Direct Drive High Resolution Passive Sampling for Characterizing the Distribution of PFAS in Groundwater and Surface-Ground Water Interfaces

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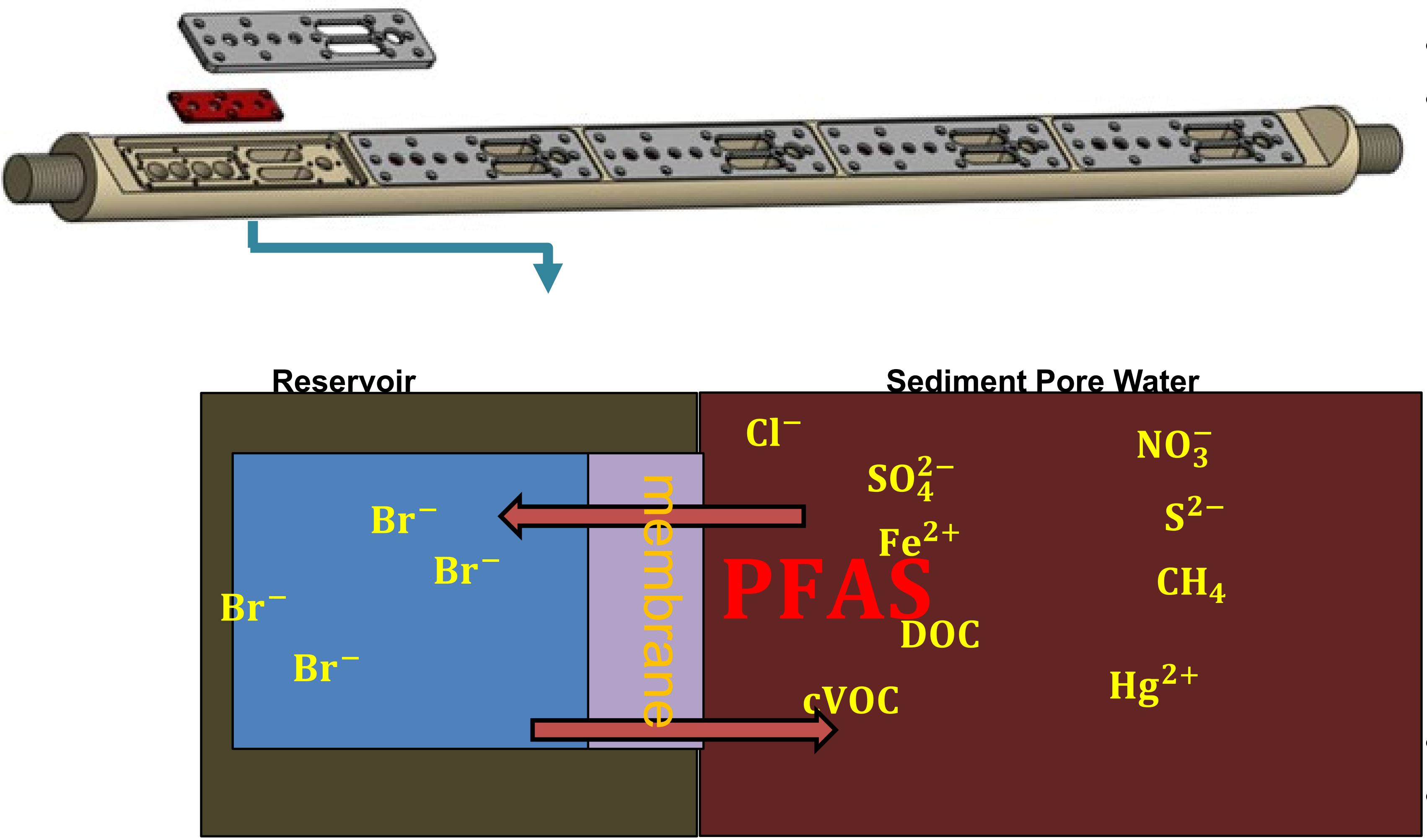
High Resolution Passive Profiler



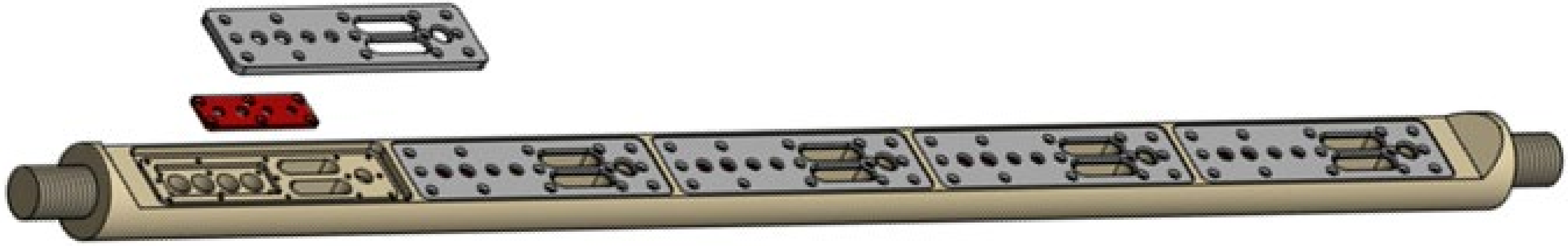
HRPP Capabilities

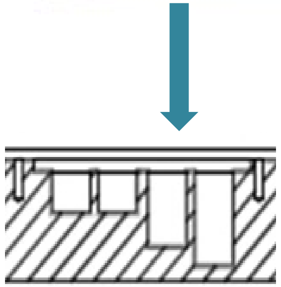
- Direct drive >30 feet bgs
- Can be coupled (4 feet to 28 feet)
- ~2-10 centimeter spatial resolution
- Measures porewater concentrations
  - Geochemical species
    - NO_3
    - Fe
    - SO_4
    - CH_4
  - Other dissolved compounds
    - PFAS
    - DOC
    - CVOCs
    - Metals
    - ClO_4
- Measures porewater velocities
- Equilibrates approximately 3 weeks

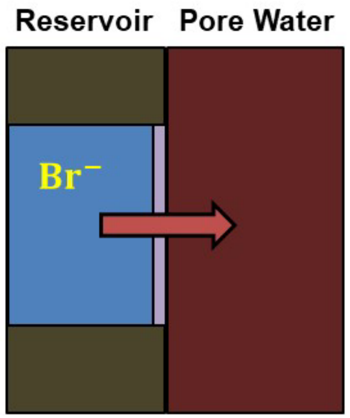
Schneider[S], H., **W.A. Jackson***, C. Schaefer, P. Hatzinger. (2020) High-Resolution Characterization of a Chlorinated Solvent Impacted Aquifer Using a Passive Profiler. *Groundwater Monitoring and Remediation*. 40(4): 27-43

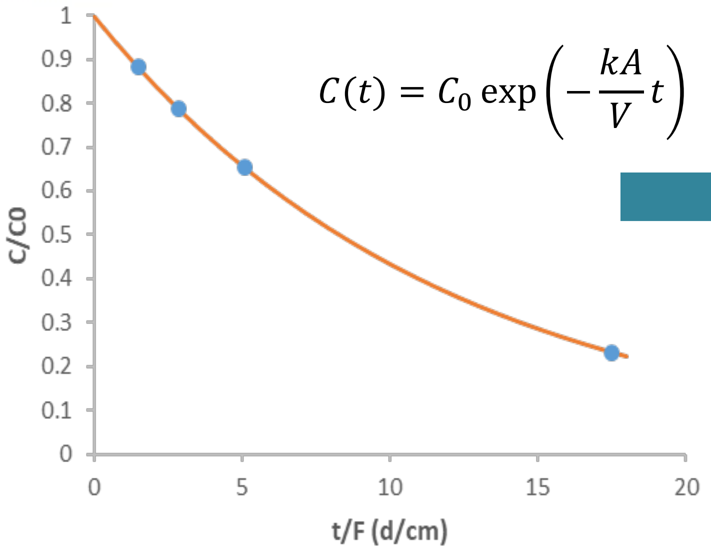
Technology/Methodology Description

High Resolution Passive Profiler-Pore Water Velocity

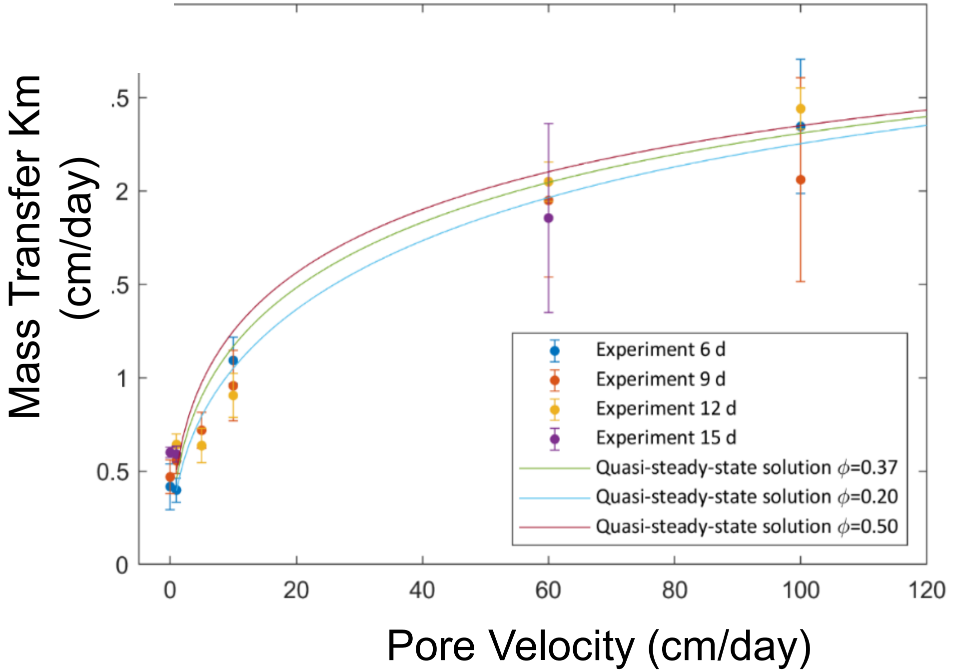






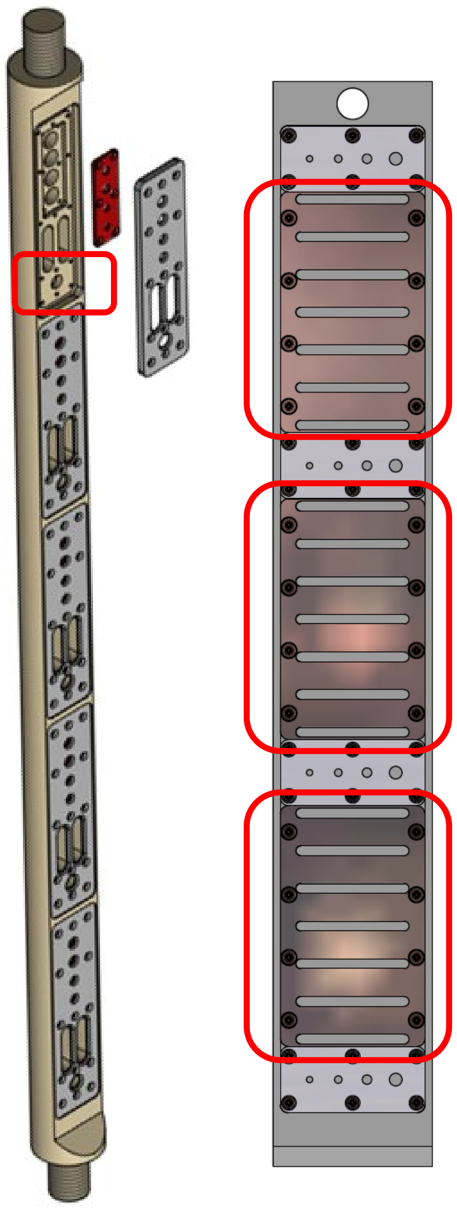


$$C(t) = C_0 \exp\left(-\frac{kA}{V}t\right)$$



Schneider[S], H., **W.A. Jackson***, K. Rainwater, D. Reible, S. Morse, P. Hatzinger, U. Rubalcava[S]. (2019) Estimation of Interstitial Velocity Using a Direct Drive High Resolution Passive Profiler. *Groundwate*r. 57:6 915-924

Microbial Abundance and CSIA

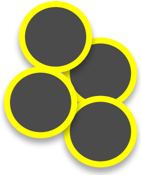


BioSep® beads

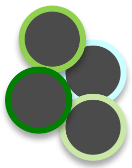
Nomex + Activated Carbon

Bio-traps

Microbes attach to beads



Contaminants adsorb to beads



qPCR

- Microbial populations
- Key functional genes for degradation of chemicals

CSIA

- If degradation:

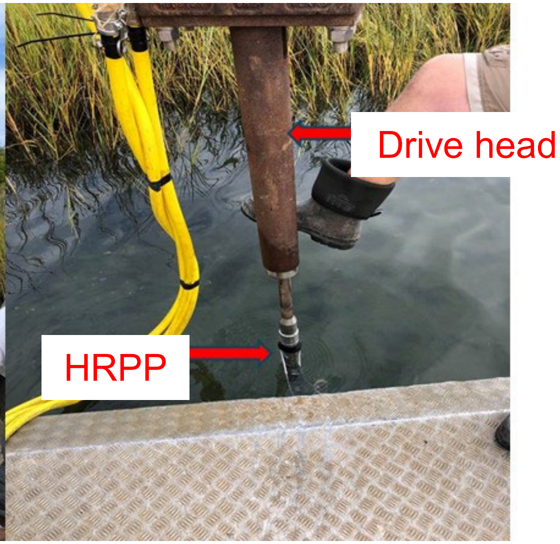
$$d(\delta^A X) > 0$$

Deployments and Sampling

Geoprobe

Manual

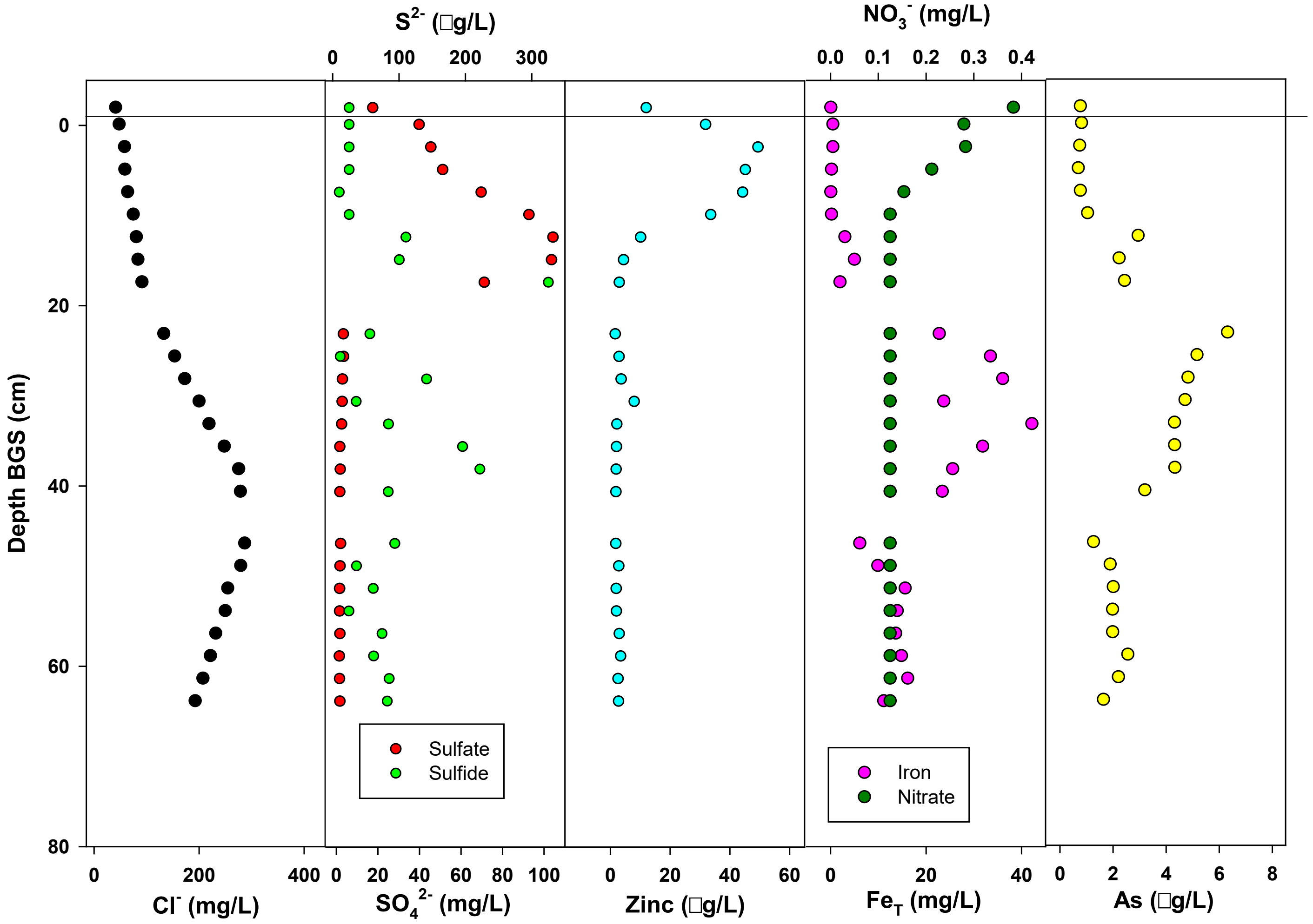
Vibracore Drive Head



Sampling

Previous Applications

- Metal Availability (Canal Creek)
- Chlorinated Solvent Fate and Transport
  - Calf Pasture Point
  - NASNI Site 9- San Diego
  - Alameda NAS
  - BARC



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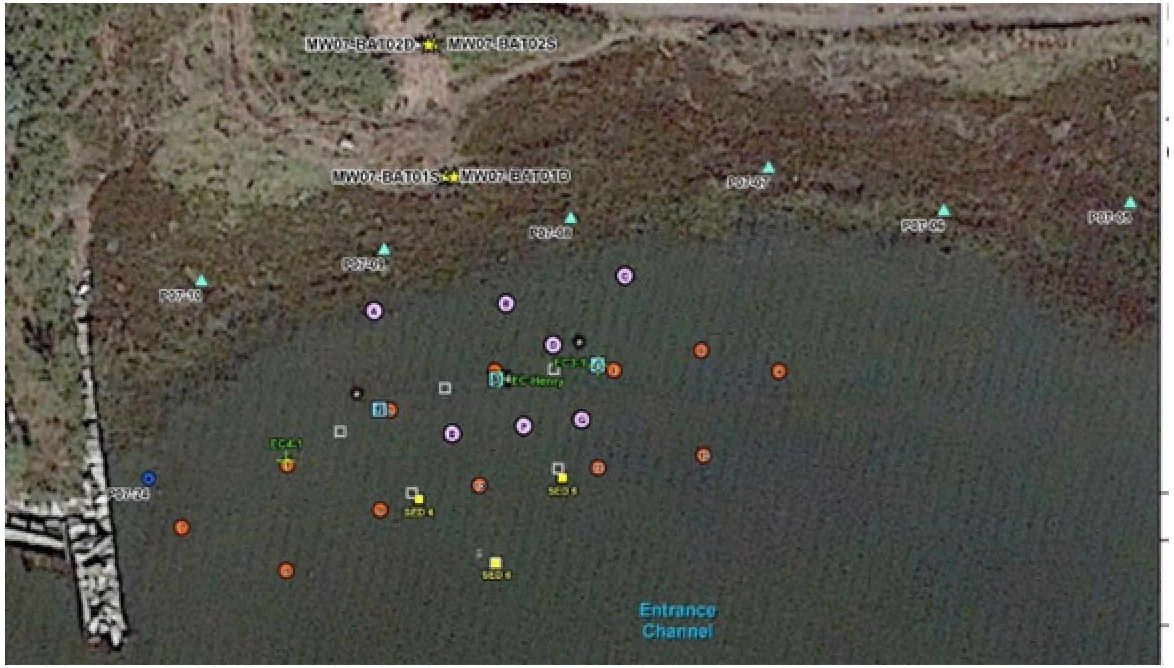

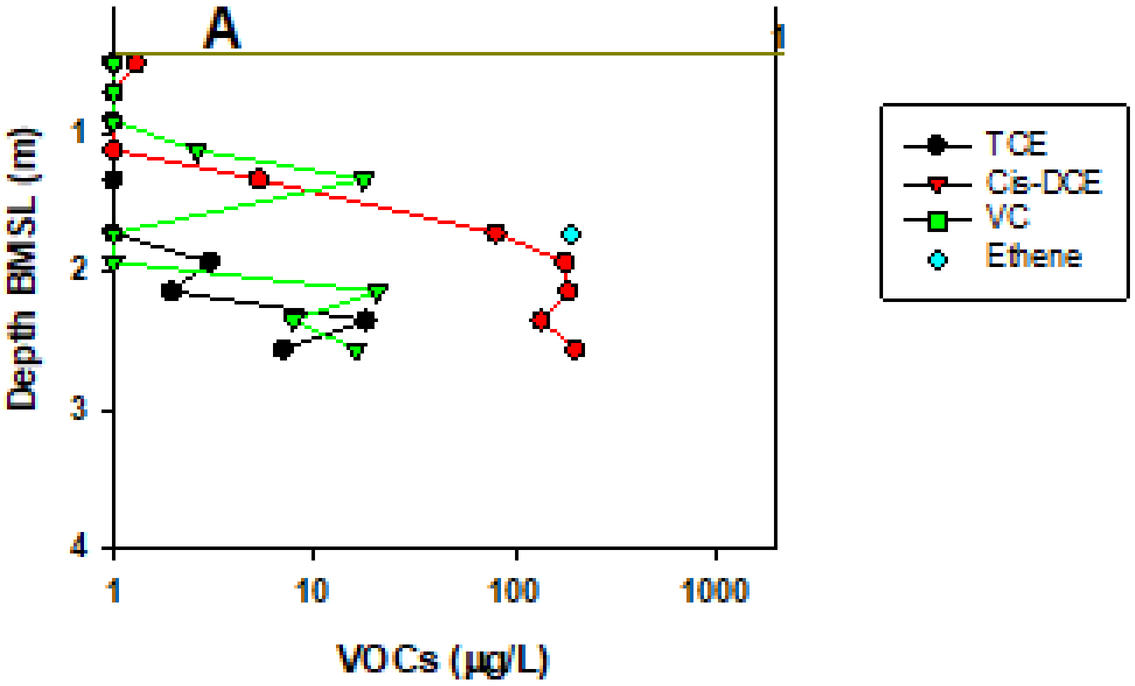

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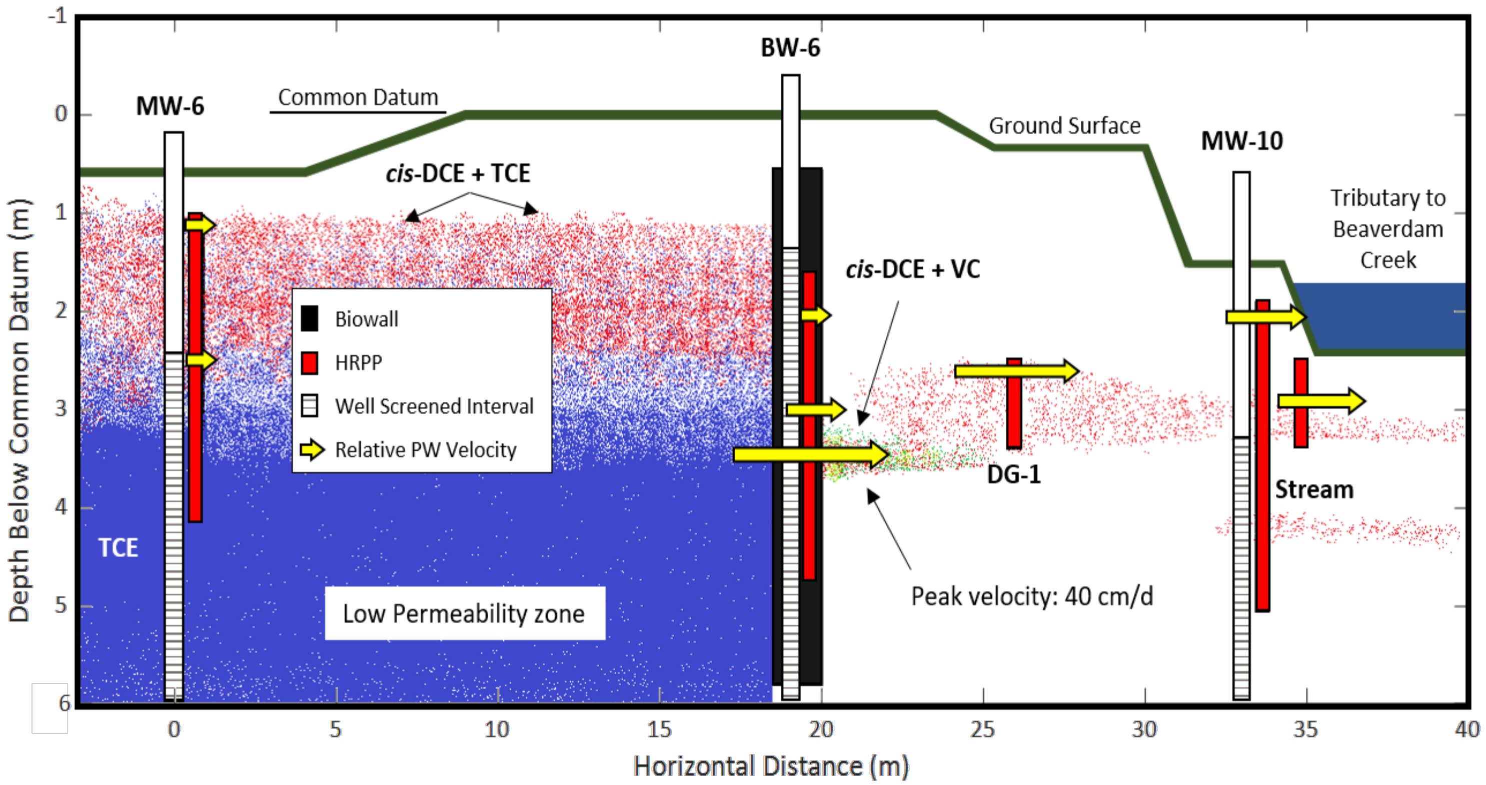
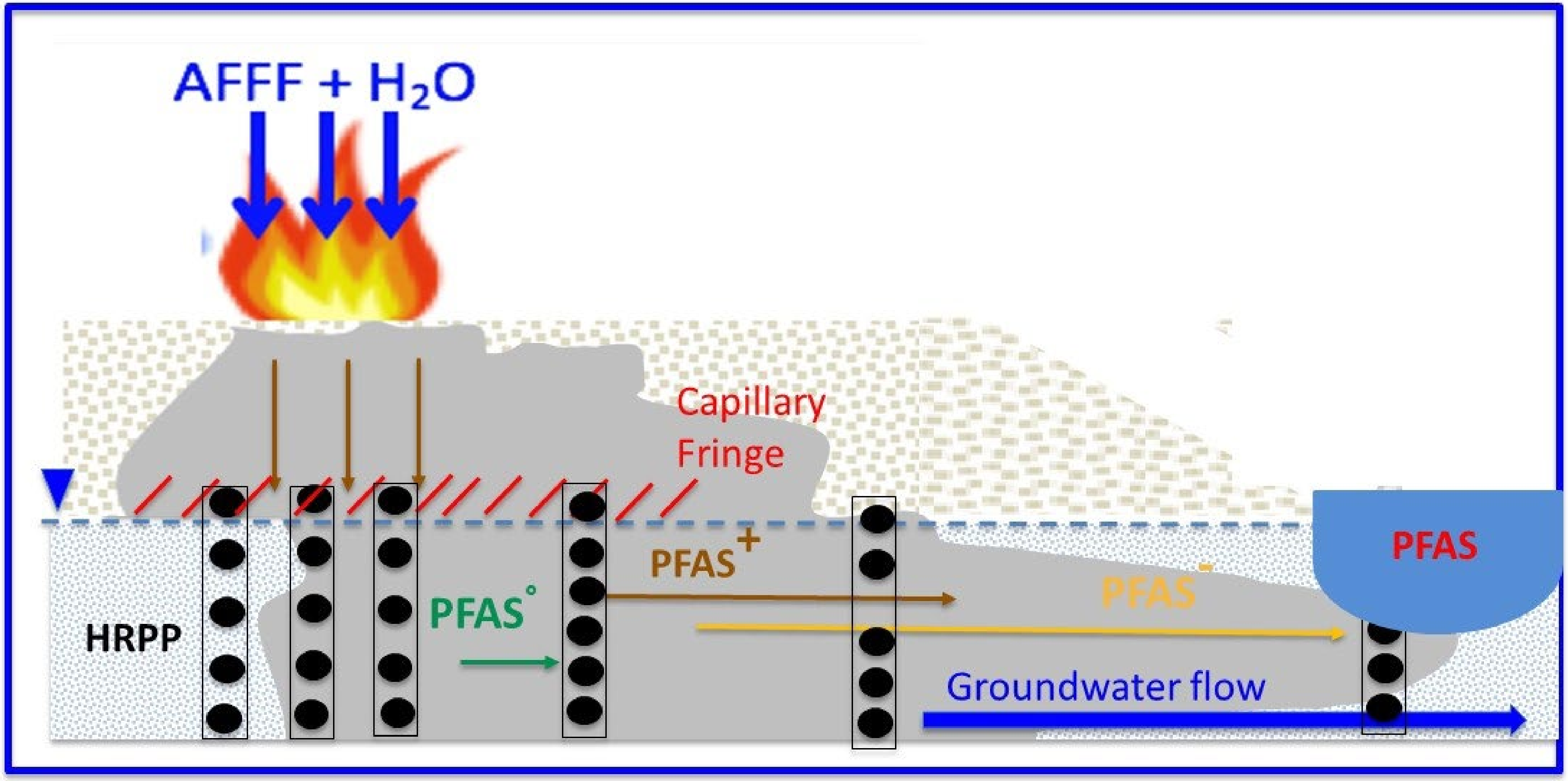
cVOC Breakthrough a Biowall



Application of PFAS Passive Sampler



Source Zone Assessment

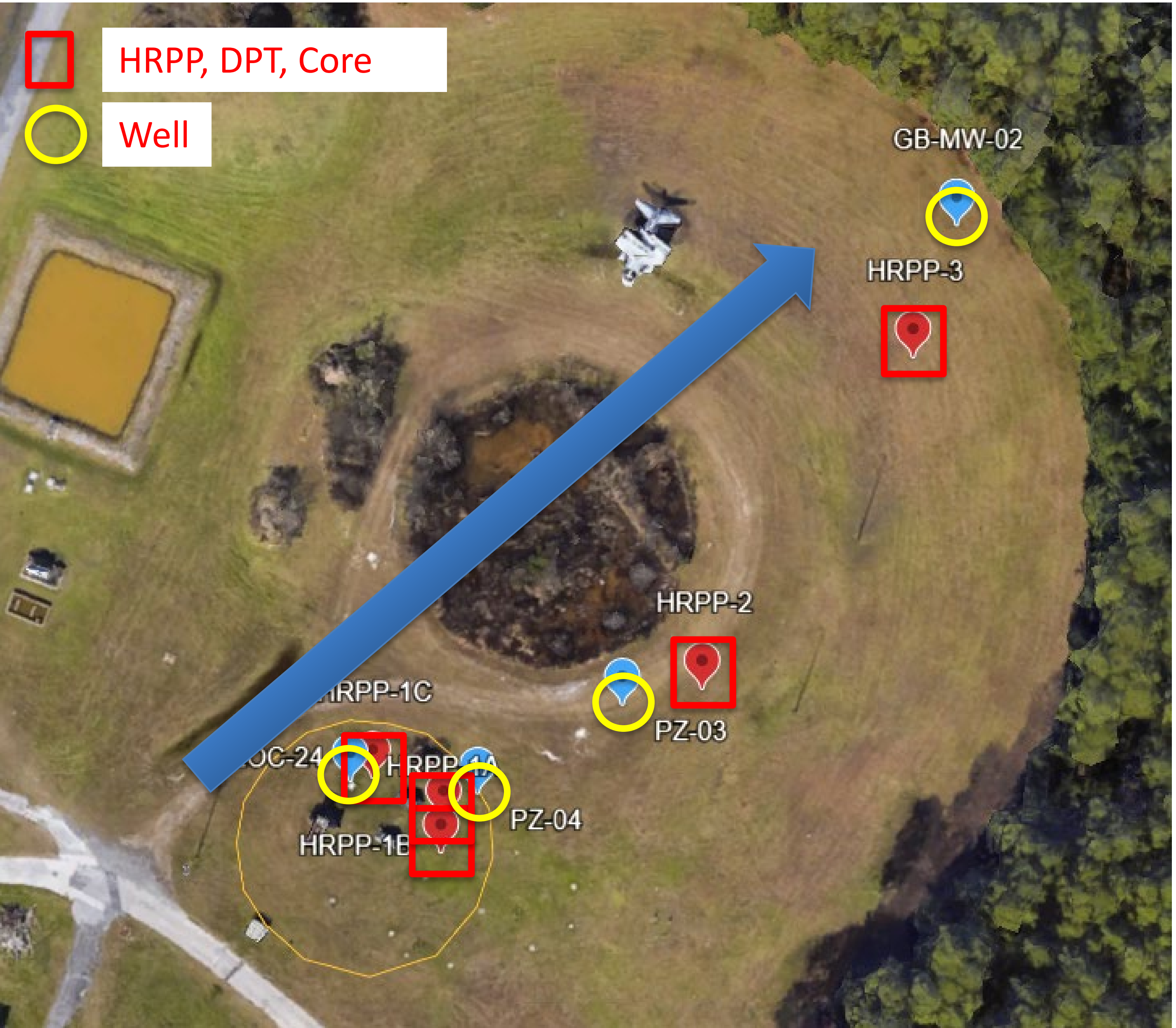
Plume Migration and Composition

Contaminated Groundwater Discharge to Surface Water

Applications

- Heterogenous Formations
- Low Permeability Zones
- Exposure in Biotic Zone
- Groundwater Interfaces
- Air-water interfaces
- High Resolution Profiles
- Evaluation of injected amendments
- Mass rebound
- Mass Flux

NAS Site Sampling Conducted



Activities

HRPP (Deployed over three days)

- HRPP deployed in source zone (3 locations)
  - 4-25ft BGS
  - 4-16ft BGS
  - 4-12ft BGS
- HRPP Deployed mid-plume (4-25ft BGS)
- HRPP Deployed down gradient (4-25ft BGS)

Cores

- Core acquisition attempted at each HRPP location
  - Poor recovery at some depths

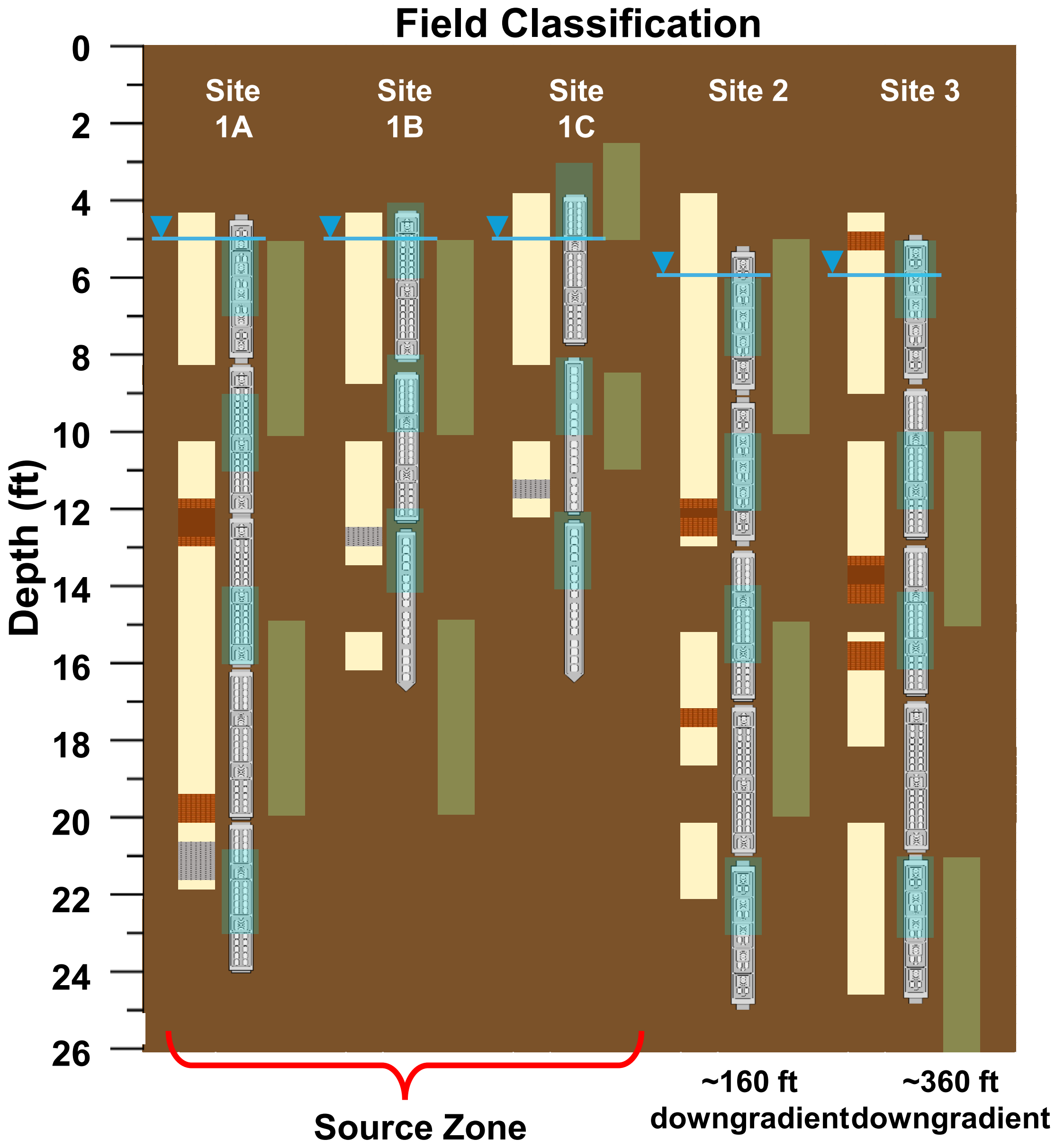
DPT

- GW samples acquired at each HRPP location
  - Multiple Depths
  - Low production, significant solids in some cases

Wells- GW sampled at near by wells

HPT- Conducted at each HRPP location

Depth of Acquired Samples and Field Texture Analysis



	ML	Silt
	SP	Poorly graded sand, gravelly sand
	SC	Clayey sand
	CL	Lean clay

DPT Discrete Well Sample

Traditional Well Sample

Sample Types

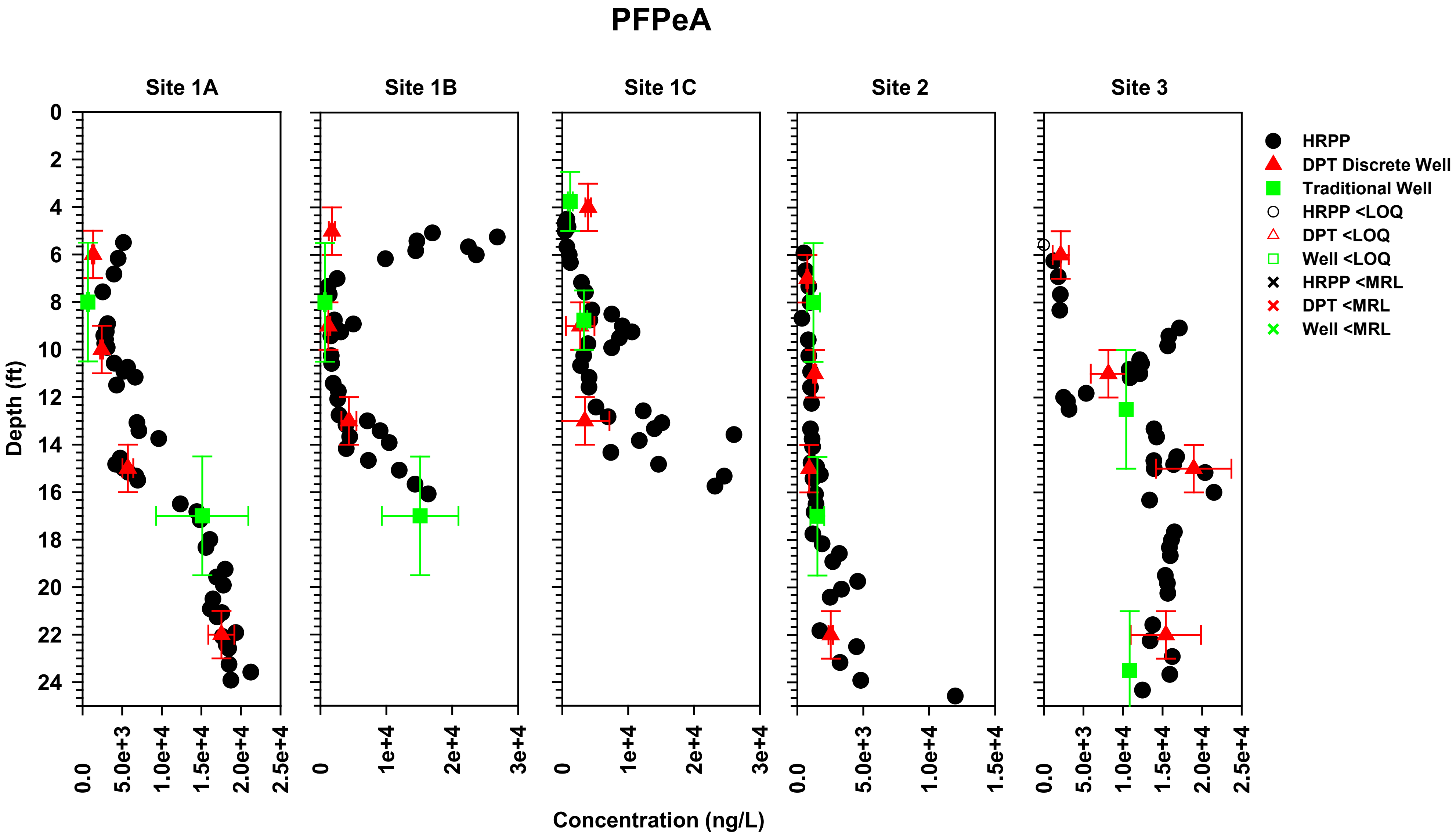
- Wells,
- DPT-GW
- Soil Cores
- HRPP

Sample Analysis Being Conducted

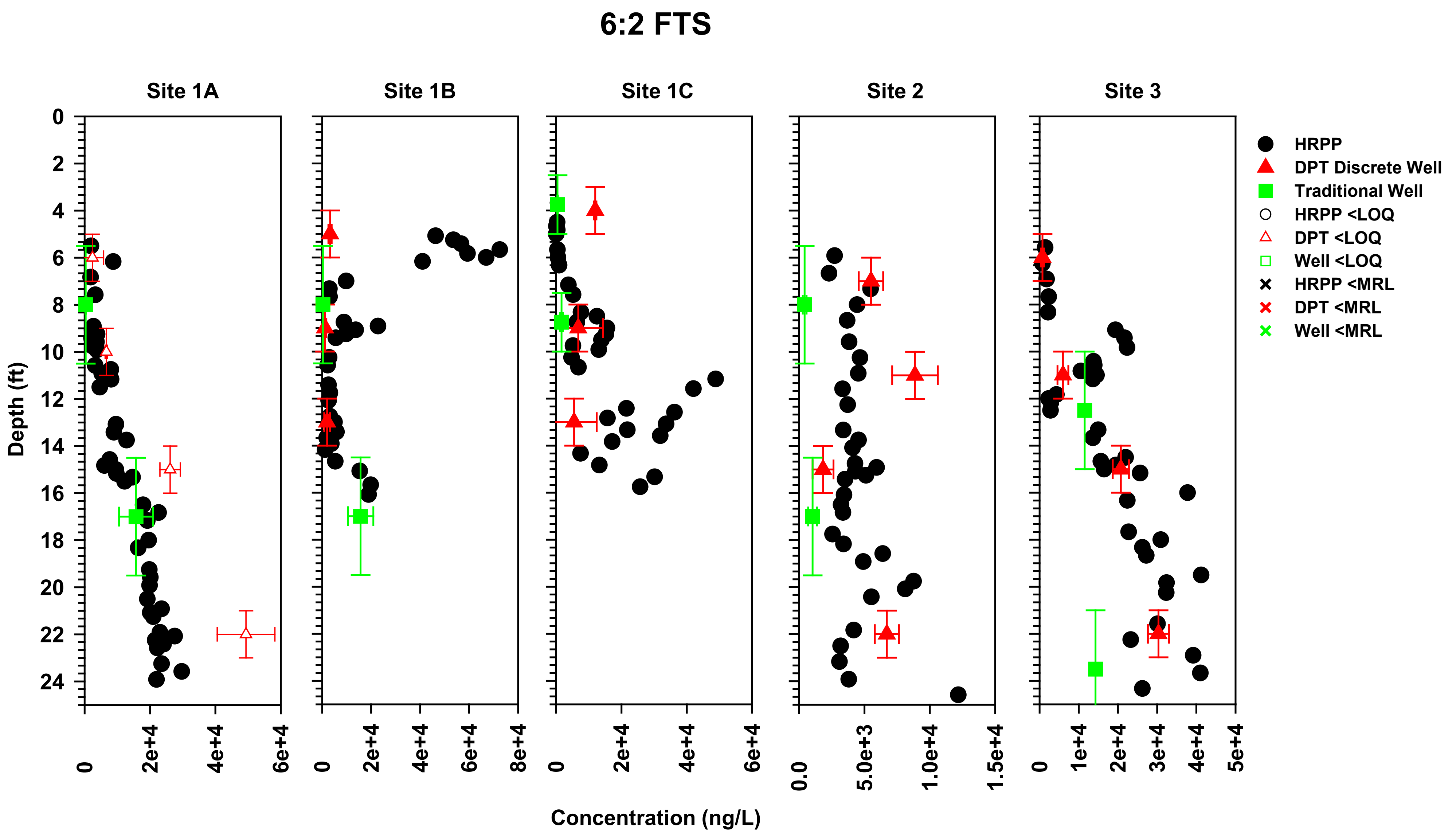
- PFAS Target (EPA 1633)
- PFAS Non-Target
- TOP/TOF
- NO_3^-, SO_4^{-2}, Cl^-
- DOC
- Pore Velocity

Deployment and Retrieval

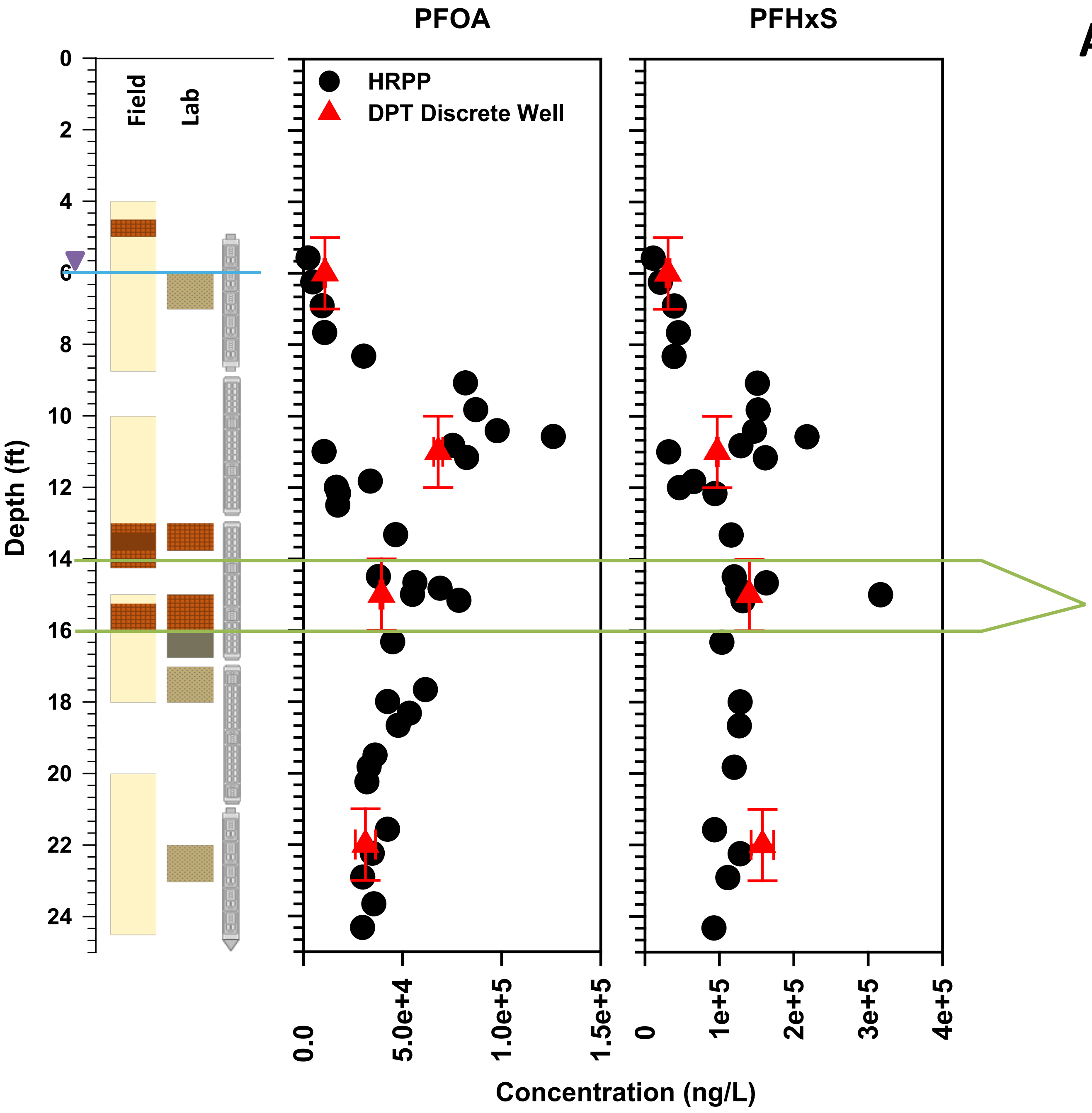
Example Concentration Profiles



Example Concentration Profiles



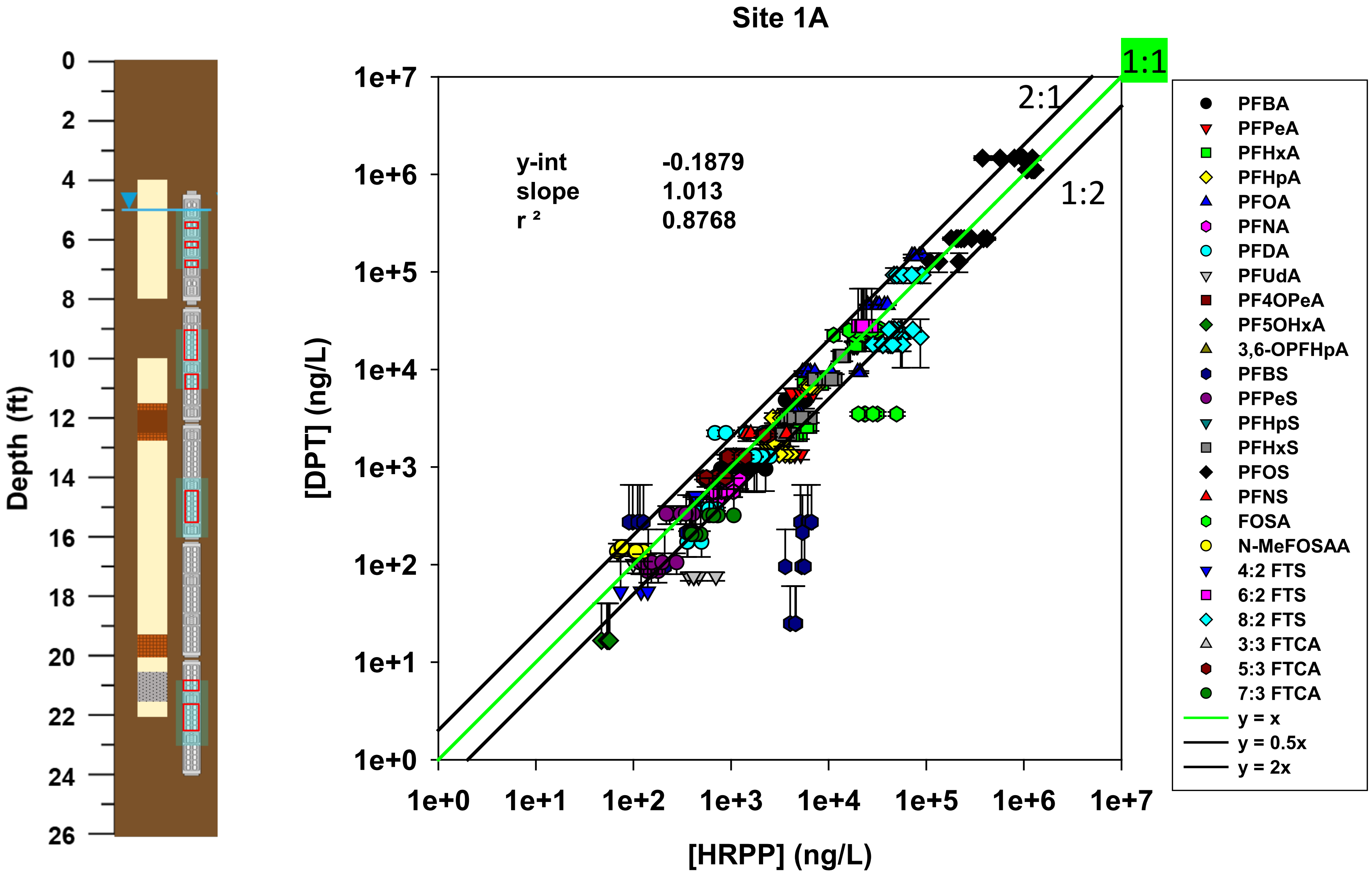
Advantages of High Resolution Sampling



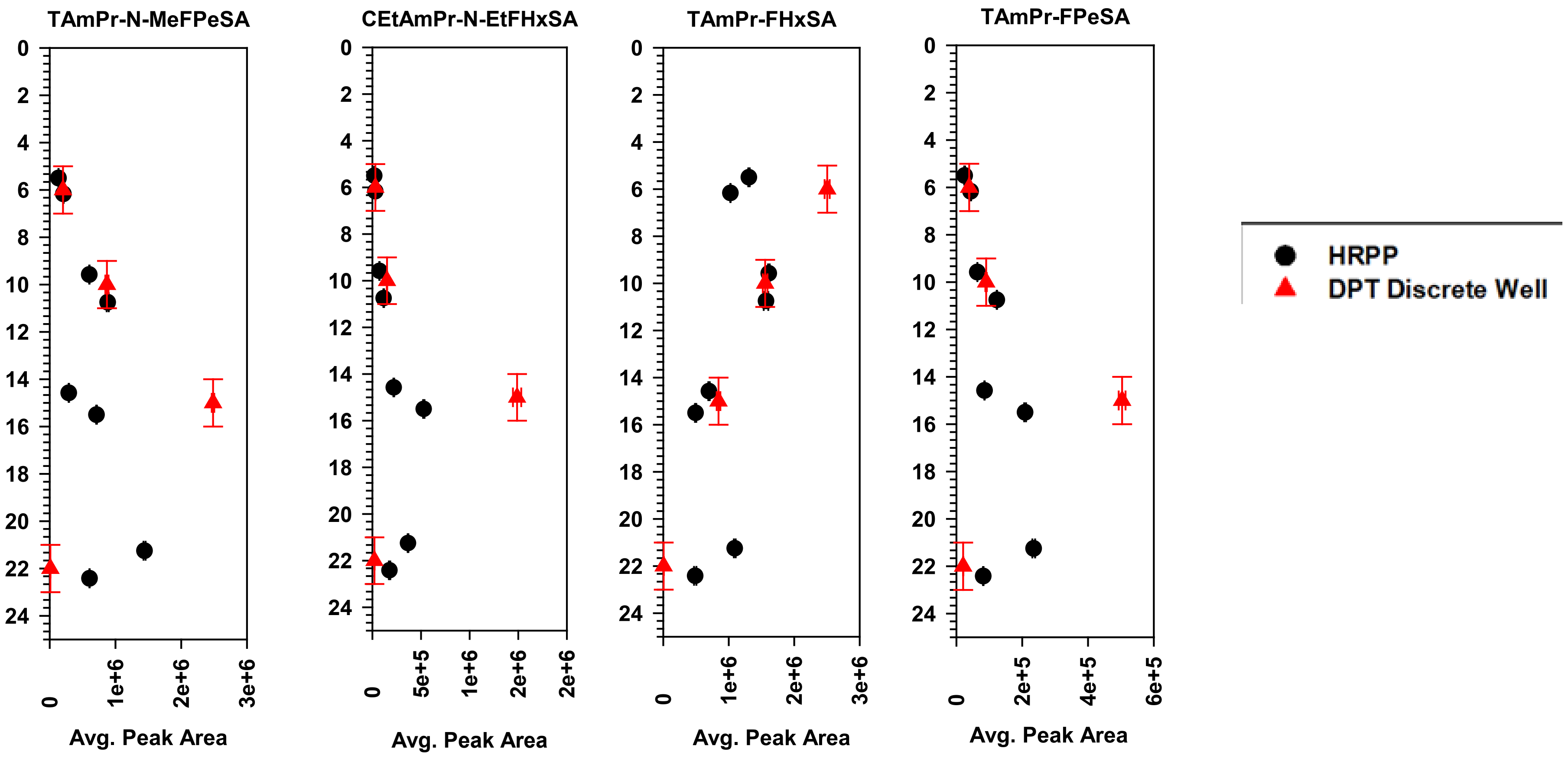
	ML	Silt
	SM	Silty sand
	SP-SM	Poorly graded sand with silt
	SP	Poorly graded sand, gravelly sand
	SP-SC	Poorly graded sand with clay
	SC	Clayey sand
	CL	Lean clay

- **HRPP quantifies peak in PFAS concentrations in the clay layer ~ 14-16’ bgs**
- **DPT discrete well sample did not pull enough water from the low permeability layer to represent this peak in the average**

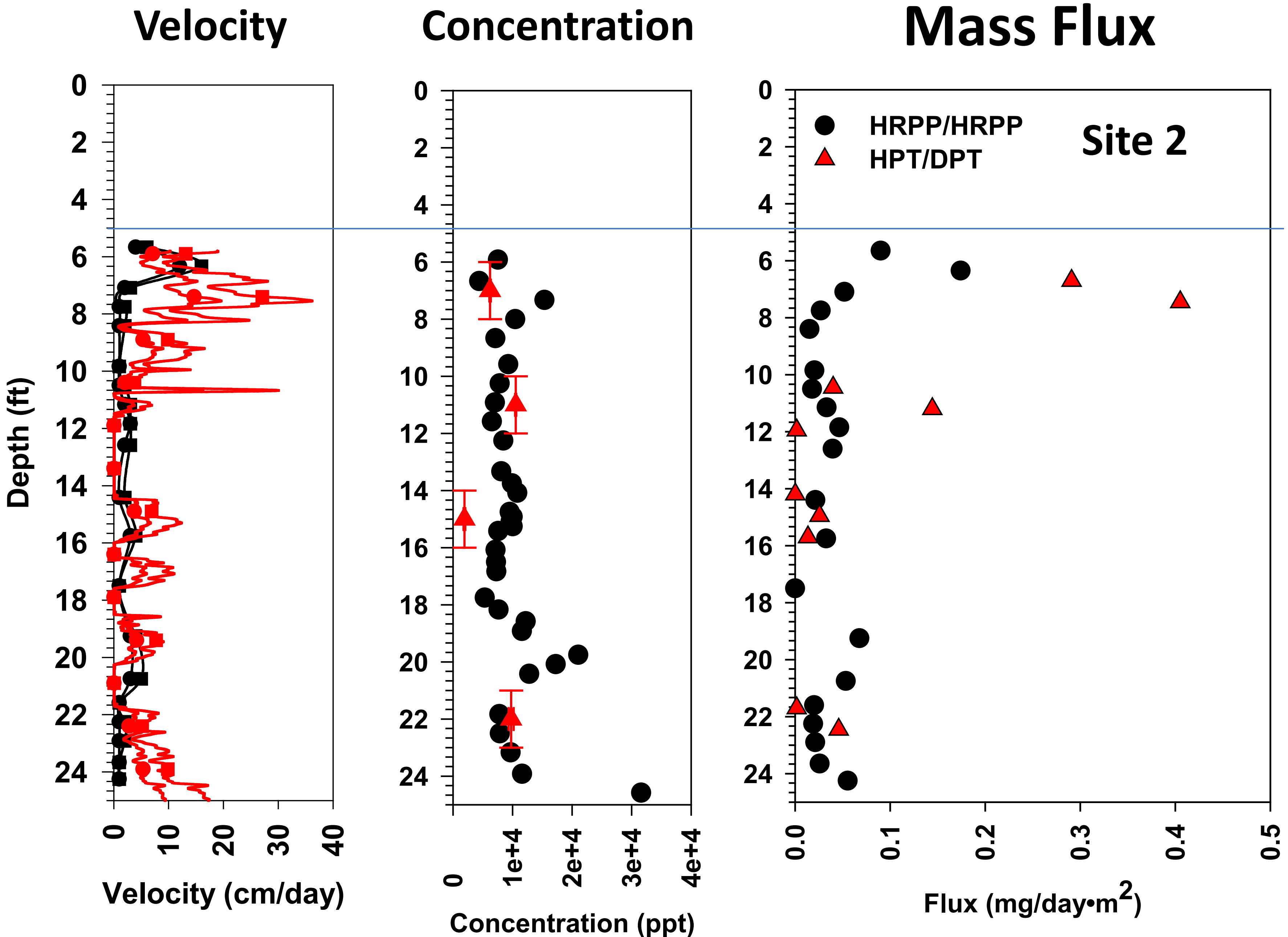
Relationship Between DPT and HRPP PFAS Concentrations at Site 1



Example Concentration Profiles Non-Target



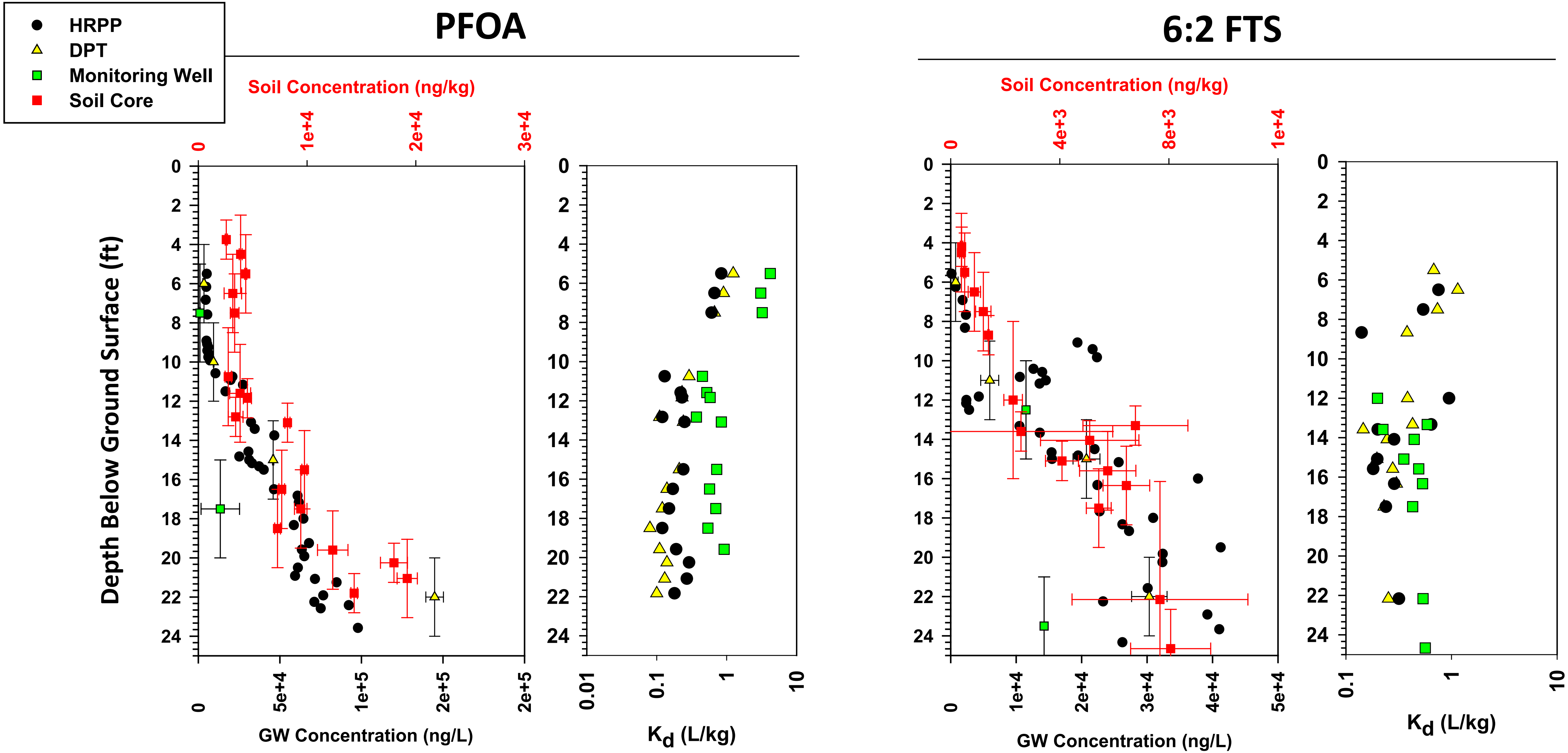
PFOA Comparison between HRPP and DPT/HPT Data-Mass Flux



DPT Velocity function of:

1. Hydraulic gradient?
2. Hydraulic Conductivity

Depth Dependent-Site Specific Partition Coefficients



Joint Base Cape Cod, MA Field Deployment and Sampling Work

HRPP Installed @ 23 locations in Lake

0-3ft 7 HRPP

0-4ft 16 HRPP

0-8ft 3 HRPP

HRPP Installed (Geoprobe) at lake shore (0-20ft BGS)

Piezometers

Installed 10 locations

sampled 2-5 depths

Wells

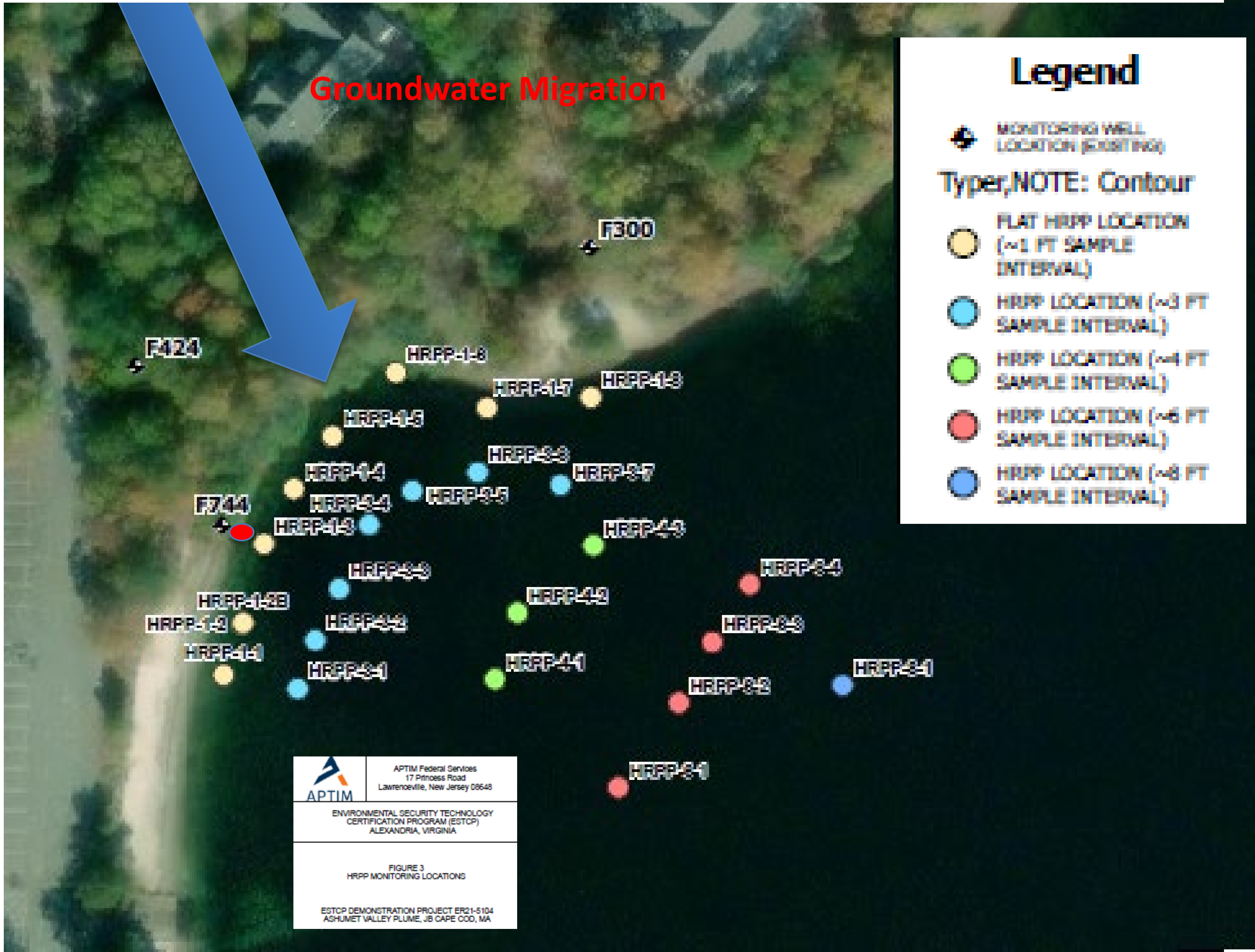
F424 (10 depths)

F300 (13 depths)

F744 (11 Depths)

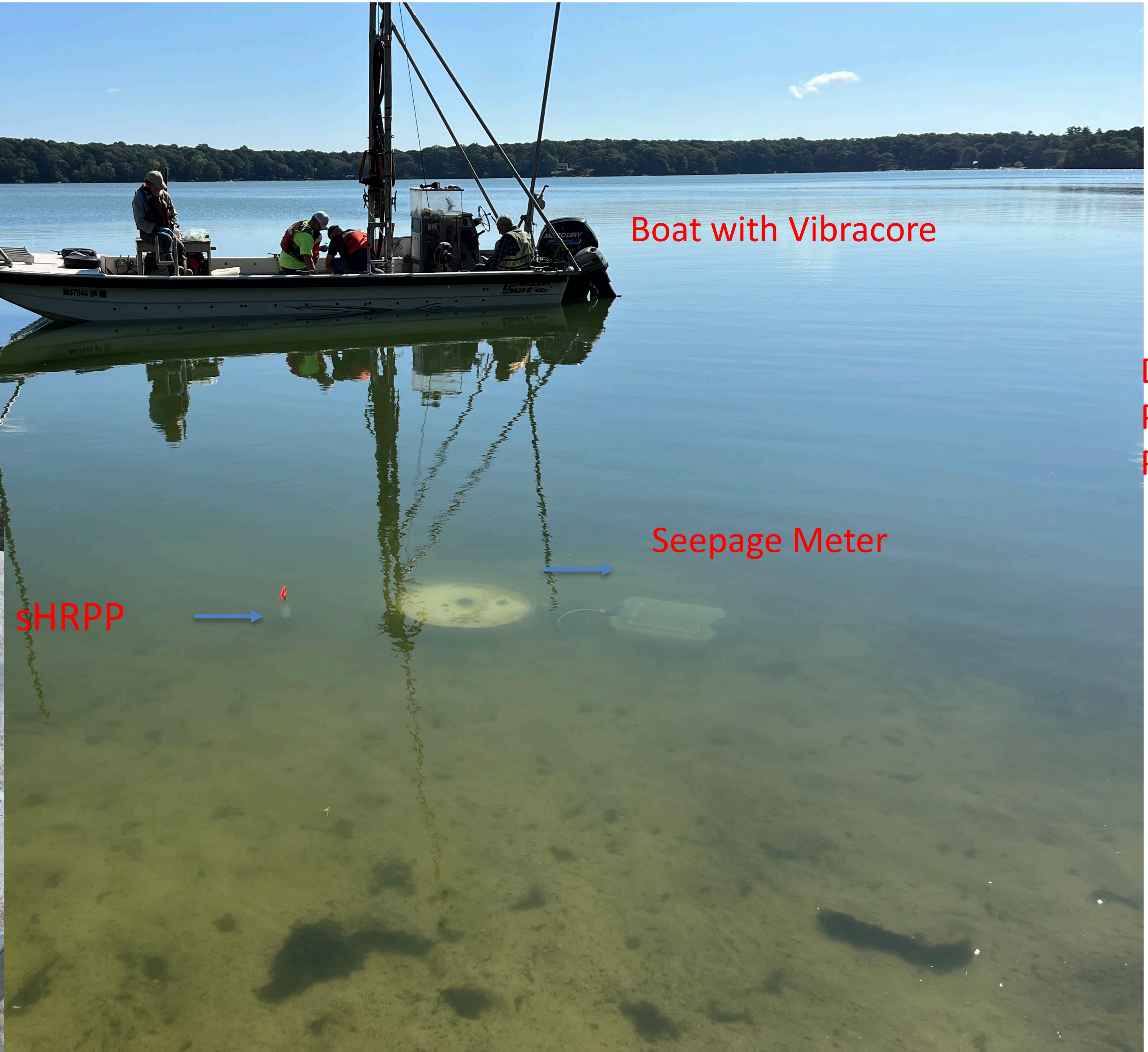
Seepage Meters deployed at 1ft and 3ft contours

Piezometer head measurements along centerline.

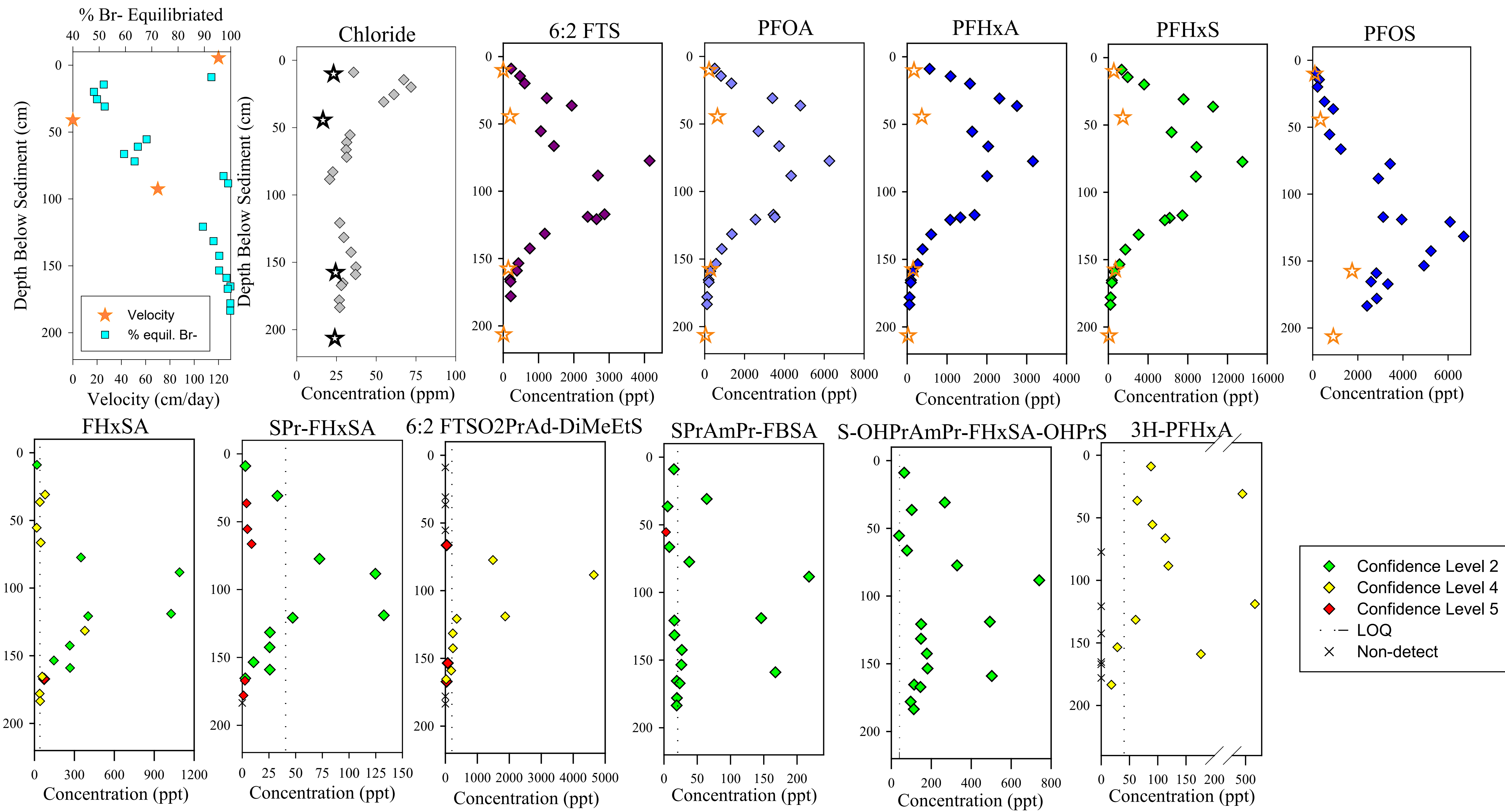


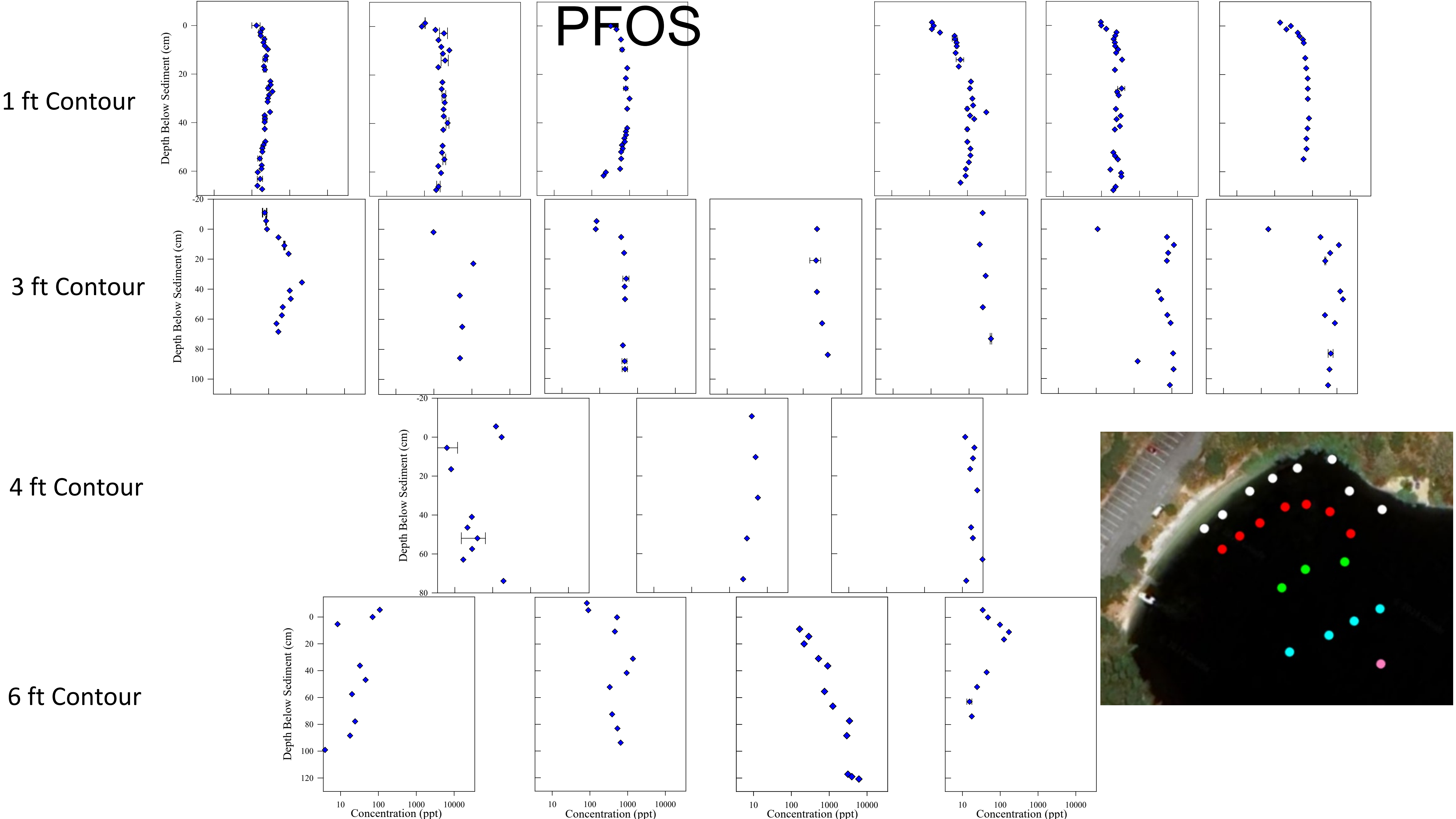
Deployment Site at Ashumet Pond

Deployment Site at Ashumet Pond



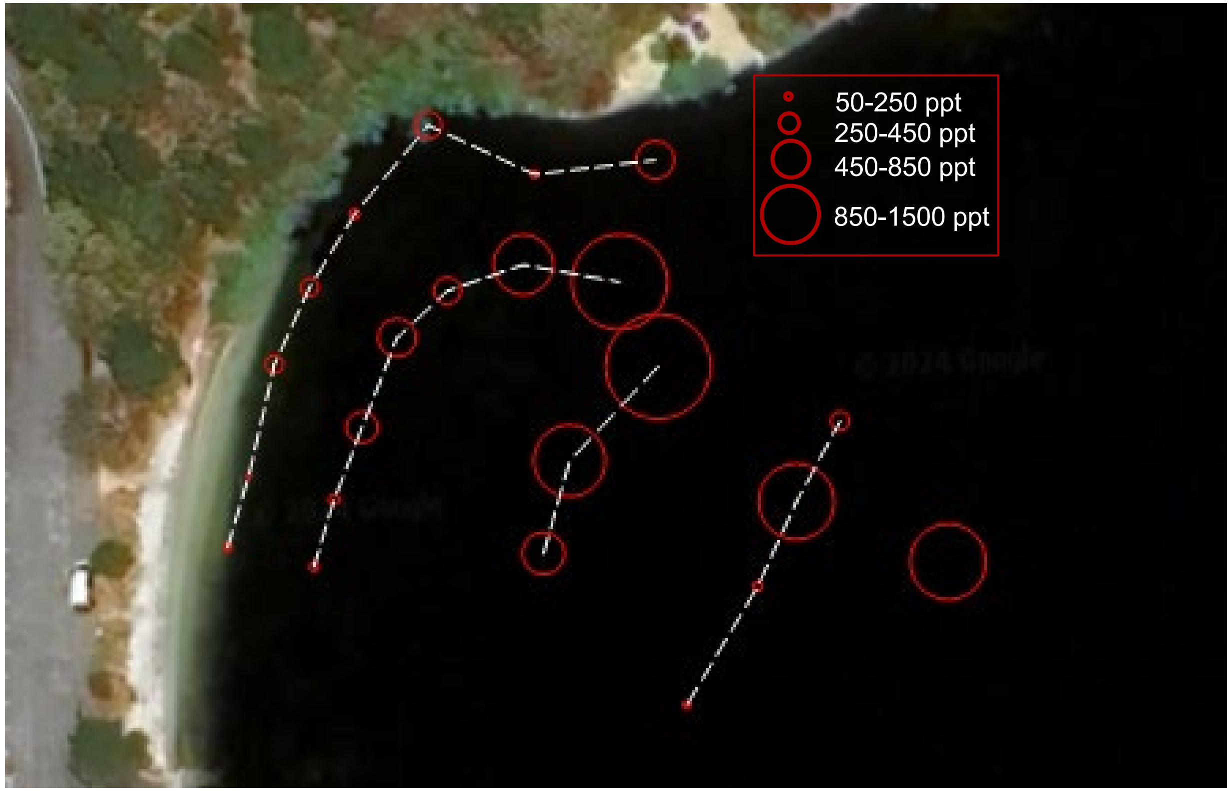
Drive Point Piezometer


% Br- Equilibriated
Depth Below Sediment (cm)
Velocity
% equil. Br-
Velocity (cm/day)
Chloride
Concentration (ppm)
6:2 FTS
PFOA
PFHxA
PFHxS
PFOS
Concentration (ppt)
FHxSA
SPr-FHxSA
6:2 FTSO2PrAd-DiMeEtS
SPrAmPr-FBSA
S-OHPrAmPr-FHxSA-OHPrS
3H-PFHxA
Confidence Level 2
Confidence Level 4
Confidence Level 5
LOQ
Non-detect

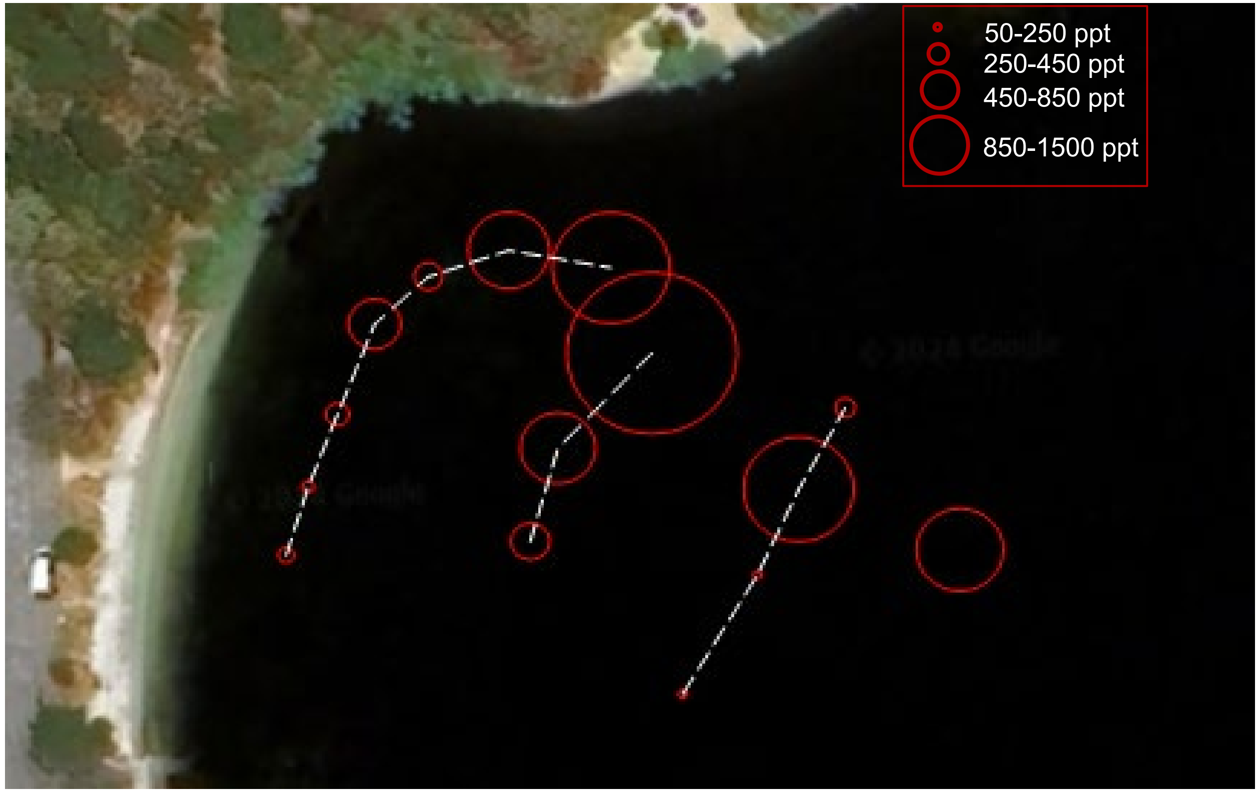

PFOS
1 ft Contour
3 ft Contour
4 ft Contour
6 ft Contour
Depth Below Sediment (cm)
Concentration (ppt)
10
100
1000
10000
0
20
40
60
80
100
120
-20

Where is the greatest impact on pond?

Average PFAS at Depths
0-60cm



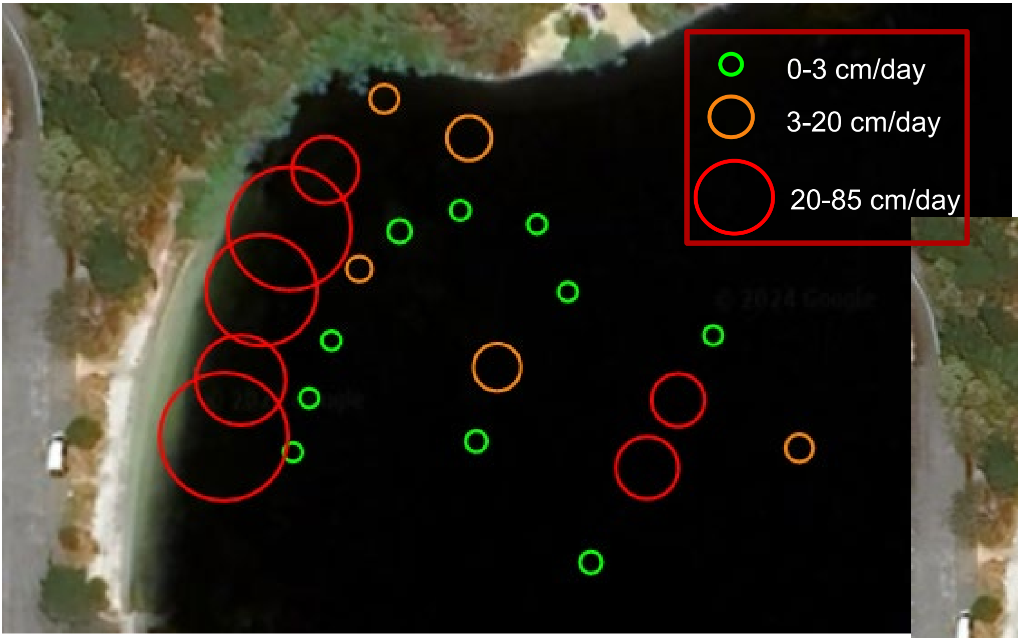
Average PFAS at Depths
0-120cm



*Averaged for PFBA, PFPeA, PFHxA, PFHpA, PFOA, 6:2 FTS, PFNA, PFOS, and PFHxS

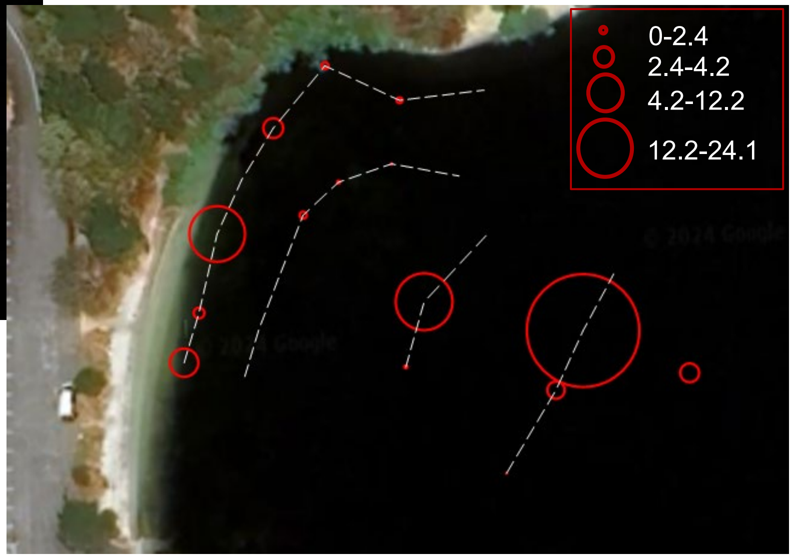
Potential Advective Flux to Pond

Average HRPP Site Velocities (cm/day)



Average PFAS Concentrations at Depths 0-60cm

Average Flux at Depths 0-60cm ($ng{*}cm^{-2}{*}day^{-1}$)



Conclusions

- HRPP can produce high resolution depth profiles of concentrations and mass flux
- HRPP is able to evaluate low permeability zones as well as capture impact of formation heterogeneity
- HRPP can determine flux of PFAS, cVOCs, Metals to surface water, porewater exposure concentrations, and locations of upwelling
- Combined data can be used to develop more accurate site transport models
- HRPP can allow for improved assessment of in situ remediation efforts (e.g., colloidal activated carbon injection and capping)

Acknowledgments

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  - Dr. Jennifer Guelfo
  - Dr. Todd Anderson
  - Dr. Morgan Eldridge
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APTIM

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