Monitoring to assess the effectiveness of an activated carbon sediment amendment to remediate contamination at a site located at the Puget Sound Naval Shipyard & Intermediate Maintenance Facility, Bremerton, WA

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Naval Base Kitsap Port Ops

Quigg Bros Inc.

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Major Funding Provided by:

- **Environmental Security Technology Certification Program (ESTCP), Department of Defense**
- **Navy's Environmental Sustainability Development to Integration (NESDI) Program**
- **Naval Facilities Engineering Command Northwest**
- **Puget Sound Naval Shipyard & IMF**

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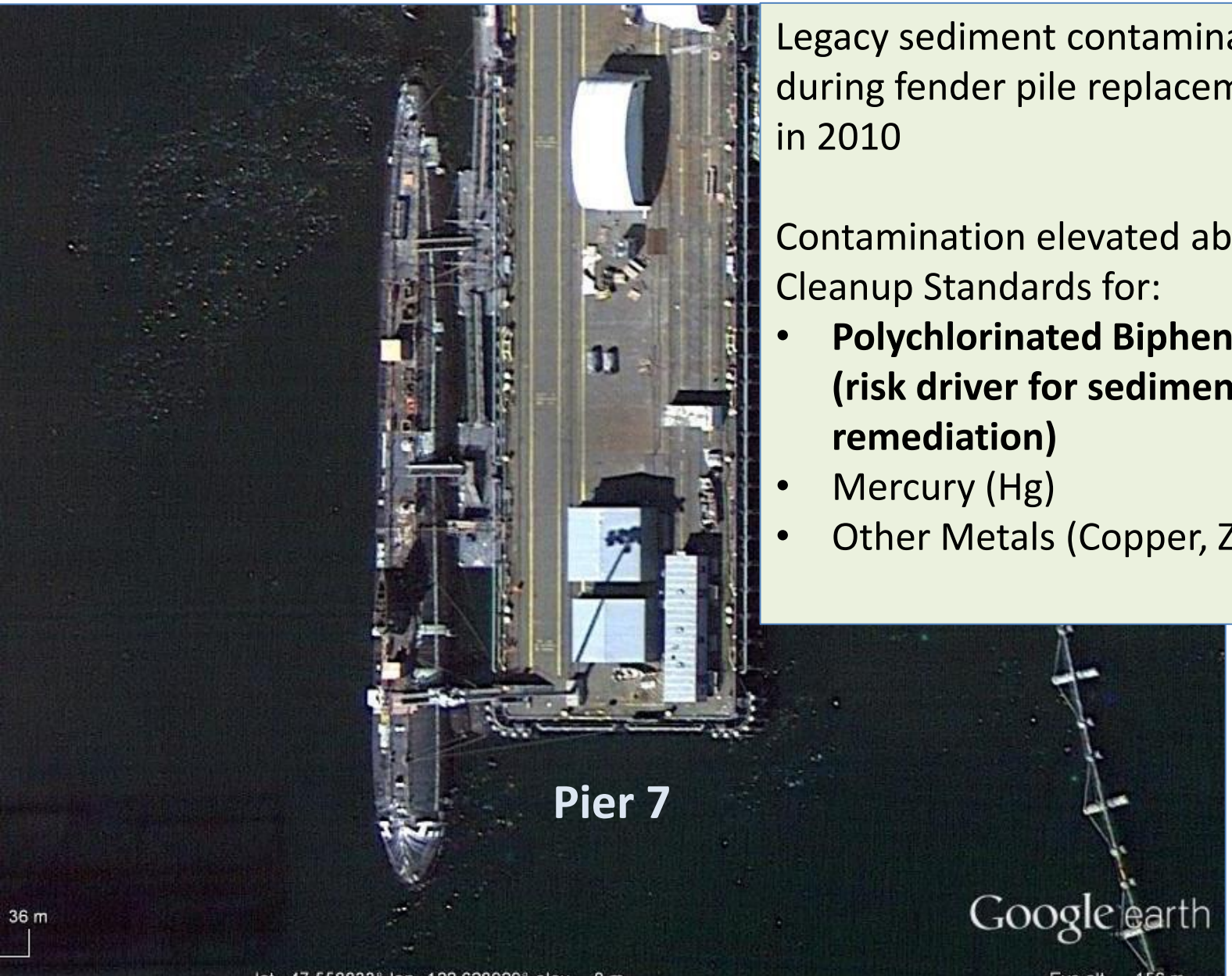
Outline of Talk

- Background/Purpose
- Placement Description
- Monitoring
  - Baseline
  - 10 Month Post-Placement (T=10 Months)
- Costs
- Summary


Sinclair and
Dyes Inlets
Pacific Ocean

Naval Base Kitsap Bremerton, Puget Sound Naval Shipyard & IMF (Bremerton Naval Complex)

Pier 7 Site Location



Legacy sediment contamination found during fender pile replacement project in 2010

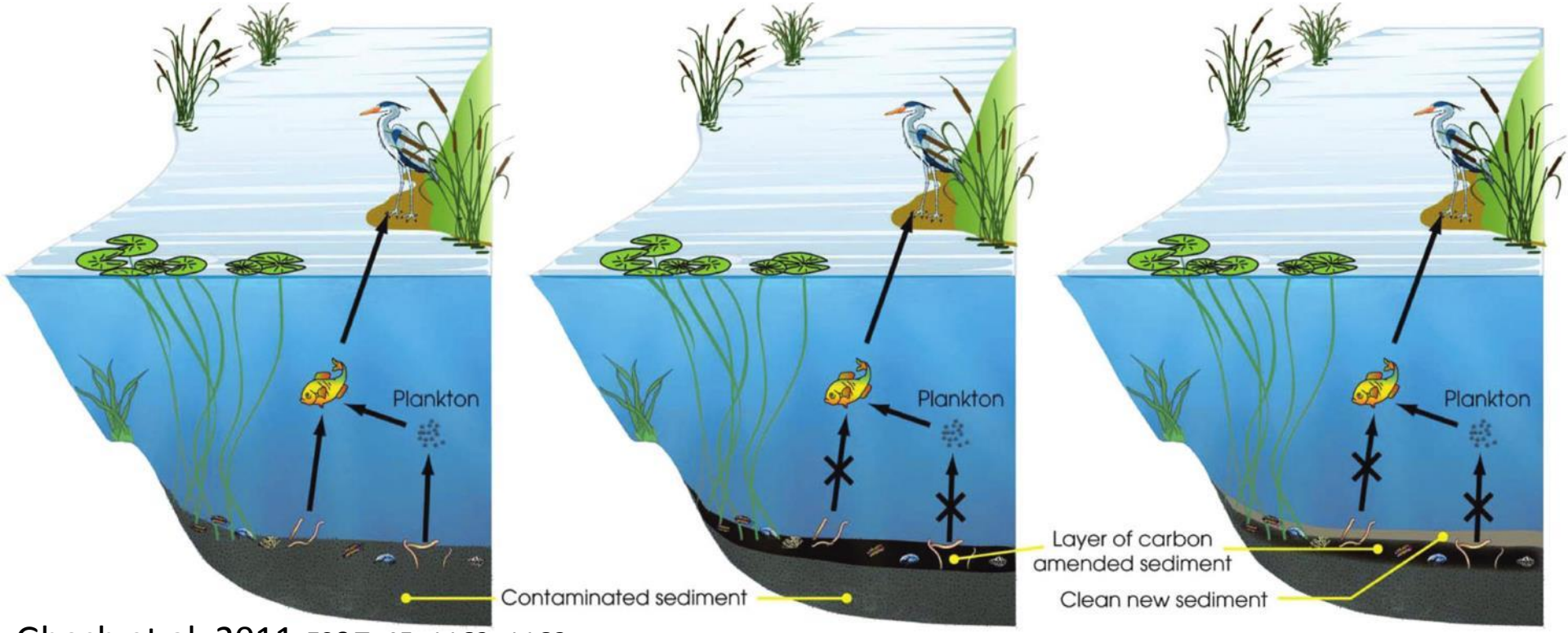
Contamination elevated above State Cleanup Standards for:

- **Polychlorinated Biphenyls (PCBs) (risk driver for sediment remediation)**
- Mercury (Hg)
- Other Metals (Copper, Zinc)

Why Amend with Activated Carbon?

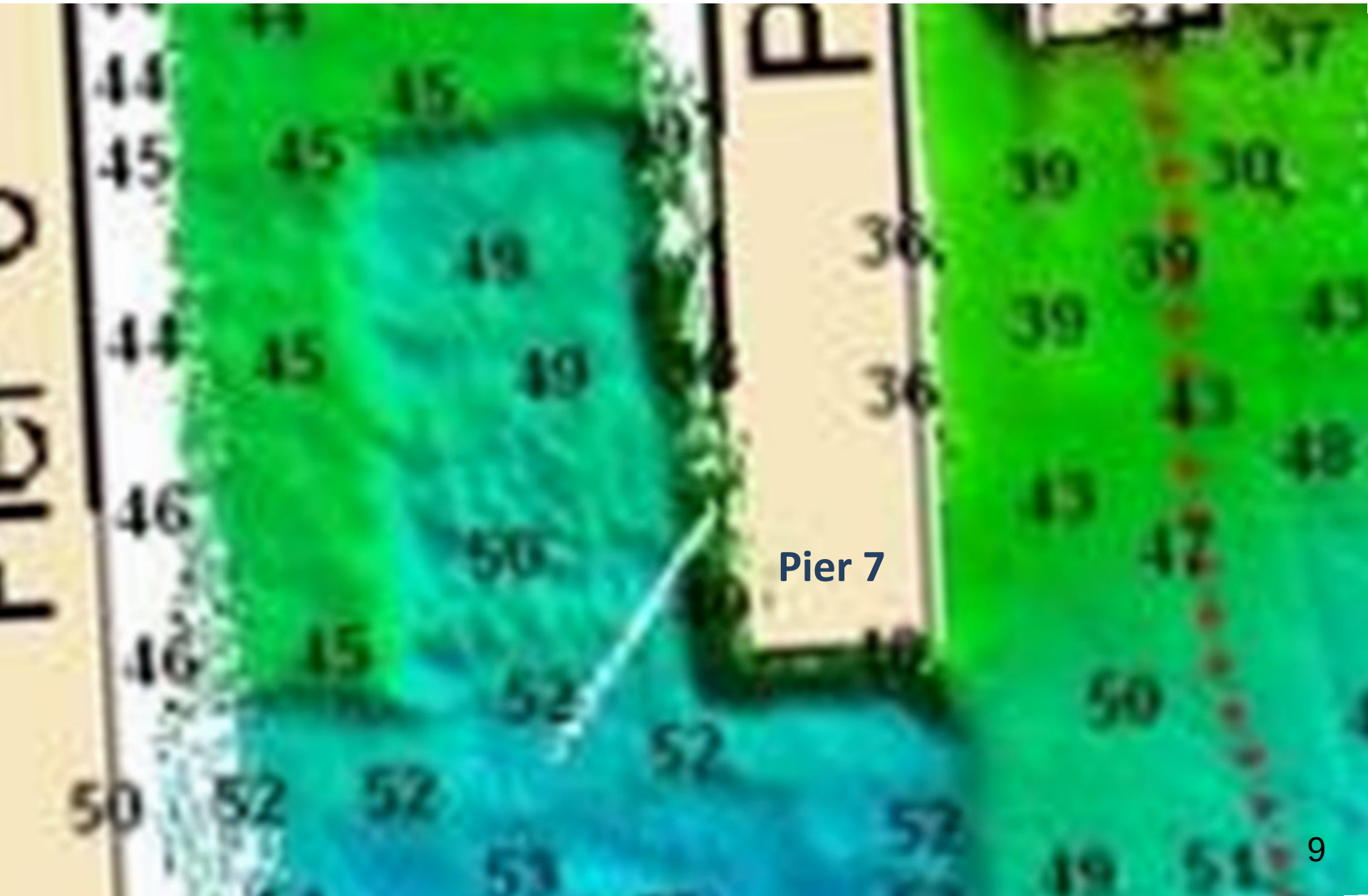
- Less obtrusive than dredging/capping
- Focused on reducing bioavailability and mobility
- Shorten ecosystem recovery time
- Expand site management options for active harbors
- Less costly and more expedient

Need Large Scale Demonstrations to Gain Acceptance

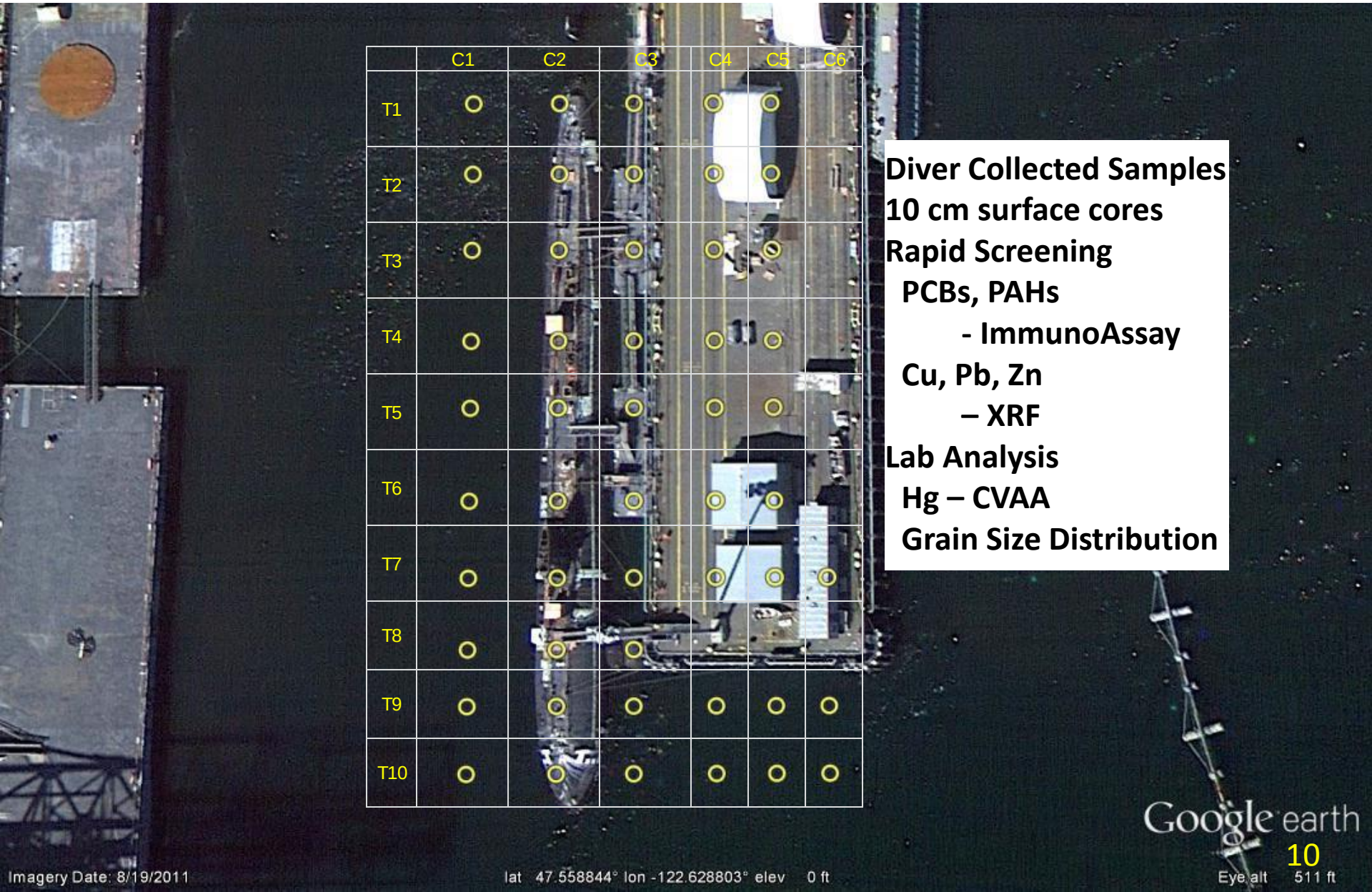


Ghosh et al. 2011 *ES&T 45, 1163–1168*

Bathymetry in the vicinity of Pier 7



Pier 7 Screening Analysis - Methods



Pier 7 Screening Grids Sediment PCB ng/g (ppb)

Washington State Sediment Quality Criteria (WA SQC)
Max Cleanup Level (WA MCL)

Total PCBs	
Average TOC=3.1%	
WA SQC	372 ng/g
WA MCL	2015 ng/g

	C1	C2	C3	C4	C5	C6
T1	234	192	91	46	152	
T2	176	151	28	261	58	
T3	170	96	285	74	48	
T4	341	140	113	133	11	
T5	111	594	159	150	74	
T6	243	262	6650	305	439	
T7	224	261	129	655	193	105
T8	227	129	163			
T9	91	74	74	73	84	80
T10	161	24	126	92	134	115

Bulk Sediment Sample Obtained for Laboratory Evaluation

Pier 7 Amended Cap Demonstration Project

Schedule

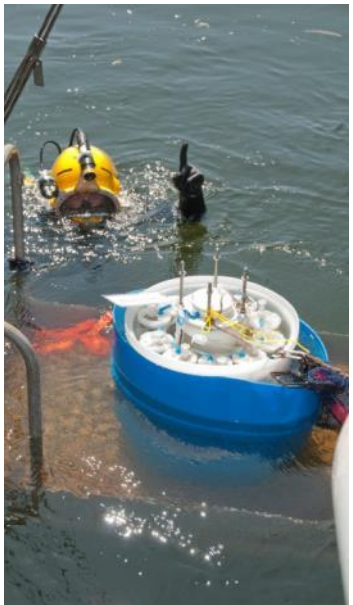
- 2011 Laboratory Evaluation Study Results Support **GO**
- 2012:
  - Aug 1-17 Pre-placement Monitoring
  - Oct 9 Received AquaGate Shipment
  - Oct 15-19 Placement
  - Oct 30-31 Placement Verification (**T=0.5 month**)
- 2013
  - Jan (**T=3 month**) Monitoring
  - Aug (**T=10 month**) Monitoring
- 2014
  - July (T=21 month) Monitoring
- 2015
  - Sep (T=36 month) Monitoring

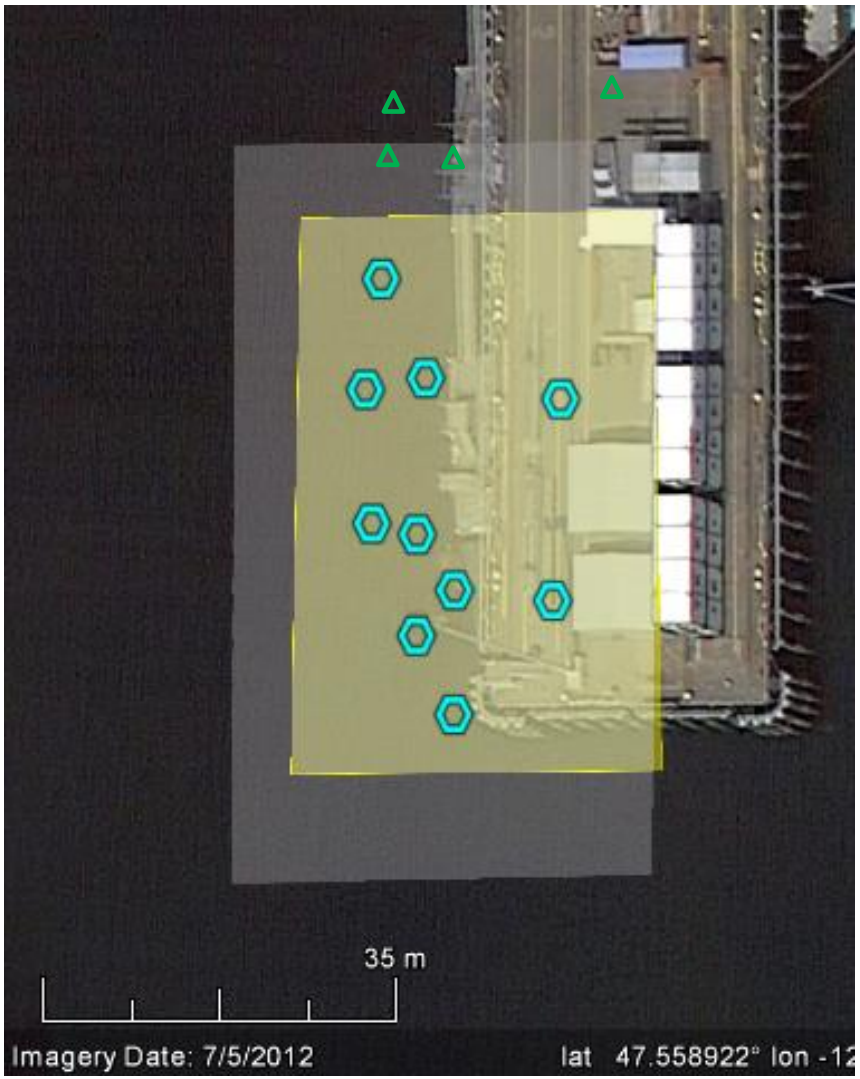
Remedial Action under CERCLA as part of the Record of Decision for site clean up

Monitoring for Baseline and T=10 months

Establish Baseline

- SEA Ring Chambers Deployed at 10 stations for 14 Days
  - Bioaccumulation of PCBs and Hg
    Clam – *Macoma nasuta*
    Worm – *Nephtys caecoides*
    Passive Sampler – Diffusive Gradient in Thin films (DGT)
  - Toxicity
    Amphipod – *Eohaustorius estuarius*
  - Physical, chemical and biological characterization (including TOC/Black Carbon)
- Sediment Profile Imaging (SPI) Camera at ~ 50 locations, extending beyond target footprint





Amendment Target Area
SPI Monitoring
SEA Ring Chamber
Reference Site


SEA Ring chambers


Clam


Worm


Amphipod


Divers use syringe to “inject” worms

Sediment Ecotoxicity Assessment

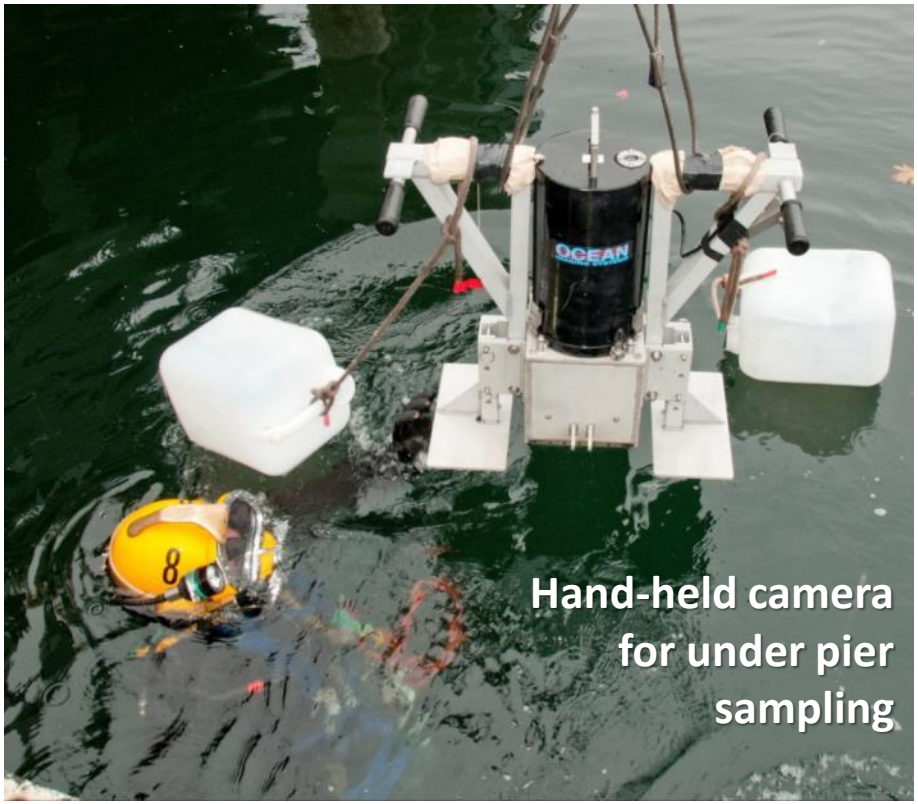
SEA Ring


SEA Ring chambers penetrate into sea floor

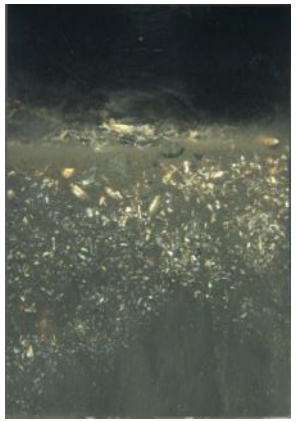

SEA Ring chamber on bottom


SEA Ring after retrieval

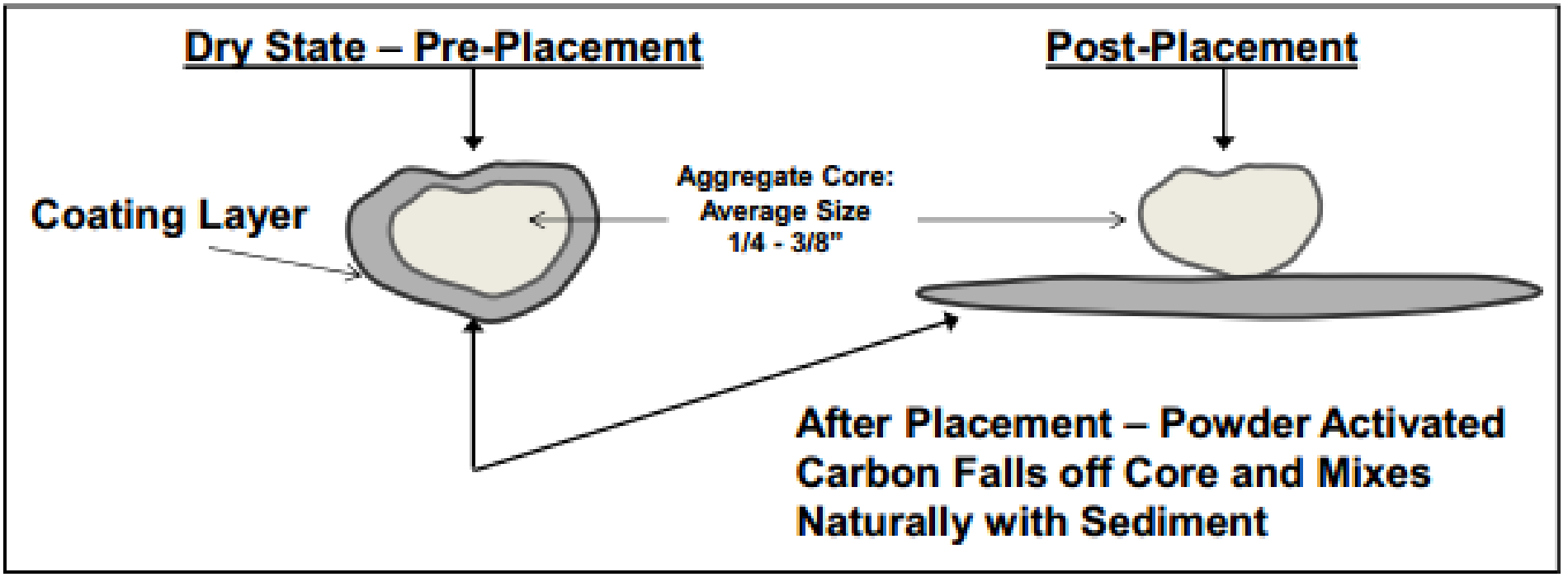
Sediment Profile Imaging (SPI) Camera



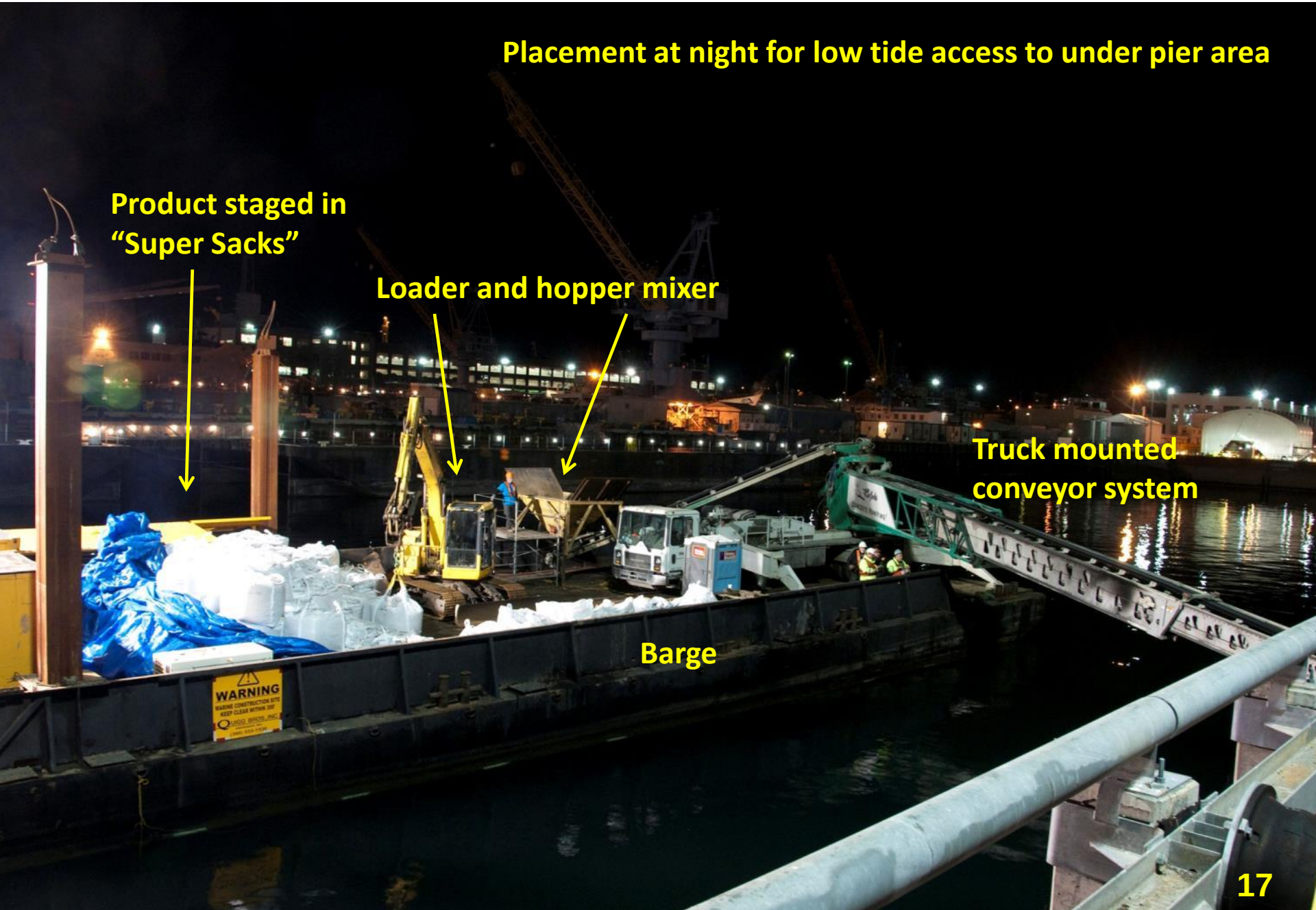
Sediment Profile Images



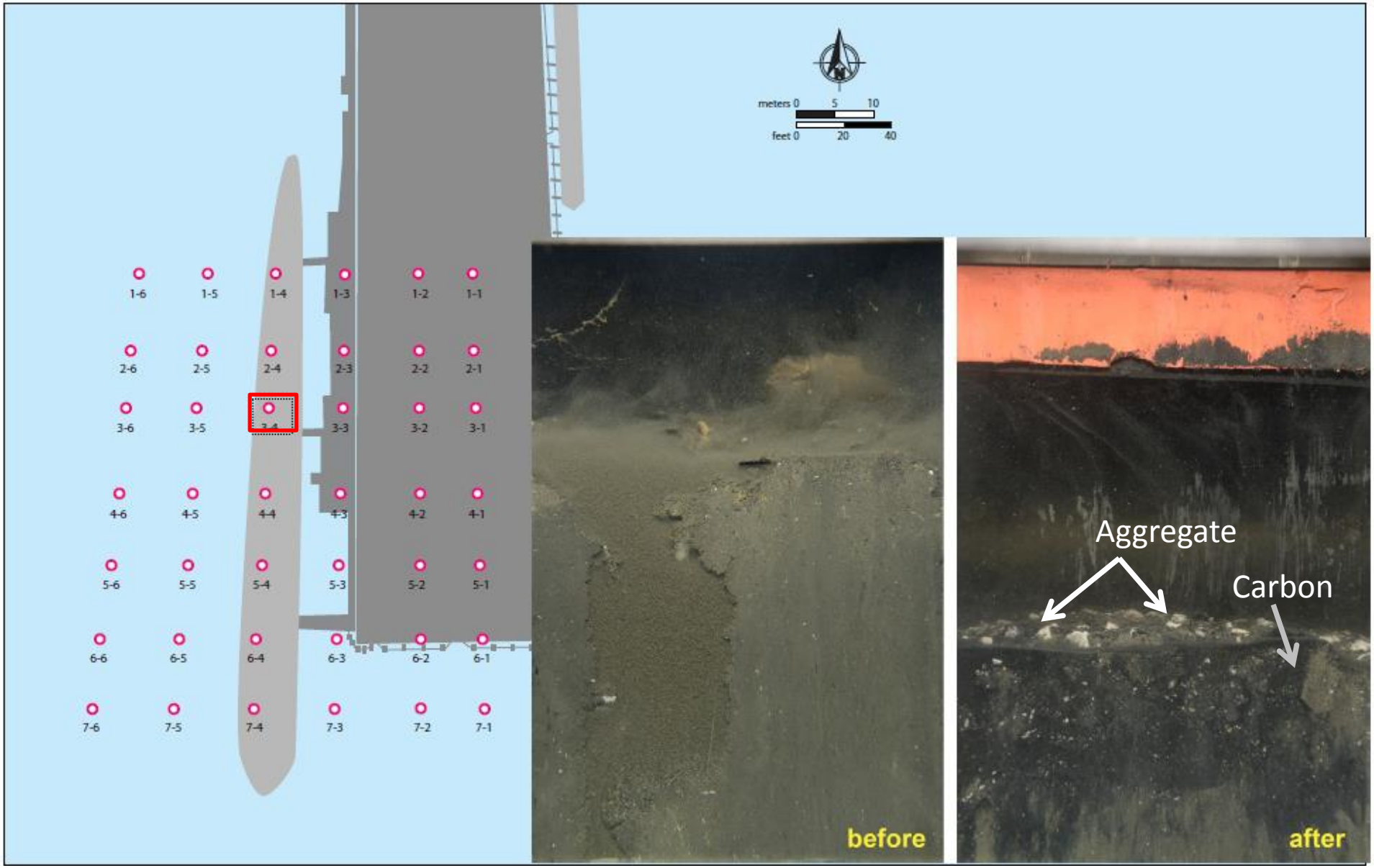
AquaGate+PAC™ Composite Aggregate

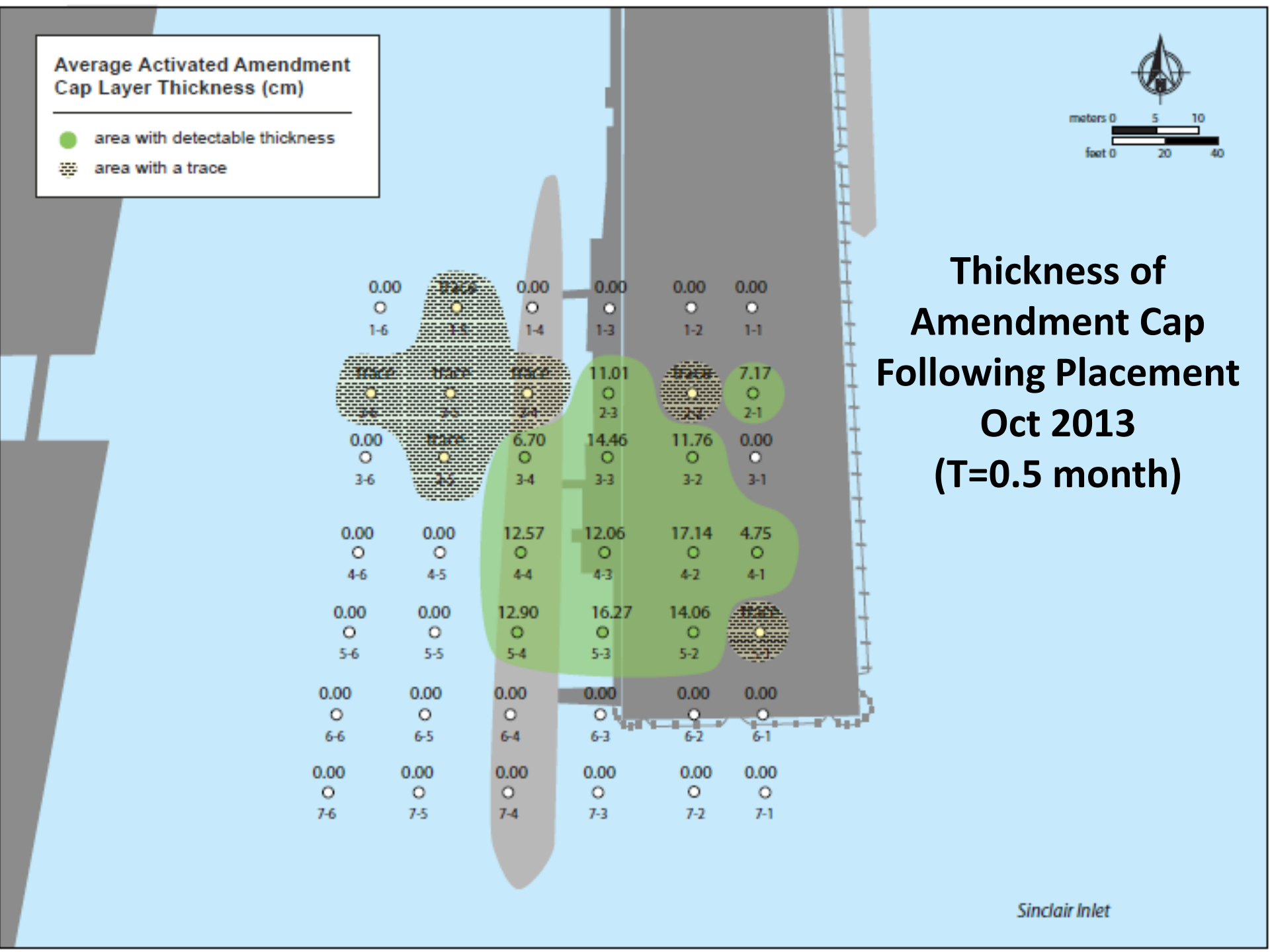


Product Staging and Placement



Sediment Profile from SPI camera

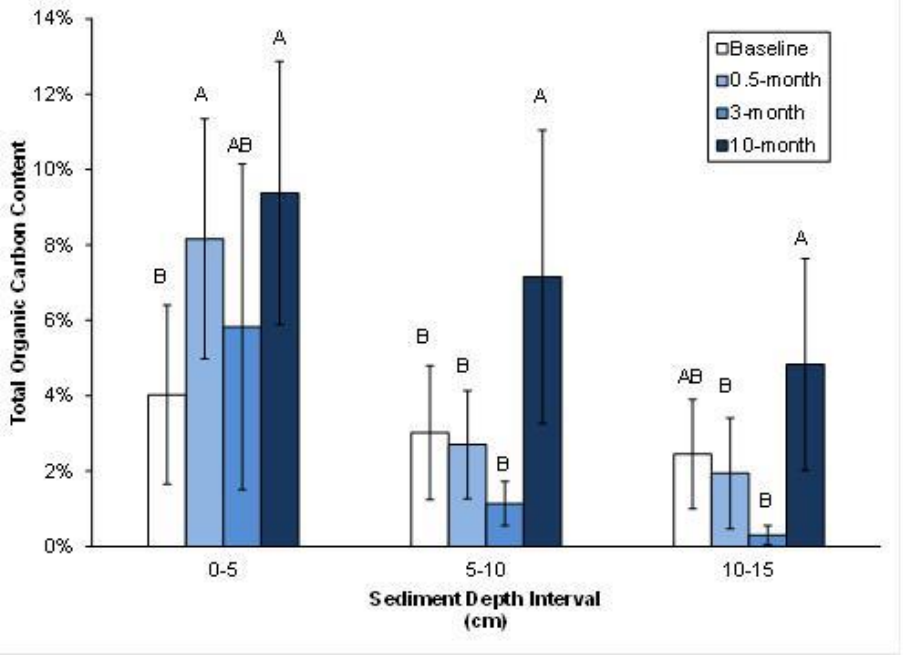




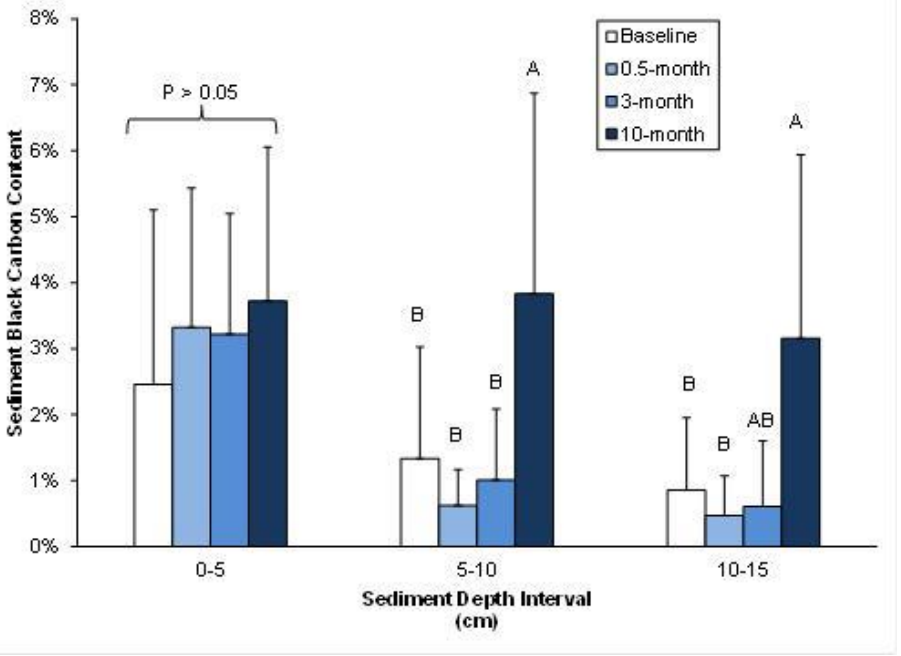
Thickness of Amendment Cap Following Placement Oct 2013 (T=0.5 month)

Total Organic Carbon (TOC) and Black Carbon in Sediment

TOC

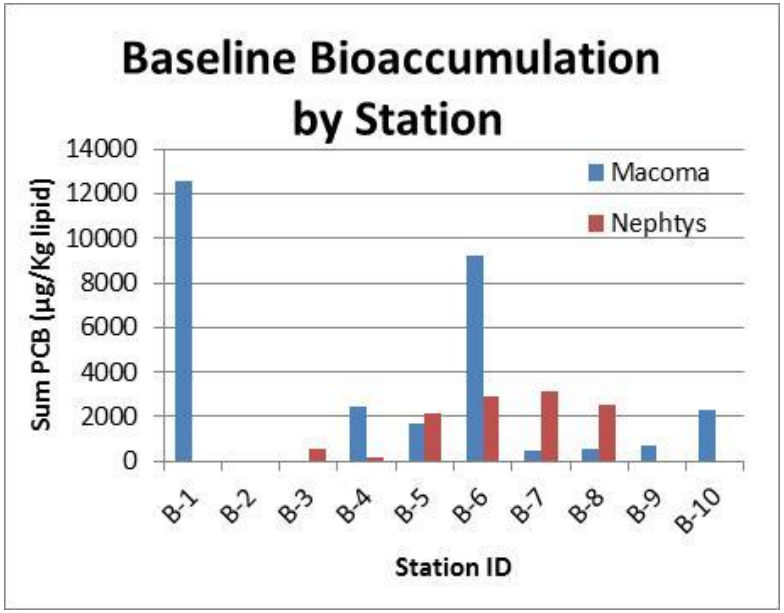


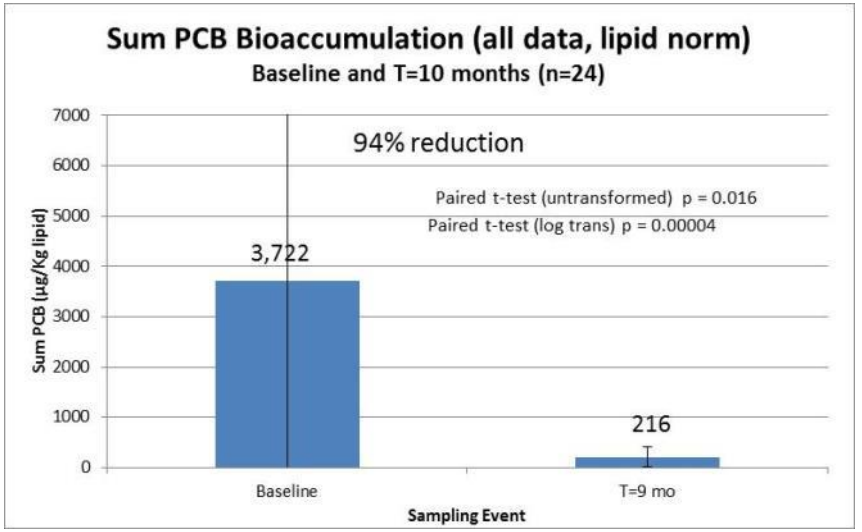
Black Carbon

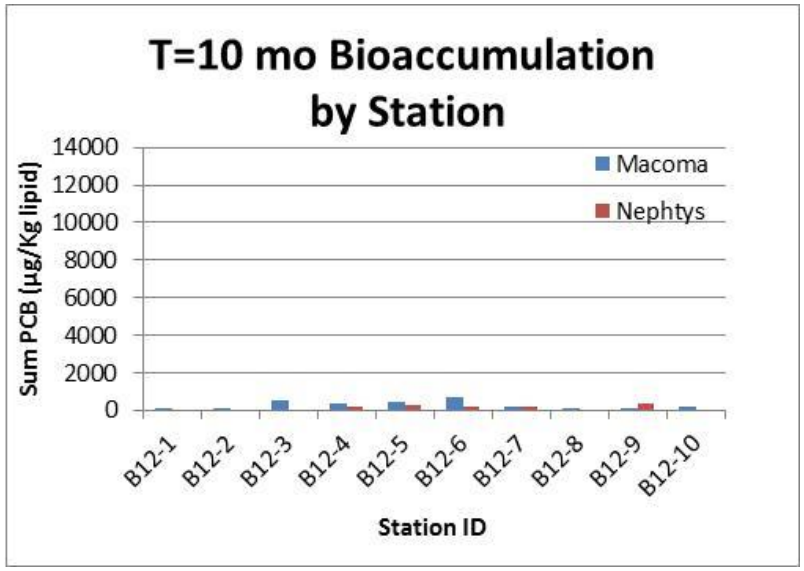


- Measurements confirm increase in carbon content in sediment
  - Expected increase in carbon following installation; ~2x increase in surficial (0-5 cm) layers from 4% to 8% TOC.
  - At 10-mo there appears to be an increase in carbon at deeper levels.
  - Variability across site; look at trends not mass balance.
  - Further investigation into sample processing and analysis methods to address bias.

In Situ Bioaccumulation in Clams and Worms



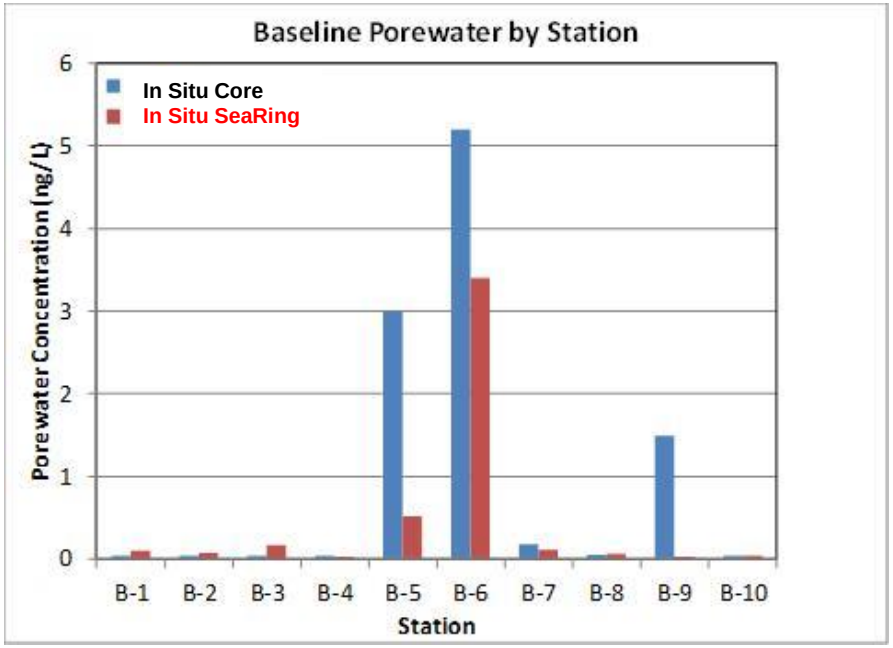


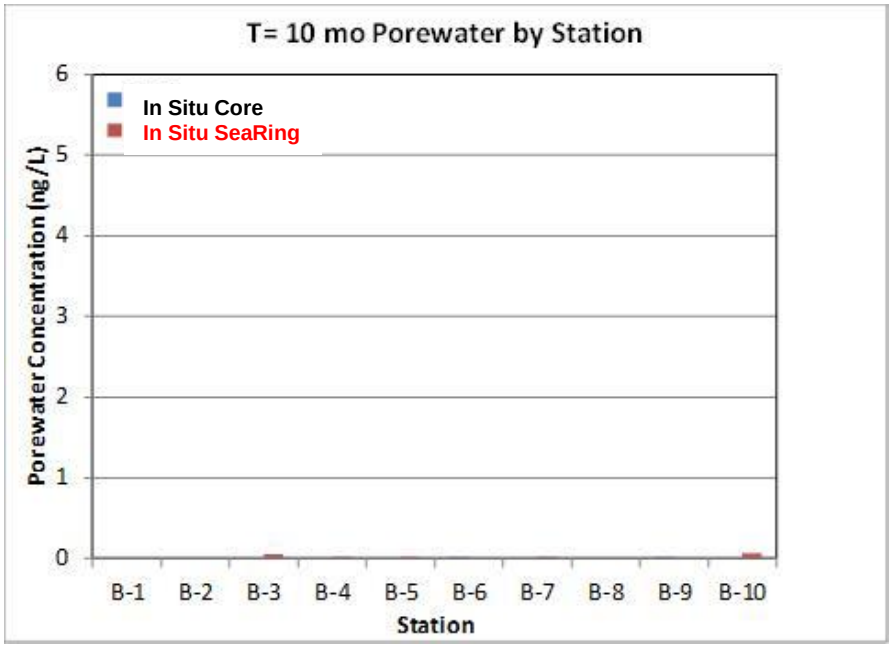


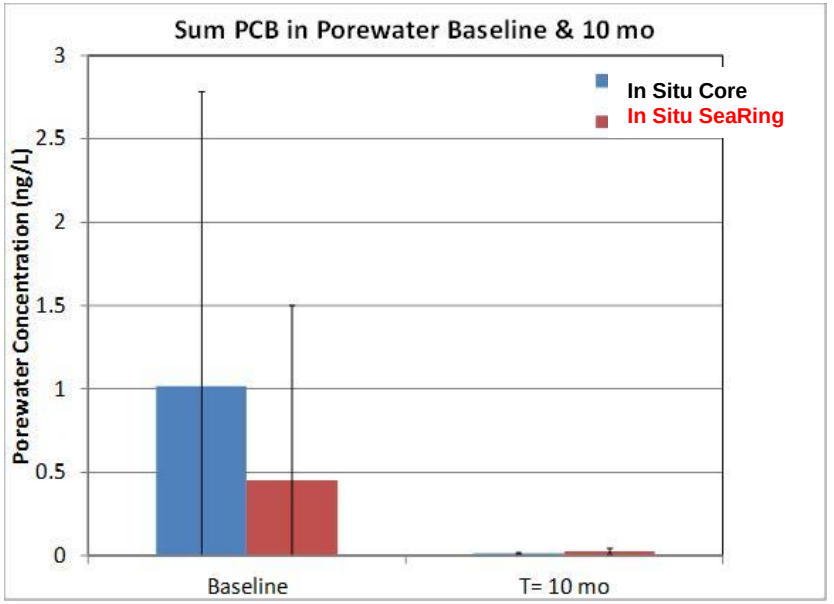
Significant reduction (~90%) in PCB bioavailability to sediment invertebrates

- Concurrence with 90% reduction observed in the initial lab study.
- Sum of detected PCB congeners for all organisms used in bioaccumulation exposures during Baseline and T=10-mo post-remedy.
- Paired t-tests showed highly significant differences between baseline and post-remedy.
- Reduction in PCB bioaccumulation was apparent in both species: *Macoma nasuta* and *Nephtys caecoides*.
- Reduction in PCB bioaccumulation consistent across stations.

PCBs in Porewater Measured by Passive Samplers

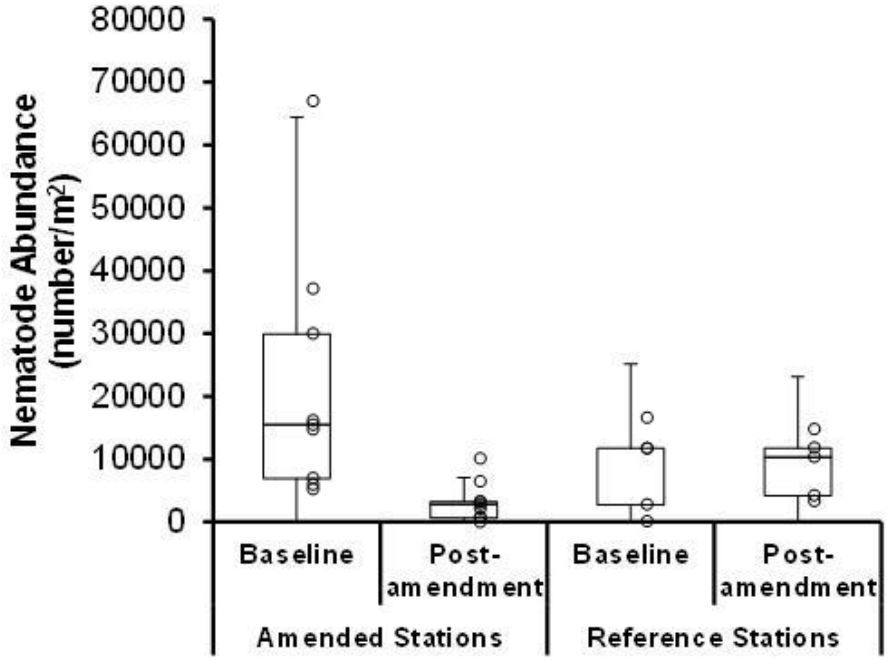


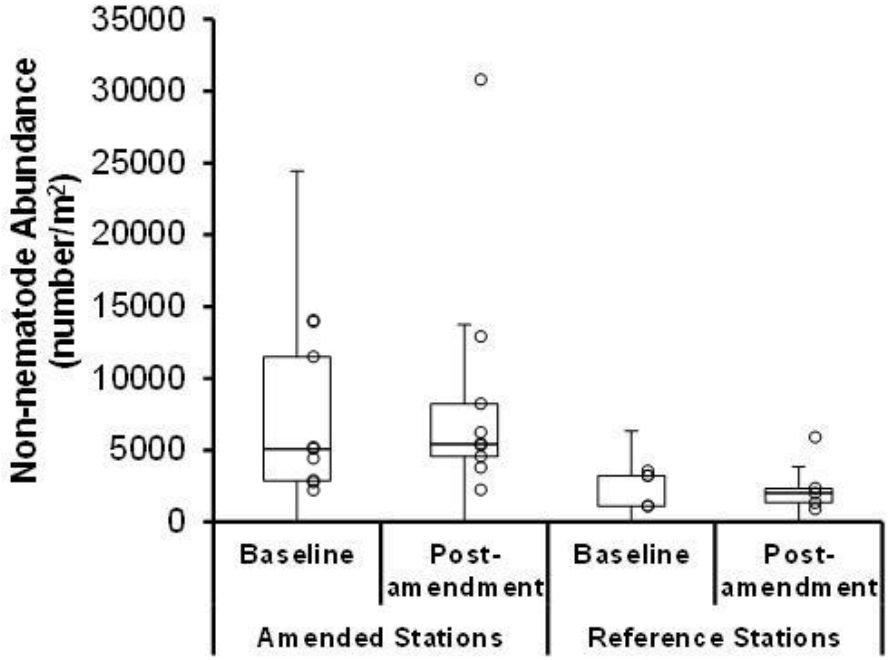




- **Similar reduction (~95-99%) in PCBs in porewater as observed in invertebrate tissues**
  - Concurrence with reduction observed in the initial lab study.
  - Sum of detected PCB congeners for both SPME exposures (in situ SeaRing and in situ cores) used during Baseline and T=10-mo post-remedy.
  - 99% and 95% reduction in mean based on SeaRing and Cores, respectively.
  - Reduction in PCB levels in porewater was apparent in both in-situ (SEA Ring) exposures and lab core exposures.
  - Reduction in PCBs in porewater was consistent across stations.

Benthic Census Evaluation (Tracking Purposes Only)





Slight shifts in community structure observed

- Abundance at the amended stations decreased between baseline and 10-month (post-amendment) surveys, but was driven by nematode abundance decreases.
- Abundance of non-nematode invertebrates at the amended stations was comparable to that of the reference stations.

Cost for Monitoring and Placement*

Monitoring (per event)		
Field Work	$ 97,000	
Dive Support	$ 27,000	
Laboratory Analysis	$ 59,000	
Reporting	$ 40,000	
	$ 223,000	
Placement		cost/ton
Product (140 tons)	$ 56,000	$ 400
Shipment	$ 42,000	$ 300
Staging/Delivery	$ 140,000	$ 1,000
Verification	$ 16,000	$ 114
	$ 254,000	$ 1,814
Placement Unit Cost		
Area Treated	0.502	acre
Placement Cost/ft^2	$ 11.62	

* Costs do not include management, oversight, and coordination.

Summary

- Conducted full scale demonstration of AC placement in active harbor
- Verified placement in berthing and under pier areas
- Established baseline to evaluate performance
- Short term performance verified
- Post placement monitoring is on going to verify persistence

For More Information See:
http://www.mesodat.org/Public/Pier7/Index.htm