



Demonstration of an Activated Carbon Sediment Amendment at the Puget Sound Naval Shipyard & Intermediate Maintenance Facility, Bremerton, WA

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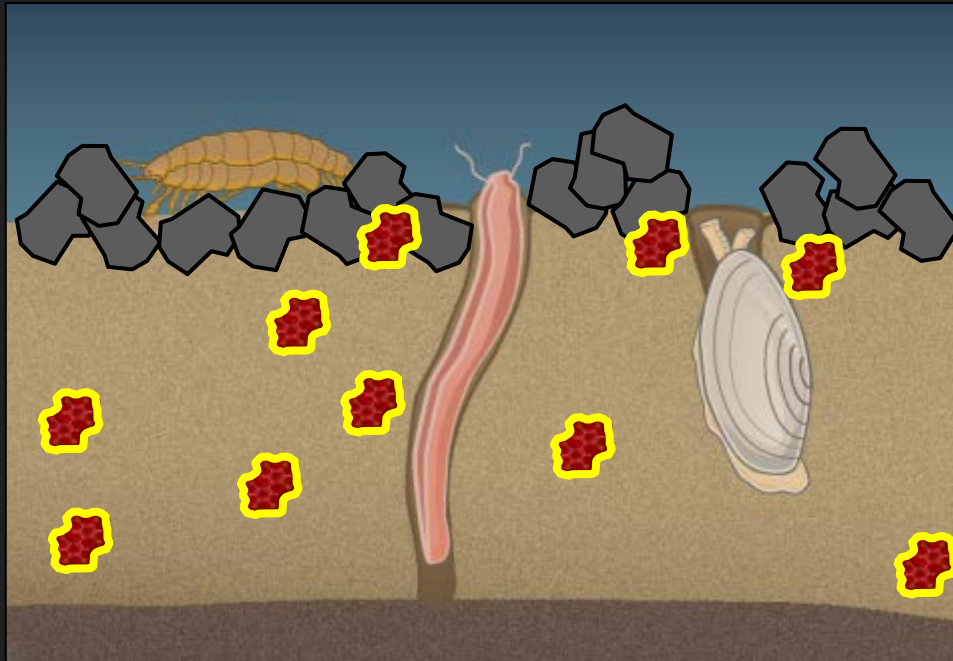
Western Dredging Association, Pacific Chapter
2013 Annual Meeting
October 25, 2013
Renaissance Hotel
Long Beach, California



Overview

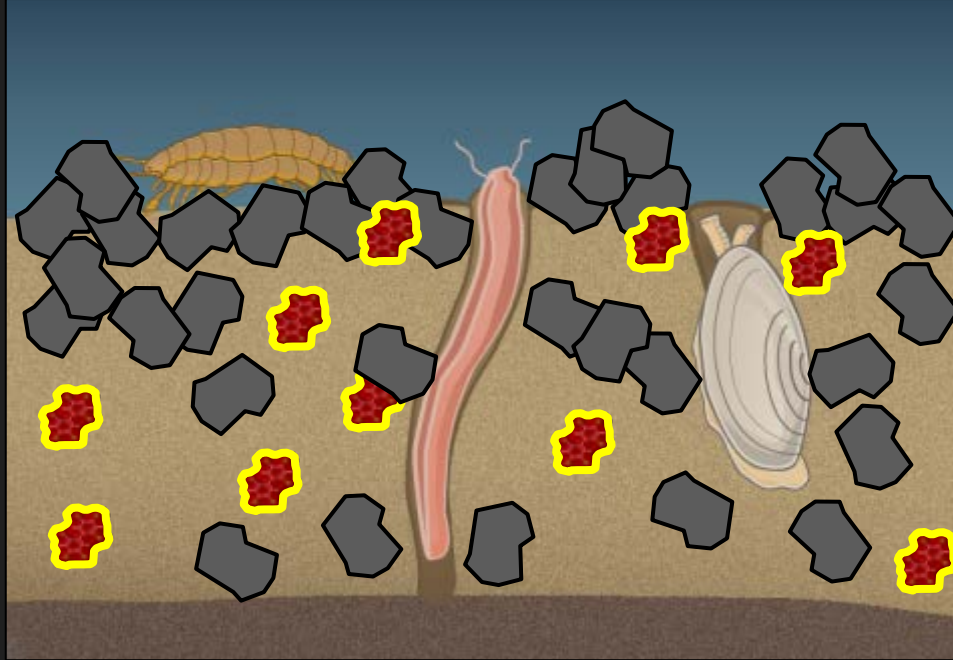
- Reactive amendment capping
 - Addition of materials (carbon) to aquatic sediment to sorb bioaccumulative chemicals
 - Not an isolation barrier

Reactive Amendment Capping



- Reactive amendment added to surface of sediment

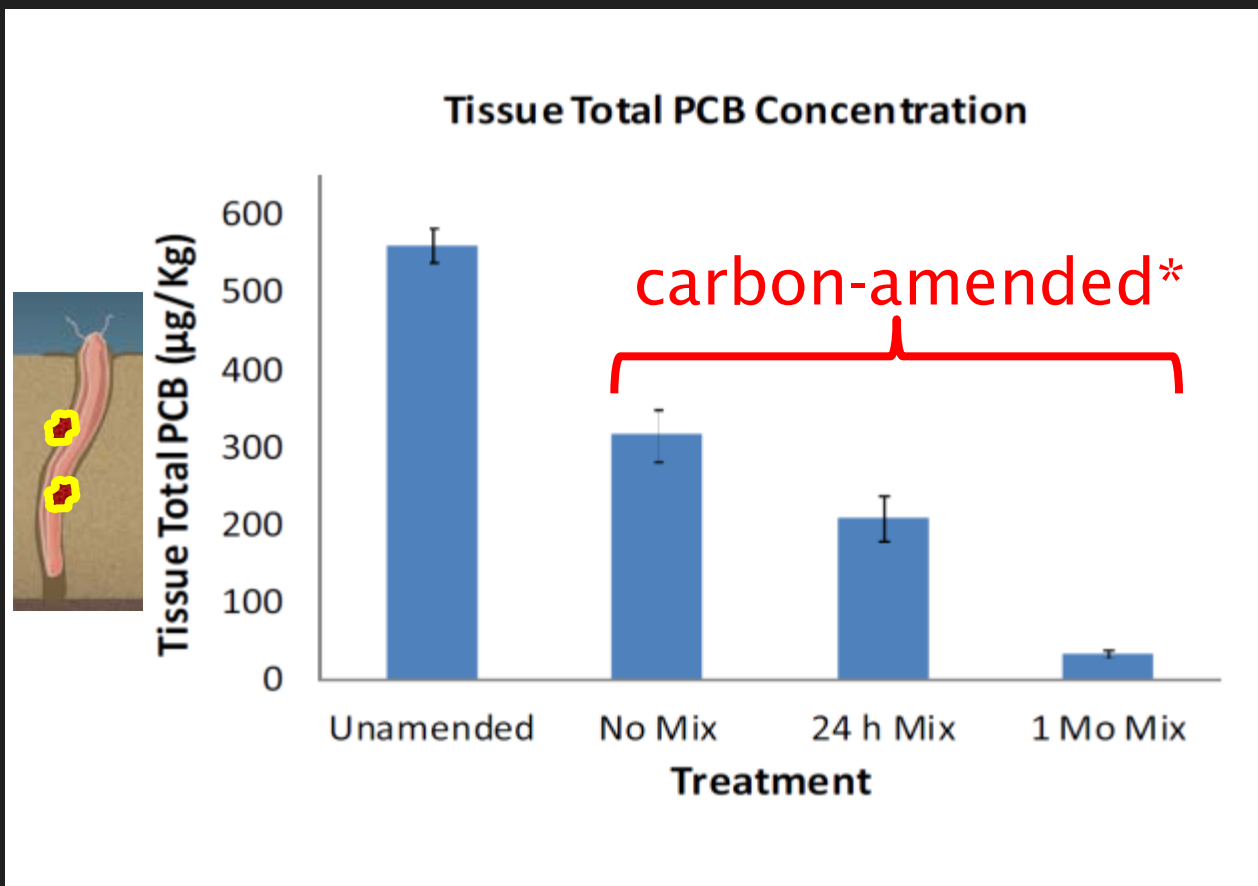
Reactive Amendment Capping



- Reactive amendment mixes in to biologically active layers of sediment and sorbs freely-dissolved chemicals, reducing availability

Example Effectiveness

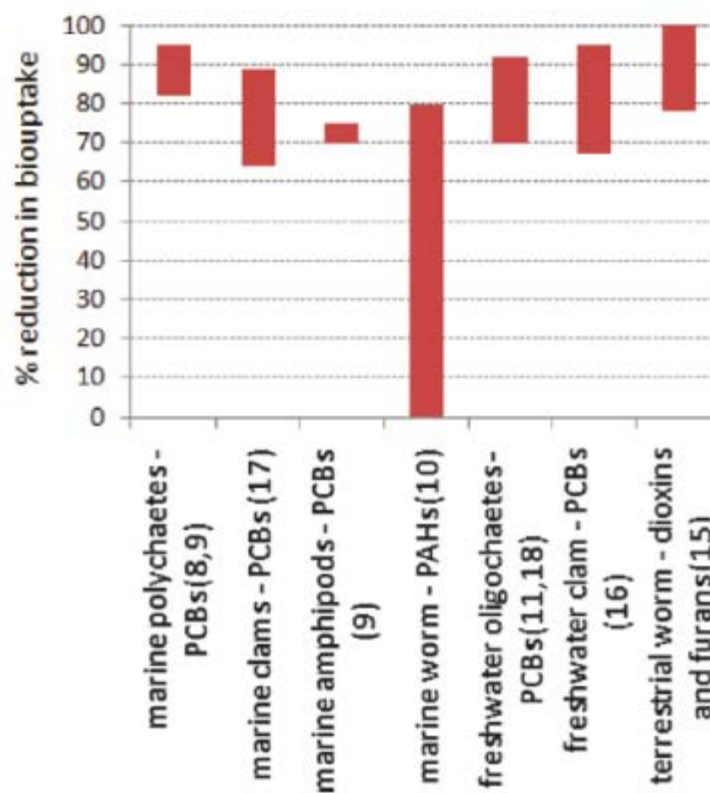
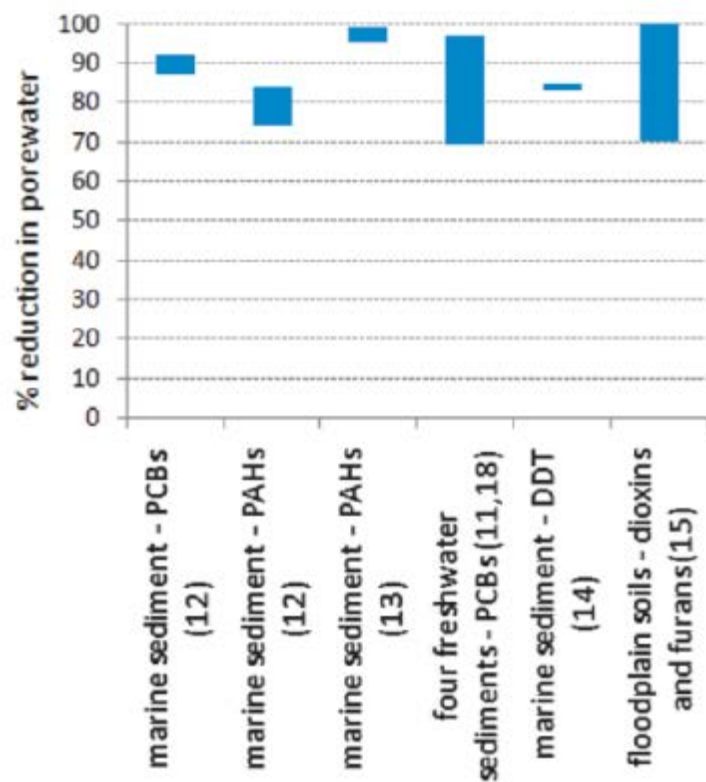
- Bench-scale tests indicate a ~50-90% reduction in PCB availability to sediment invertebrates



*Amendment added at rate to increase sediment carbon content by 3.5%

Example Effectiveness

- Other bench-scale and pilot field tests indicate similar 70-90% reduction in organic contaminant availability



Pros and Cons

- **Pros**

- Costs: ~\$10-15/ft²
 - Much less expensive than dredging (3-10X); Comparable to capping
- Application under/near infrastructure (piers, bulkheads)

- **Cons**

- Unfamiliar/unproven (academic projects)
- Engineering (delivery) challenges
 - Carbon floats
 - Accuracy in placing amendment under/near infrastructure
- Long-term efficacy in question
- Possible adverse effects on invertebrates
- Focus on organics

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Objectives of
our Bremerton
Demonstration

Demonstration Approach

Demonstration Approach

- Demonstration and validation of reactive amendment capping to reduce PCBs, Pier 7, Puget Sound Naval Shipyard & Intermediate Maintenance Facility, Bremerton, WA



Demonstration Approach

- Targeted 0.4-acre area with PCBs in sediment (~100-6,000 $\mu\text{g}/\text{kg}$)
- 40-50 feet deep
- Active pier



Portion of footprint under-pier

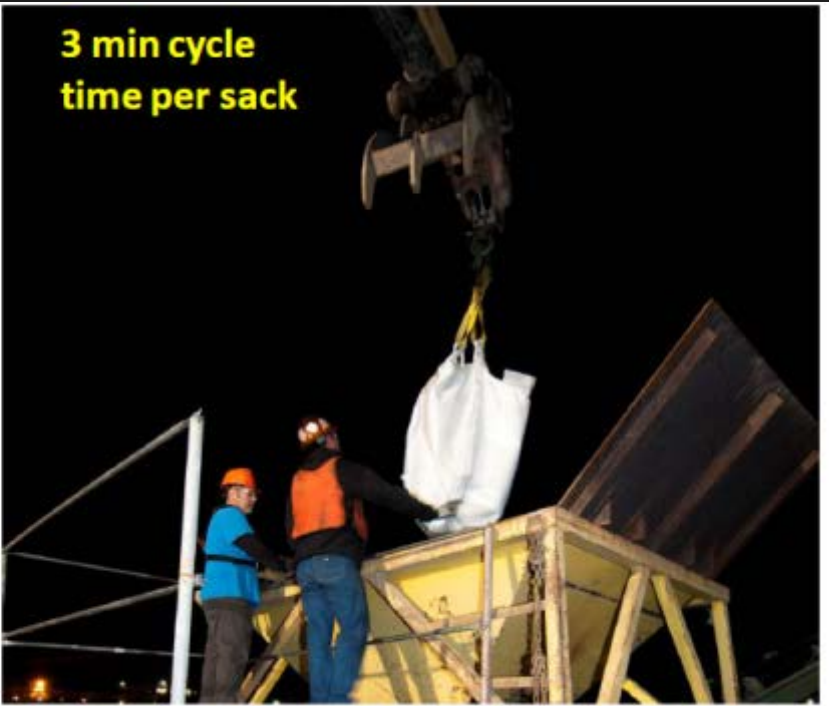


Demonstration Approach

- Activated carbon (AquaGate + PAC™) delivered via barge-mounted conveyor



Demonstration Approach



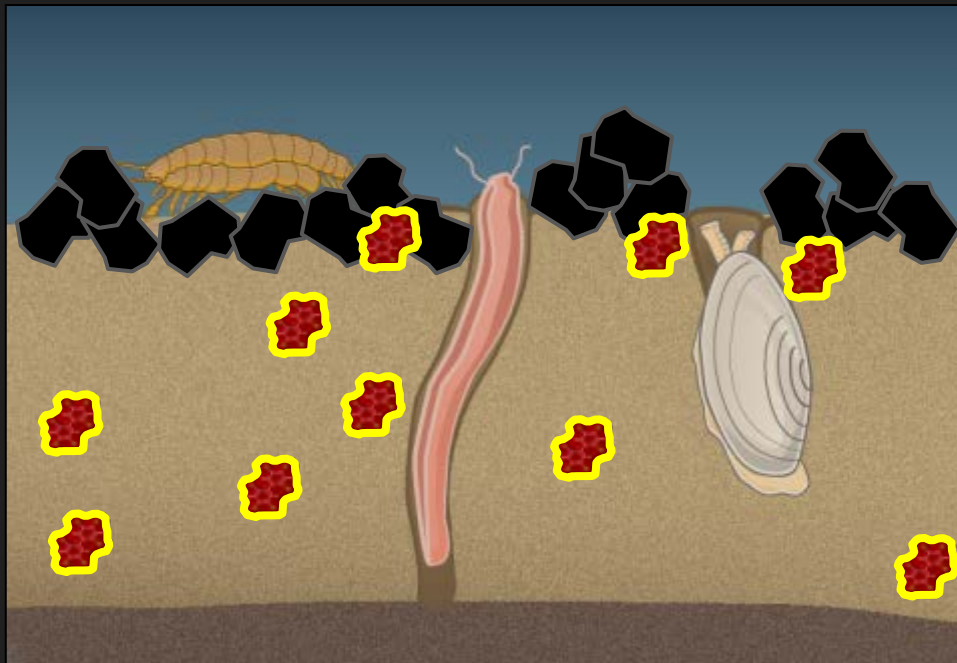
Demonstration Approach



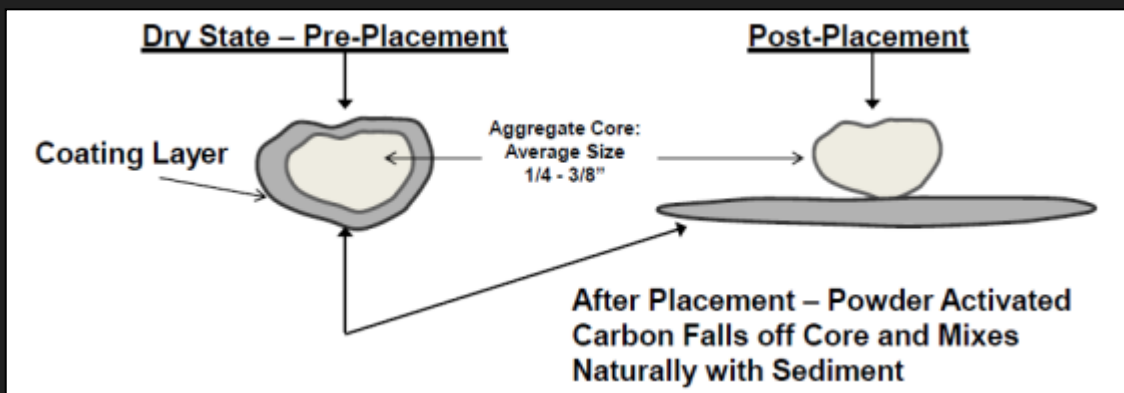
Demonstration Approach



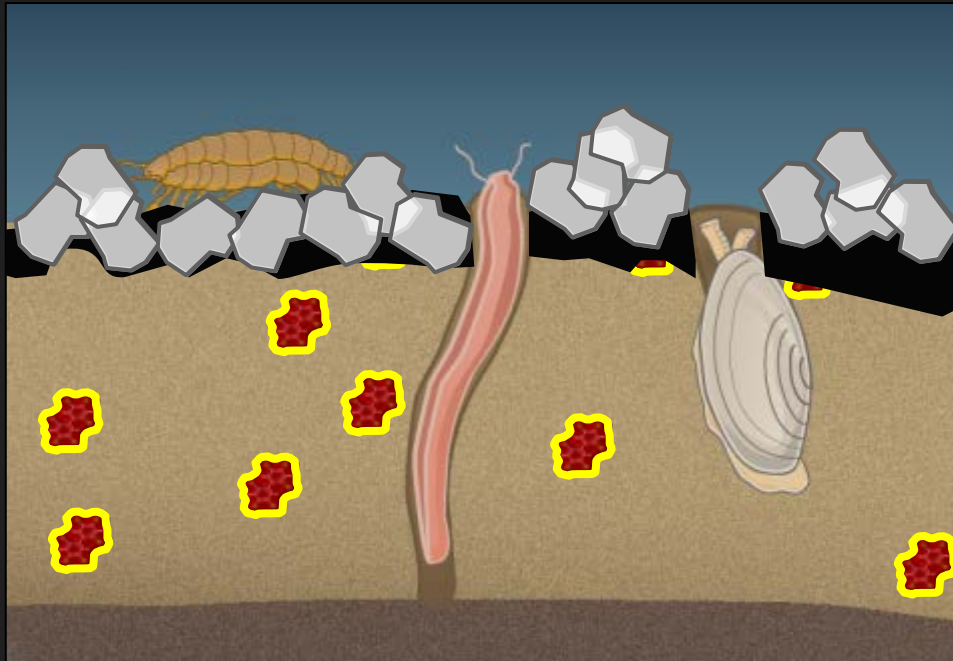
Demonstration Approach



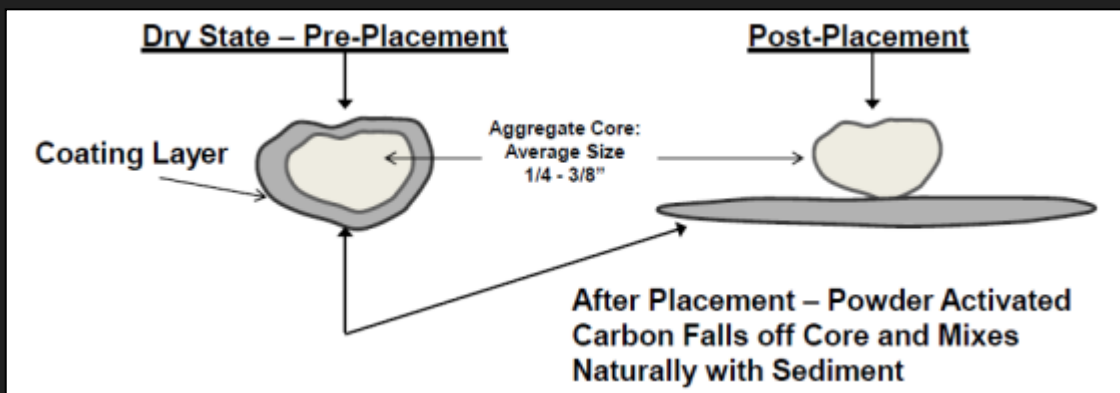
- Targeted 5-cm (2-inch) amendment layer
- AquaGate + PAC™ settles primarily on sediment surface (minor penetration for soft sediment)



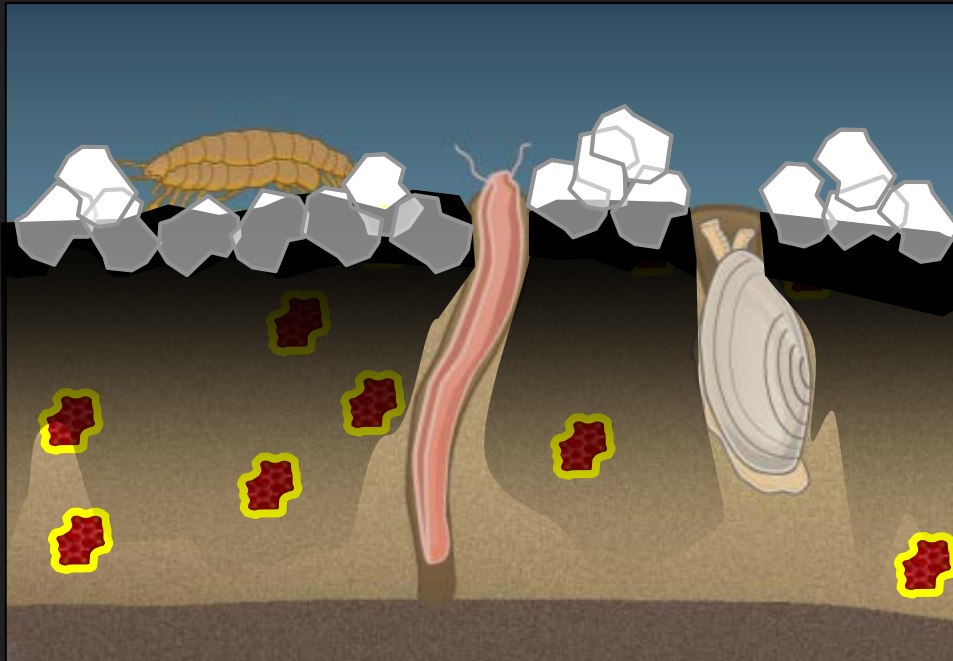
Demonstration Approach



- Within 1-2 hours, activated carbon sloughs off from aggregate core



Demonstration Approach



- Over time, activated carbon further penetrates surface sediment via settling, bioturbation, and deposition

Evaluation of Amendment Application

Measurements

- Initial spatial coverage
- Initial amount (vertical)
- Stability/mixing over time

Line of Evidence	n	Time (Months)					
		0	0.5	3	10	22	34
Visual Observation, Diver Cores	10	●			●	○	○
Total Organic Carbon & Black Carbon, Diver Cores	10	●	●	●	●	○	○
Sediment Profile Imagery (SPI)	42	●	●		●	○	○

●: collected; ○: planned

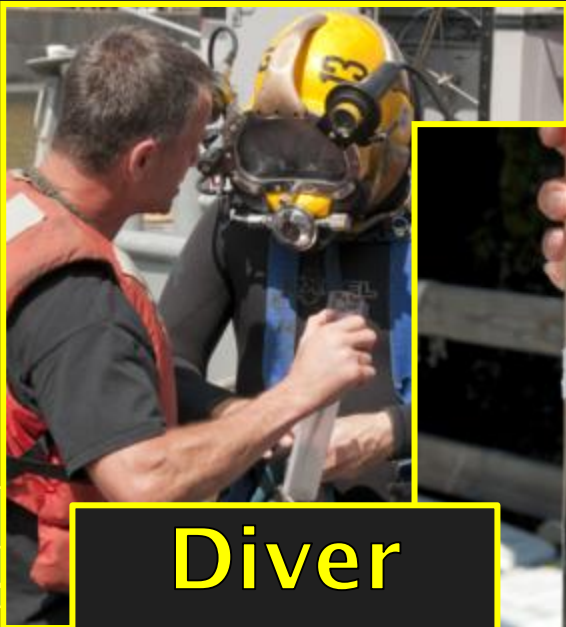


Measurements

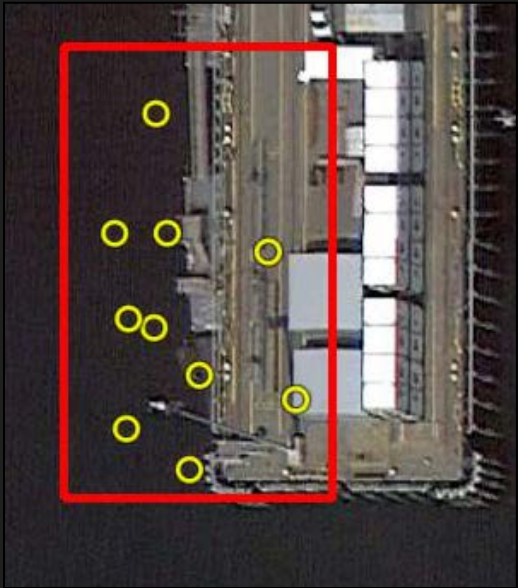
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Diver Cores



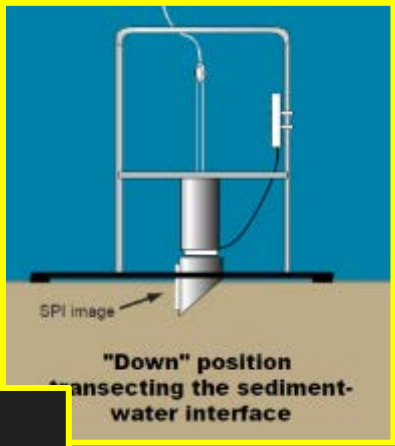
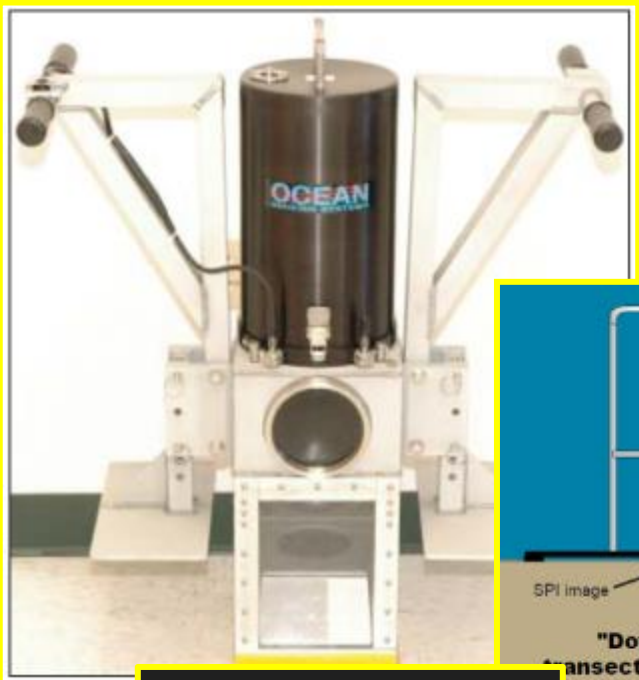
IRON

Measurements

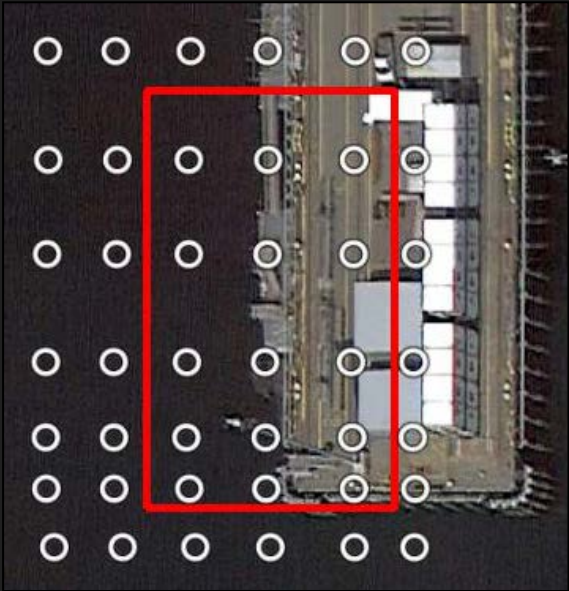
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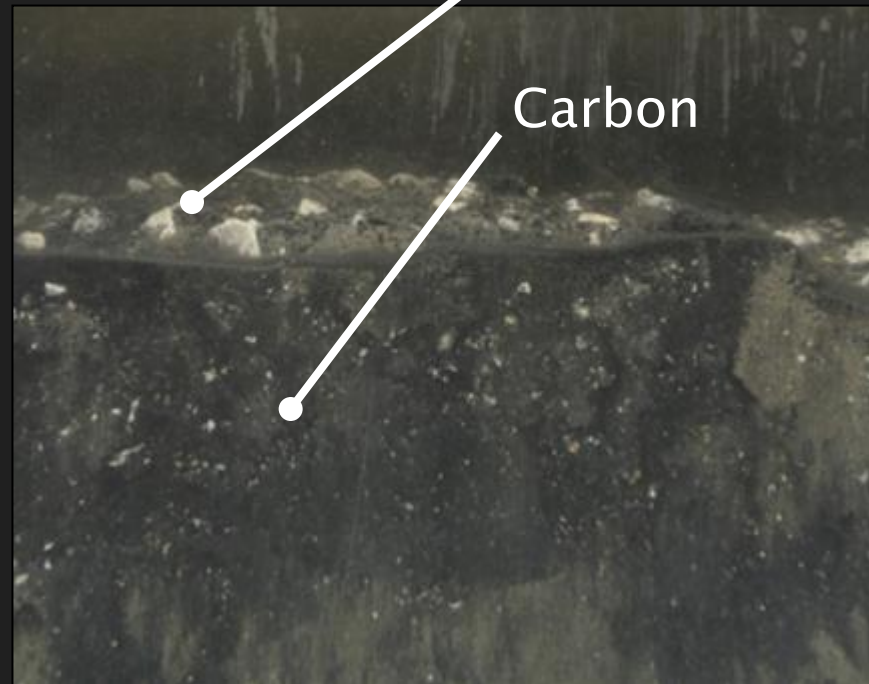
SPI



Sediment Profile Imagery



Before



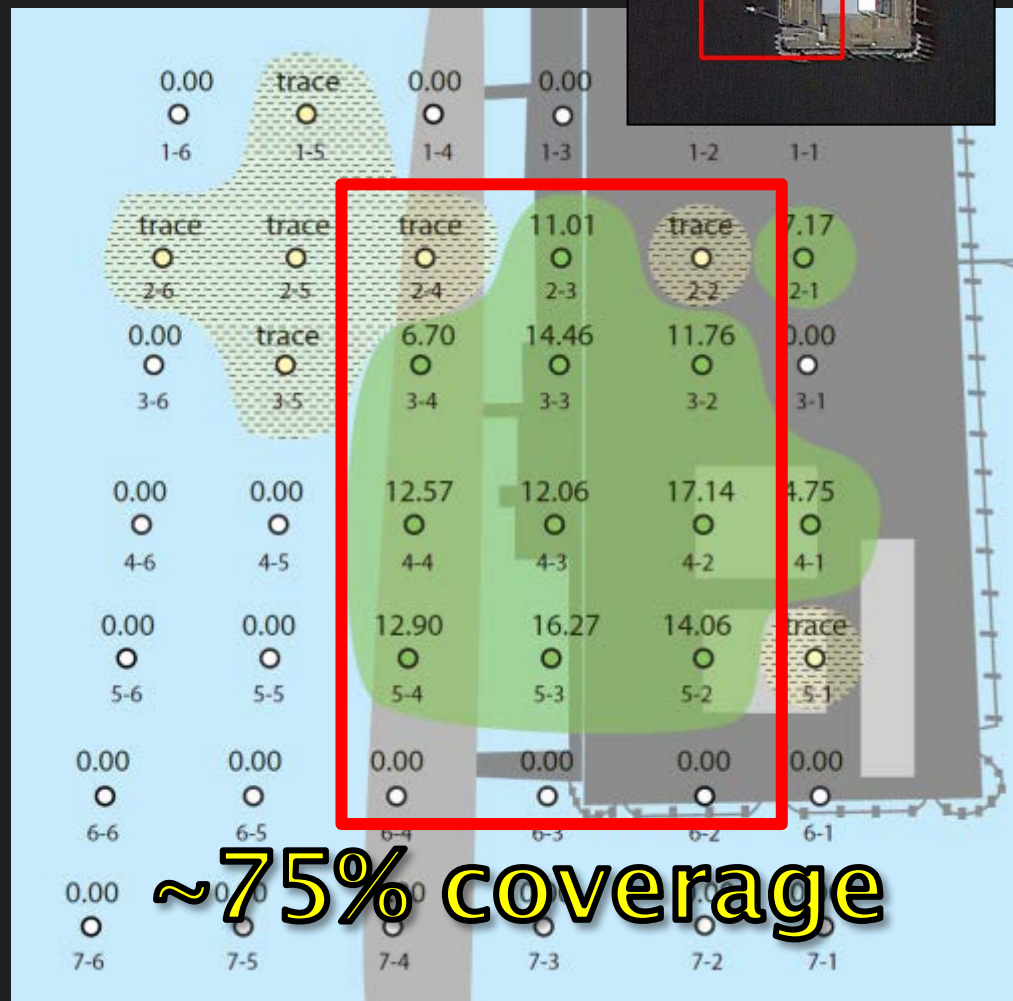
**2 Weeks Post
Amendment**

Initial (0.5-month) Coverage

- ~75% of target area received at least a trace of amendment
 - ~70% of the target area received target thickness (5 cm) or more
- Green area averaged 13 cm (SD 2.9)

Average Activated Amendment Cap Layer Thickness (cm)

- area with detectable thickness
- ▨ area with a trace



10-month Diver Cores

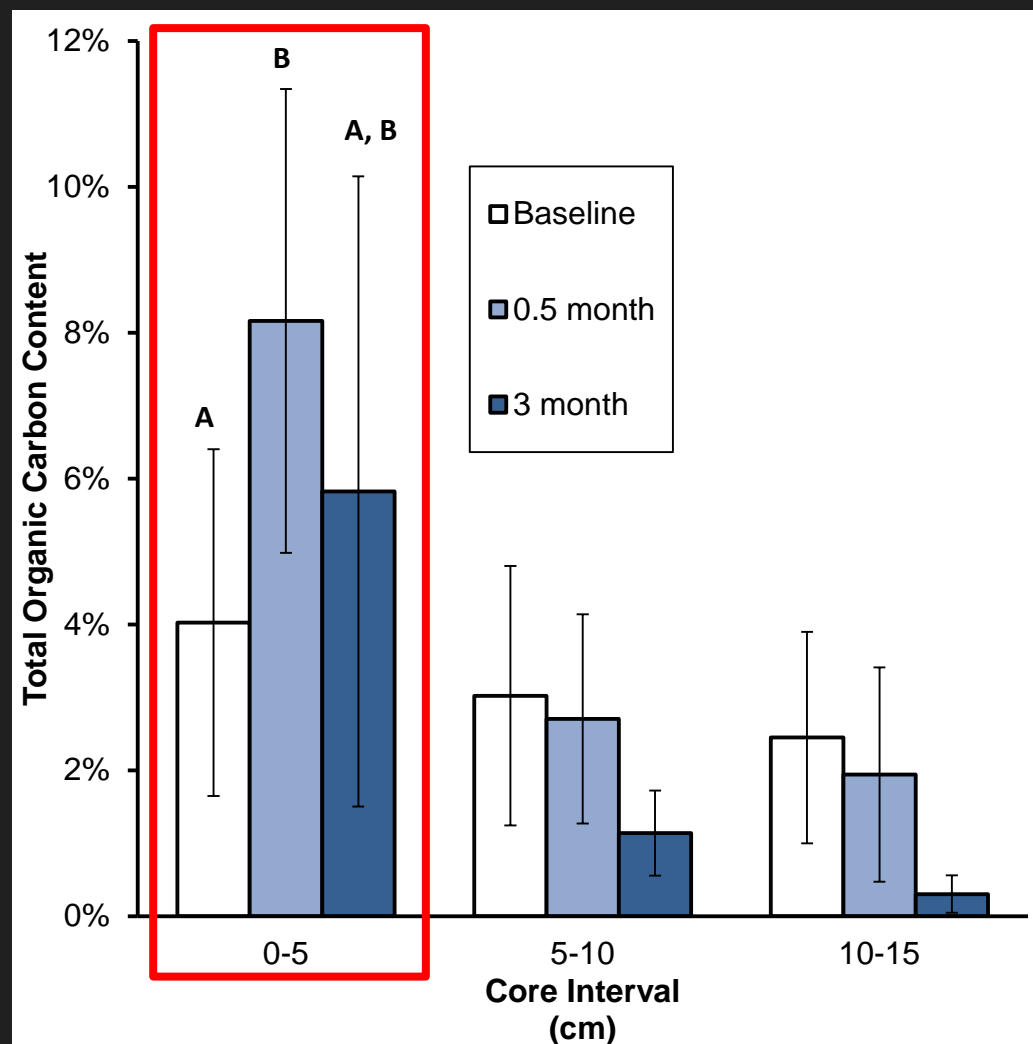
- Aggregate still in place after 10 months
 - Core data indicate similar coverage and amendment thickness 10 months post-application
- Percentage of stations with aggregate, by depth
 - Top 5 cm: 90% of stations
 - 5-10 cm: 60% of stations
 - 10-15 cm: 40% of stations
- *10-month SPI results not yet available*



Was Carbon Content Increased?

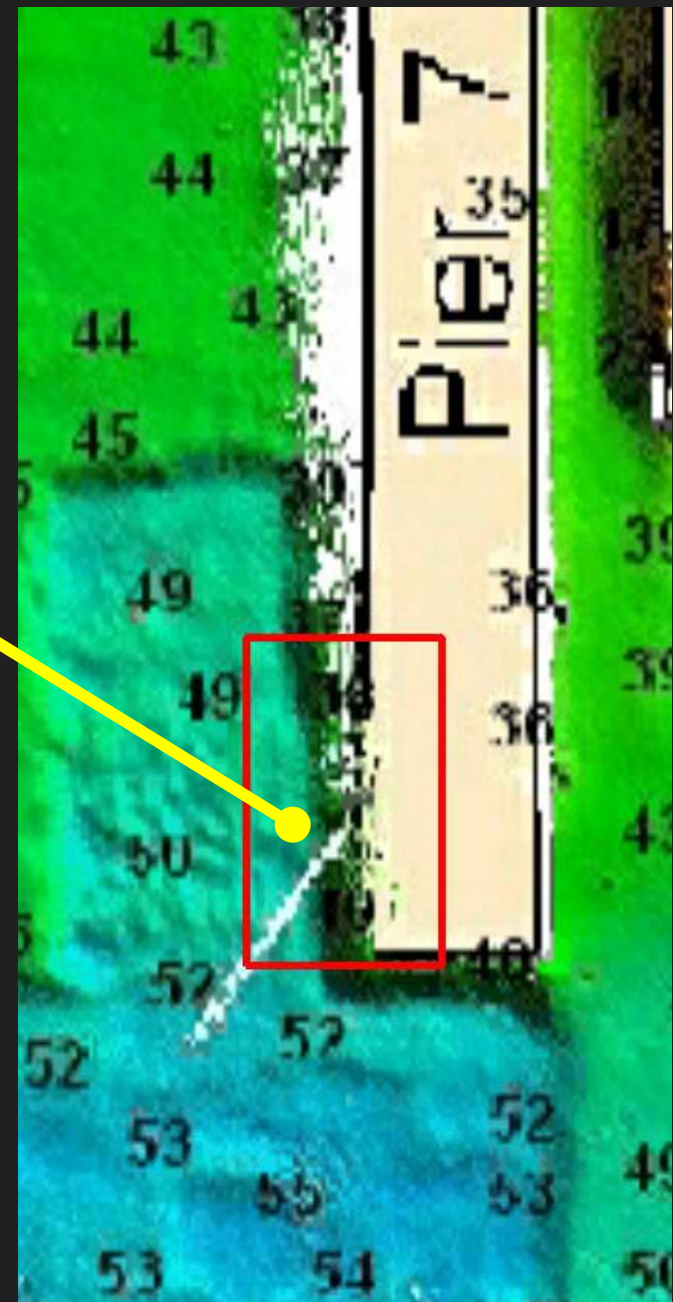
0.5- and 3-Month TOC/BC Data

- TOC/BC data highly variable
- TOC in top 5 cm
 - Significant increase of ~4% 0.5 months after amendment addition
 - 3-month data inconclusive
 - Slight (1-2%) differences between monitoring events when measurements vary widely from location to location)
 - Carbon mixed in or eroded?
- *10-month TOC/BC results not yet available*



Video Survey (Divers)

- Video survey by divers (10-month monitoring) confirmed aggregate coverage even on steep slopes ($\sim 45^\circ$) adjacent to Pier 7



Evaluation of PCB Availability

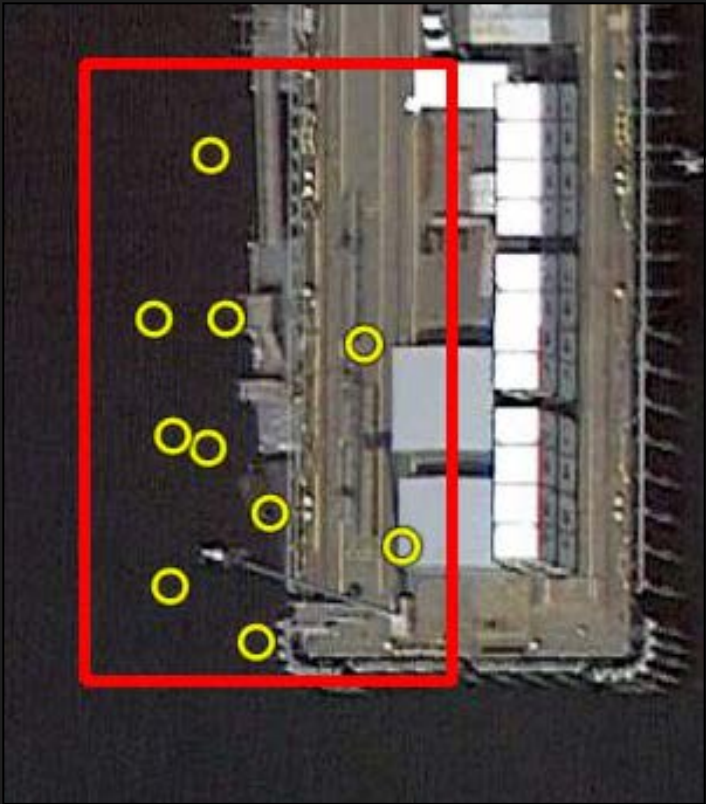
Measurements

- PCB availability before and after

Line of Evidence	n	Time (Months)					
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14-d <i>in situ</i> Bio-accumulation Tests	10	●			●	○	○
Sediment Porewater	10	●			●	○	○

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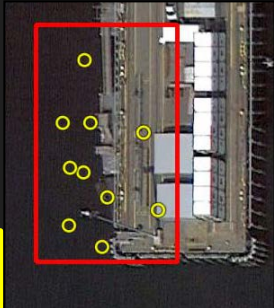
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Measurements

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SeaRing



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Measurements

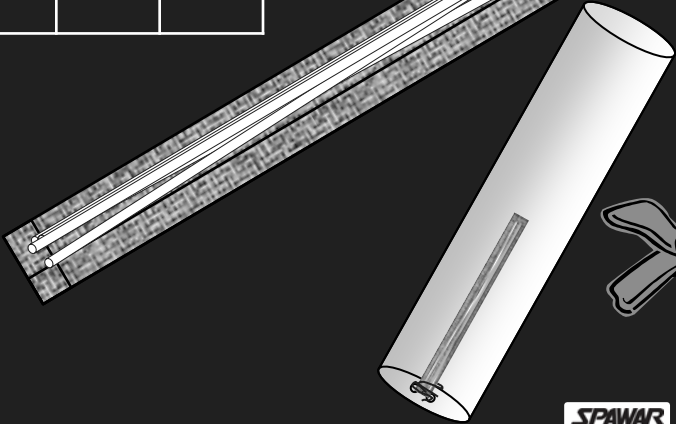
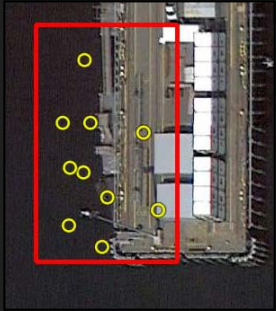
- PCB availability before and after

in situ
SPME

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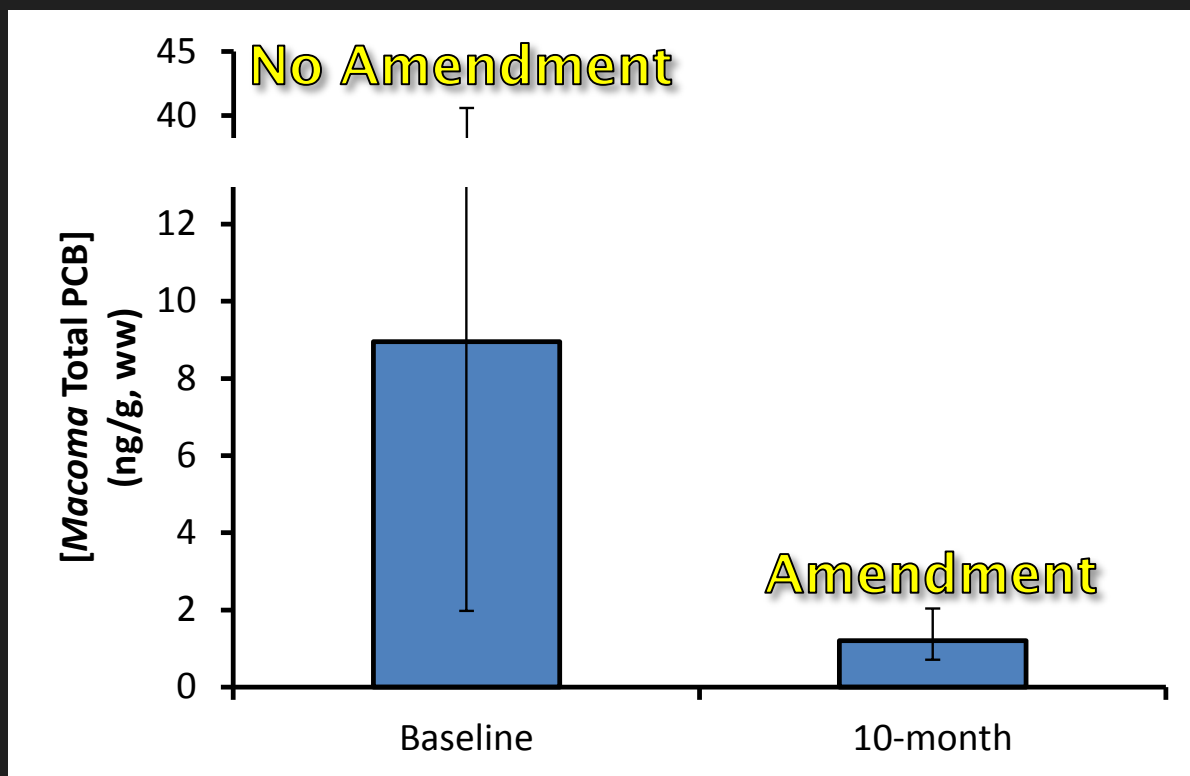
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10-month porewater results not yet available



In situ PCB Bioaccumulation

- Significant reduction (~90%) in PCB bioavailability to sediment invertebrates (draft data)
 - Concurrence with 90% reduction in concentrations in tissues as observed in the initial lab study
 - Reduction not due effect of dilution due to aggregate addition (no significant difference in [PCB sediment])



Evaluation of Effects of the Amendment on the Native Benthic Community

Grabs

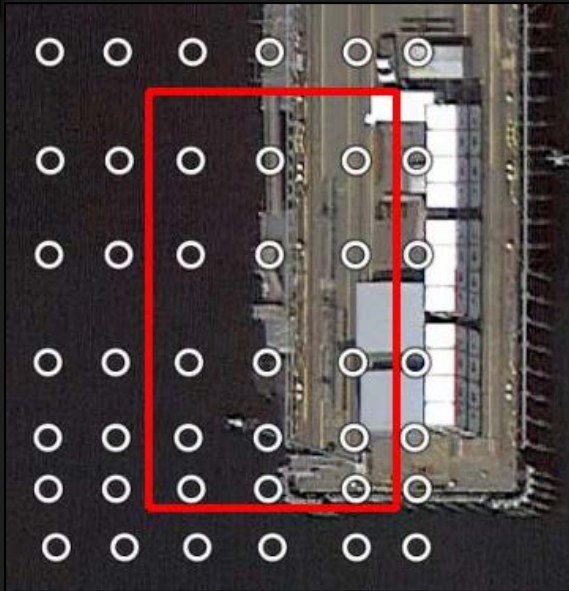
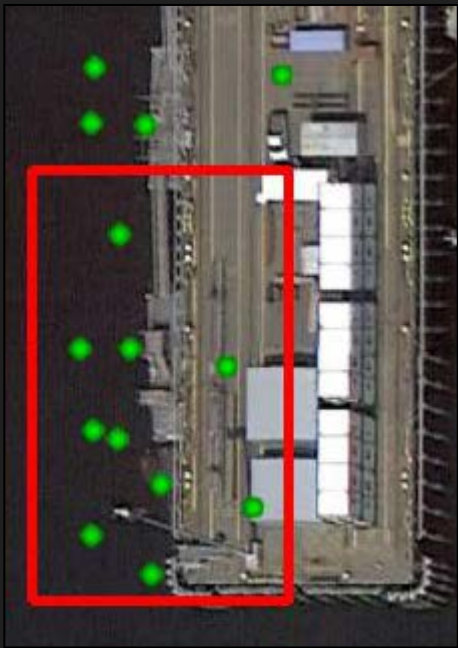
- Benthic community before and after

Line of Evidence	n	Time (Months)					
		0	0.5	3	10	22	34
Benthic Census Grabs	14	●			●	○	○
Sediment Profile Imagery (SPI)	42	●	●		●	○	○

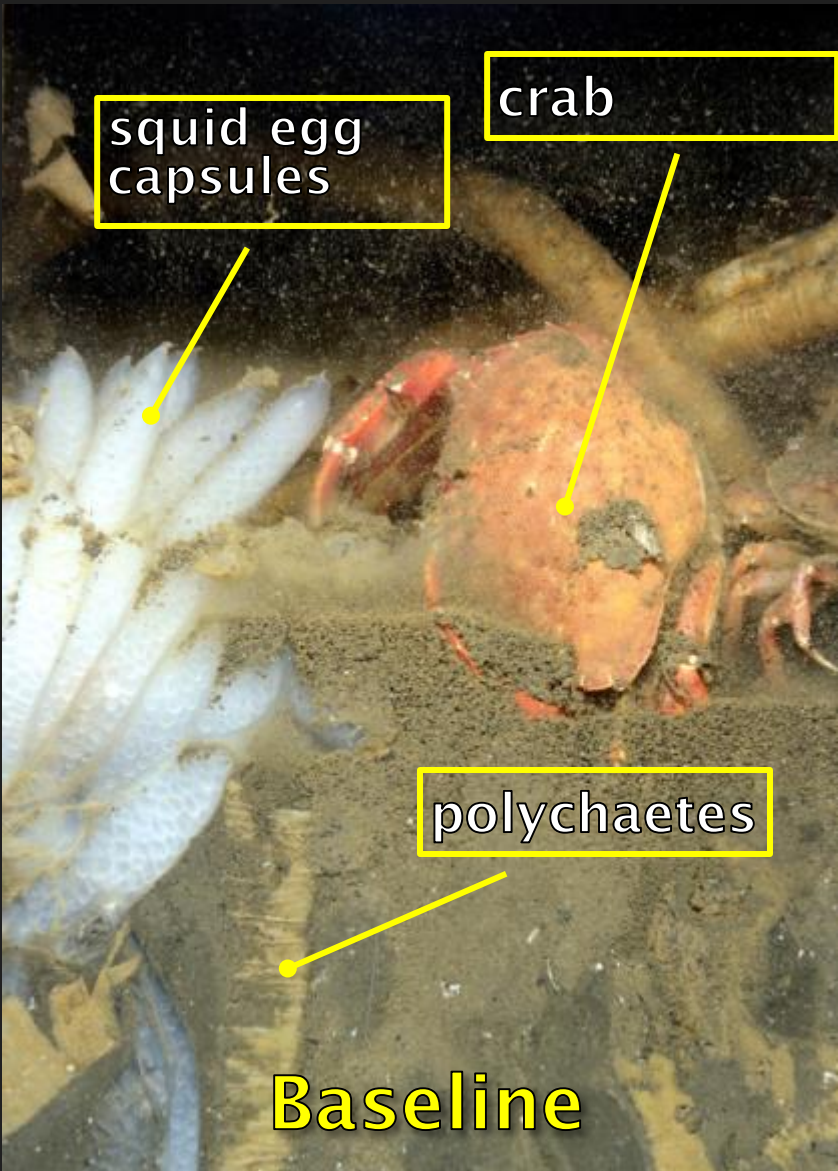
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10-month SPI and grab results not yet available

SPI



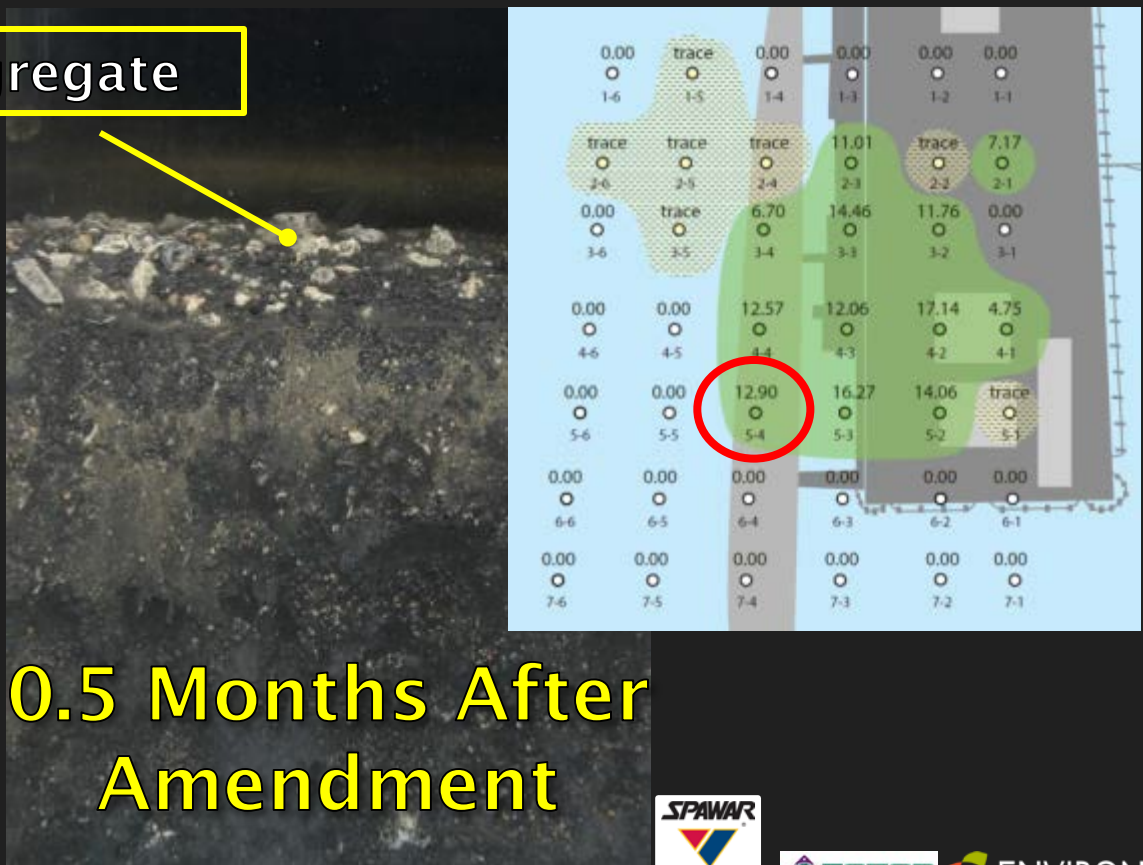
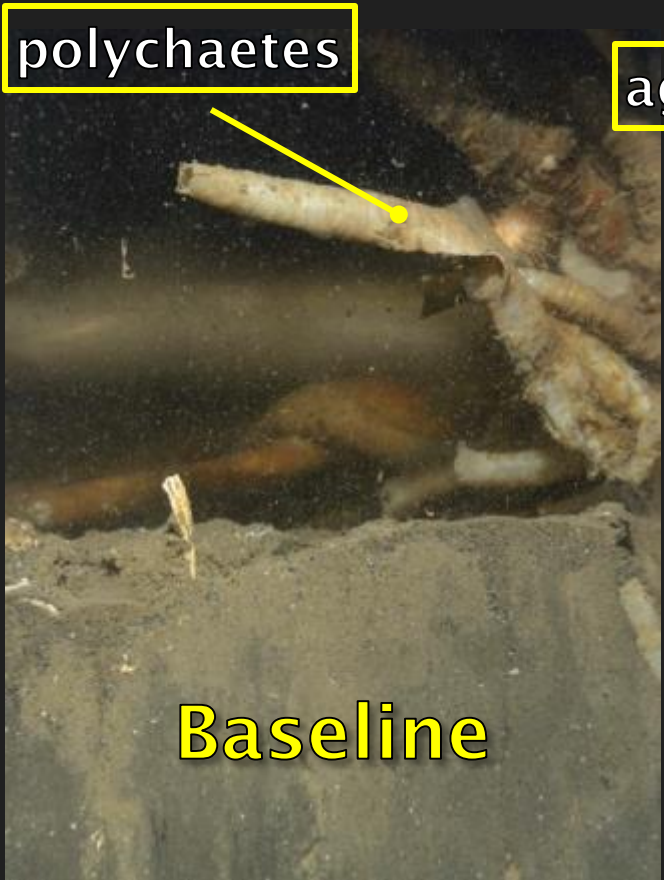
Sediment Profile Imagery



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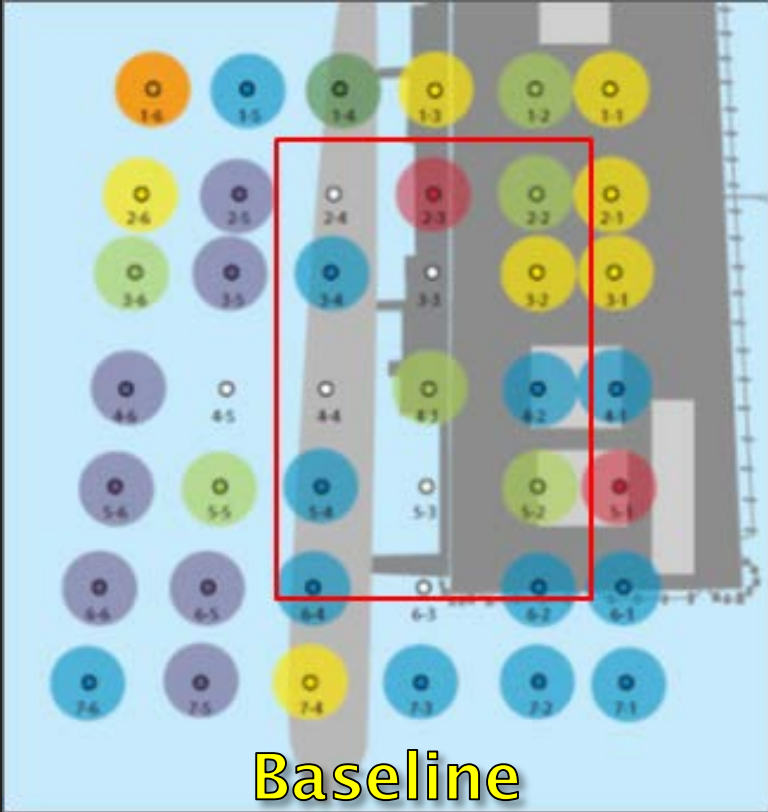
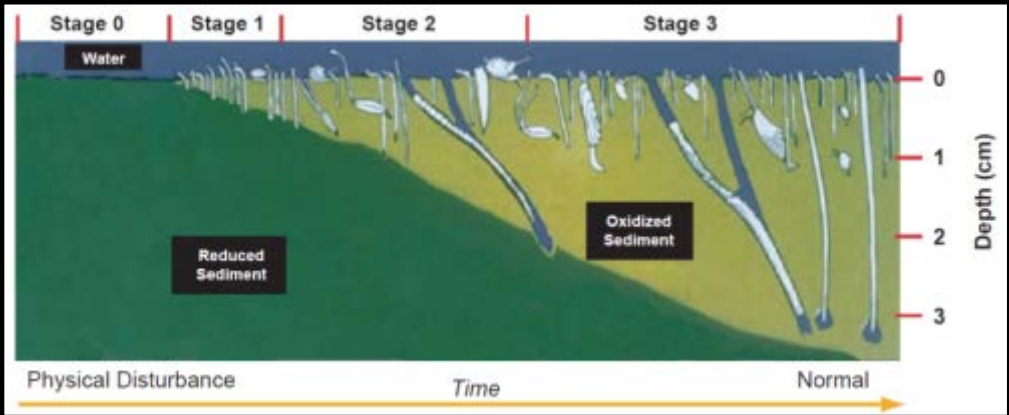
Baseline vs. 0.5 Month

- Partial minor disruption of the sabellid polychaete community in the amendment area due to burial
 - Before amendment, 6 of the 24 stations with sabellid polychaetes; After amendment: 3 of the 24 stations

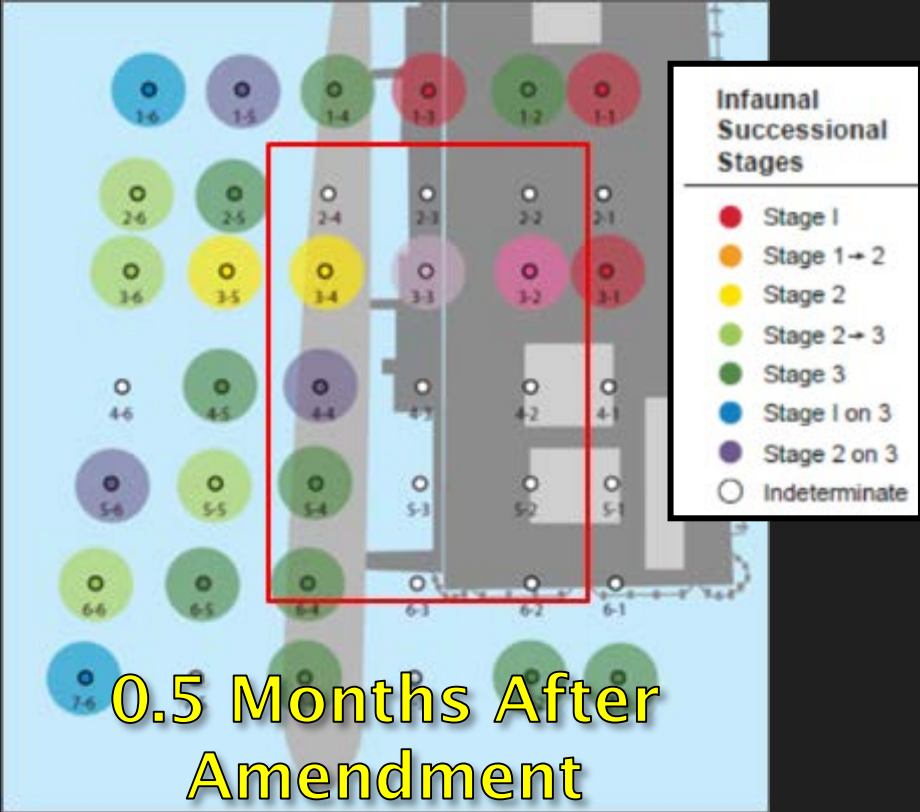


Sediment Profile Imagery

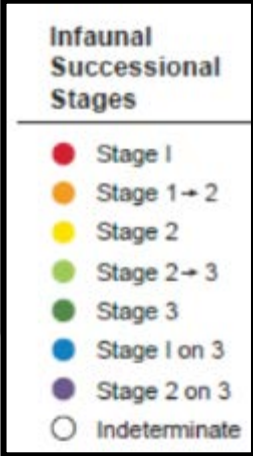
Benthic Successional Stage



Baseline

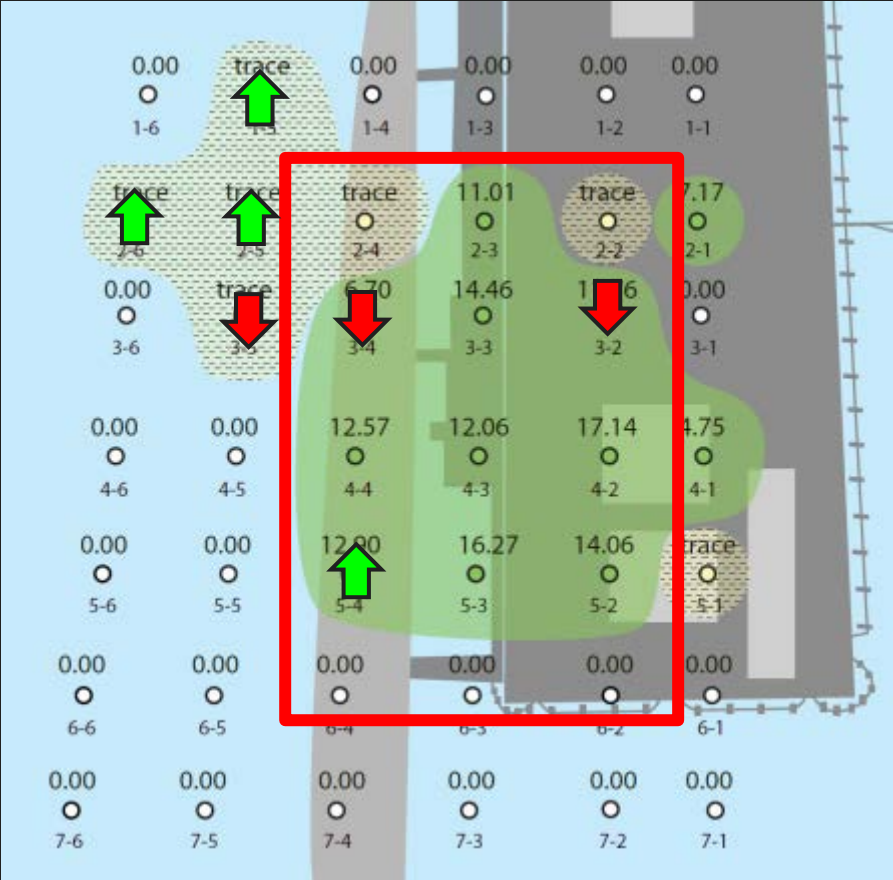


0.5 Months After Amendment

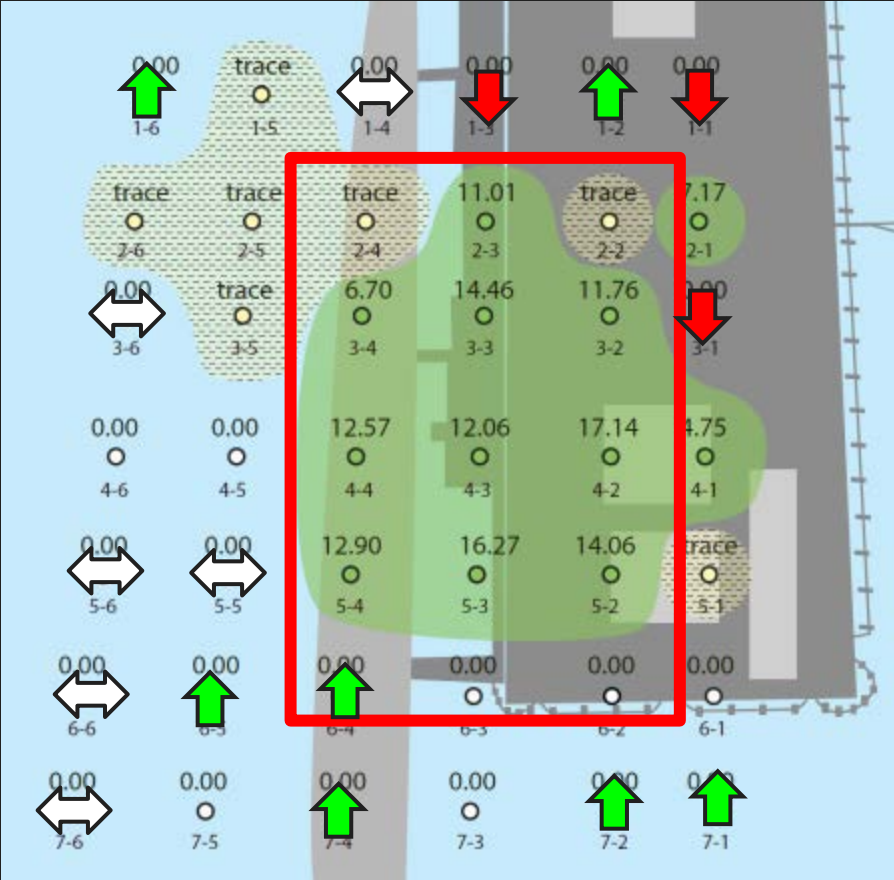


Sediment Profile Imagery

Change in Benthic Successional Stage 0.5-months After Amendment



Amendment
3 of 7 (43%) Stations
Indicated Decrease (↓)
($P = 0.83$)



No Amendment
3 of 16 (19%) Stations
Indicated Decrease (↓)
($P = 0.17$)

Conclusions

- **Activated carbon amendment successful and promising effective remedial alternative**
 - PCB availability reduced by 90%
 - Engineering
 - Successful under-pier/on slope
 - Accuracy: ~75% of total footprint covered
 - Increase in organic carbon in surface sediment
 - Amendment present 10-months
 - Side-effects
 - Inconclusive/very minor native benthic community effects 0.5 months after amendment (sabellid polychaetes)
- Additional 10-month data coming; 22- and 34-month monitoring in 2014 and 2015

Acknowledgements

- Project led by US Navy SPAWAR Systems Center Pacific, Principal Investigator Dr. D. Bart Chadwick
- Funding provided by US Department of Defense Environmental Security Technology Certification Program (ESTCP), Project ER-201131
 - <http://www.serdp.org/Program-Areas/Environmental-Restoration/Contaminated-Sediments/ER-201131/ER-201131>
 - Web search for “ER-201131”



Acknowledgements

- Pier 7 collaboration team

- ENVIRON

- Melissa Grover, Jenn Arblaster, Victor Magar, Marlene Meador, David Moore

- US Navy SPAWAR Systems Center Pacific

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- Hart Crowser

- Brad Helland

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- Mark Wicklein, John Pittz, Dwight Leisle

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- Nautilus Environmental

- Adrienne Cibor

- AMEC

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- SDSU Research Foundations

- Renee Dolecal

- US Naval Base Kitsap Port Ops

- Crews of tug MARGARET MARY and barge ABERDEEN





Thanks for Listening

