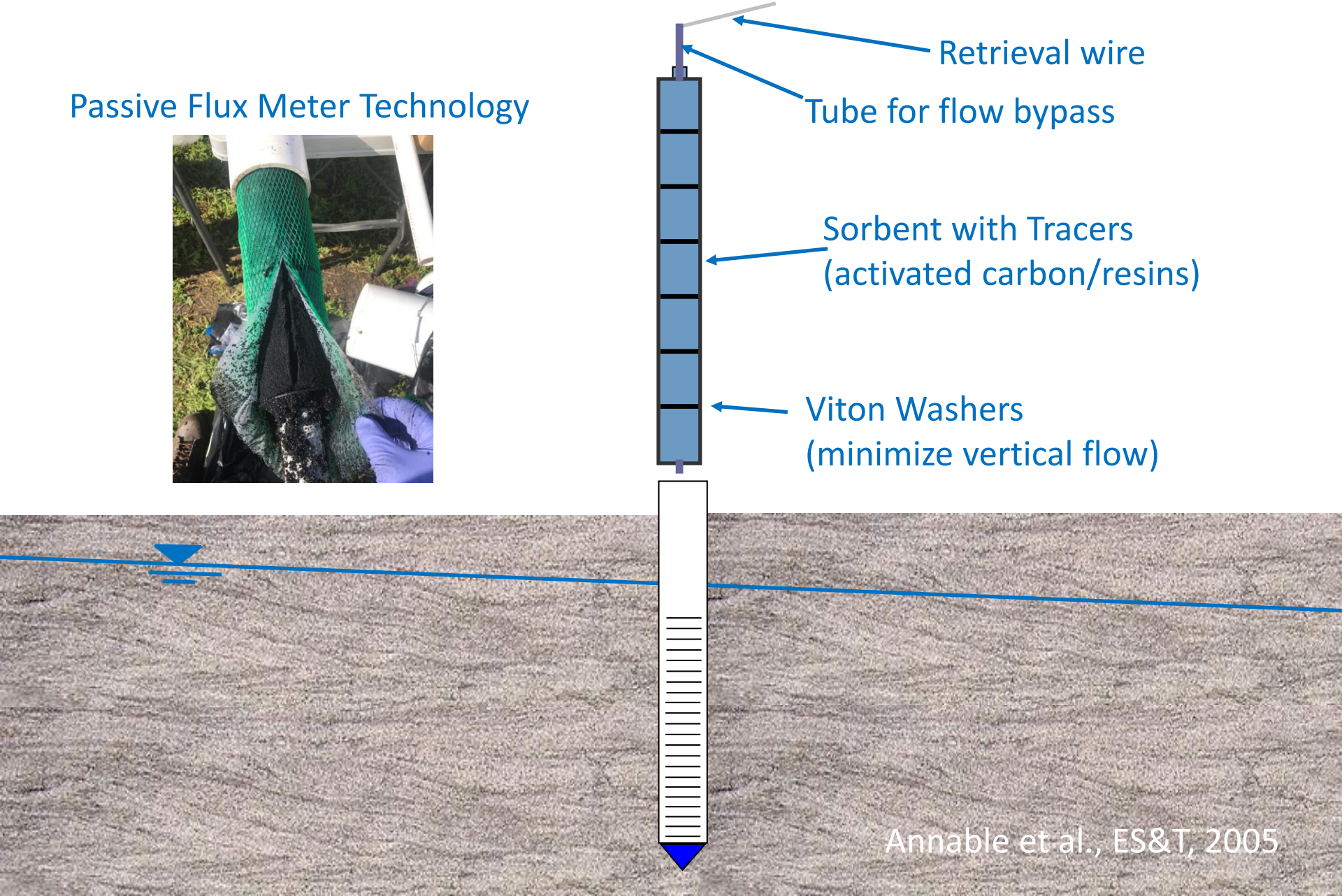
Post-bioaugmentation



Well SPW-3-1


Br
EST model fit
Total TCE
EST model fit
1.00
0.80
0.60
0.40
0.20
0.00
C/Co
C/Cmax
0
1
2
3
4
5
Pore volume

Passive Flux Meter Technology



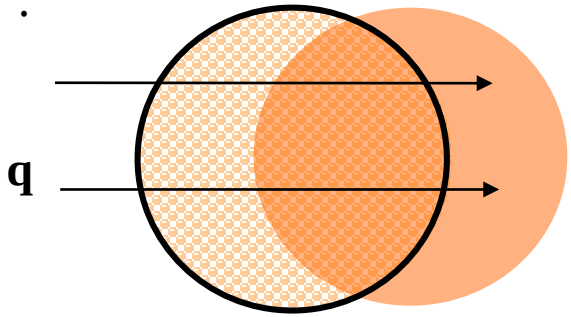
Annable et al., ES&T, 2005

Passive Flux Meter (PFM) Concepts

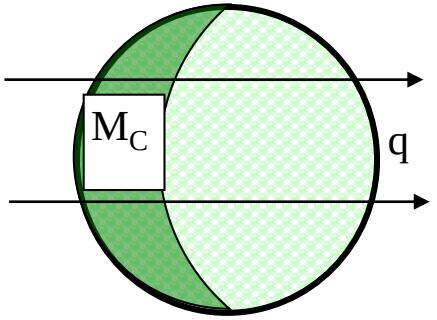
$$J_C = q_w \cdot C_c$$

Contaminant Flux Water flux

From PFM's



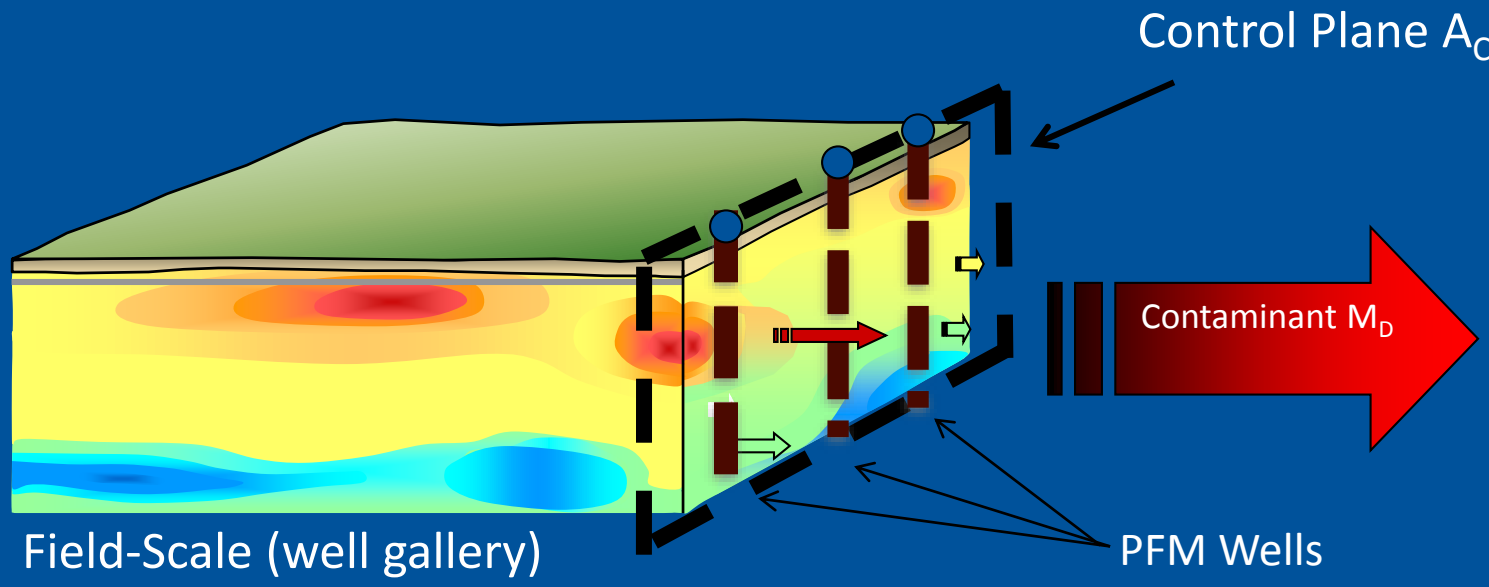
Displaced resident tracers for groundwater flux



Captured contaminants for contaminant fluxes

Hatfield et al., Journal of Contaminant Hydrology, 2004

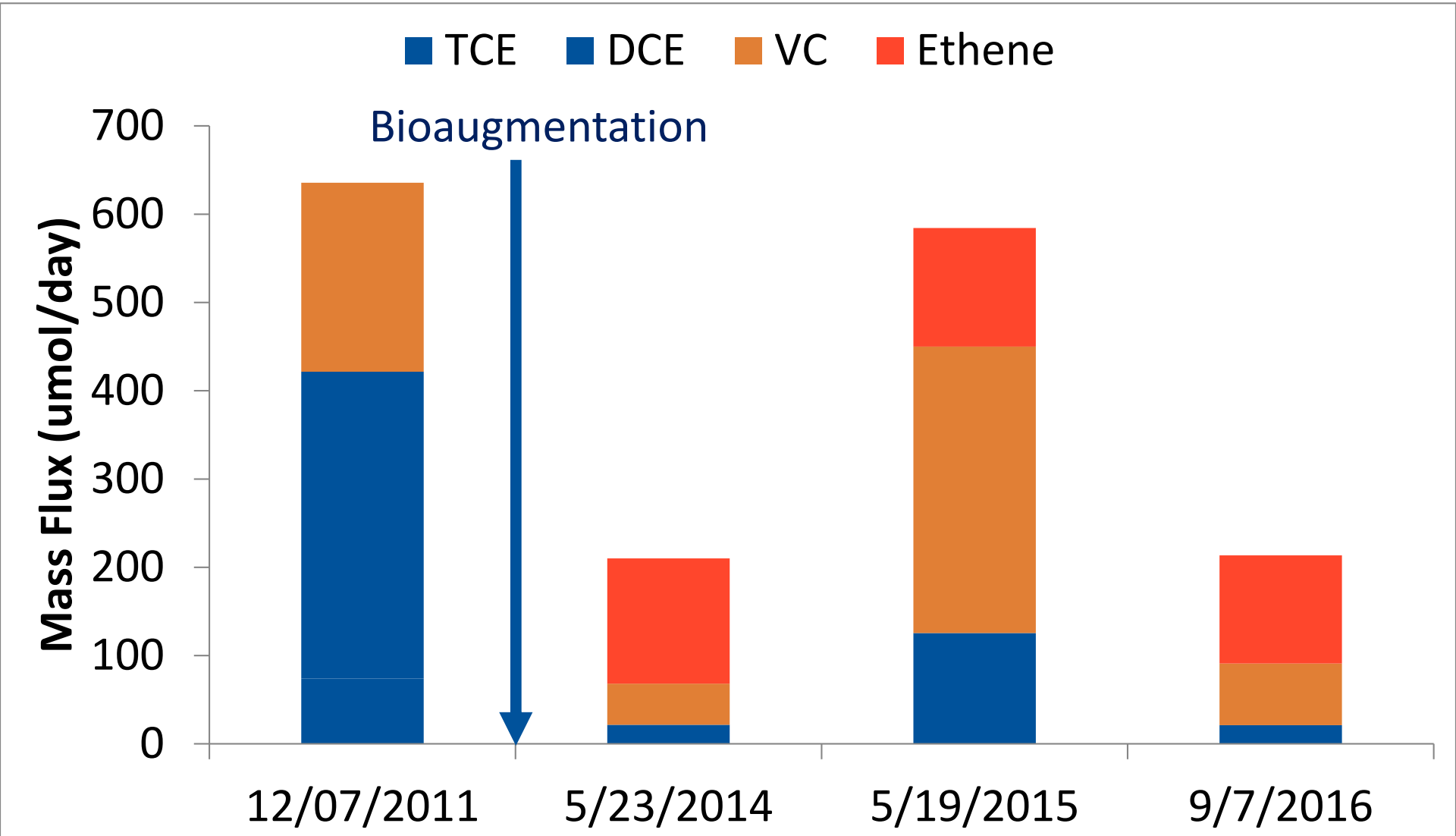
Transect Method



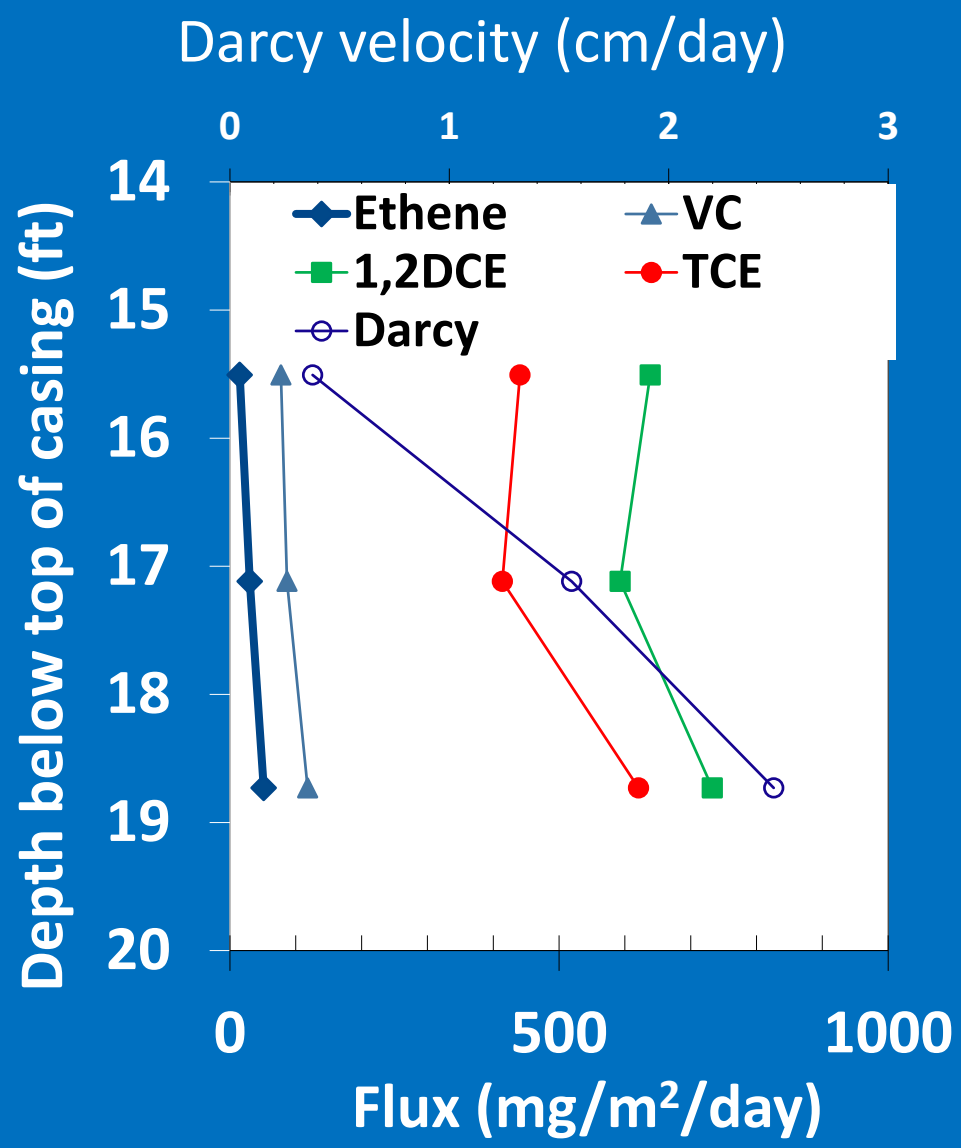
$$M_D = \int_A J dA$$

Units
[M/T]

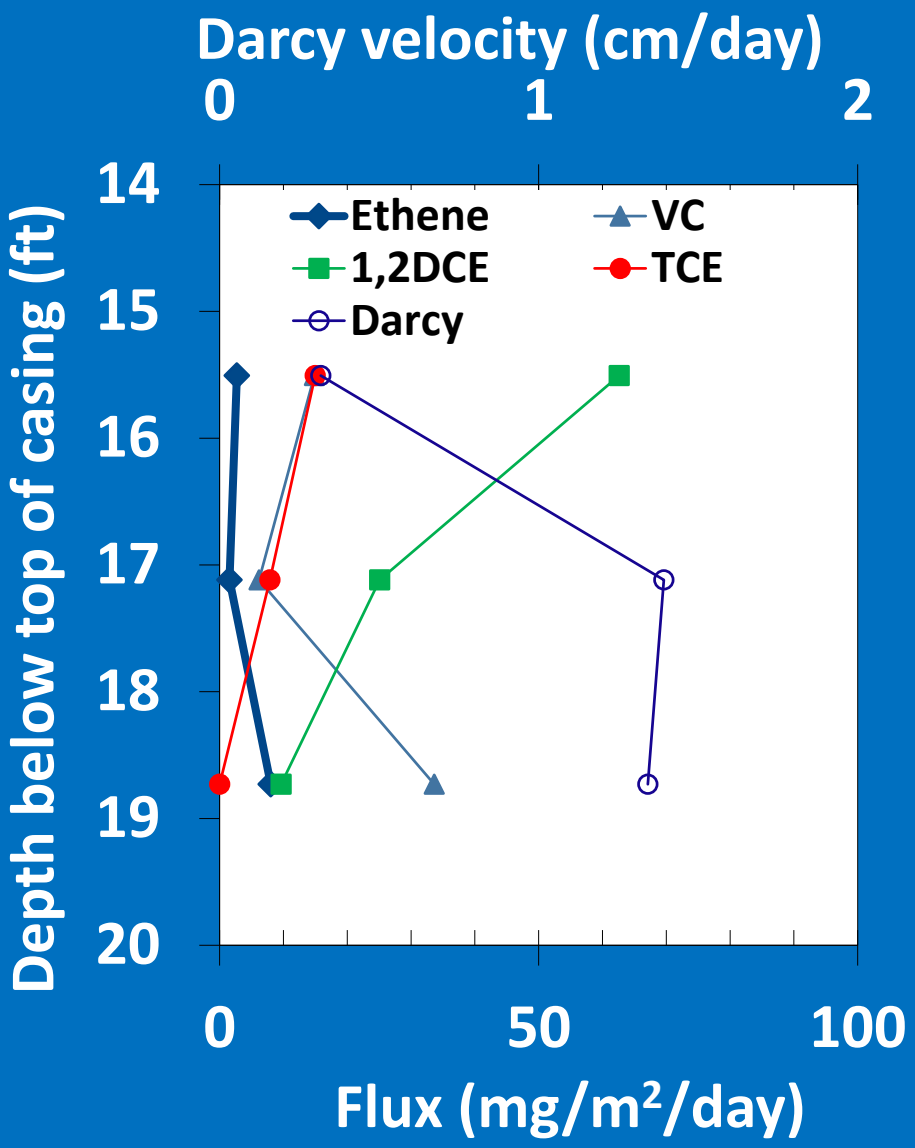
Mass Flux of Chlorinated Solvents



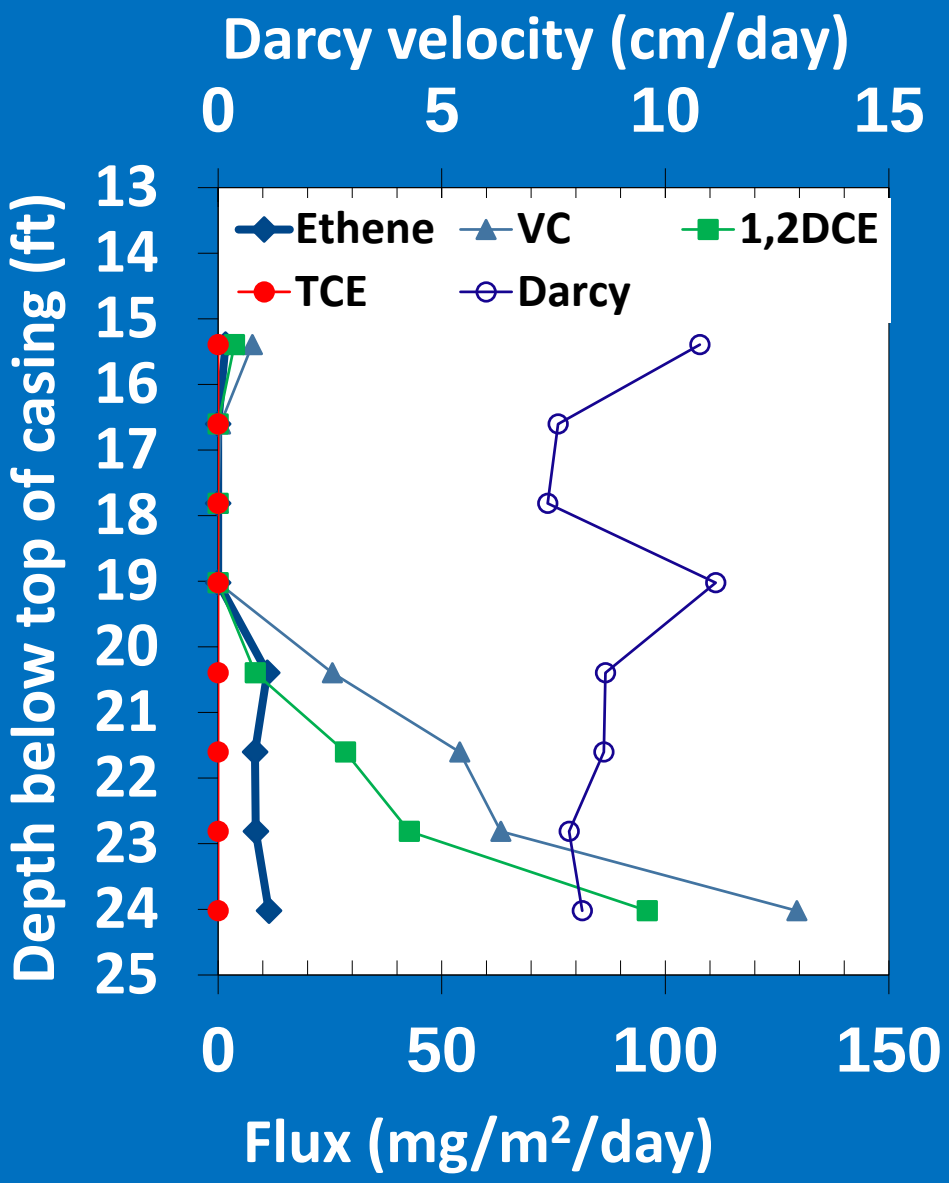
SPW-3-1 (05/19/15)



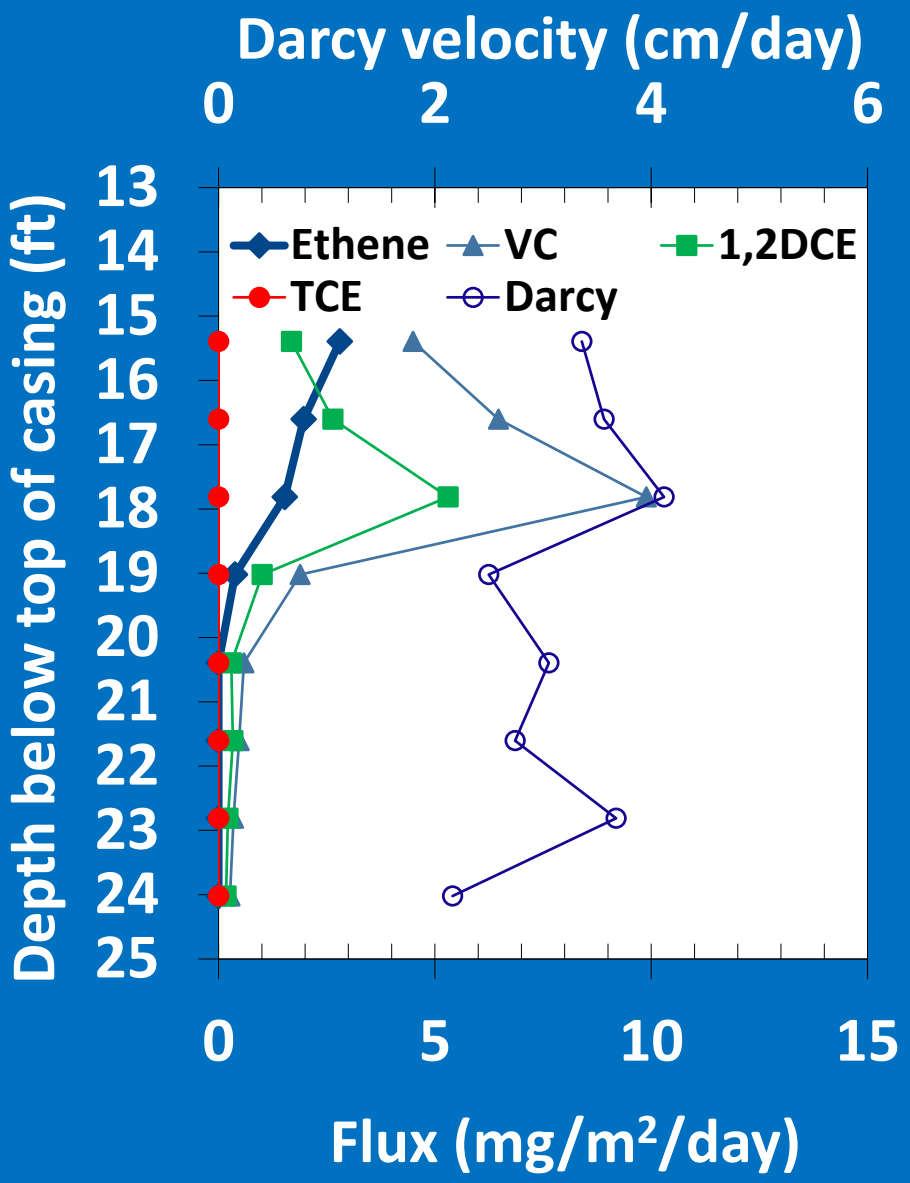
SPW 3-1 (09/16/17)



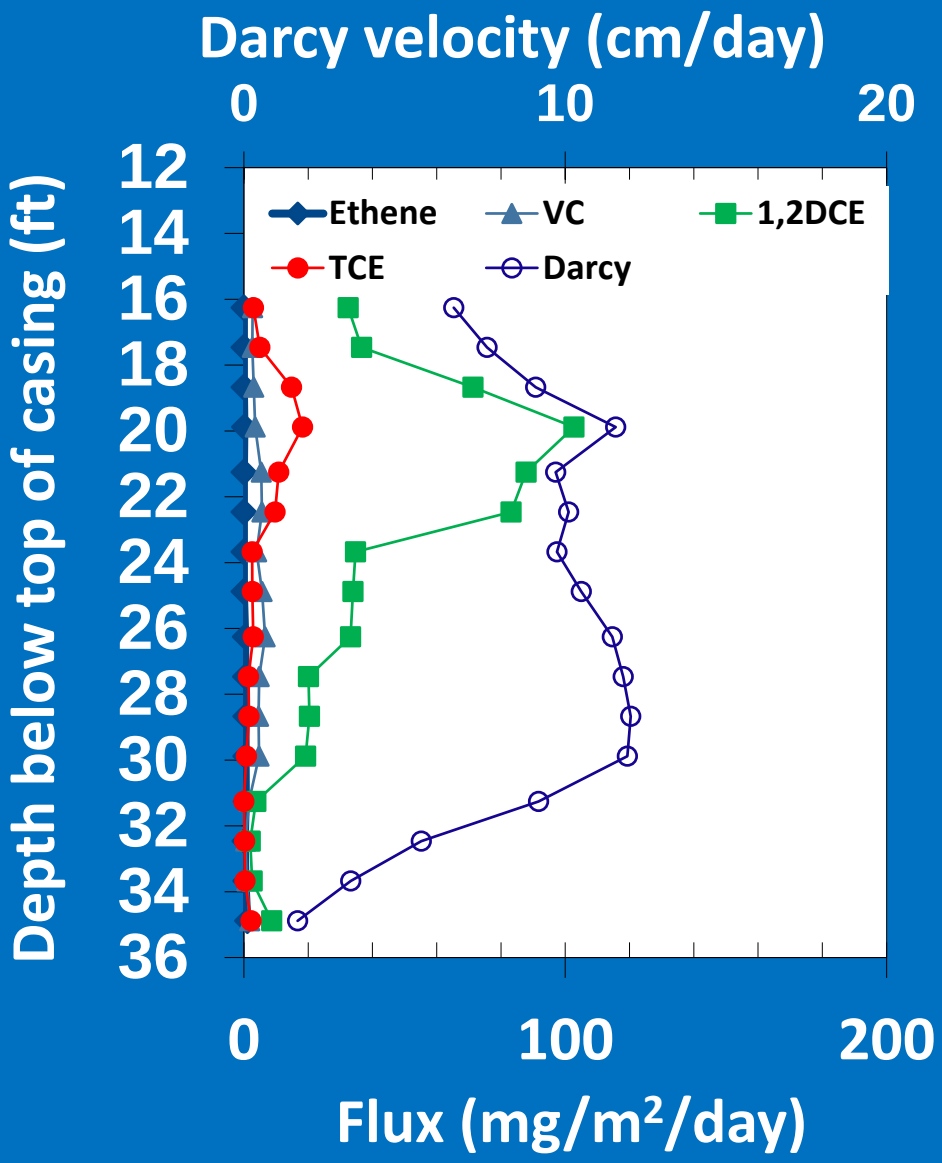
PEW-02 (05/19/15)



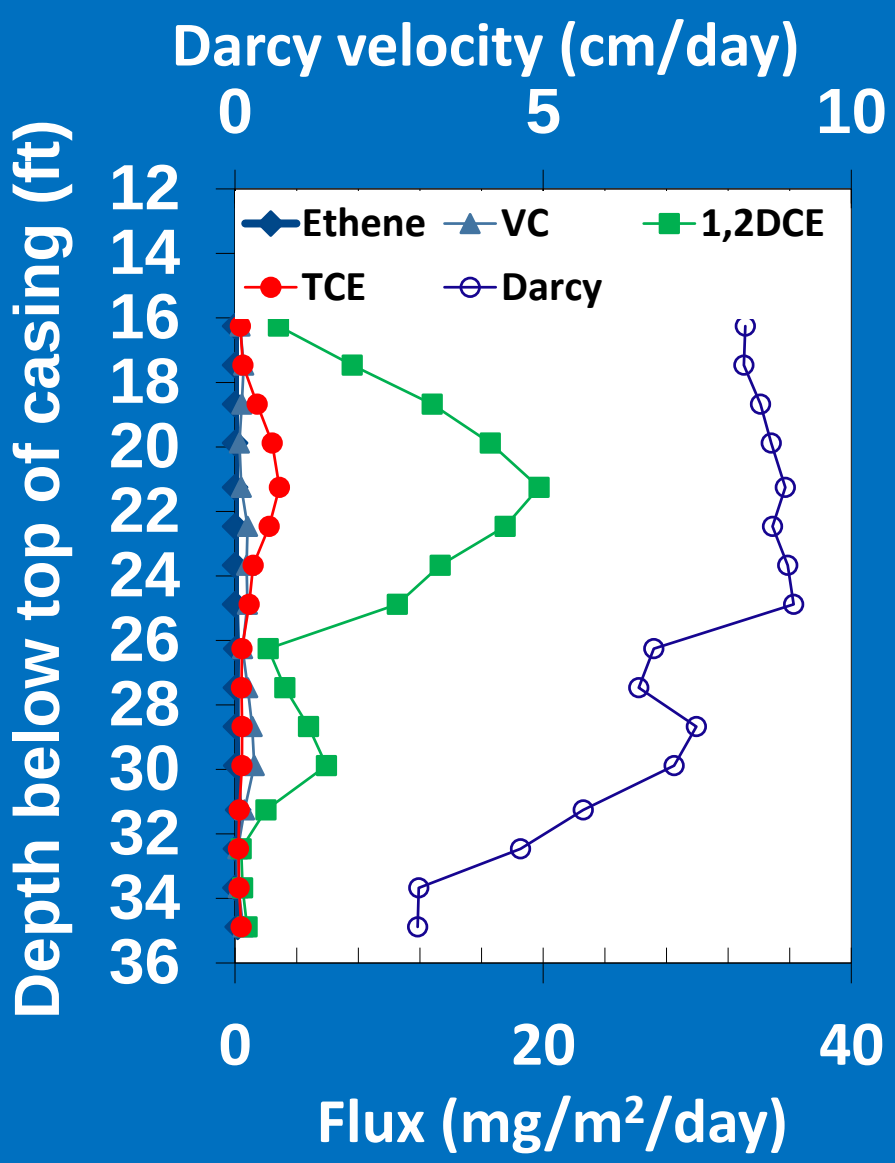
PEW-02 (09/07/16)



MWP-2 (05/19/15)



MWP-2 (09/06/17)



Conclusions

- 22% decrease in DNAPL mass based on Push-pull test
- DNAPL mass shifted from TCE to cis-DCE dominated NAPL
- 90% mass flux reduction since enhanced bioaugmentation

Future Work

- Develop monitoring technologies to measure biomass flux
- Develop numerical and analytical models to model biodegradation decay rates based on contaminant mass flux rates

Acknowledgements

- This project is funded by ESTCP ER-201428
- Tim Ault (CB&I)
- Kenneth Lee (CB&I)
- Dr. Fang Wang (University of Florida)