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The webinar will begin promptly at
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"Advances in the Assessment and In Situ Treatment of Contaminated Sediments"

December 15, 2016

SERDP DOD • EPA • DOE | ESTCP

Welcome and Introductions

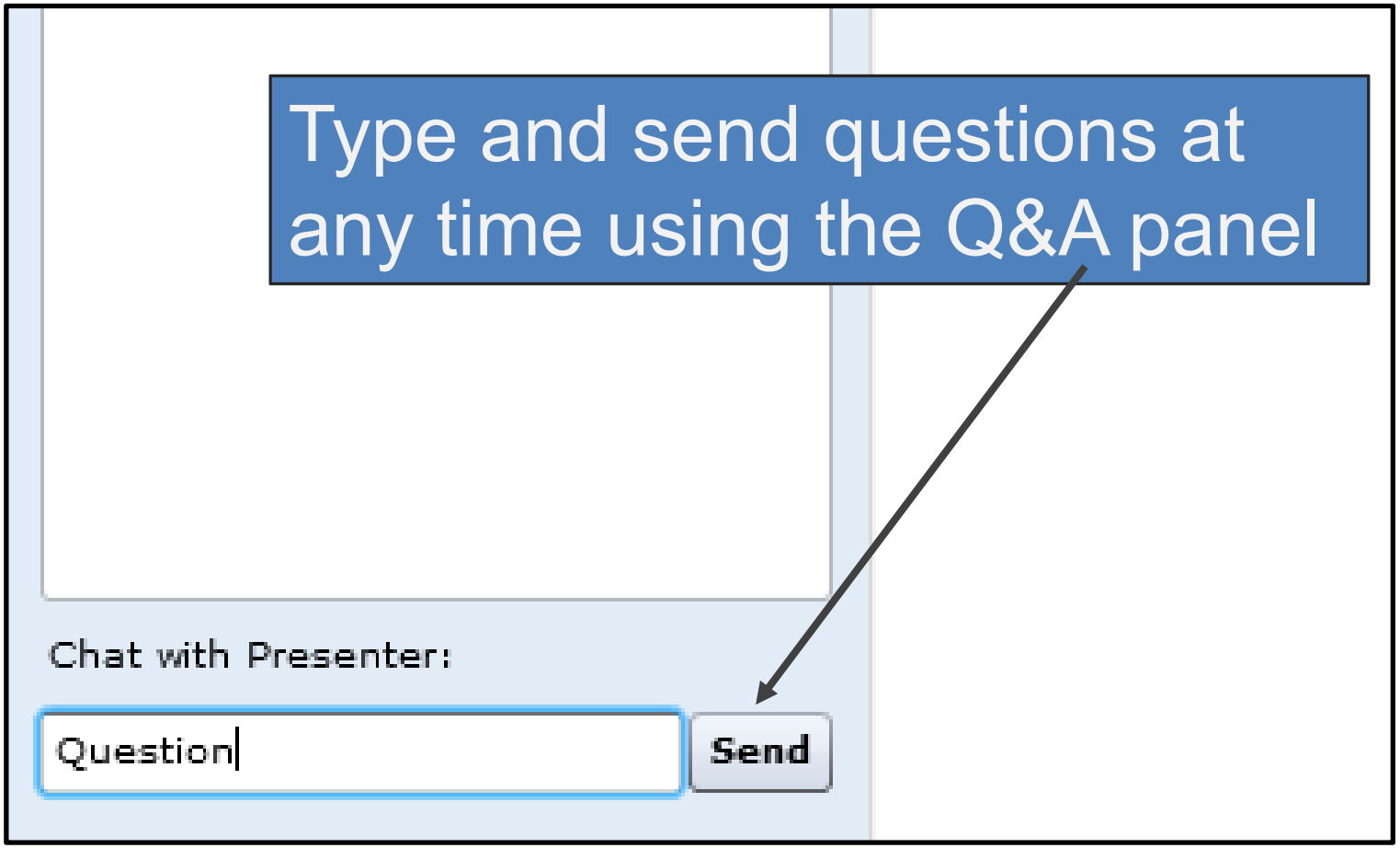
Michael Kavanaugh, Ph.D., P.E.
Webinar Facilitator

SERDP DOD • EPA • DOE | ESTCP

Webinar Agenda

- **Webinar Logistics** (5 minutes)
  Dr. Michael Kavanaugh, Geosyntec Consultants
- **Overview of SERDP and ESTCP** (5 minutes)
  Dr. Robin Nissan, SERDP and ESTCP
- **Demonstration of an In Situ Toxicity and Bioaccumulation Testing Technology for More Realistic Exposure Assessment** (25 minutes + Q&A)
  Mr. Gunther Rosen, SPAWAR Systems Center
- **Pilot-Scale Performance of In Situ Treatment with Reactive Carbon Amendments for Contaminated Sediments at an Active DoD Harbor Site** (25 minutes + Q&A)
  Dr. Bart Chadwick, SPAWAR Systems Center
- **Final Q&A session**

How to Ask Questions



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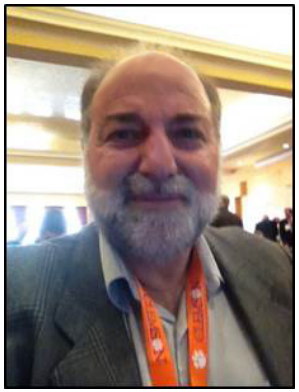
SERDP and ESTCP Overview

Robin Nissan, Ph.D.

SERDP and ESTCP, Weapons Systems and Platforms Program Manager



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SERDP

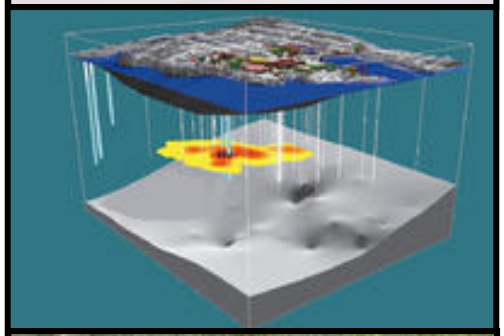
- Strategic Environmental Research and Development Program
- Established by Congress in FY 1991
  - DoD, DOE and EPA partnership
- SERDP is a requirements driven program which identifies high-priority environmental science and technology investment opportunities that address DoD requirements
  - Advanced technology development to address near term needs
  - Fundamental research to impact real world environmental management

ESTCP

- Environmental Security Technology Certification Program
- Demonstrate innovative cost-effective environmental and energy technologies
  - Capitalize on past investments
  - Transition technology out of the lab
- Promote implementation
  - Facilitate regulatory acceptance

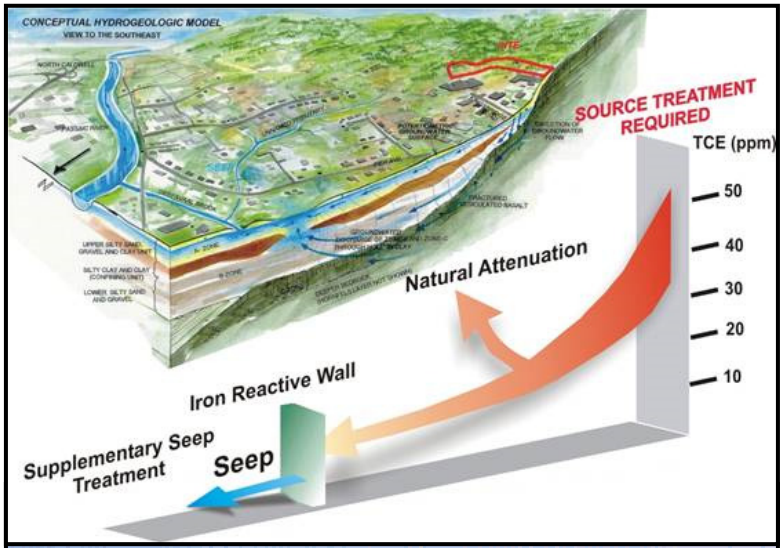
Program Areas

1. Energy and Water
2. Environmental Restoration
3. Munitions Response
4. Resource Conservation and Climate Change
5. Weapons Systems and Platforms



Environmental Restoration

- Major focus areas
  - Contaminated groundwater
  - Contaminants on ranges
  - Contaminated sediments
  - Wastewater treatment
  - Risk assessment



SERDP and ESTCP Webinar Series

Date	Topic
January 12, 2017	**Award Winning Projects** Energy and Water
January 26, 2017	**Award Winning Projects** Weapons Systems and Platforms
February 9, 2017	**Award Winning Projects** Environmental Restoration
February 23, 2017	**Award Winning Projects** Resource Conservation and Climate Change
March 9, 2017	**Award Winning Projects** Munitions Response

For upcoming webinars, please visit

http://serdp-estcp.org/Tools-and-Training/Webinar-Series

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Demonstration of an In Situ Toxicity and Bioaccumulation Testing Technology for More Realistic Exposure Assessment

Gunther Rosen
SPAWAR Systems Center

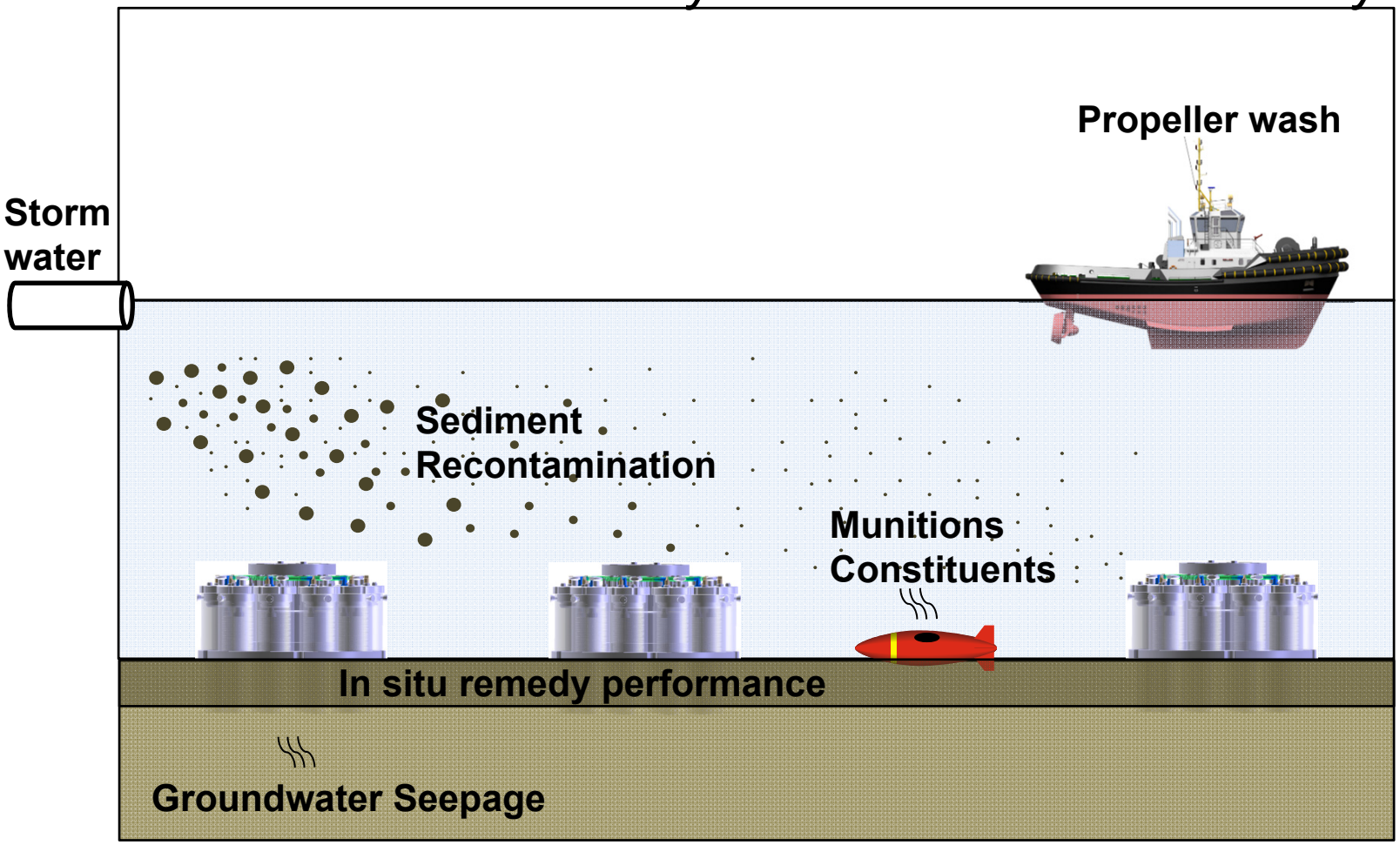
SERDP DOD • EPA • DOE | ESTCP

Agenda

- Problem statement
- Advantages and disadvantages of in situ bioassays
- Sediment Ecotoxicity Assessment (SEA) Ring
  - Description and development
  - Performance at DoD sites
    - Marine Corps Base Quantico (thin layer cap monitoring)
    - Naval Base San Diego (storm water monitoring)
- Technology transition status

Problem Statement

Examples of DoD environmental stressors and remedies that can't be accurately assessed in the laboratory



In Situ Exposure Assessment

Advantages

- Improved realism
- Integration of spatial and temporal variability
- Integrate natural and anthropogenic factors
- Minimal sample disruption
- Reduced sample collection costs
- Elimination of sample holding time concerns

Disadvantages

- Reduced control
- Water quality disturbances (mesh clogging)
- Physical disturbances of test chambers
- Predation and competition
- Equipment loss (e.g. weather, vandalism)
- Possible requirement for divers

Traditional In Situ Exposure Chamber Designs

- Well-established, used for decades
- Passive exchange of ambient water using fine mesh screens
- Assumption that water quality is maintained
- Generally not standardized

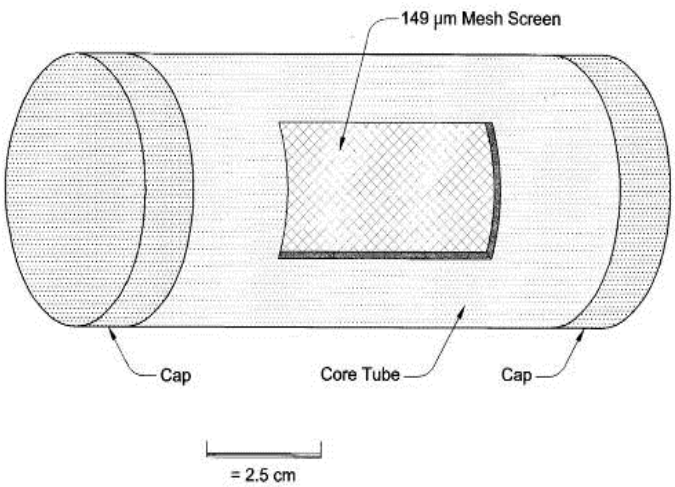
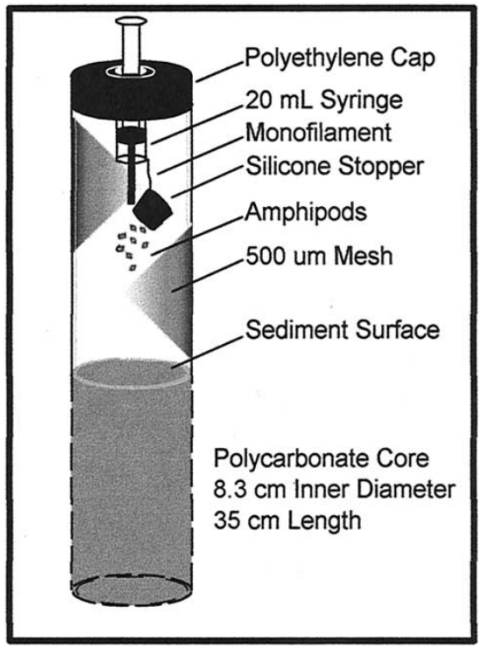


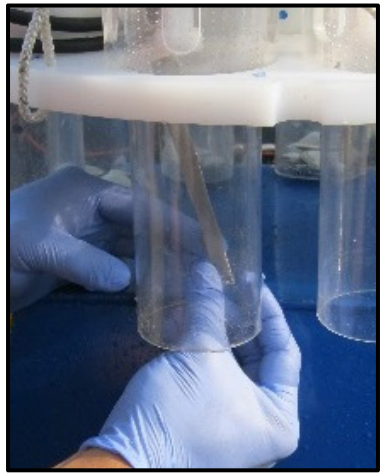
FIGURE 4
In situ test chamber used for benthic macroinvertebrates. (Reprinted with permission from Ireland et al., 1996.)

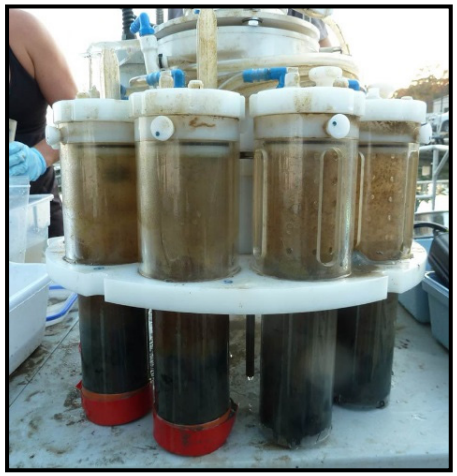


Anderson et al., 2004. Arch. Environ. Contamin. Toxicol. 46 (1): 52-60
Burton et al., 2005. Environ. Pollut. 134 (1): 133-144

SEA Ring Design

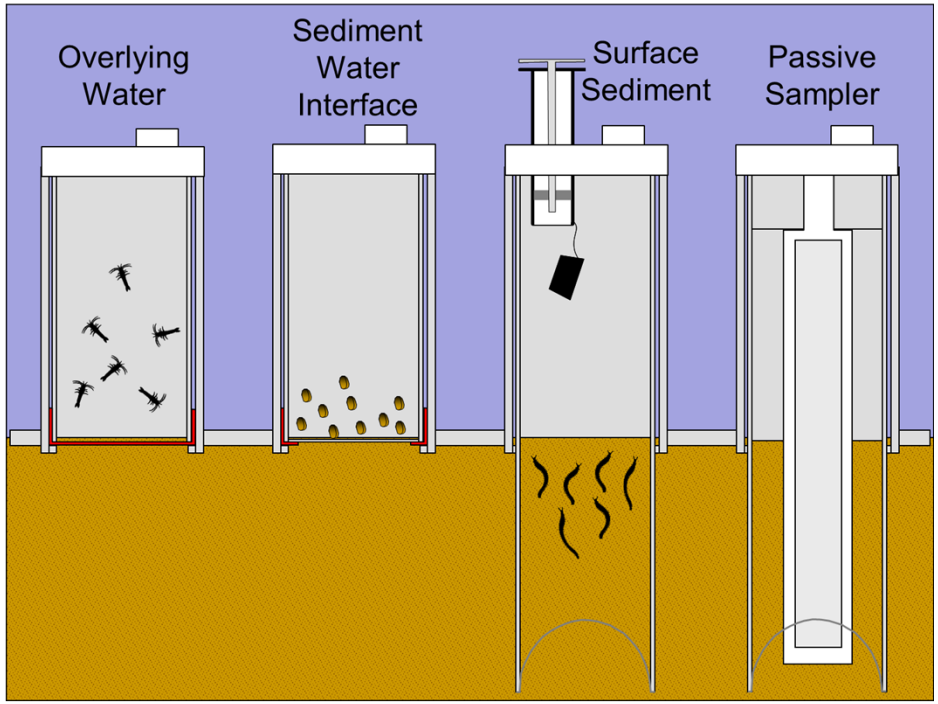
- Low power circulation pump system
- Programmable pump cycling
- Pre-filter to reduce clogging
- Solid (no mesh) chambers
- Integrated chamber cap
- Replaceable exposure chambers
- Non-toxic and cleanable components





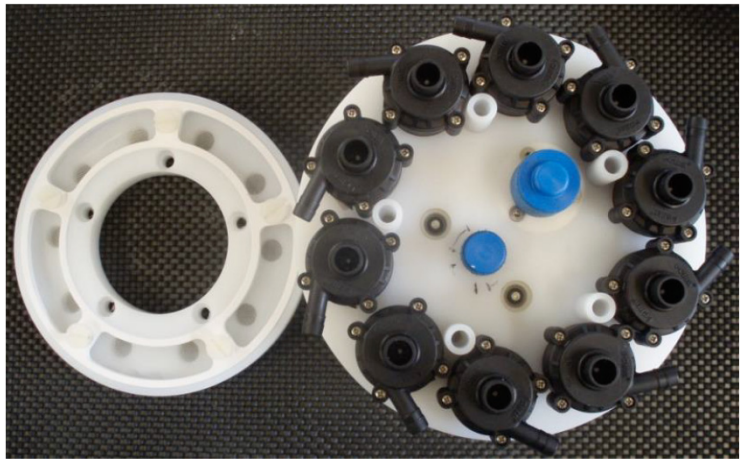
SEA Ring Design *(Cont'd)*

- Exposure to multiple compartments to identify sources
- Water column, sediment, sediment-water interface exposures
- Integration of passive samplers and water quality loggers



Typical Components

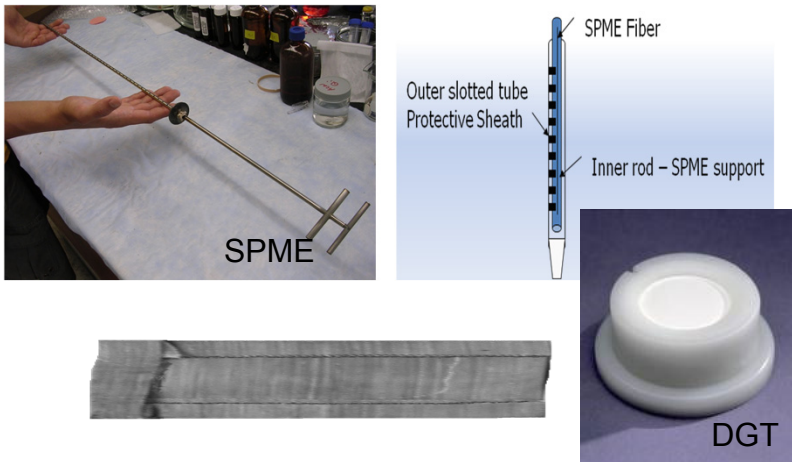
Integrated Pumping System



Water Quality Sensors

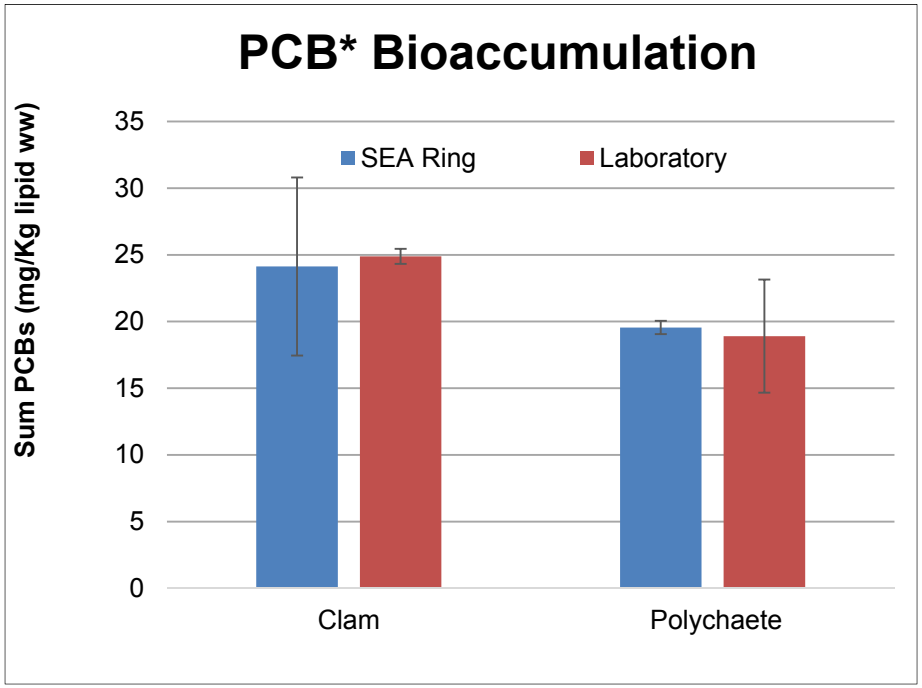
Sediment Capture Devices

Passive Samplers

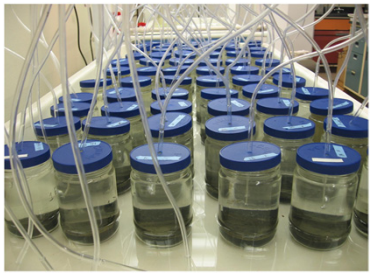


SEA Ring Verified by EPA

- US EPA Environmental Technology Verification (ETV)
  - 3rd party verification
- Controlled comparison of lab methods with SEA Ring
- Aqueous and sediment toxicity (5 species)
- Sediment bioaccumulation (3 species)
- Test acceptability criteria met for all exposures



*Sum NOAA 18 Congeners, PSNS Pier 7 sediment, 3 replicates for tissues



Macoma nasuta

Neanthes arenaceodentata

McKernan et al, 2014
http://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=285833

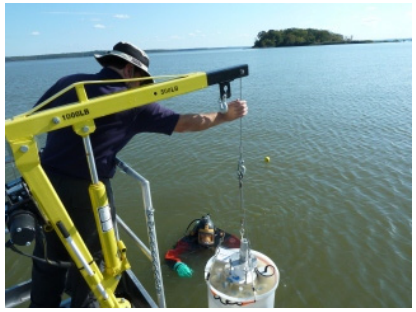
Puget Sound Naval Shipyard – Pier 7

- Reactive amendment effectiveness
- AquaGate + PAC™
- Objective: PCB sequestration
- Bioavailability assessed using in situ bioaccumulation and passive sampling
  - *Macoma nasuta* (clam)
  - *Nephtys caecoides* (polychaete)
  - SPME (PDMS coated fibers)
- See Part 1 of webinar (Dr. Bart Chadwick)

Marine Corp Base Quantico

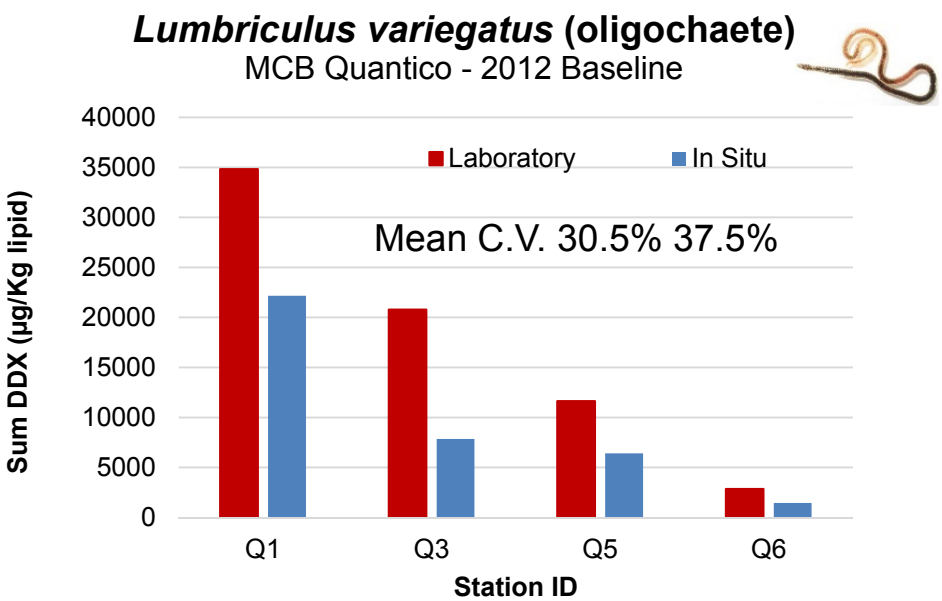
Thin-Layer Cap Monitoring

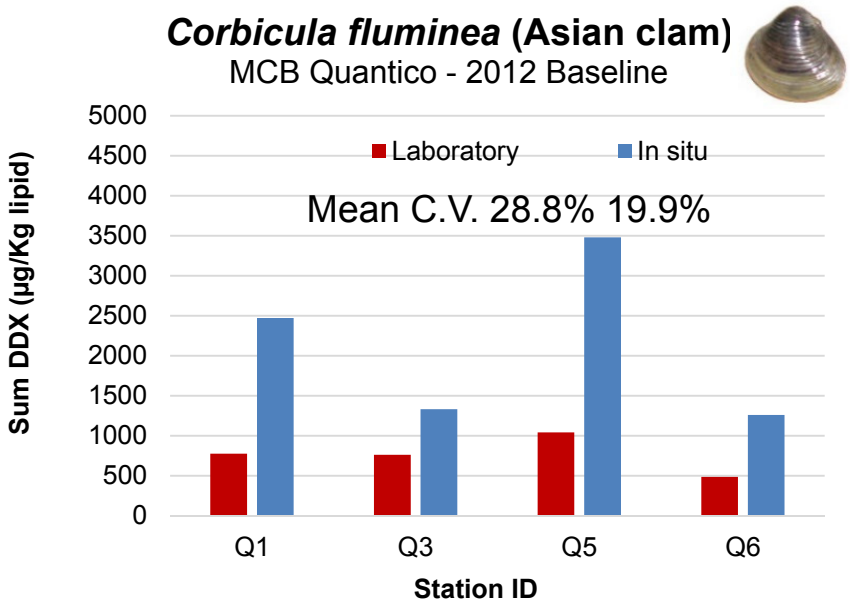
- Marine Corps Base Quantico, Site 99, Quantico Embayment
- 6” of capping material (sand) on surface sediments
- Contaminants of concern: DDTs (organochlorine pesticides)
  - Sum of 4,4´-DDD, 4,4’-DDE, 4,4’-DDT
  - Baseline and post-remedy monitoring comparisons
- Two species
  - *Lumbriculus variegatus*
    - Freshwater oligochaete
  - *Corbicula fluminea*
    - Asian clam (ubiquitous)
- Ex situ and in situ passive sampling
  - 14-day exposures



Differences between In Situ And Lab Marine Corps Base Quantico

- Different feeding strategies/exposure routes
- In situ and ex situ results are <u>different</u>!
- Variability comparable between in situ and laboratory





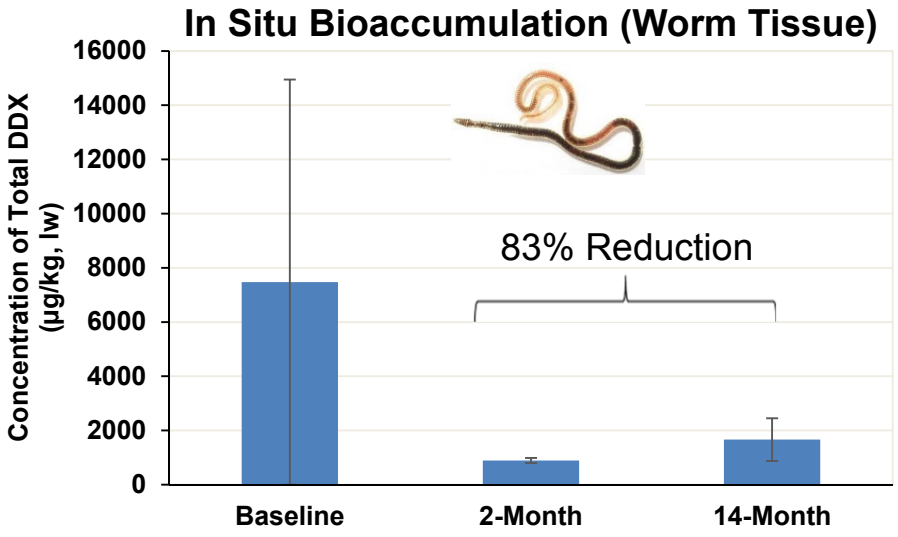
Reduced DDX Bioavailability

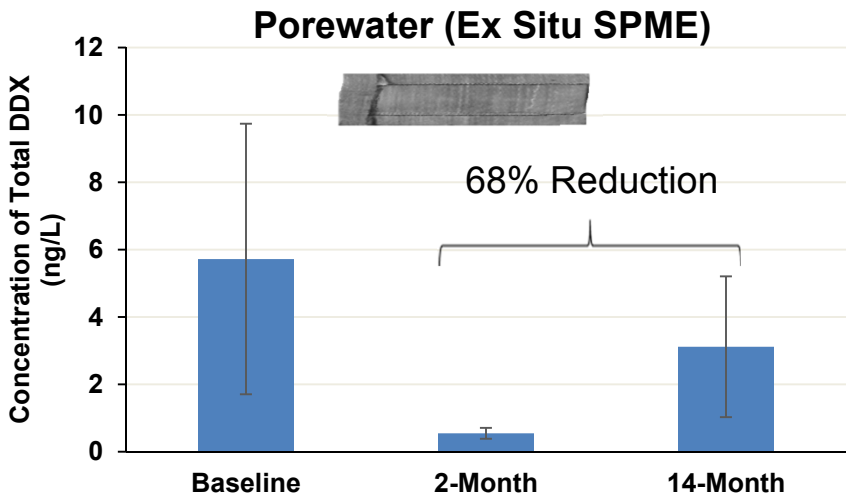
- Substantial reduction in tissue and pore water concentrations
- Strong correlation between in situ bioaccumulation and ex situ SPME (r = 0.8)

Ex situ SPME

In situ SPME

10 µm layer of polydimethylsiloxane (PDMS)
Comparisons made using results from top 5 cm



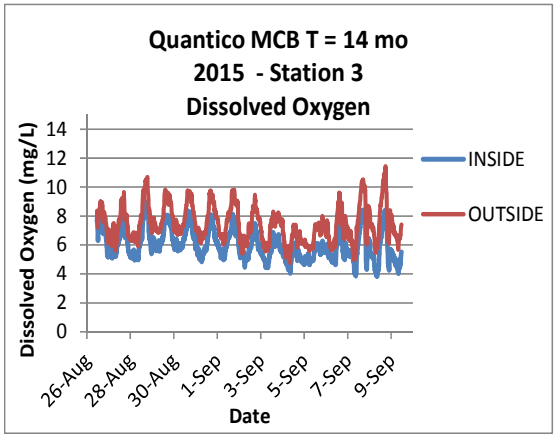


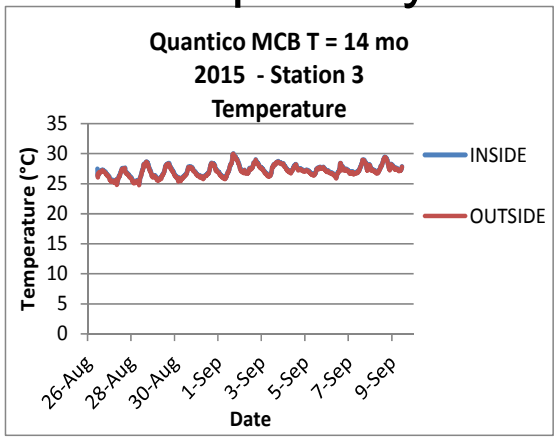
Water Quality Maintenance

Marine Corps Base Quantico

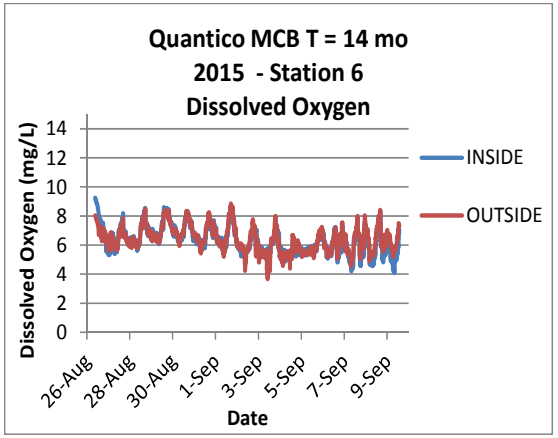
- Continuous monitoring of parameters inside and outside chambers to ensure test acceptability

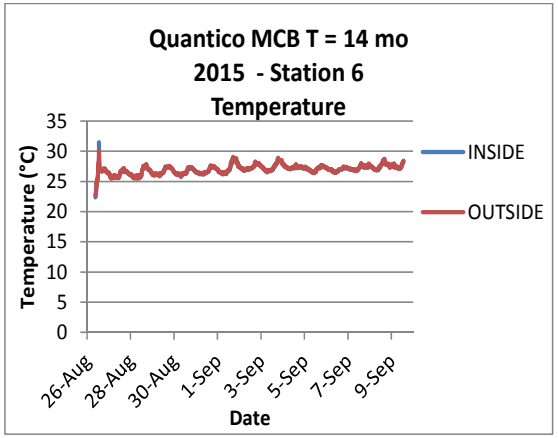
Sand Cap





Reference Site (fines)

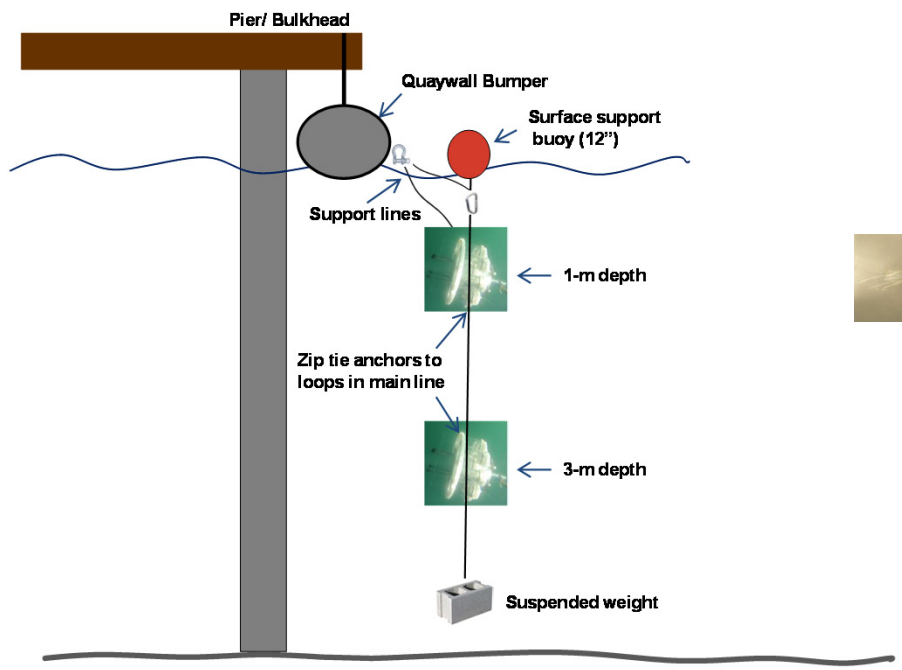


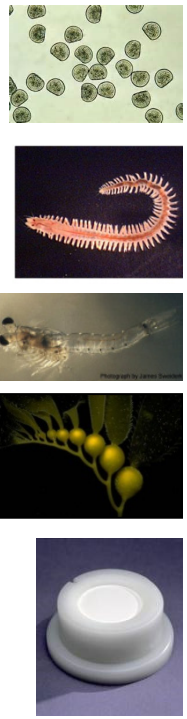


Naval Base San Diego

In situ storm water monitoring

- Increasingly stringent storm water compliance (NPDES permits)
- Long term-Navy monitoring shows end-of-pipe not indicative of receiving water exposure/impacts (Katz et al., 2006)
- Assess realistic impacts to receiving environment



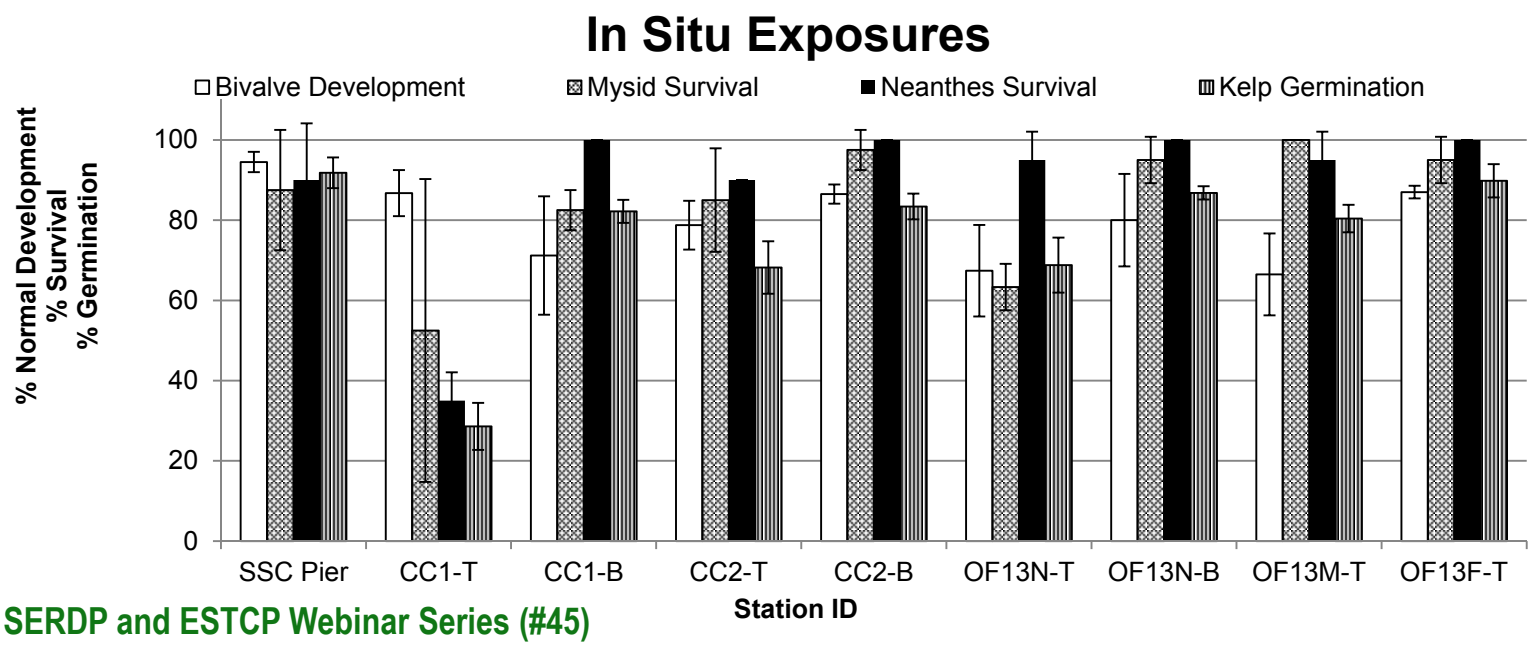


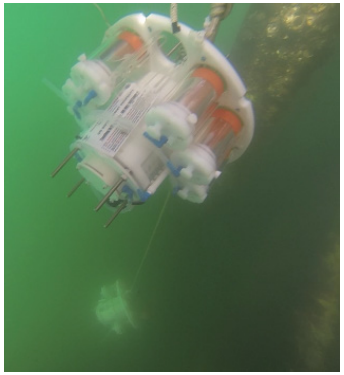
Katz et al., 2006. SPAWAR Systems Center San Diego Technical Report 1938
http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA451054

Naval Base San Diego

In situ storm water monitoring

- Good performance of all species at Reference sites
- Greatest adverse effects associated with reduced salinity in top meter at Chollas Creek site (CC1-T)
- High toxicity observed in laboratory with some grab samples

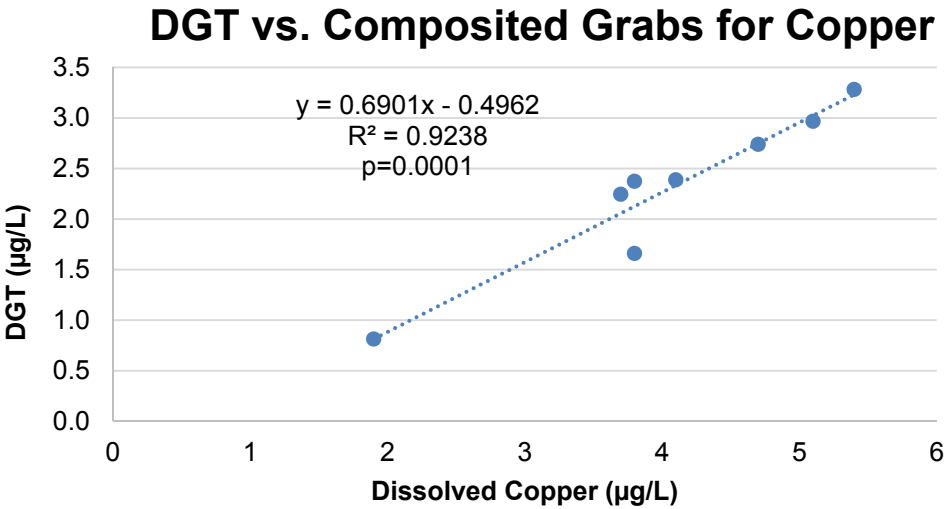




Naval Base San Diego

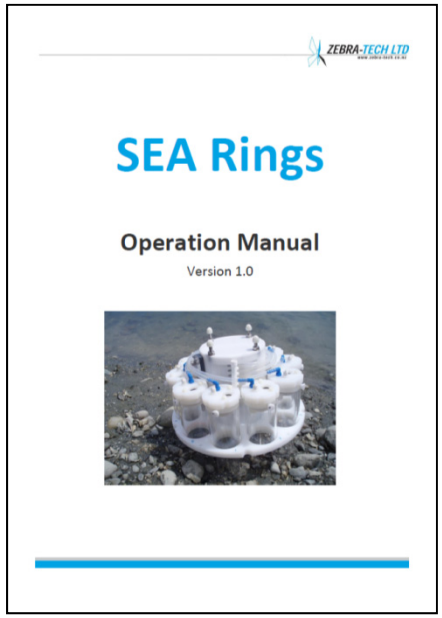
In situ storm water monitoring

- Diffusive gradient in thin films (DGTs) provide bioavailability measure in SEA Ring deployments
- Time averaged concentrations from DGT correlated with composite sampling



Technology Transfer

- Commercial availability of hardware
- Commercial service provider
- EPA Environmental Technology Verification
- Direct collaboration with DoD and industry end users
- Use long-term to support monitoring in California Areas of Special Biological Significance (ASBS) Program
- Growing personnel expertise and number of units available
- Publications and presentations at multiple scientific symposia
- U.S. Patent #8,011,239



Video

DEPLOYMENT AT PSNS

Conclusions

- SEA Ring technology increasingly used and commercially available
- In situ assessments more realistic and in some cases only means of accurate exposures
- When appropriately used, can meet test acceptability criteria required of laboratory methods
- Better decision making potentially reducing costs associated with cleanup and compliance

Acknowledgements (Partial)

- SPAWAR: Dr. Bart Chadwick, Molly Colvin, Joel Guerrero, Victoria Kirtay, Dr. Bob Johnston, Brad Davidson, Chuck Katz, Ernie Arias, Pat Earley, Dr. Rob George, Ryan Halonen
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- Nautilus Environmental: Adrienne Cibor, Dr. Howard Bailey
- EPA Environmental Response Team: Dr. Marc Greenberg, Mr. Alan Humphrey
- SDSU Research Foundation: Renee Dolecal, Nick Hayman, Jacob Munson-Decker
- Ramboll Environ (Port Gamble Laboratory): Brian Hester, Jay Word, and staff
- Geosyntec: Melissa Grover, Jennifer Arblaster, Jason Conder
- EPA Environmental Technology Verification: Dr. Ramona Darlington, Amy Dindal, and team
- USACE ERDC: Dr. Guilherme Lotufo and the analytical chemistry laboratory
- Puget Sound Naval Shipyard: Ellen Brown, Mark Wicklein, Dwight Leisle
- Marine Corps Base Quantico: Fred Evans
- Naval Base San Diego: Jessica Palmer, Len Sinfield
- Texas Tech University: Dr. Danny Reible

For additional information, please visit

https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Sediments/ER-201130

Speaker Contact Information

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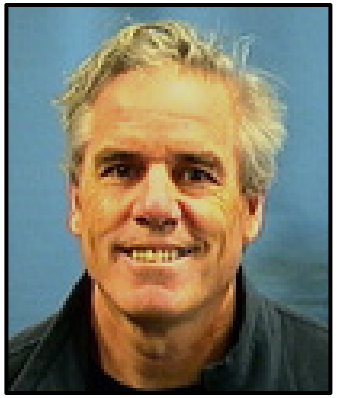
Q&A Session 1

SERDP DOD ▪ EPA ▪ DOE | ESTCP

Pilot-Scale Performance of In Situ Treatment with Reactive Carbon Amendments for Contaminated Sediments at an Active DoD Harbor Site



Dr. Bart Chadwick
SPAWAR Systems Center

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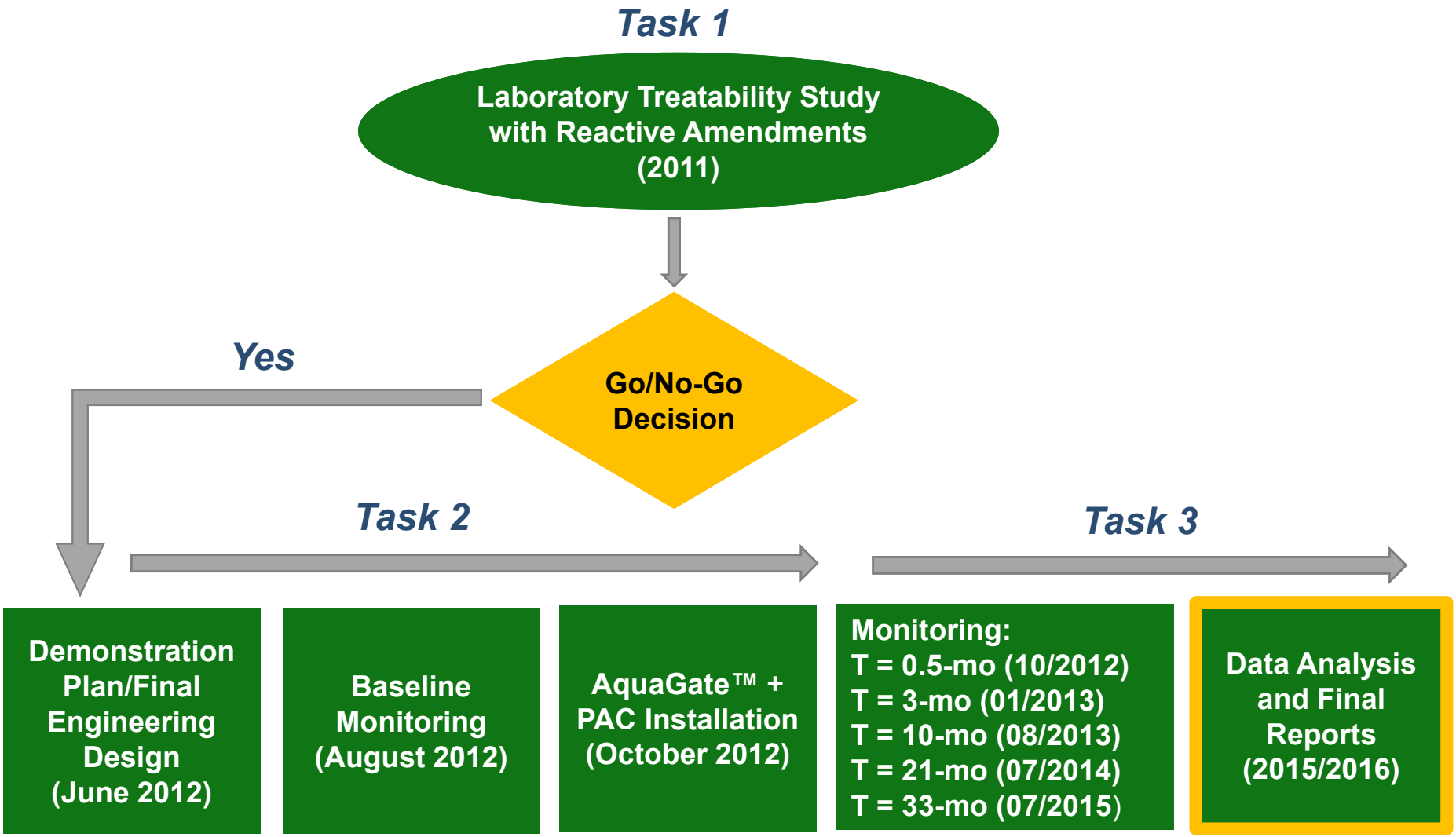
Outline

- Demonstration objectives and approach
- Amendment and demonstration site
- Lab treatability study
- Installation
- Performance monitoring
- Cost assessment
- Key points and considerations

Demonstration Objectives

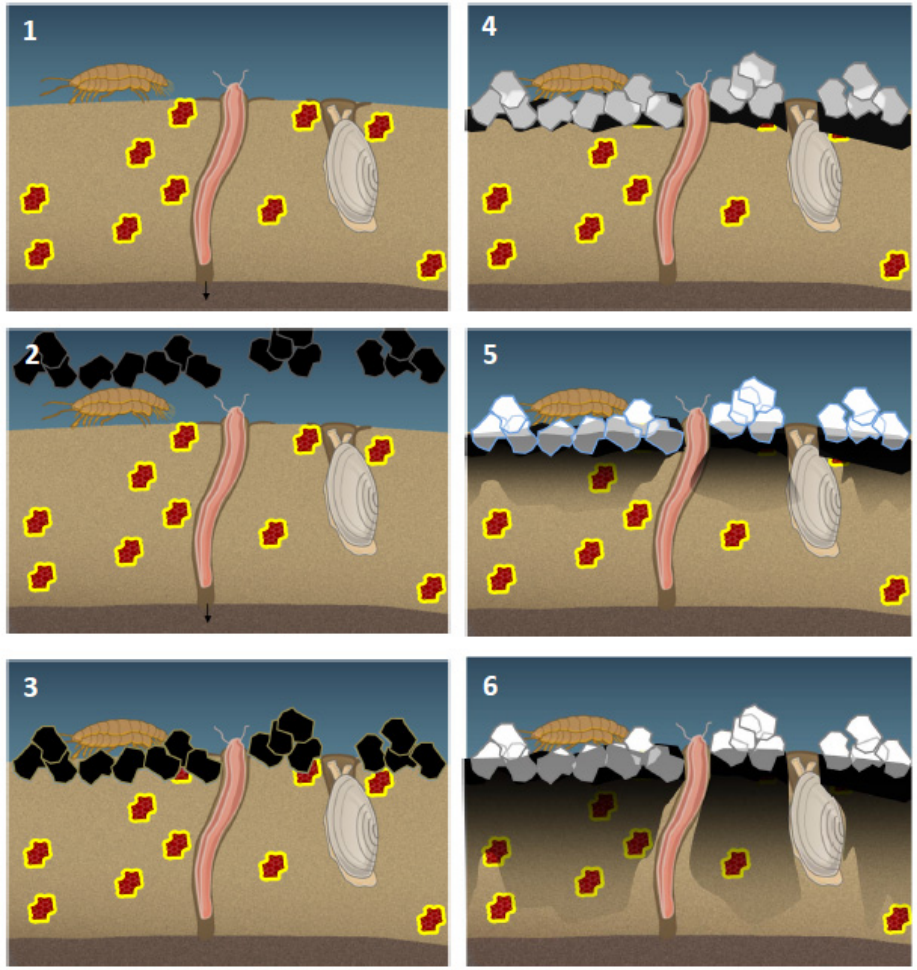
- Demonstrate and validate placement, stability and performance of reactive amendments for treatment of contaminated sediments in active DoD harbor settings
- Focus of demonstration and validation efforts
  - Amendment placement in deeper water areas that support vessel traffic as well as near piers and structures
  - Effectiveness of amendment in controlling contaminant bioavailability
  - Physical stability and longevity of the amendment in the sediment
  - Response of the benthic community to the amendment application

Project Overview



AquaGate Reactive Amendment

- AquaGate+PAC™
  - AquaBlok®, Toledo, Ohio
- Coated aggregate
  - Coating: 5% Powder Activated Carbon (PAC) with ~10% bentonite binder
  - Aggregate aids delivery of PAC to sediment surface
- Penetrates into sediment due to aggregate settling
- Vertically mixed by natural processes over time



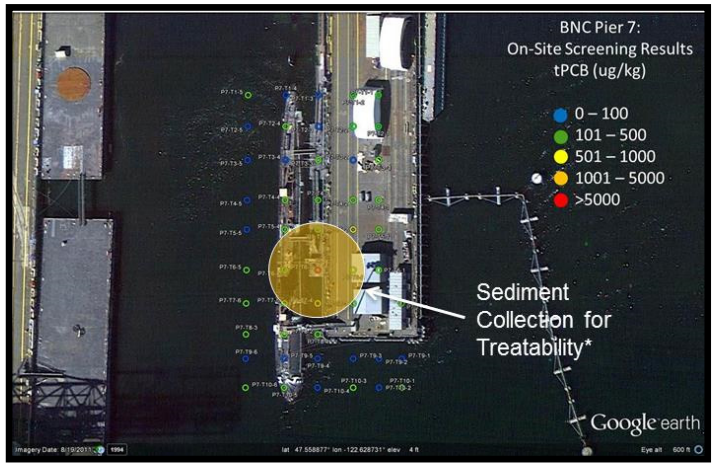
Demonstration Site

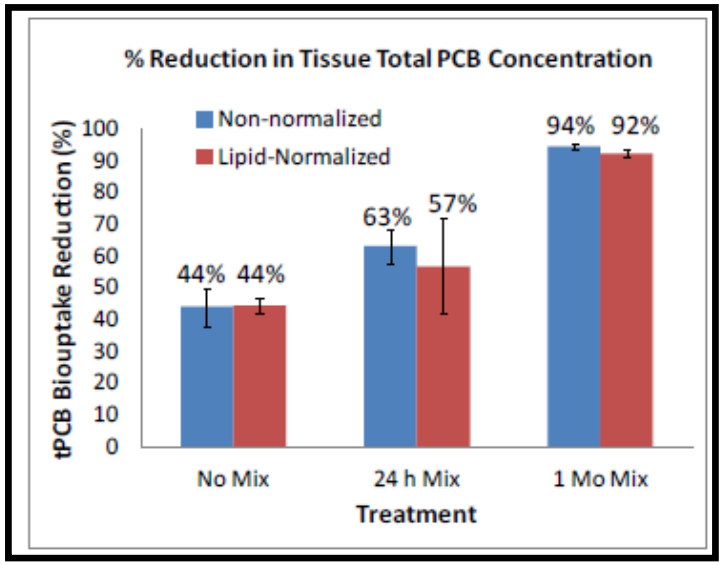
Pier 7, Puget Sound Naval Shipyard, Bremerton, WA

- Active, deep water shipyard
- Operable Unit B Marine
- Highest concentrations of Polychlorinated Biphenyls (PCBs) in surface sediment
  - Along the shoreline or adjacent to moorings and piers
  - Previously subject to cleanup (dredged)
- Post-remedy monitoring identified continued presence of elevated levels of PCBs near Pier 7
- Desire to test alternative in situ treatment methods such as reactive amendments

Laboratory Treatability Studies

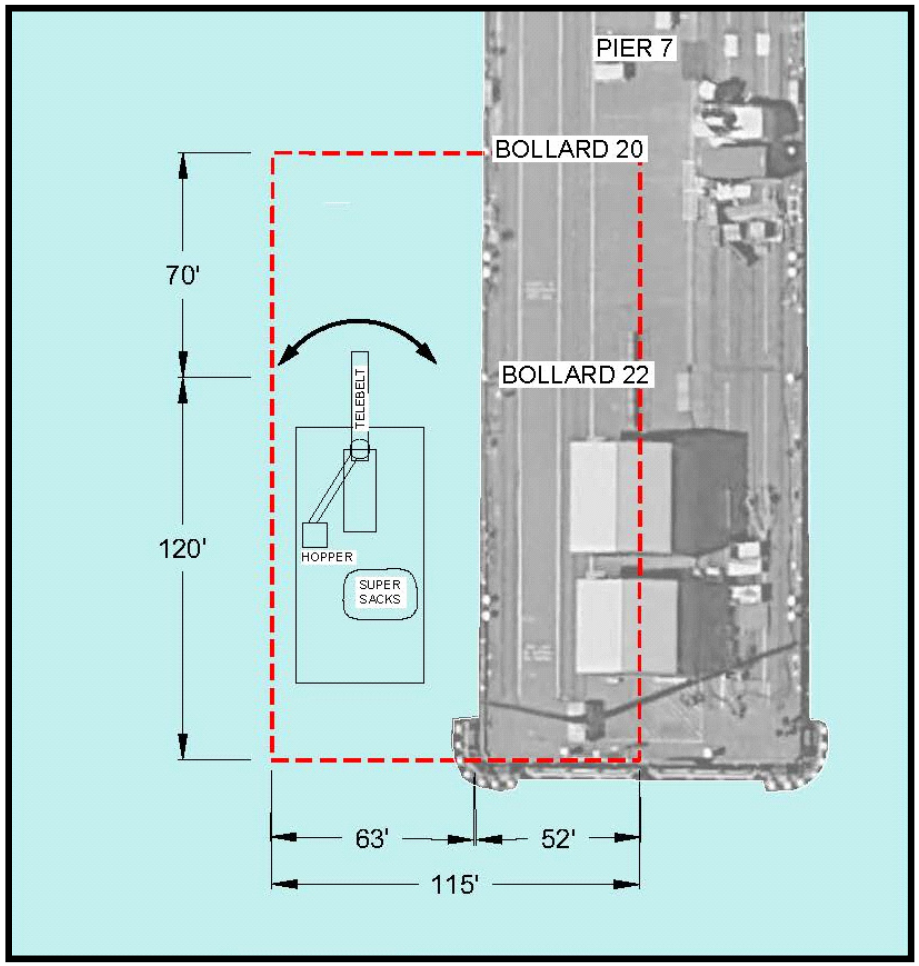
- On-site delineation of contaminant concentrations (500 ppb - 6 ppm); target area defined
- Test sediments collected from target area
- PCB biouptake by polychaetes significantly reduced by AquaGate+PAC™ amendment in site sediment
- No significant adverse toxicity effects
- Sediment Profile Imagery (SPI) distinguishes between un-amended and amended sediment layers





Pilot-Scale Installation Design

- Design placement area 115’ x 190’ (0.5 acres)
  - Adjacent to Pier 7: 190’ x 63’
  - Beneath Pier 7: 190’ x 52’
- To achieve 2-4% increase of activated carbon (AC) content, 141 tons needed
  - ~5 cm amendment thickness at application
  - Assumes 10-20 cm mixing depth over time



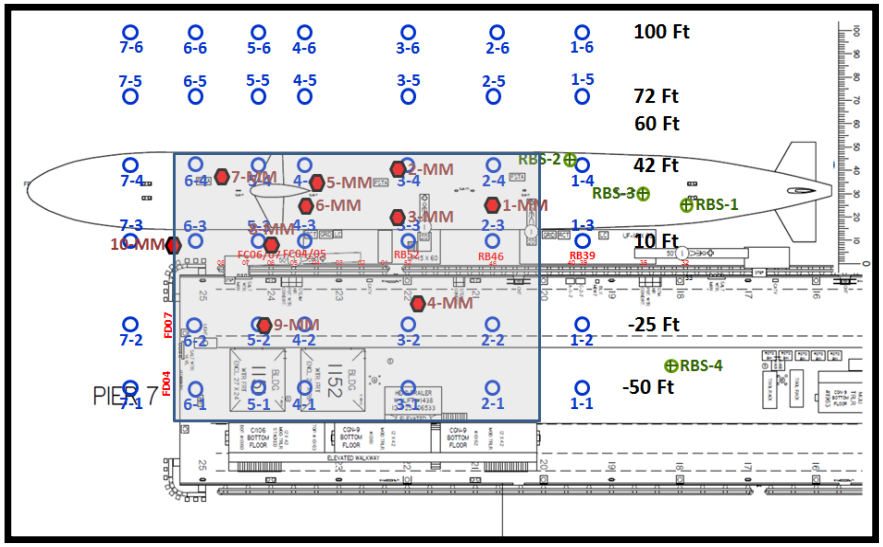
Amendment Placement

Video

AMENDMENT PLACEMENT

Performance Monitoring Design

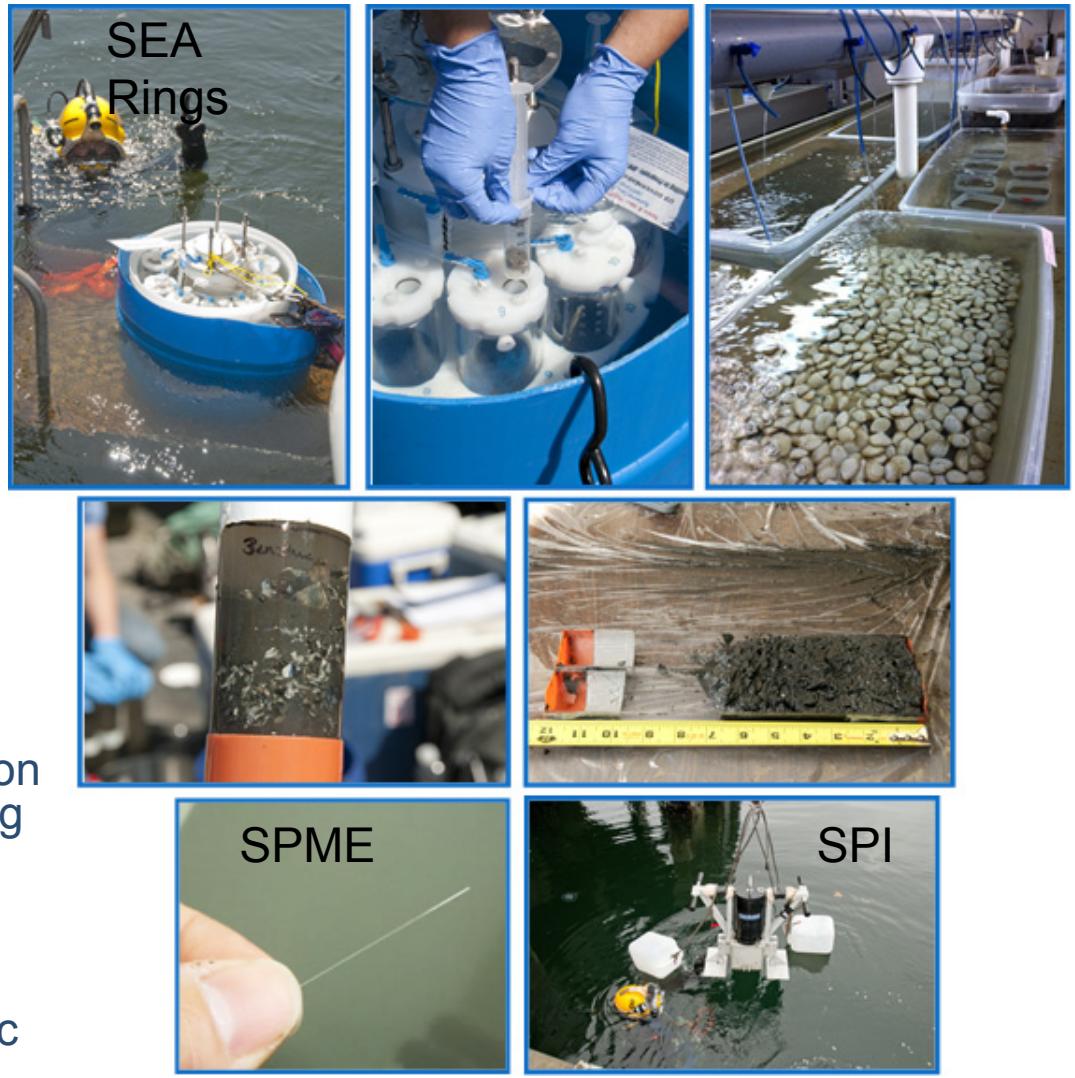
- Baseline characterization
  - 2 months prior to placement
- Placement verification
  - 0.5- and 3-months post-placement
- 3 annual monitoring events
  - 10-, 21-, and 33-months post-placement



Measurement	Number of stations
Tissue Sediment Porewater Sediment Benthic Community	10 (1-MM – 10-MM)
SPI Survey	42-51 (1-1 – 7-6)
Benthic Community Ref	4 (RBS-1 – RBS-4)

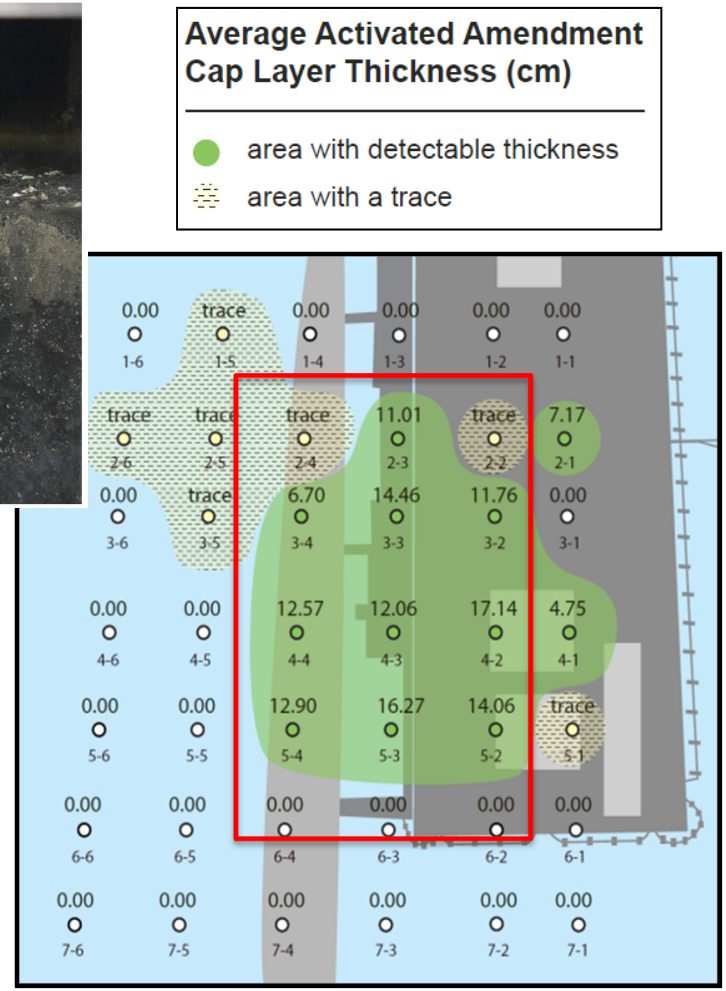
Performance Monitoring Methods

- In situ bioaccumulation
  - SEA rings
  - Two species
    - *Macoma nasuta*
    - *Nephtys caecoides*
  - 14-day deployment
  - Analytes: PCBs and mercury (tracking only)
- In situ passive sampling
  - SPME
  - 14-day deployment
  - Analytes: PCBs
- Sediment cores
  - Analytes: PCBs, grain size, total organic carbon/black carbon (TOC/BC) and mercury (tracking only)
  - Benthic community census
- SPI survey
  - Amendment presence & benthic health



Demonstrate Placement within Target Area at Target Thickness (SPI Survey)

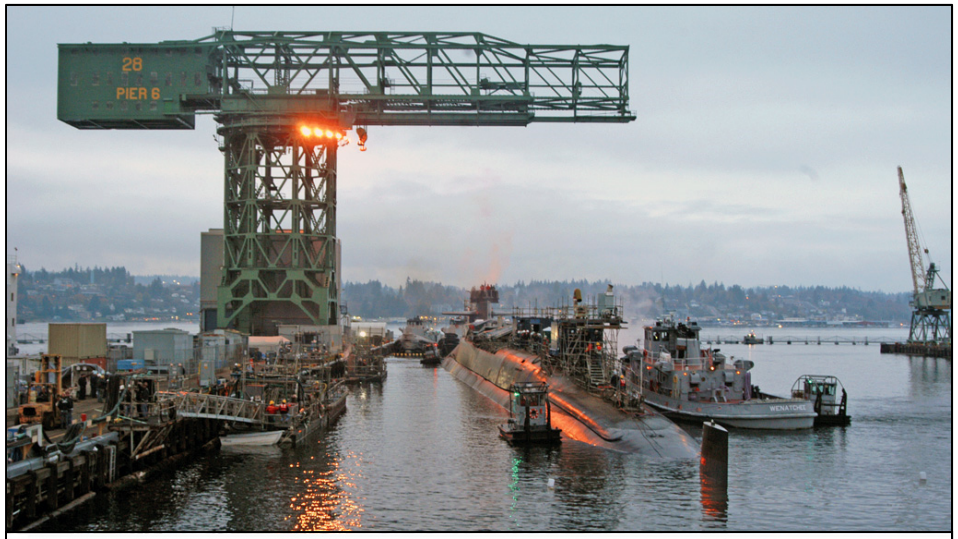
- 0.5-month monitoring event
  - No ship movements
  - ~80% of target area received at least a trace of amendment
  - ~70% of the target area received target thickness (5 cm) or more
- Thickness within target amendment area
  - Average 11 cm
  - Range 0.1 – 17 cm

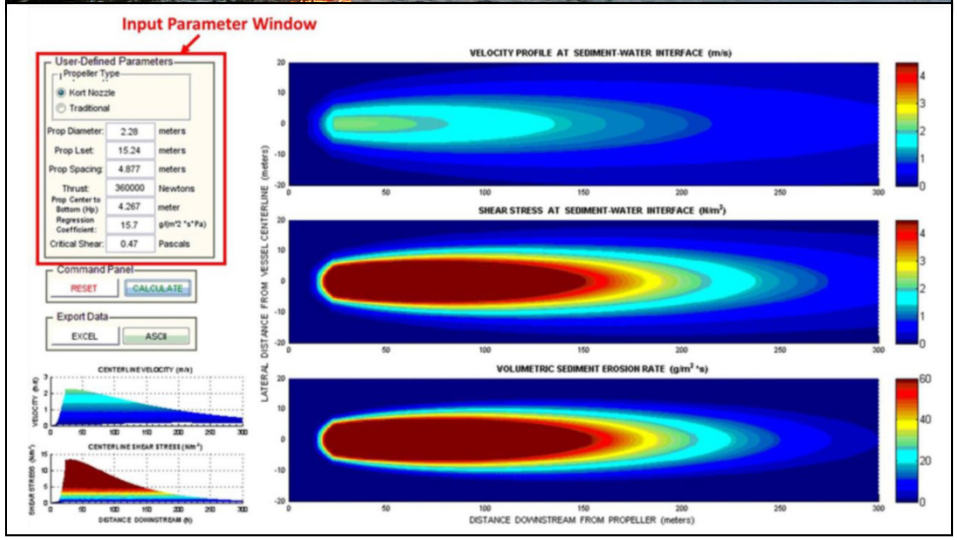


Red line indicates target amendment area

Potential Physical Disturbance

- Believed to be primarily driven by ship movements
- Typically 4 events per year at Pier 7
  - Each event estimated to erode about 20,000 kg sediment
- Scour area
  - 10-20 m wide
  - 50-150 m long
  - 1-5 cm deep

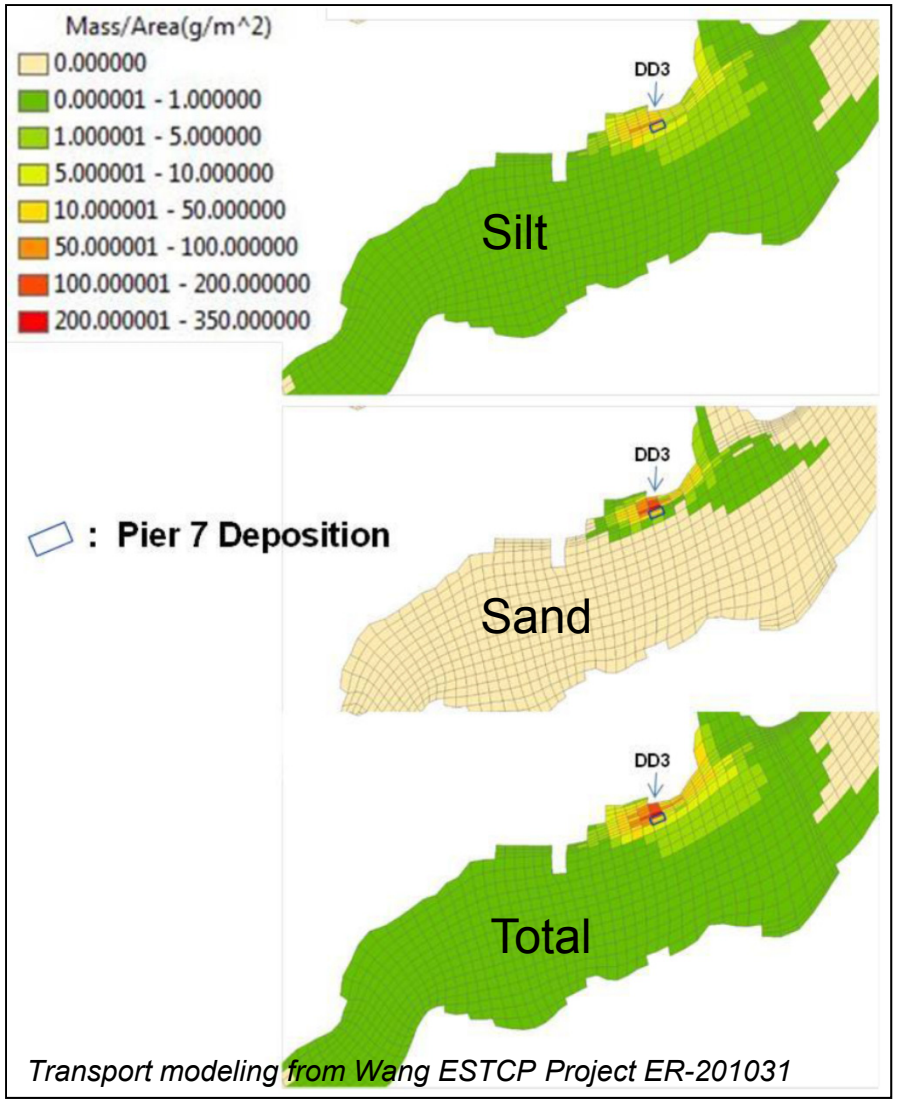




Scour modeling from PF Wang ESTCP Project ER-201031

Potential Physical Disturbance

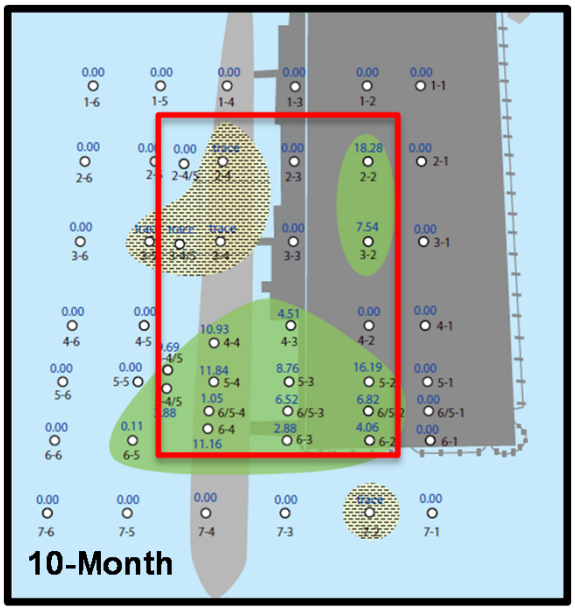
- CH3D model simulation of transport following resuspension event at Pier 7
- Eroded sediment transported laterally alongshore over 300-500 m typically
- Potential to redistribute sediment and amendment over time

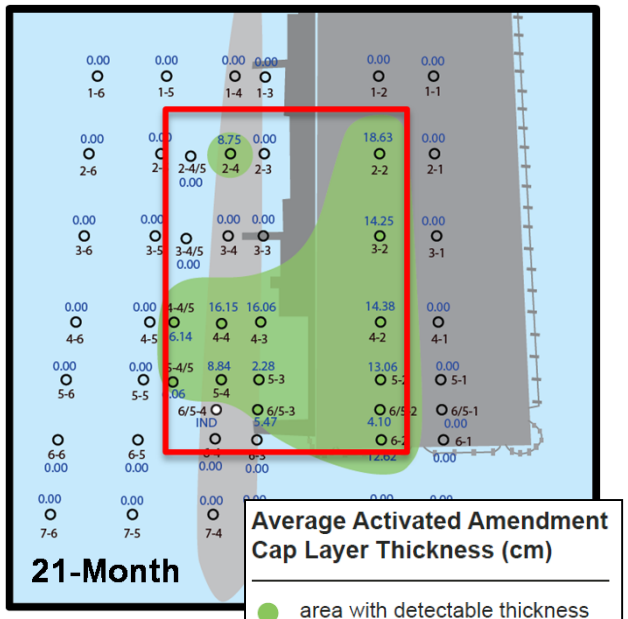


Transport modeling from Wang ESTCP Project ER-201031

Demonstrate Placement within Target Area at Target Thickness (SPI Survey)

- Lateral variations in amendment over time
- Portion of target area with amendment lower over time
  - ~80% in 0.5- and 10-month; ~70% in 21- and 33-month
- Average thickness lower in 10- and 33-month (7-9 cm respectively) compared to ~11 cm in 0.5- and 21-month

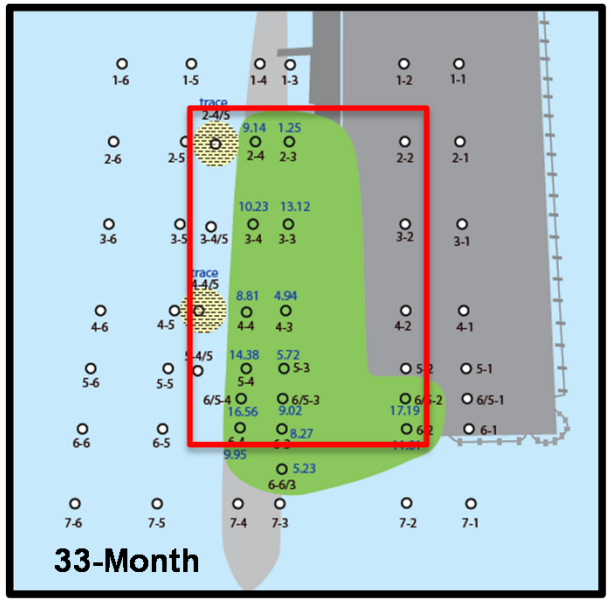




Average Activated Amendment Cap Layer Thickness (cm)

area with detectable thickness

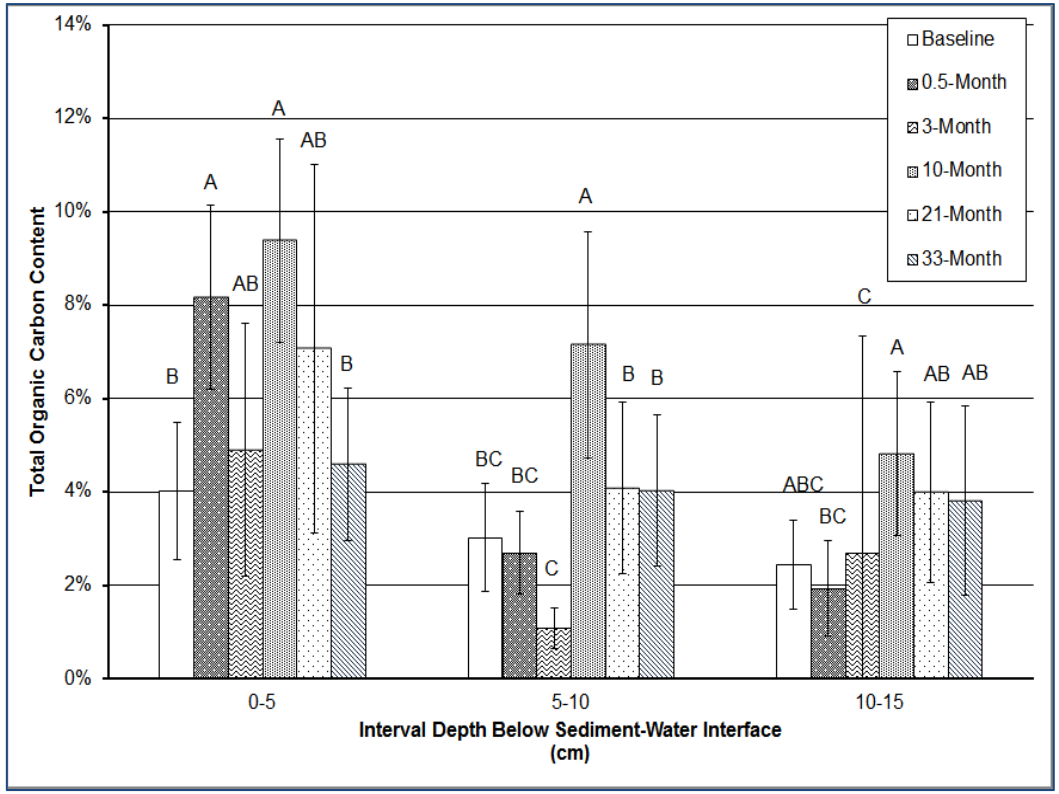
area with a trace



Red lines indicate target amendment area

Demonstrate Increase in AC Content in Surface Sediment (TOC Content)

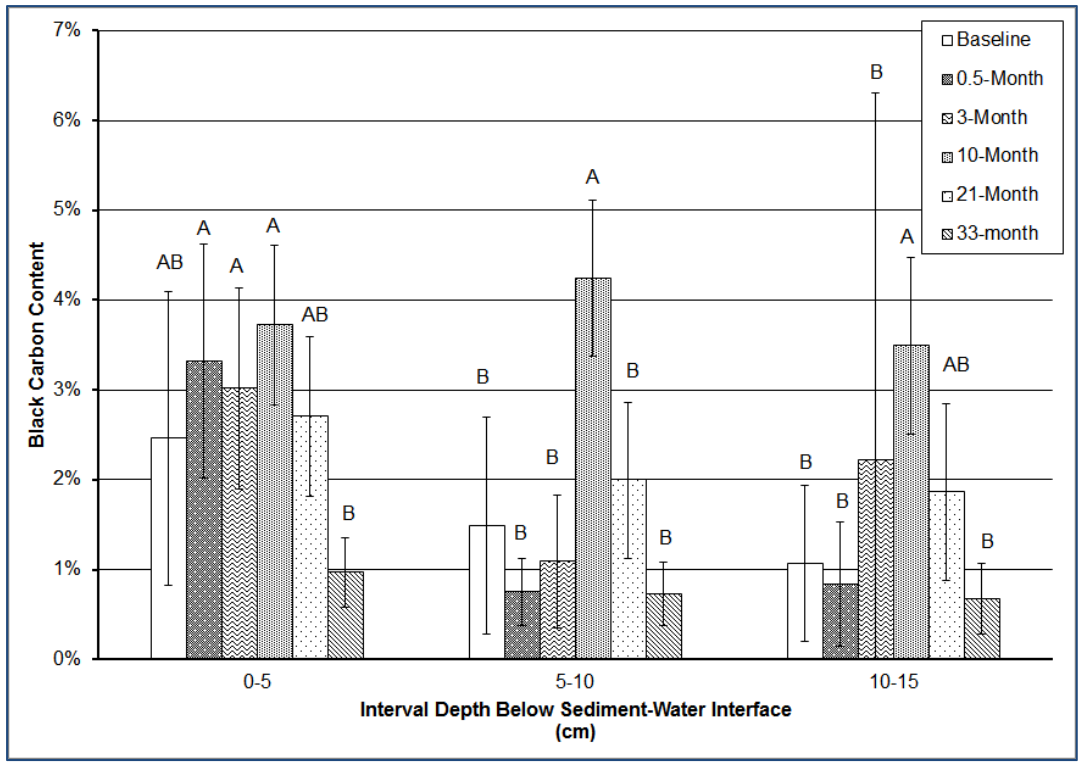
- Surface interval showed increase especially in earlier events
- Deeper intervals were comparable to baseline in earlier events, then increased in later events
- General trends consistent with surface placement mixing into deeper layers over time
- Uncertainty associated with the following
  - 3-month event possible sample processing issues
  - Generally high variability



Error bars are 95% CL
Differing letters indicate significant difference

Demonstrate Increase in AC Content in Surface Sediment (Black Carbon Content)

- Surface interval showed increase especially in earlier events
- Deeper intervals comparable to baseline in earlier events, then increased in later events
- Trends were similar to TOC with some exceptions
  - 3-month event BC was more consistent than TOC
  - 33-month BC was low across all intervals



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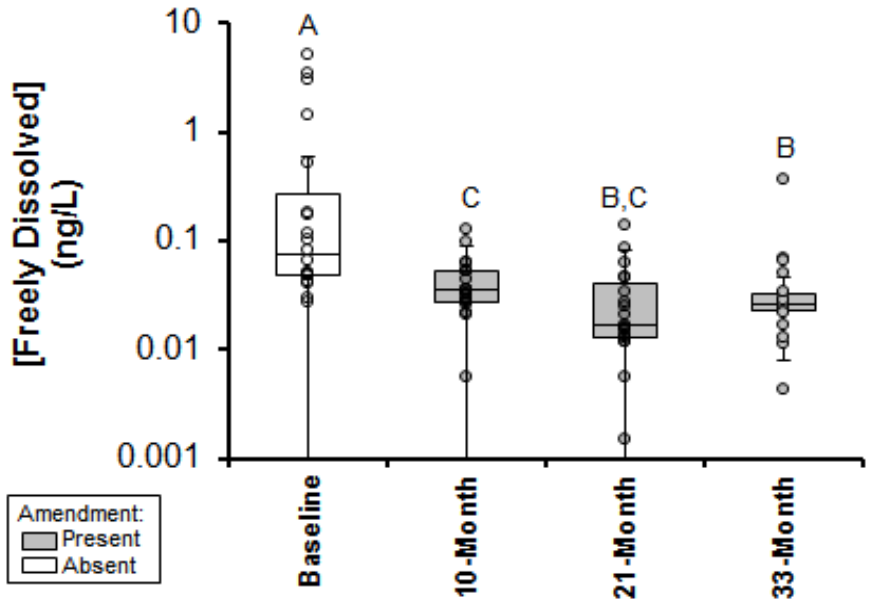
Differing letters indicate significant difference

Demonstrate Amendment Performance

Porewater Reduction (SPME)

- Significant decrease from baseline to subsequent monitoring events
- Total PCBs in porewater from baseline to 10-, 21-, and 33-month events were reduced 75%, 86%, and 81% on average



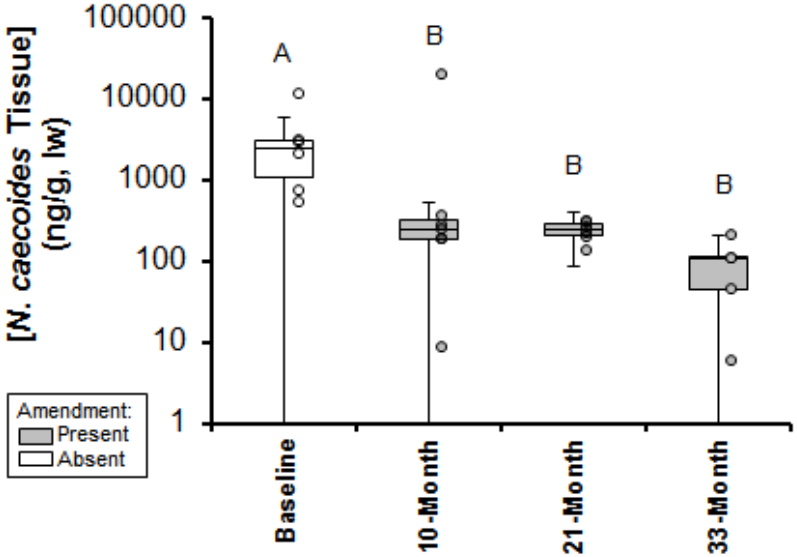
Error bars are 1.5 times IQR
Differing letters indicate significant difference

Demonstrate Amendment Performance

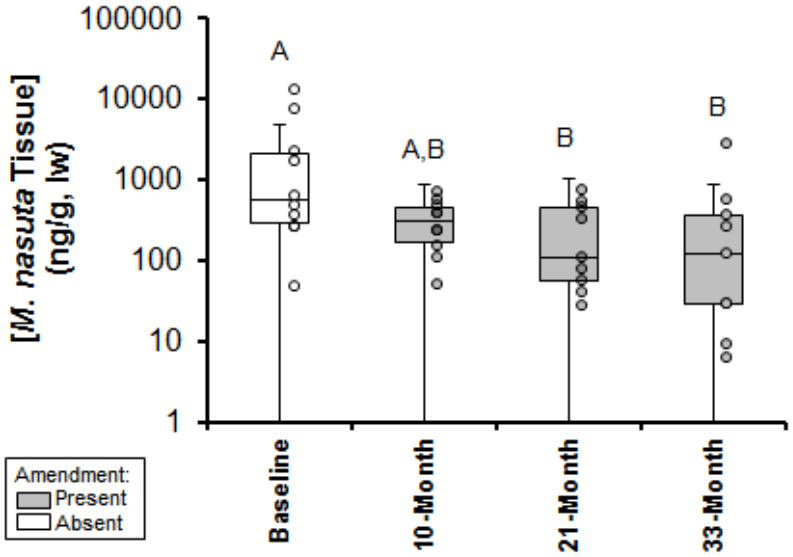
Bioavailability Reduction (Tissue)

- Decreases in bioavailability comparable to porewater reductions

Neanthes caecoides: Reduced 87%, 89%, and 97% compared to baseline



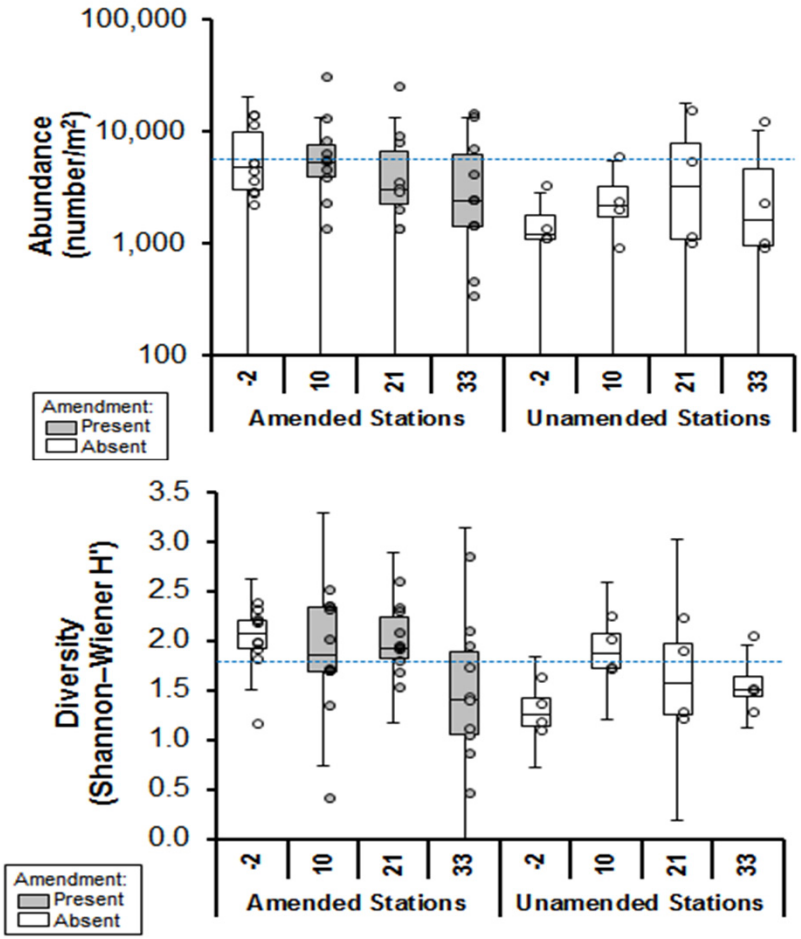
Macoma nasuta: Reduced 68%, 82%, and 88% compared to baseline



Error bars are 1.5 times IQR
Differing letters indicate significant difference

Evaluate Potential for Adverse Impact to the Native Benthic Community

- Benthic Community metrics generally comparable to baseline and/or reference
  - Abundance, evenness and dominance
- Some metrics changed from baseline but still comparable to reference areas
  - Diversity and taxa richness



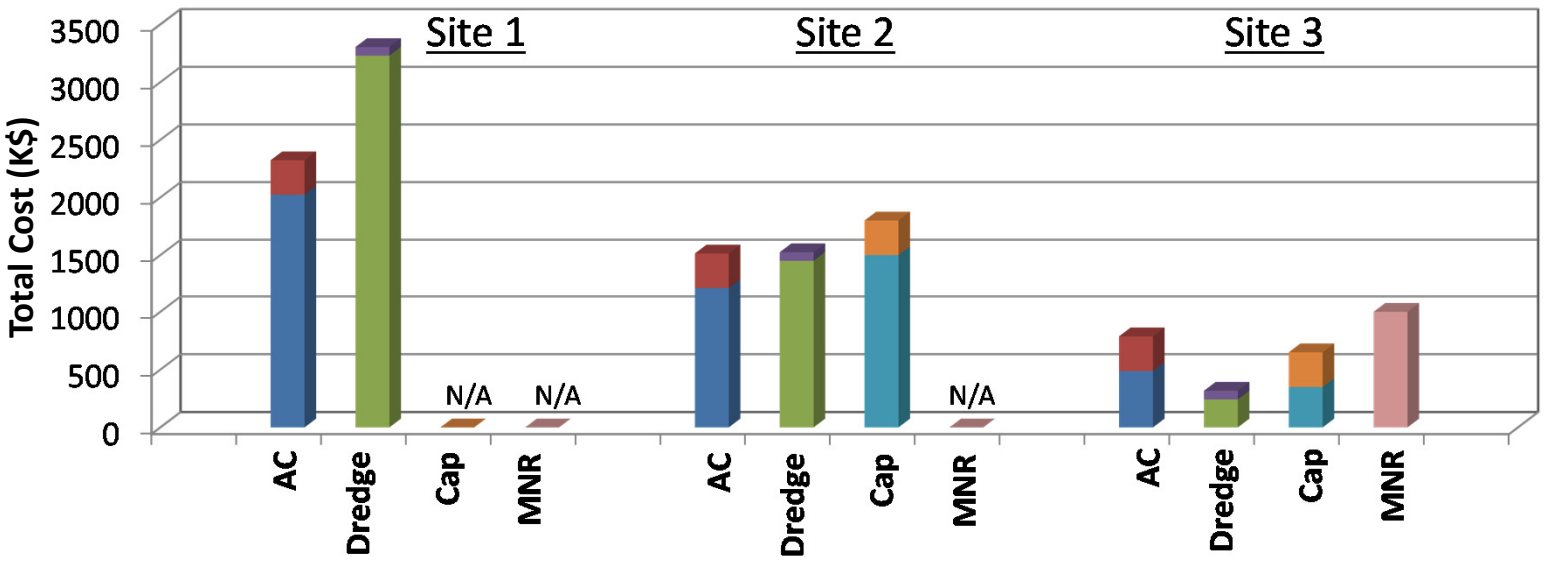
*Blue, dashed line indicates PSAMP observation

Cost Assessment

- Used cost data collected during demonstration to assess costs for three hypothetical sites compared to other traditional remedies
  - Site 1 - Larger (5 acre) site within deep waters of a harbor complex, high levels of debris, infrastructure, materials managed as hazardous wastes, contamination depth of 1 foot, scour from ship movement and currents
  - Site 2 - Medium-sized (3 acre) site in developed, coastal marine environment, steep slopes along the shore, high tidal flows, minimal debris, upland non-hazardous management, infrastructure, contamination depth of 1 foot
  - Site 3 - Small (1 acre) site along a flat bottom of a quiescent environment, highly depositional environment, upland disposal with minimal pretreatment, contamination depth of 1 foot

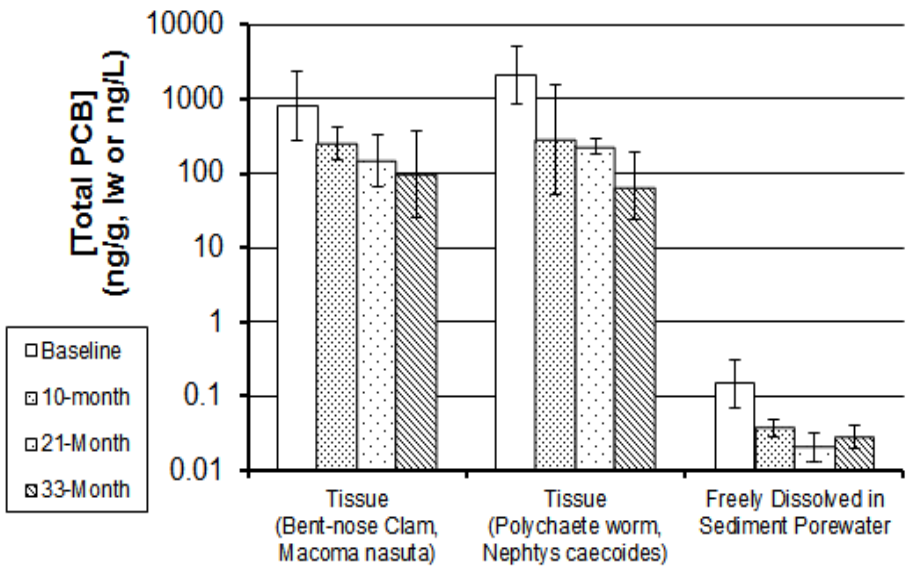
Cost Assessment

- Cost drivers
  - Material, shipment/storage, staging/placement and monitoring
- More cost-effective than dredging for sites with
  - Large dredge volume with hazardous/upland disposal
  - Refuse requiring removal prior to dredging
  - Infrastructure (piers, bulkheads, etc.)
- Comparable costs to capping



Key Points

- Activated carbon amendment is an effective remedy for PCBs under active harbor conditions
  - Effective placement within target area and target thickness achievable under active shipyard conditions
  - Sufficient stability and mixing of the activated carbon in the surface sediment
  - Significant reductions in total PCBs in tissue and porewater
  - Performance persistent for three years
  - No significant adverse impacts to benthic community observed
  - Cost competitive with other traditional remedies



Final Considerations

- Design and placement
  - Placement timing relative to ship movements
  - Remedy scale relative to transport scale
  - Working with processes vs. engineering against them
- Monitoring
  - Area-weighted approaches
  - Long-term monitoring, when do you stop
- Performance
  - Long term effectiveness >5 years
  - Only demonstrated for HOCs (PCBs)
  - Resilience advantages over other remedies
- Regulatory
  - Integrating reduced bioavailability metrics into remedial goals

Acknowledgements

- Project Team
  - Dr. Bart Chadwick (PI) and Ms. Victoria Kirtay, SSC Pacific
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- Site support and logistics
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  - Dr. Robert Johnston, SSC Pacific (at Bremerton, WA)

*Currently affiliated with Geosyntec

For additional information, please visit

https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Sediments/ER-201368

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Q&A Session 2

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