In-Situ Pore Water Sample Collection from Multiple Depth Intervals to Monitor Contaminant Bioavailability and/or Cap Performance

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Presentation Overview

1. Advantages and Challenges of Sampling Pore Water vs. Bulk Sediment
2. Innovative Device for Sampling Multiple Discrete Depth Intervals
3. Demonstrated Success – Sediment Remedial Investigation
4. Use of Device for Post Remediation Monitoring

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Measuring PAHs in Pore Water vs. Bulk Sediment

Pore Water	Bulk Sediment
More representative of bioavailable contaminant fraction (particularly for hydrophobic compounds)	May overestimate bioavailable contaminant concentration
Demonstrated better correlation to biological affects	Often poor correlation with biological affects
More difficult to collect sufficient volume of representative pore water for conventional water analysis	Straightforward sampling and analysis methods
Indirect sampling methods require assumptions for conversion to pore water concentrations	
Few established screening criteria; often defaults to surface water criteria	Established screening criteria

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Options for Characterizing Pore Water

- Indirect – Passive Samplers
  - Integrate conditions over time
  - Can be difficult to determine whether equilibrium has been reached
  - Assumptions required to convert results from sample media to concentrations in pore water
- Ex-Situ – Centrifugation of Sediment Cores
  - Disturbs sediment relative to in-situ conditions
  - Volume of recoverable pore water is limited
  - Automatically provides co-located sediment sample
- In-Situ – Direct Collection of Pore Water
  - Minimal disturbance (especially if unfiltered) and straight-forward laboratory analysis
  - Sampling methods can inadvertently collect surface water or pore water from other intervals
  - Volume of recoverable pore water limited by sediment permeability

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The Challenge - Former MGP Sediment Site in California

- Bulk sediment total PAH screening concentrations did not reflect biological impacts
  - Site-specific empirical testing provided no evidence of adverse biological effects for PAH concentrations >>ER-M
  - Characteristics of natural bay mud effectively reduce bioavailability
  - Could pore water analysis be a more reliable indicator?
- Key requirements for pore water sampling device
  - Isolate interstitial pore water from overlaying surface water
  - Sample multiple discrete depth intervals, plus surface water
  - Dedicated components, eliminating need for decontamination
  - Low-flow sampling techniques, minimizing vertical pore water migration
  - Minimal sample manipulation prior to analysis

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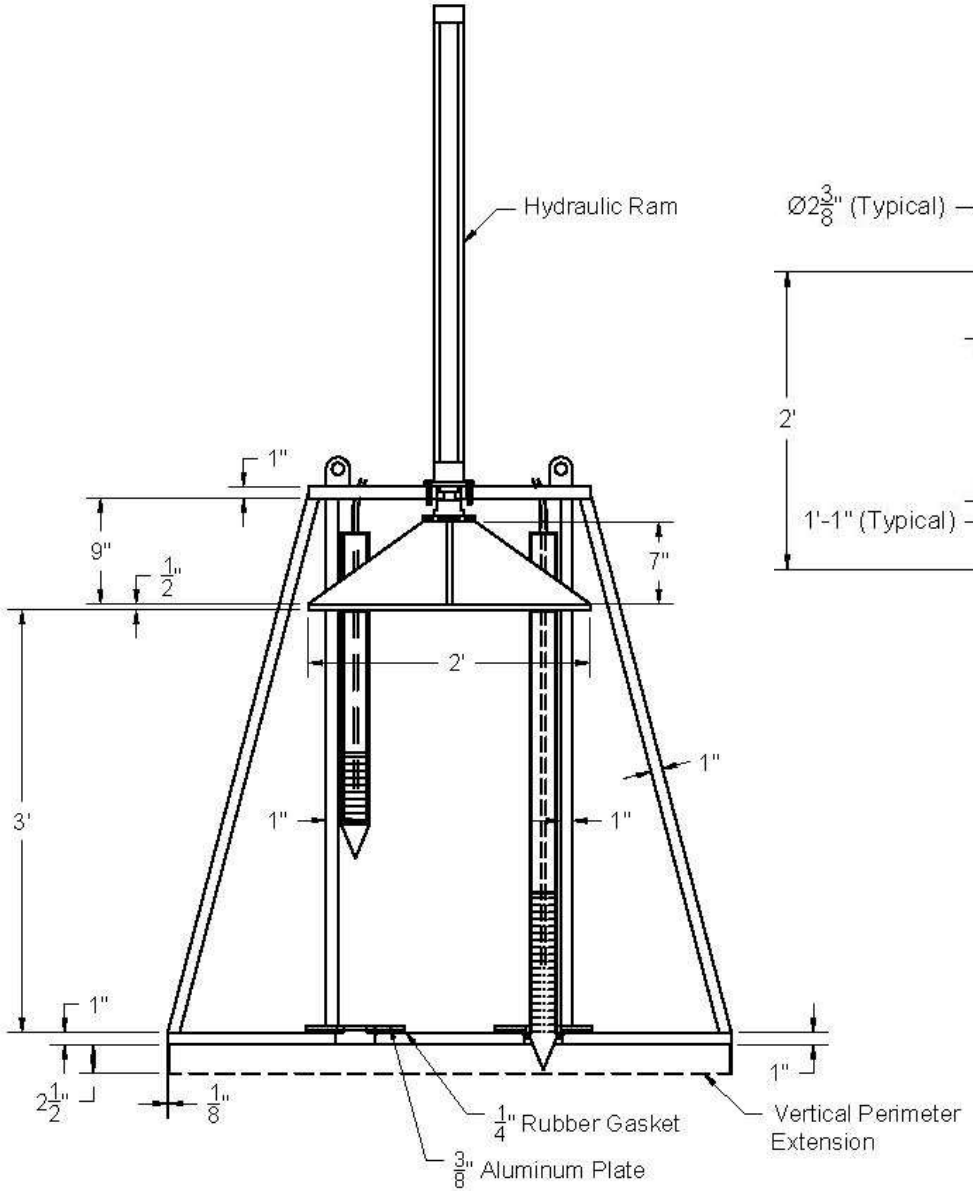
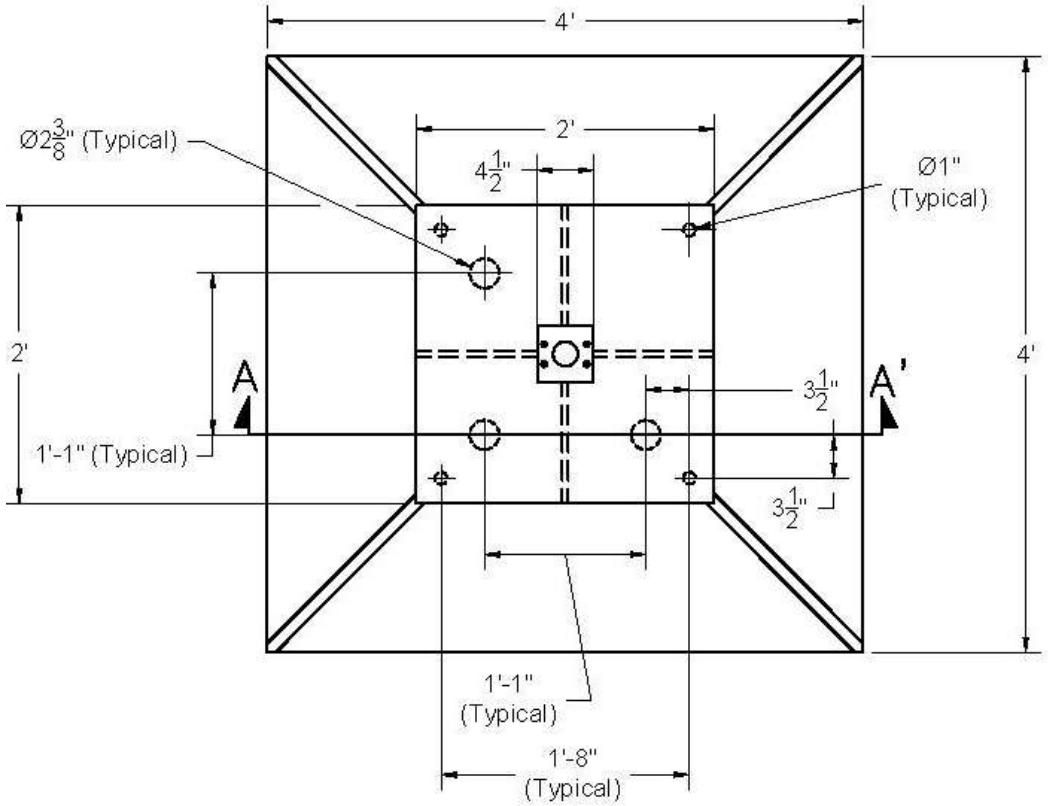
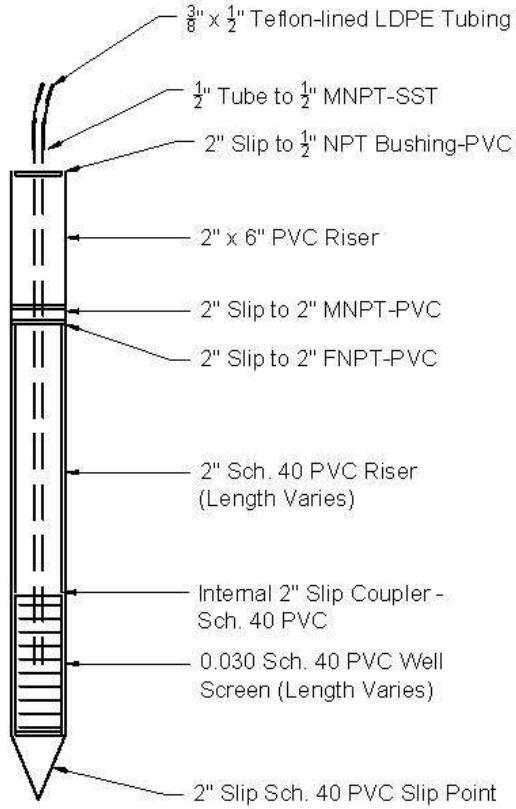
The Solution – Custom Sampling Device





PLAN VIEW



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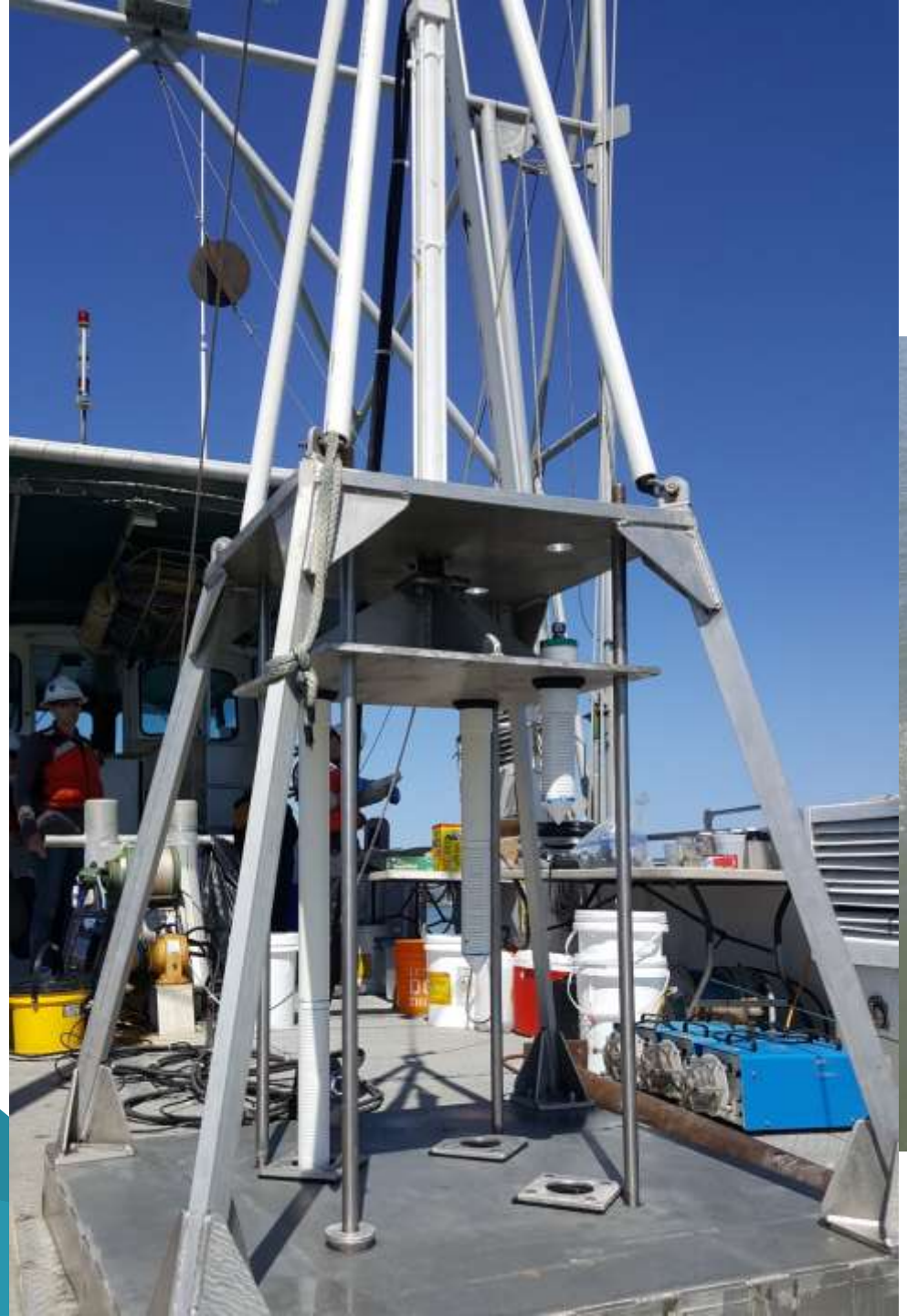
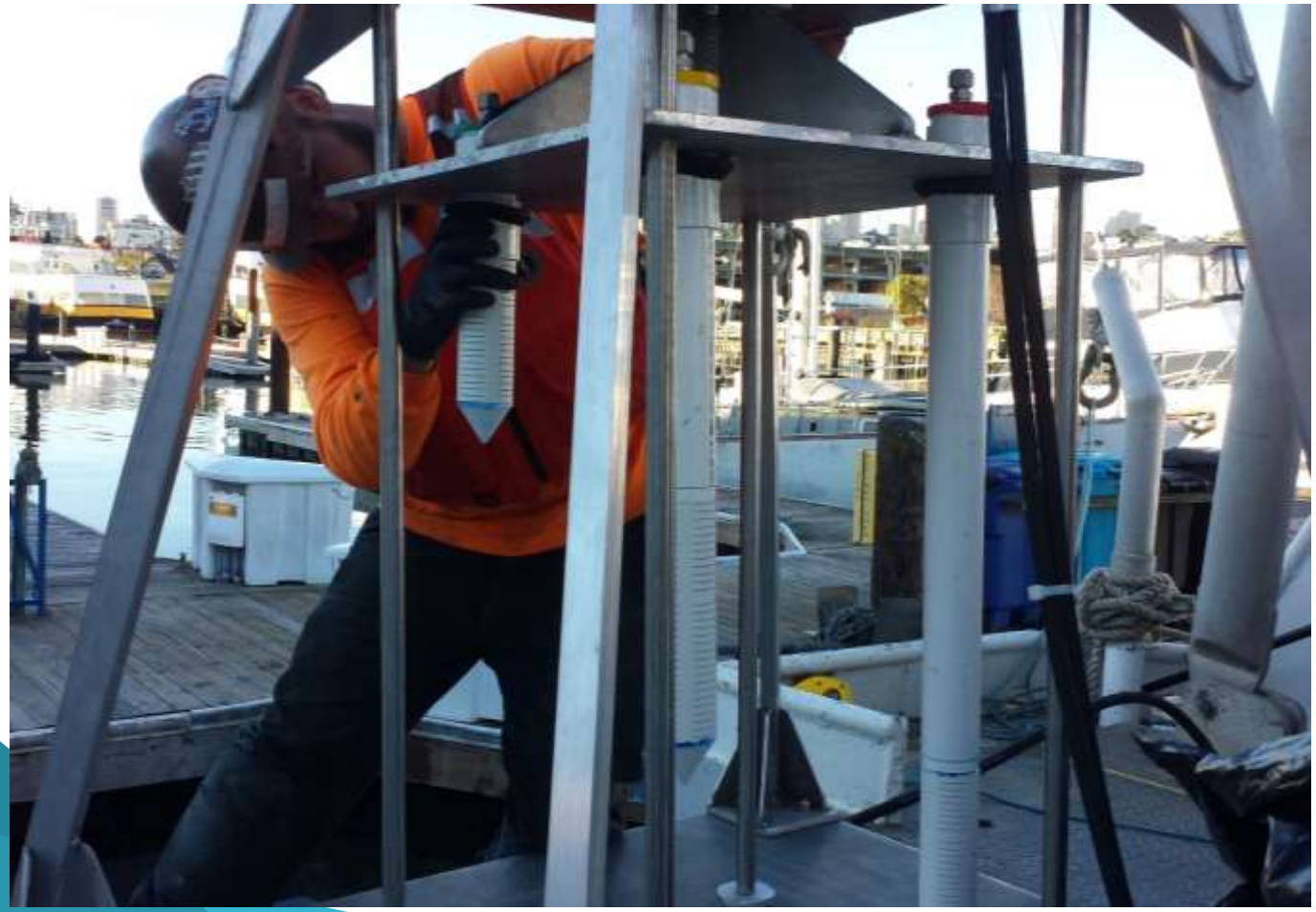


Resulting Pore Water Sampler

Assembling screens to collect samples from three depth intervals; A fourth could be added



Each pore water interval, plus surface water, has dedicated PVC screen and tygon tubing

Mud on screens and edges of baseplate confirms successful deployment

Successful Field Application

- 21 Pore water/surface water stations with a co-located gravity core
  - Part of a Remedial Investigation (RI)
- Three depth intervals (0-0.5, 1.0-1.5, and 2.0-3.0 feet below mudline)
  - Both pore water and bulk sediment
- All successful except deepest pore water interval at two stations
  - Pore water sampler met with refusal, deepest screen removed
  - No pore water recovery from very low-permeability sediment in one interval
- Volume of pore water recovered: ~200 ml to >2 L
- Vertically stratified sediment PAH concentrations: ~3,000 to >10,000,000 µg/kg
- Similar stratification in pore water PAH concentrations: ~250 to 100,000 ng/L

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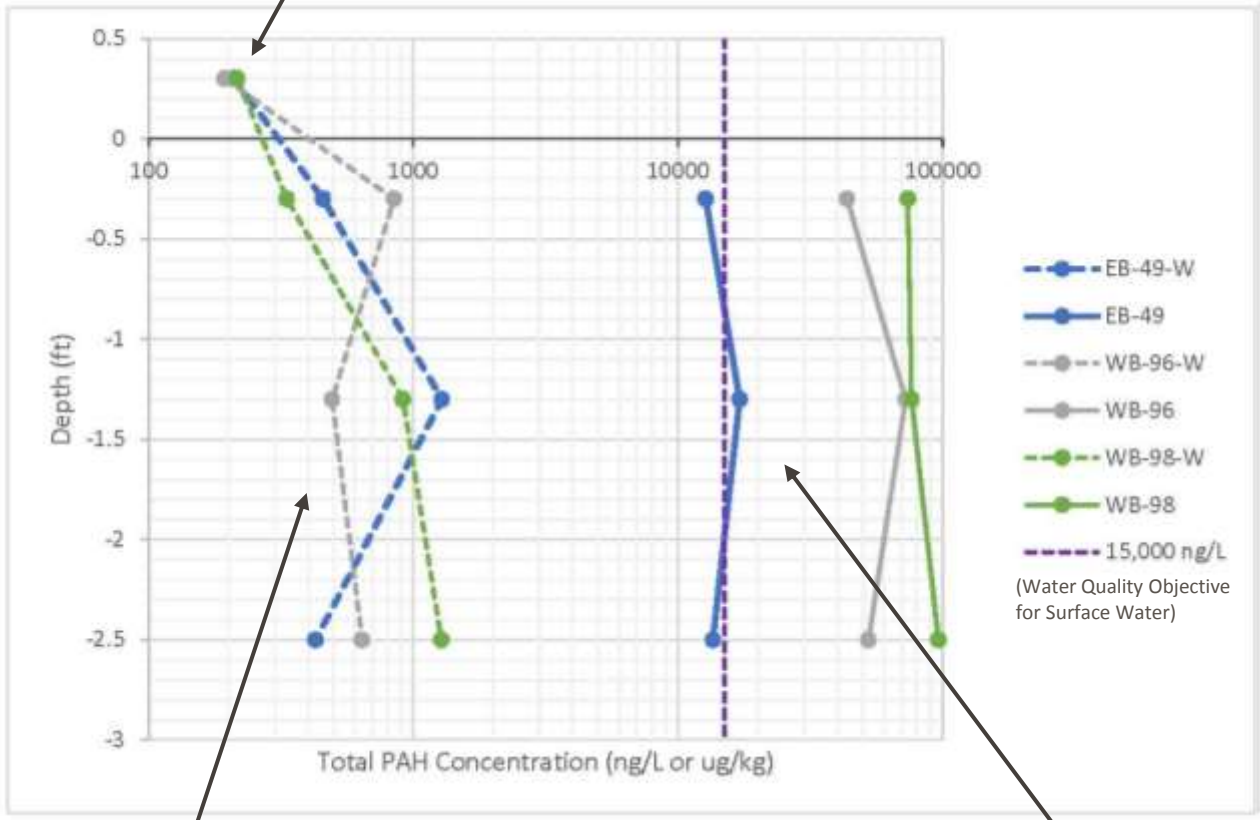
LEGEND
PHASE 1 VIBRACORE LOCATION
PHASE 1 GRAB SAMPLE LOCATION
PHASE 2 VIBRACORE LOCATION
PHASE 2 GRAB SAMPLE LOCATION
PHASE 2A VIBRACORE LOCATION
PHASE 2A GRAB SAMPLE LOCATION
PORE WATER AND GRAVITY CORE LOCATION

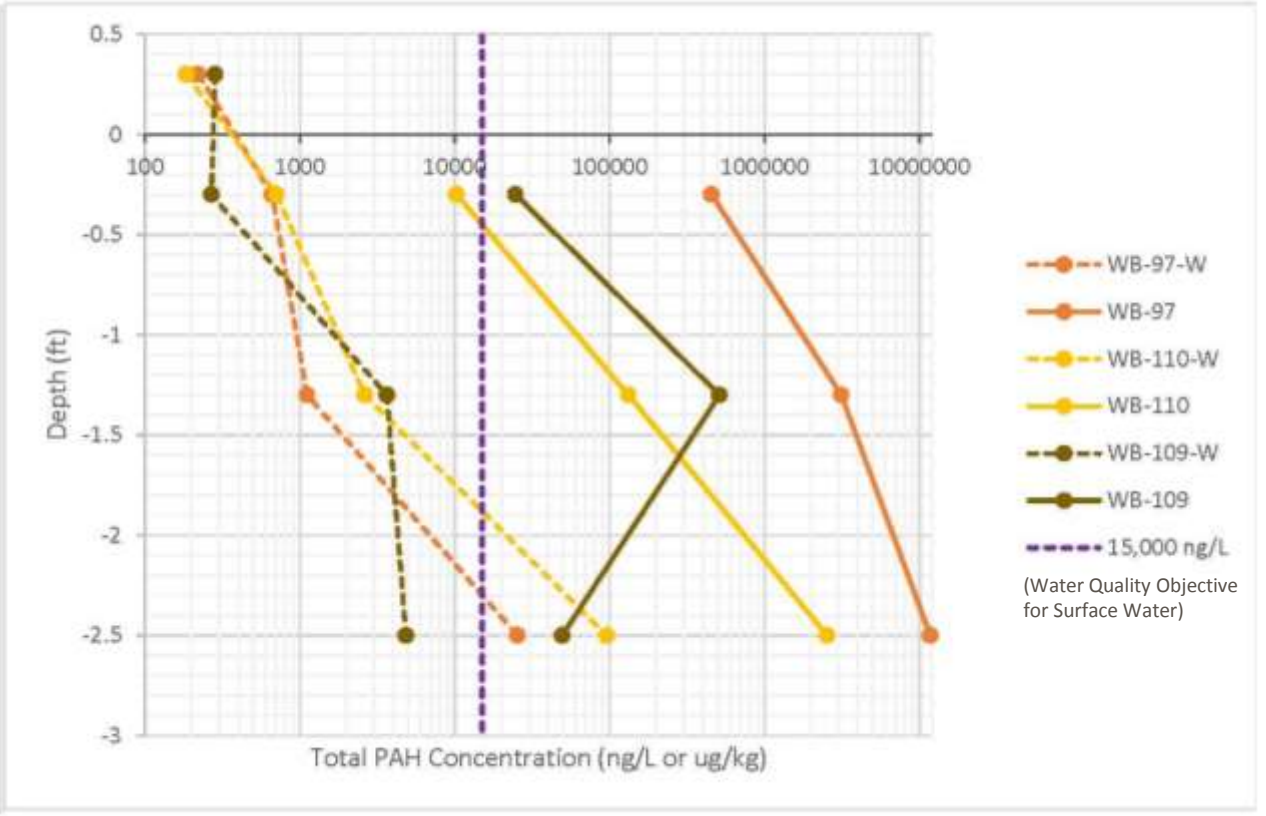
Examples of Vertical Stratification in Sediment and Pore Water

Dashed Lines = Surface water and pore water total PAH-34

Solid Lines = Bulk sediment total PAH-25

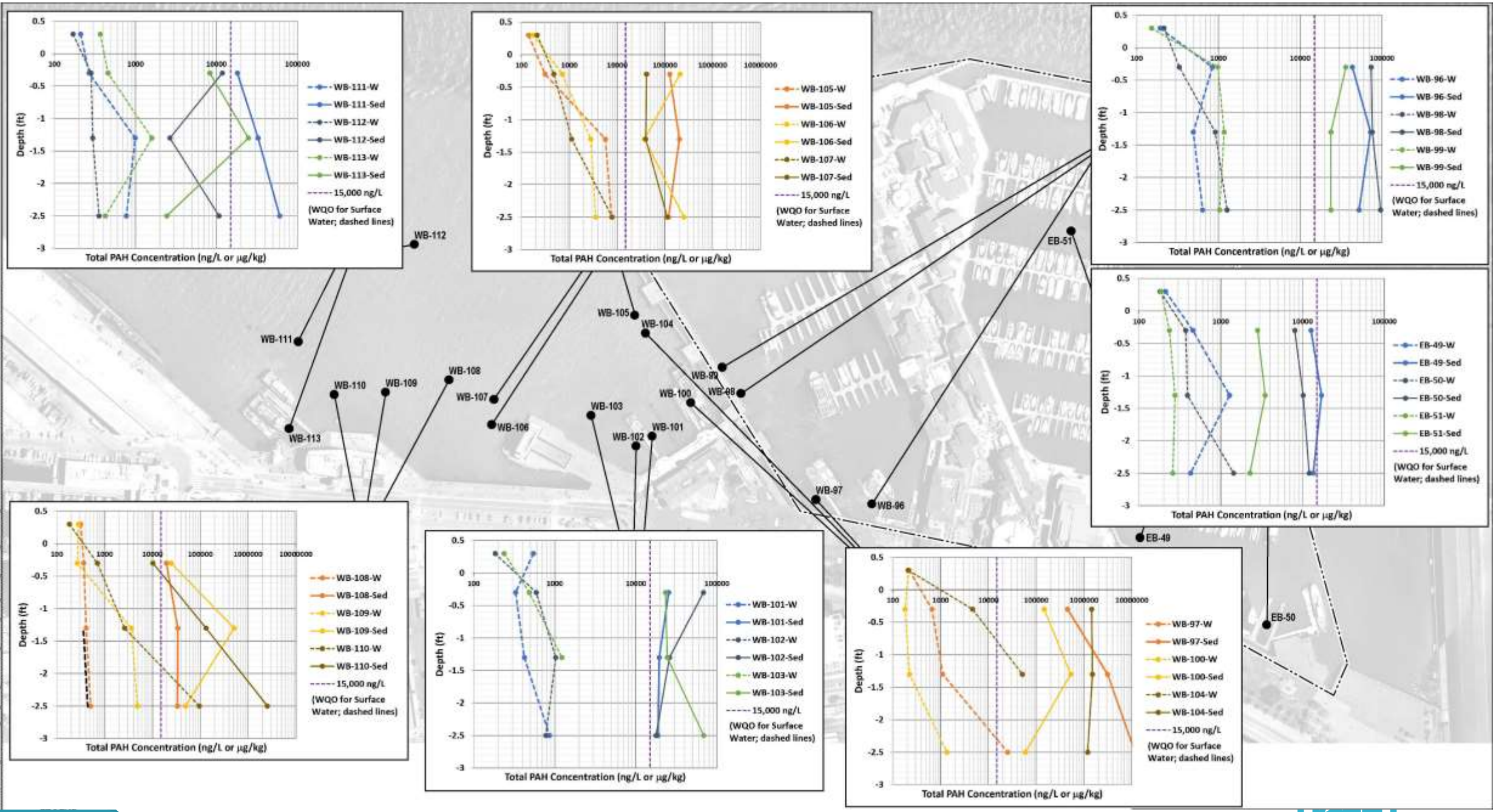
Surface Water





Pore Water at Three Depth Intervals

Bulk Sediment at Three Depth Intervals


WB-111-W
WB-111-Sed
WB-112-W
WB-112-Sed
WB-113-W
WB-113-Sed
15,000 ng/L
(WQO for Surface Water; dashed lines)
Depth (ft)
Total PAH Concentration (ng/L or µg/kg)
WB-105-W
WB-105-Sed
WB-106-W
WB-106-Sed
WB-107-W
WB-107-Sed
WB-96-W
WB-96-Sed
WB-98-W
WB-98-Sed
WB-99-W
WB-99-Sed
EB-49-W
EB-49-Sed
EB-50-W
EB-50-Sed
EB-51-W
EB-51-Sed
WB-108-W
WB-108-Sed
WB-109-W
WB-109-Sed
WB-110-W
WB-110-Sed
WB-101-W
WB-101-Sed
WB-102-W
WB-102-Sed
WB-103-W
WB-103-Sed
WB-97-W
WB-97-Sed
WB-100-W
WB-100-Sed
WB-104-W
WB-104-Sed
WB-112
WB-111
WB-113
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WB-108
WB-107
WB-106
WB-105
WB-104
WB-99
WB-98
WB-100
WB-103
WB-102
WB-101
WB-97
WB-96
EB-51
EB-49
EB-50

Application for Post Remediation Monitoring

- May eliminate need for bulk sediment analysis
- Pore water can be reliably sampled/analyzed, and measures bioavailable PAH concentrations
- Post-remedial pore water monitoring

  (Conservative compliance criterion = surface water quality objective)
  - Full Dredge = 3 intervals (to 3 ft bss) within dredge footprint; 2 intervals (to 1.5 ft bss) around dredge perimeter
  - Engineered Cap = 1 interval (0.5 ft bss) above cap; 3 intervals (to 3 ft bss) around cap perimeter
  - MNR = 3 intervals (to 3 ft bss) within and around the perimeter of the remedy area
- Use of pore water criterion for remedy performance monitoring
  - Compatible with advection/diffusion-driven cap design basis
  - Focuses “effectiveness” monitoring on most bioavailable (i.e., dissolved) phase

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