Results from the West Sound Mussel Watch Monitoring and Effectiveness Monitoring of an Activated Carbon Sediment Amendment at a Contaminated Site

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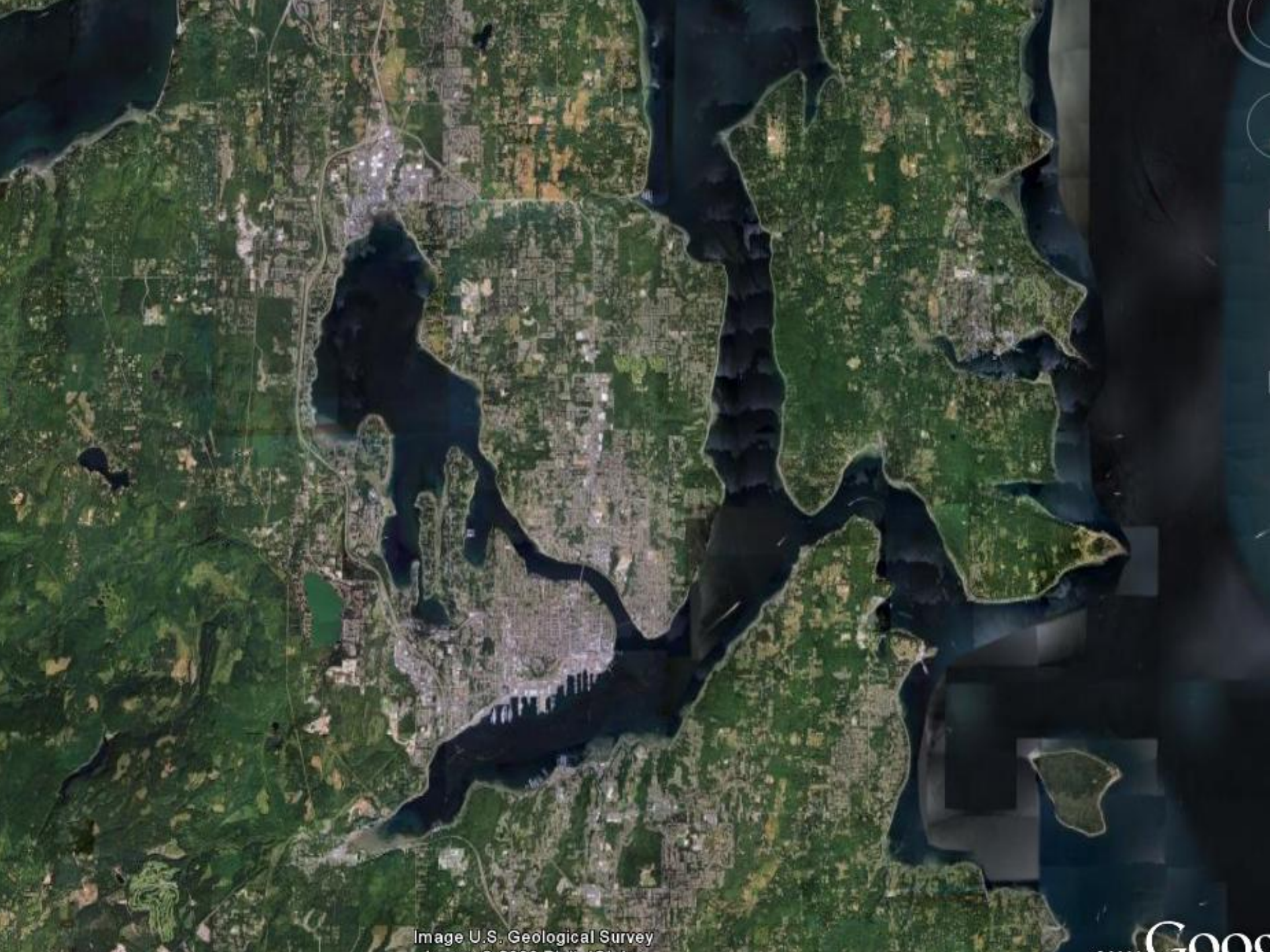
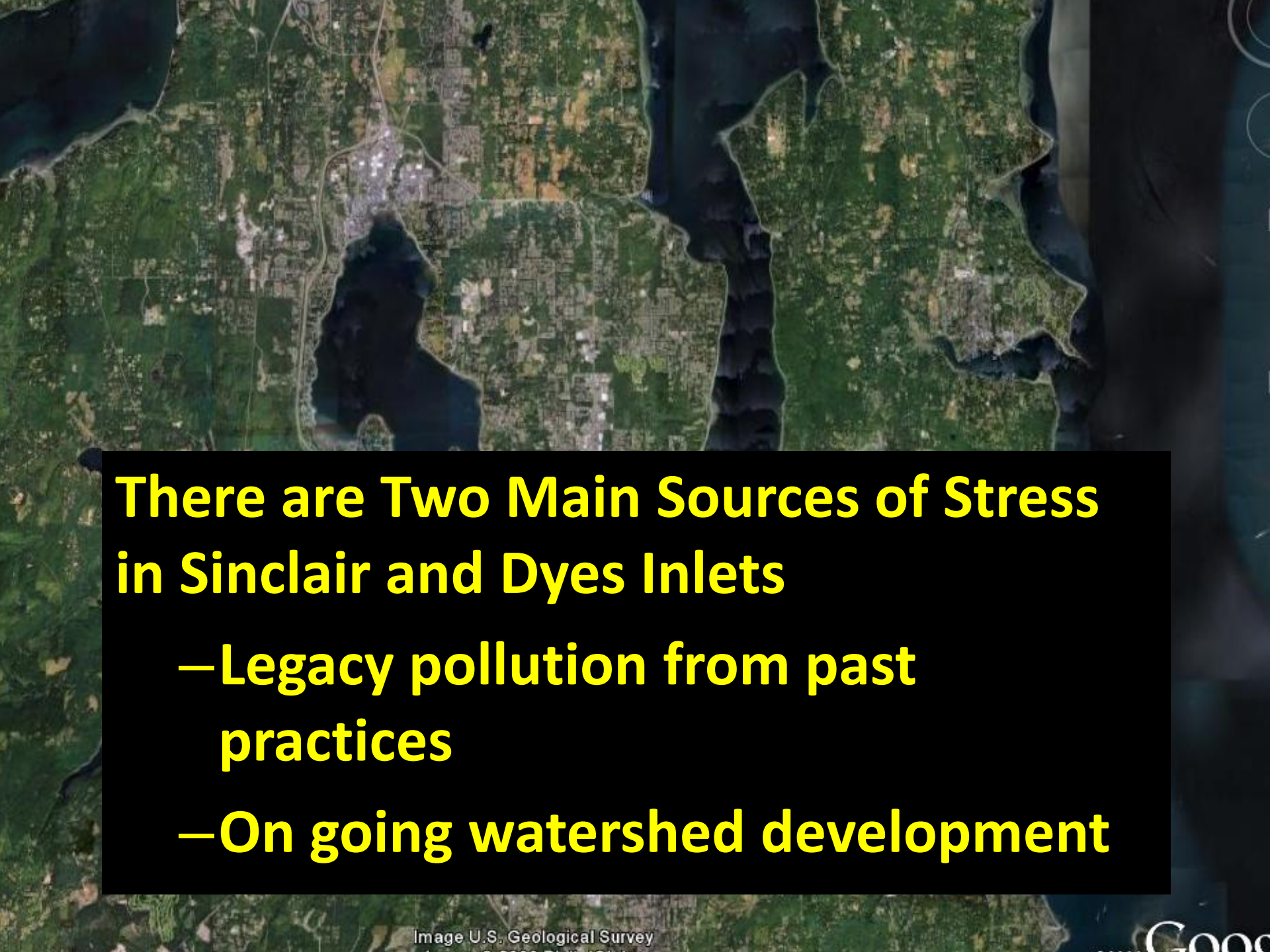
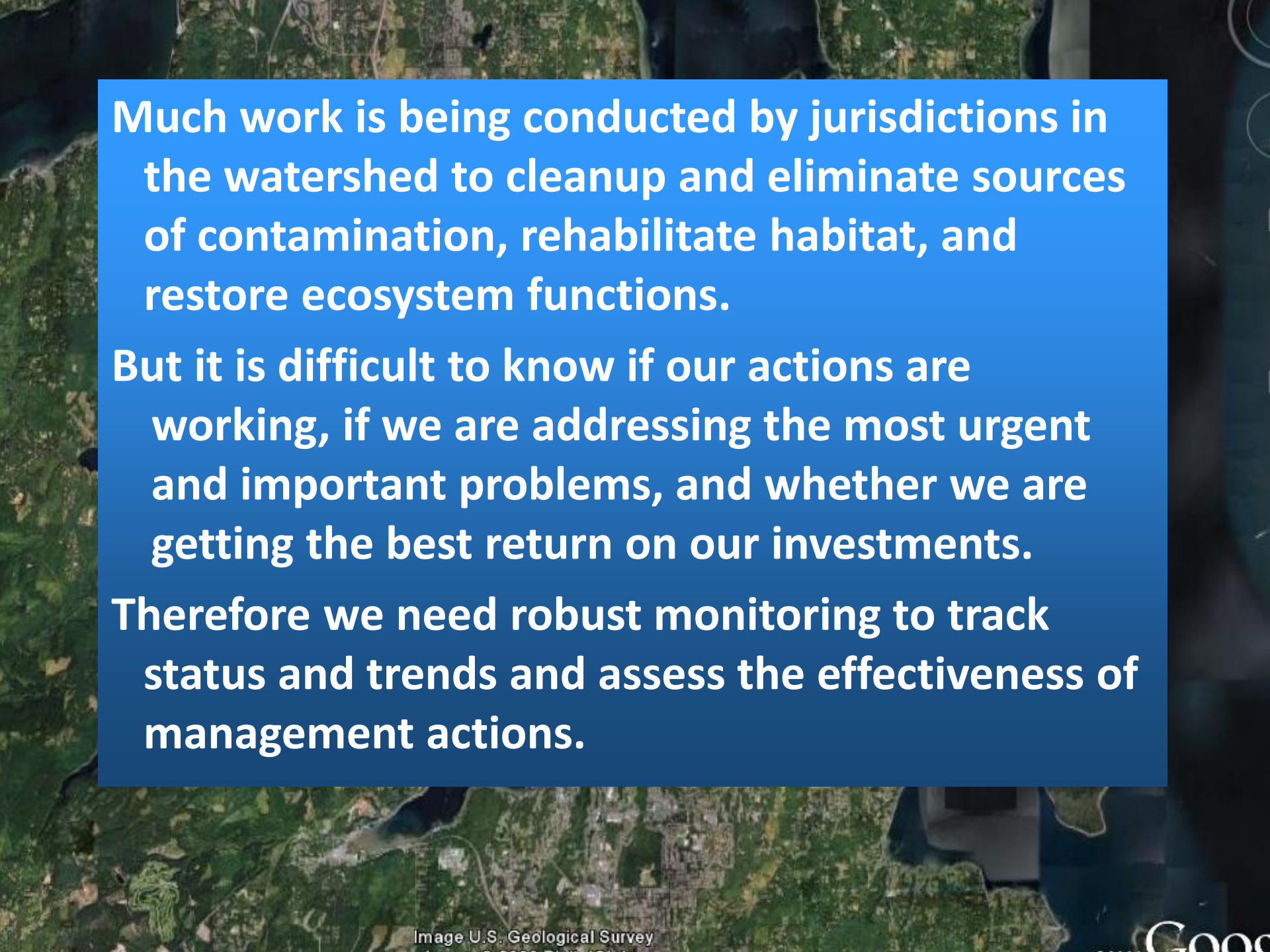


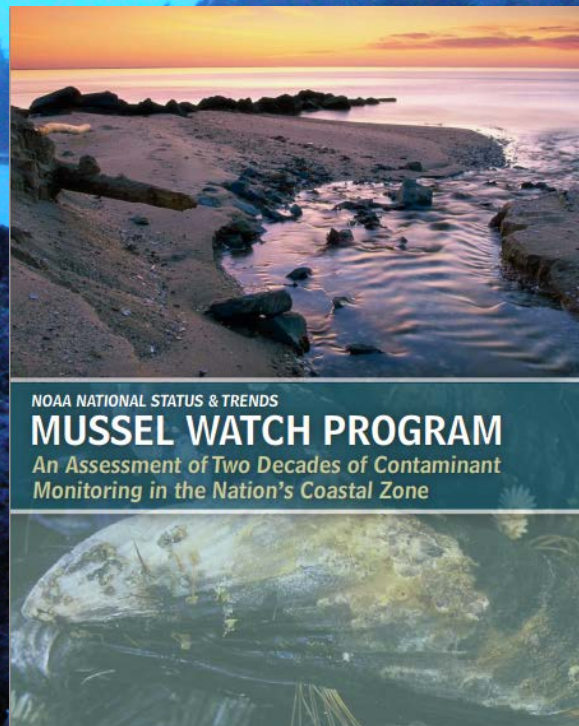
Image U.S. Geological Survey


There are Two Main Sources of Stress in Sinclair and Dyes Inlets
–Legacy pollution from past practices
–On going watershed development
Image U.S. Geological Survey


Much work is being conducted by jurisdictions in the watershed to cleanup and eliminate sources of contamination, rehabilitate habitat, and restore ecosystem functions.
But it is difficult to know if our actions are working, if we are addressing the most urgent and important problems, and whether we are getting the best return on our investments.
Therefore we need robust monitoring to track status and trends and assess the effectiveness of management actions.
Image U.S. Geological Survey

Mussel Watch Sampling

- Partnering with WDFW and Local Stakeholders
- Coordinated with National Mussel Watch Program
- West Coast Sampling Winter of Even Years (12/09-2/10)
- Representative Sampling Site Locations
  - 3 Stations/Site
  - Size Distribution
  - Composite Sample for Chemistry Analysis
    - Metals, PAHs, PCBs, $\delta^{13}C$, $\delta^{15}N$, and Lipids



Mussel Watch Sampling

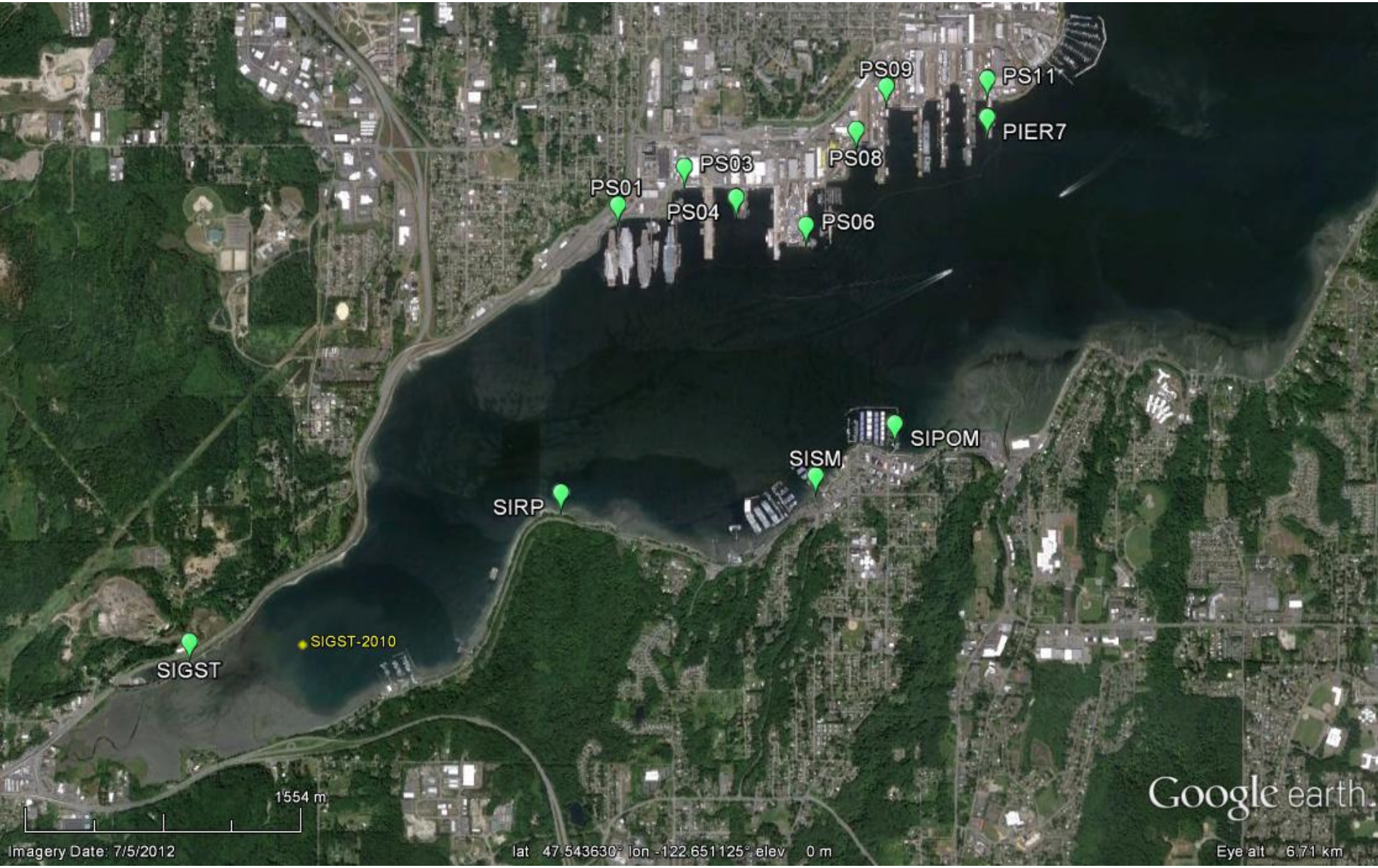
ENVVEST Mussel Watch Stations 2010 and 2012

LBPMSC
KPTPIER
APKIANA
KPTLAG
APHCB
POPBWN
DYOTS
POPIPD
POPISP
DYOBAP
PWNLP
SIWP
MLPIER
PIER7
PS11
PS06
PS09
SISM
SIPOM
SIRP
SIGST

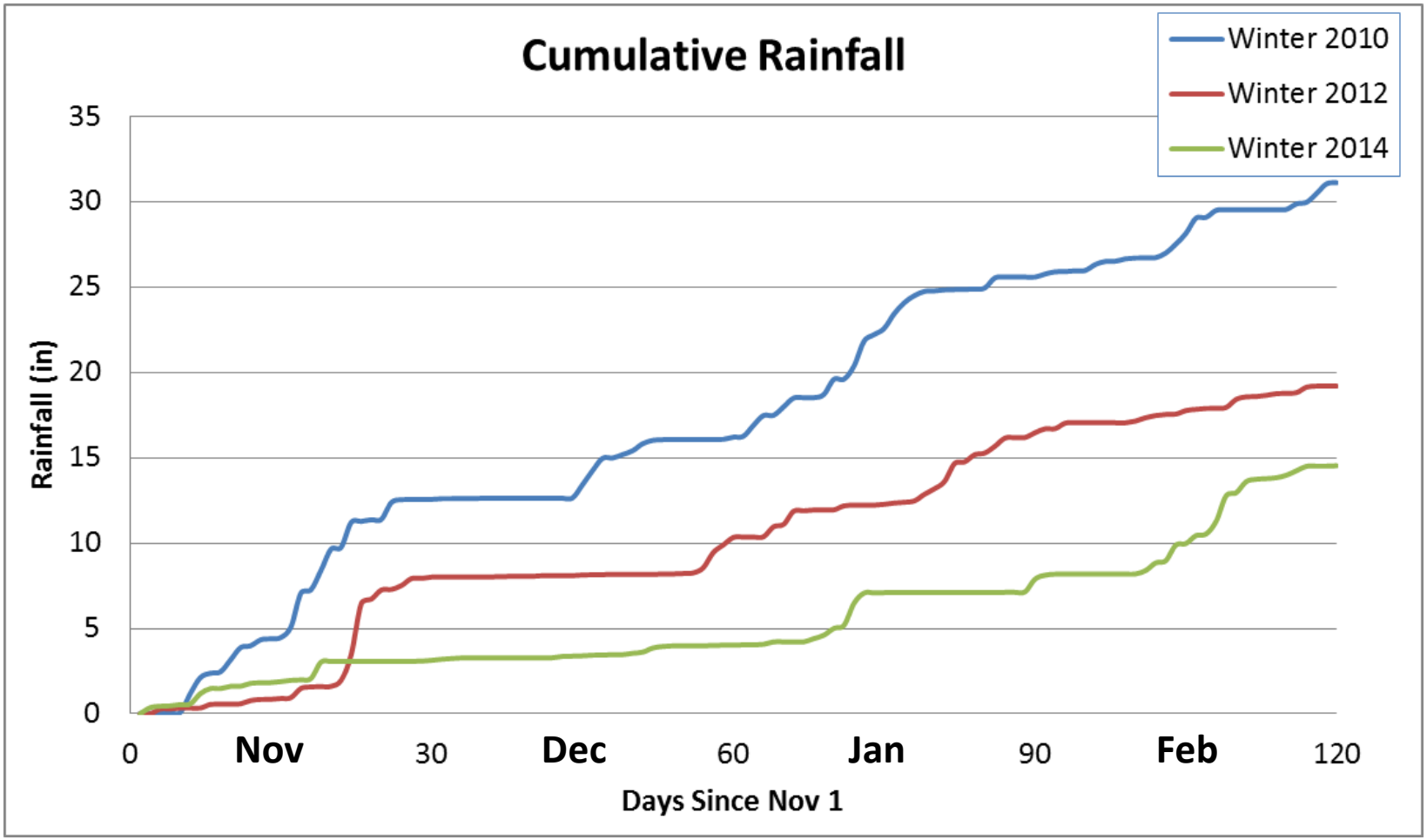
Participating Jurisdictions

- City of Bremerton Parks & Rec
- City of Bainbridge Island
- Port of Bremerton
- Port of Brownsville
- Port of Illahee
- Port of Poulsbo
- Port of Silverdale
- Private Landowner
- Suquamish Tribe
- US EPA/NOAA Manchester Lab
- US Navy Naval Base Kitsap
- US Navy Naval Underwater Weapons Center
- US Navy Puget Sound Naval Shipyard & IMF
- Washington Department of Fish and Wildlife
- Washington State Parks Illahee

Mussel Watch Sinclair Inlet

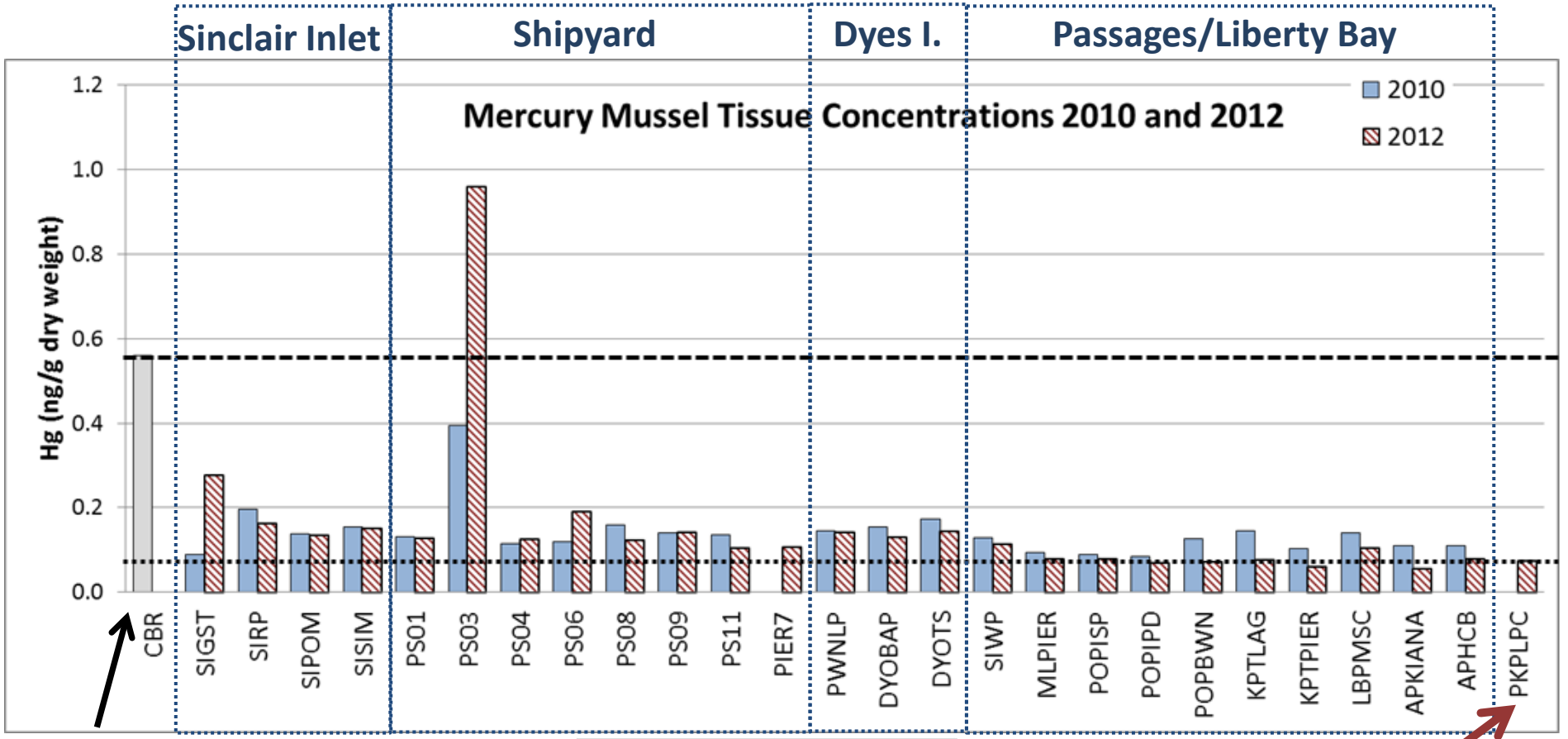


Winter Sampling Nov - Feb



Sum of average daily rainfall reported from Kitsap County rain gauges (CoCoRaHS 2014)

Mercury (Hg)



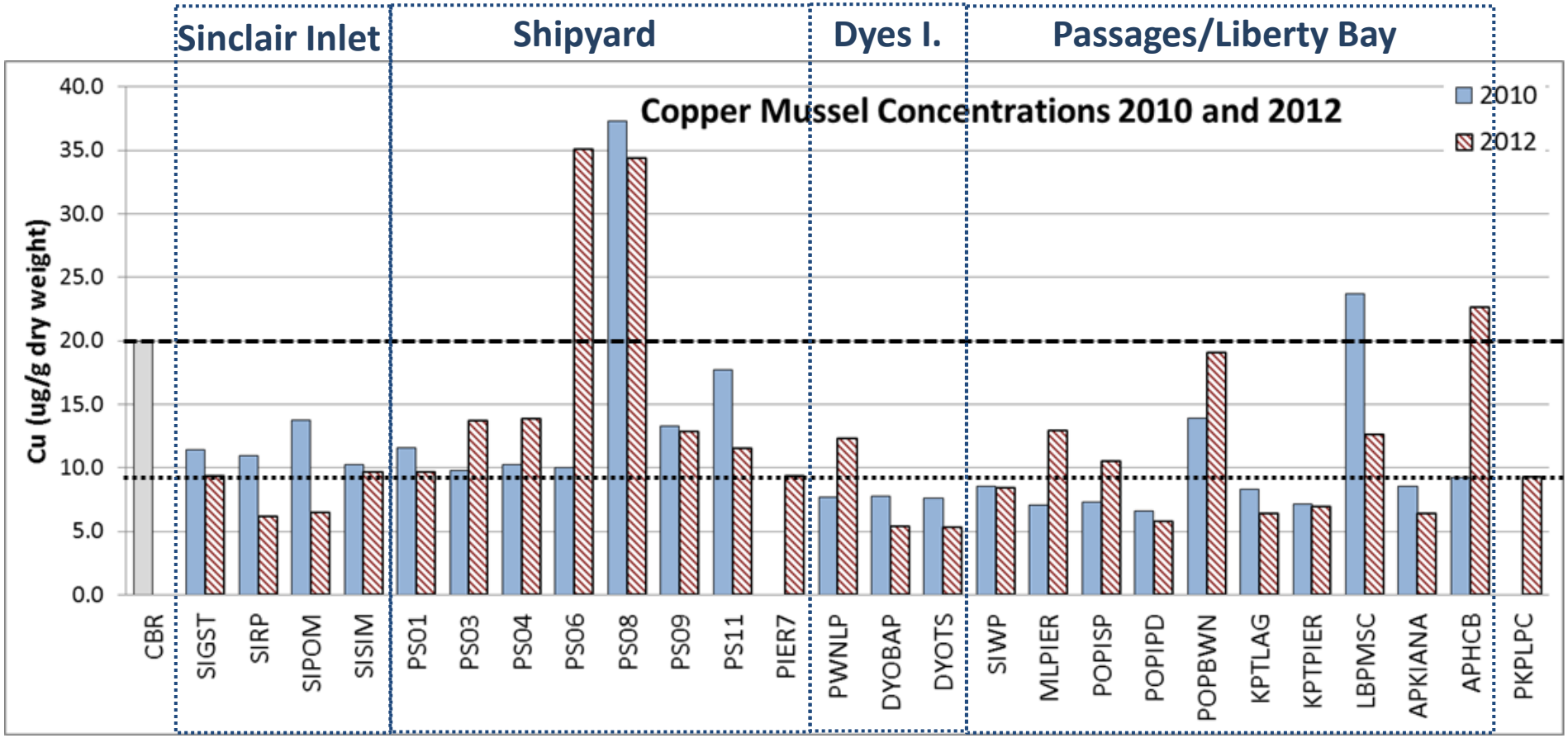
Critical Body Residue

National MW Range
ppm dry weight

	Hg
Low	0.00 - 0.17
Medium	0.18 - 0.35
High	0.36 - 1.28

Seafood Market (Penn Cove, Whidbey Island)

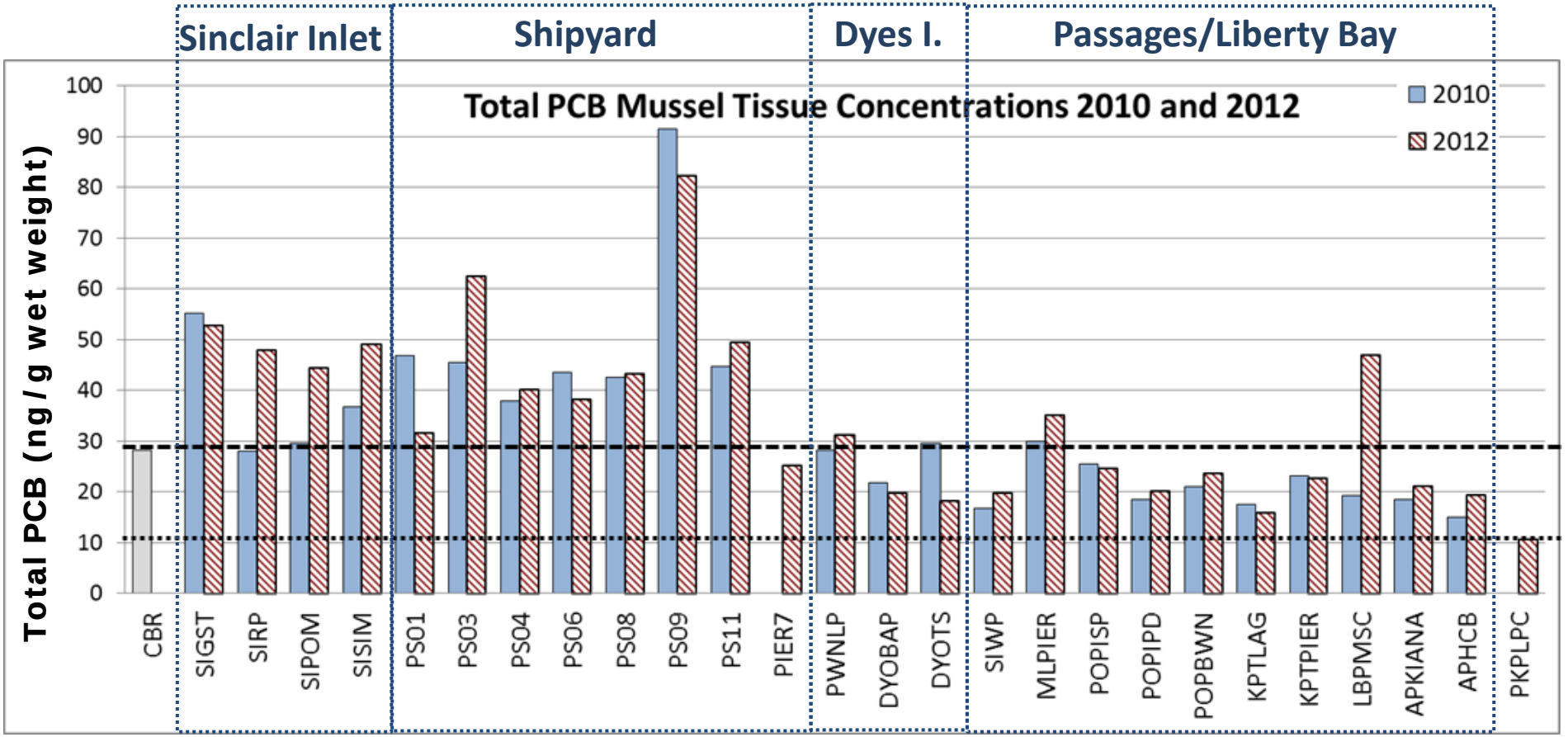
Copper (Cu)



National MW Range
ppm dry weight

	Cu
Low	5 - 16
Medium	17 - 39
High	40 - 857

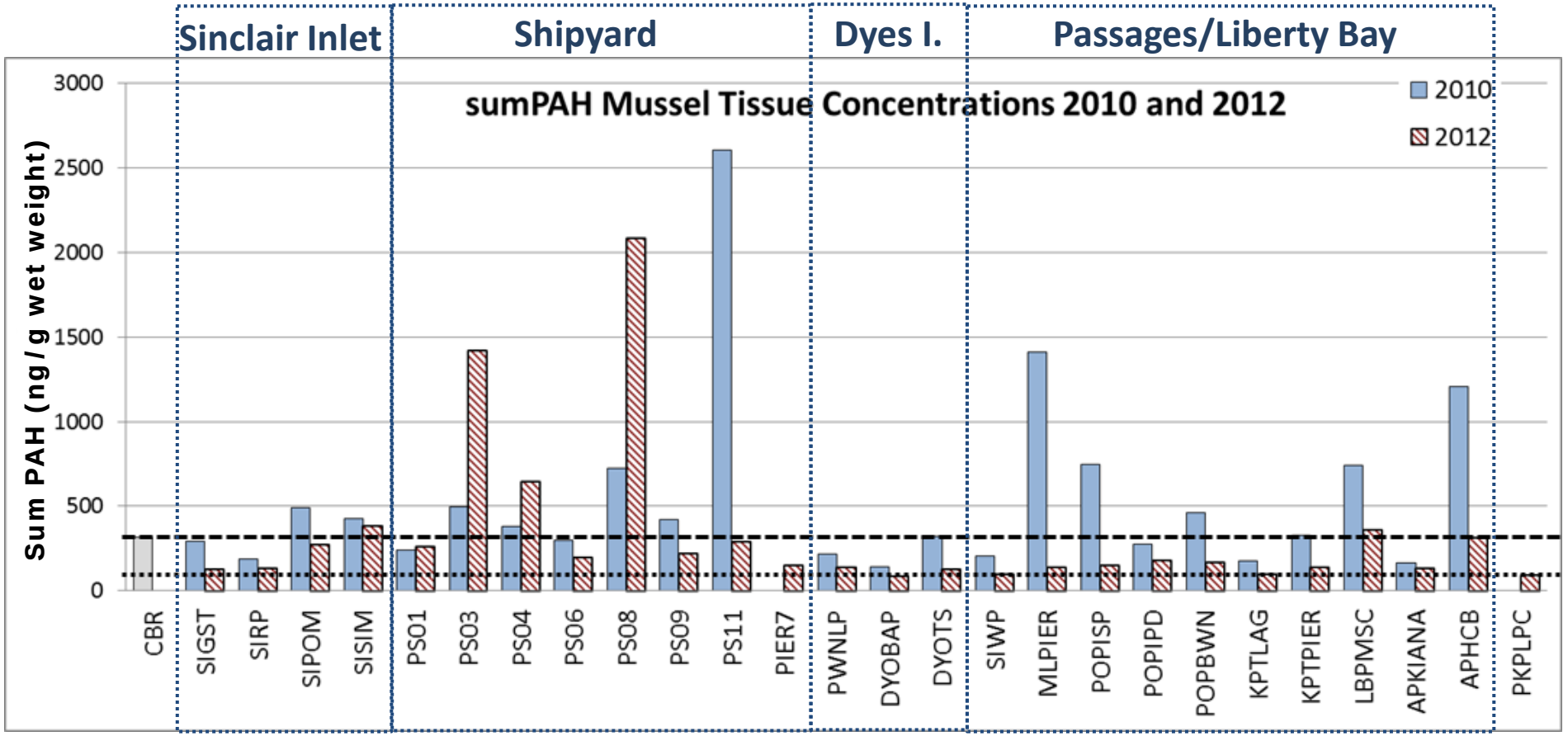
Total Polychlorinated Biphenyl (PCB)



National MW Range
ppb wet weight

	PCBs
Low	0.4 - 21.3
Medium	21.5 - 66.6
High	66.8 - 197

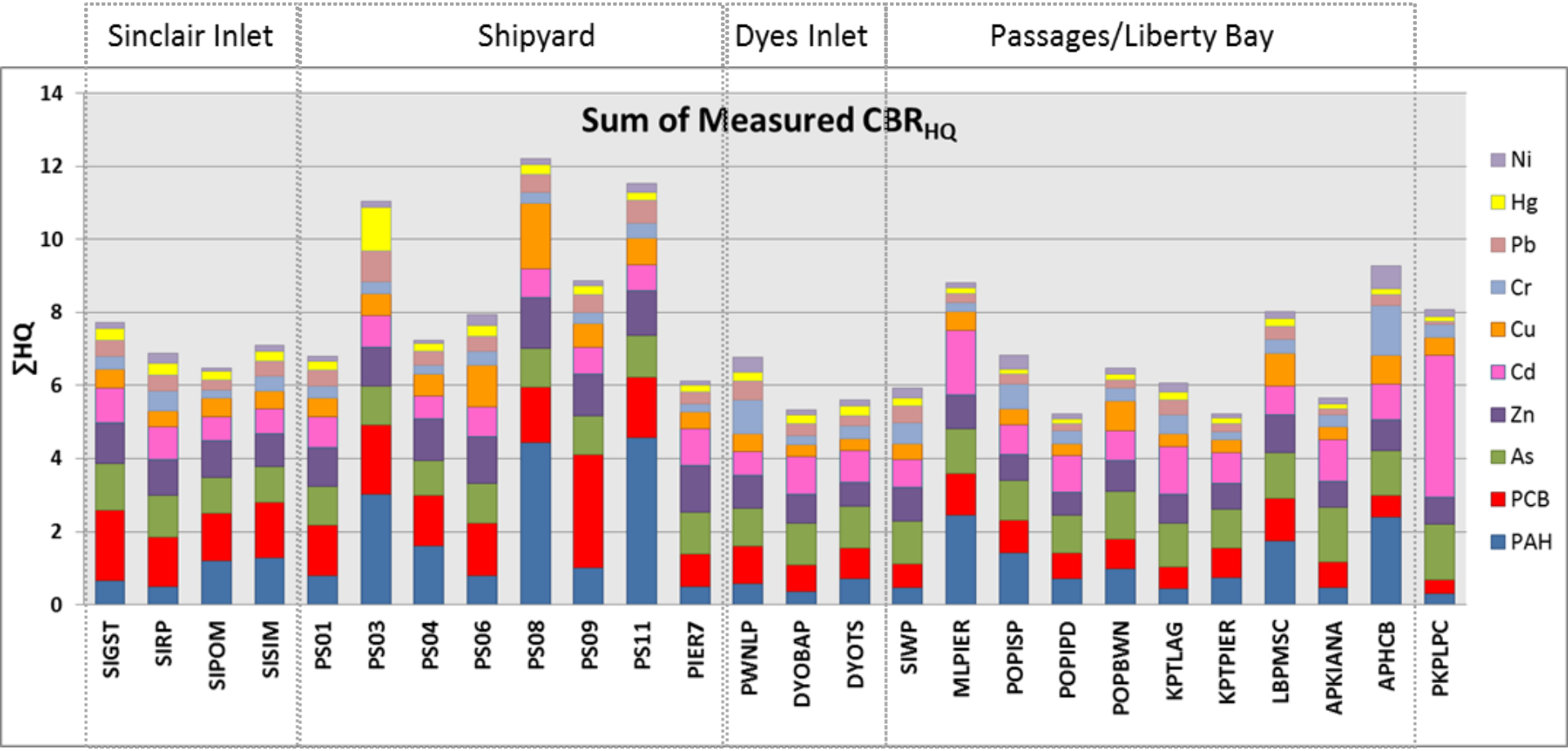
Sum of Polycyclic Aromatic Hydrocarbon (PAH) Compounds



National MW Range
ppb wet weight

	PAHs
Low	9 - 165
Medium	166 - 618
High	618 - 1054

Hazard Index for Critical Body Residues



Possible Ecological Effect – Critical Body Residue

$CBR_{HQ} > 2$; $CBR_{HQ} = Concentration/CBR_i$

$CBR_{HI} > 10$; $CBR_{HI} = \Sigma CBR_{HQi}$ where $i = 10$

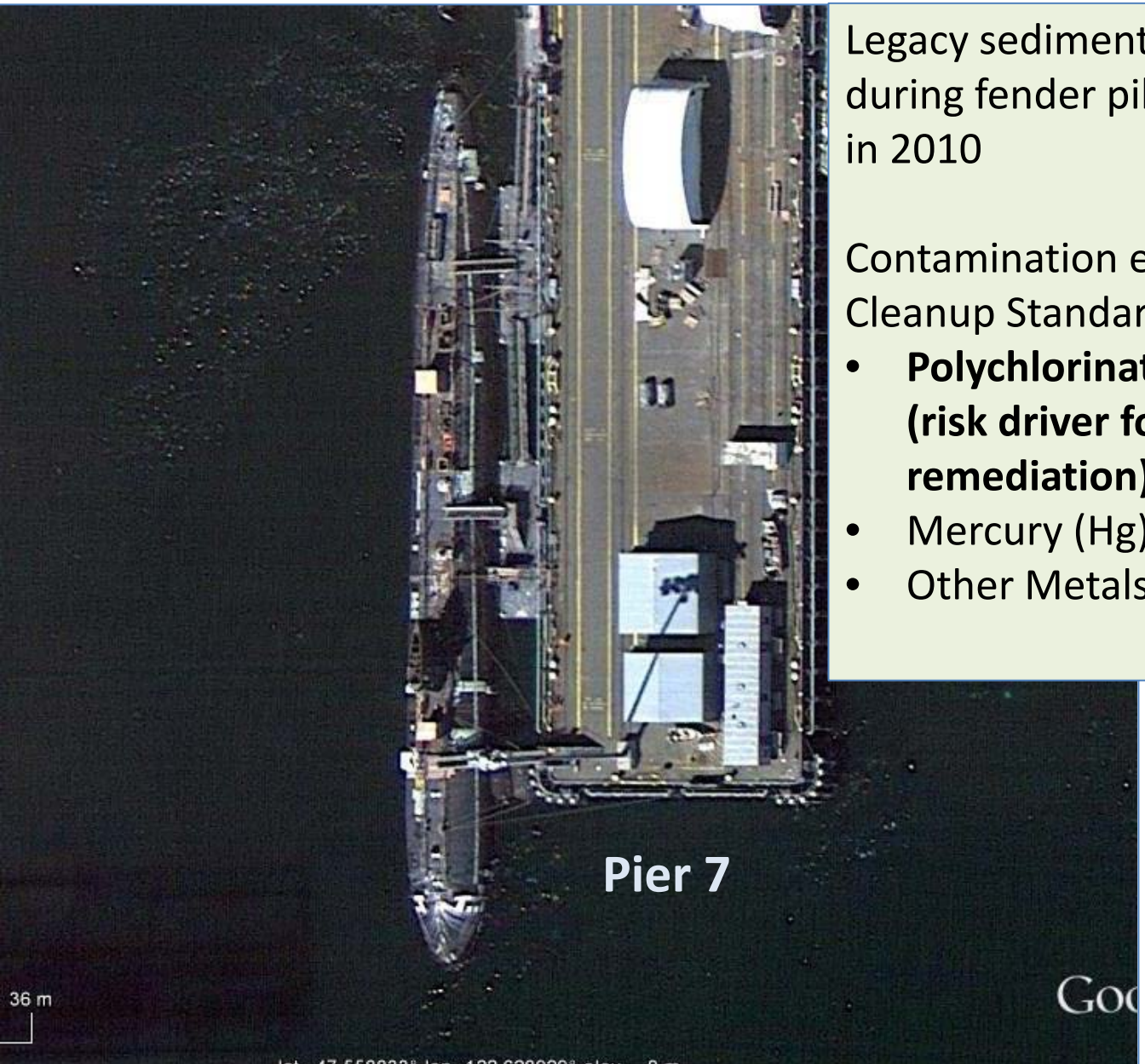
Mussel Watch Summary

- Monitoring Program is focused on tracking environmental quality in the Inlets
  - Can identify problems for further investigation and correction
  - Can be used to evaluate effectiveness of corrective actions
- What are the Biota Telling Us?
  - Some Areas were elevated with PAHs, PCBs, and metals
  - 3 of 24 sites had increased risk of ecological effects
  - Contaminants of concern were PAHs (3 sites), PCBs (2 sites), Hg (1 site), and Cu (1 site)
- Monitoring framework provides context for interpretation
  - Better information = better management

Monitoring the effectiveness of an activated carbon sediment amendment at a contaminated site located at the Puget Sound Naval Shipyard & Intermediate Maintenance Facility (PSNS&IMF), Bremerton, WA

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

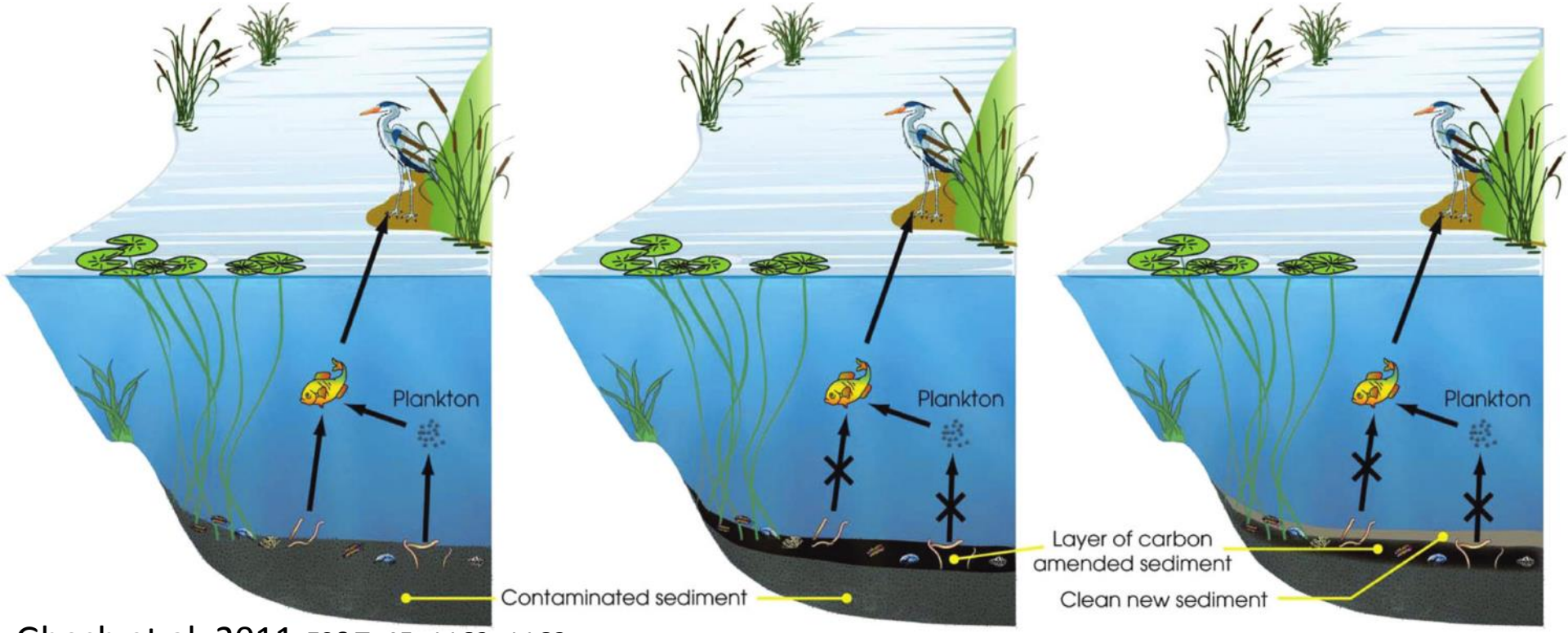
Contamination elevated above State Cleanup Standards for:

- **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



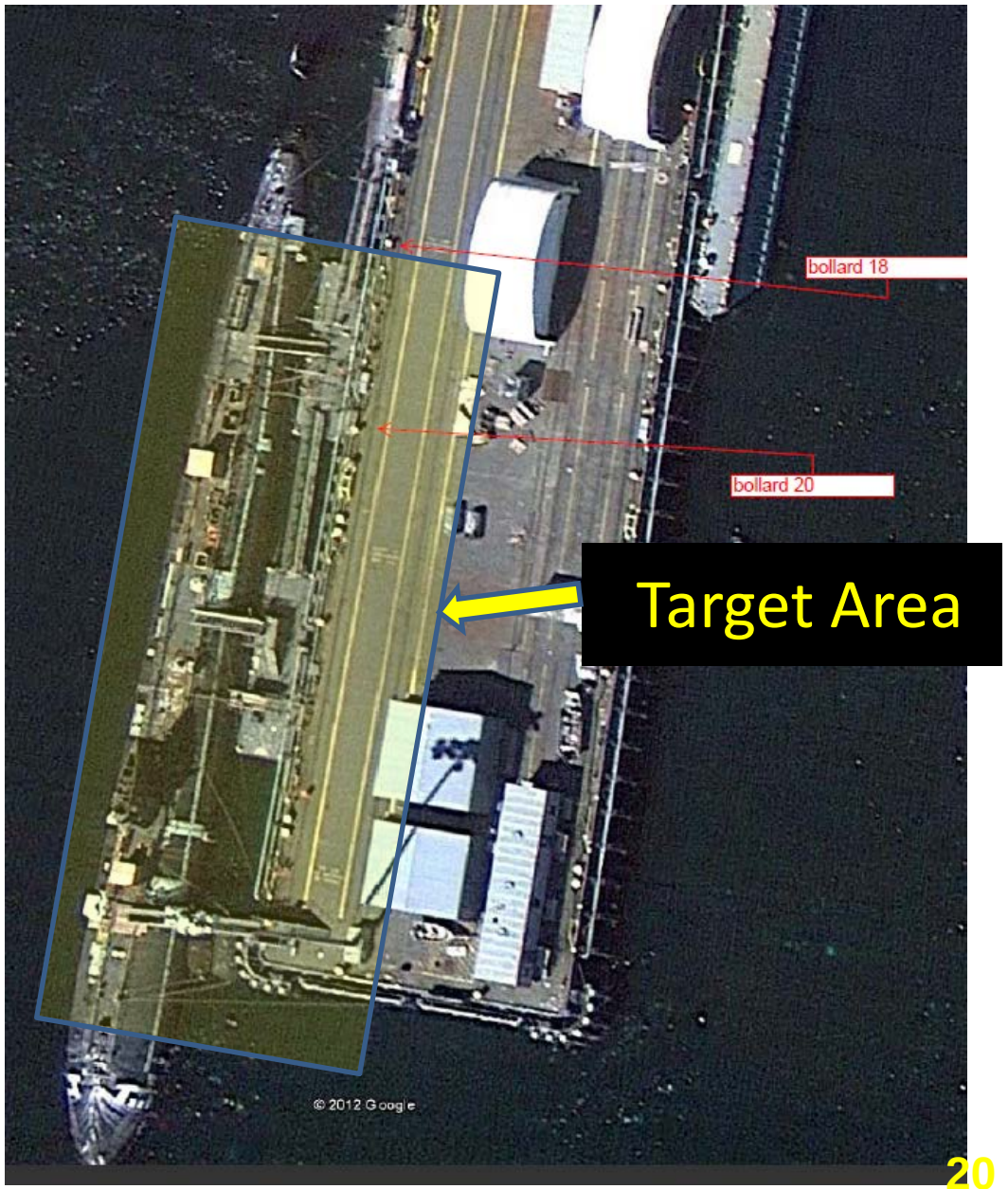
Ghosh et al. 2011 *ES&T 45, 1163–1168*

Pier 7 Amended Cap Demonstration Project

Schedule

- 2011 Laboratory Evaluation Study Results Support **GO**
- 2012:
  - Aug 1-17 Pre-Placement Monitoring (**Baseline**)
  - 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=22 month**) Monitoring
- 2015
  - July (**T=34 month**) Monitoring

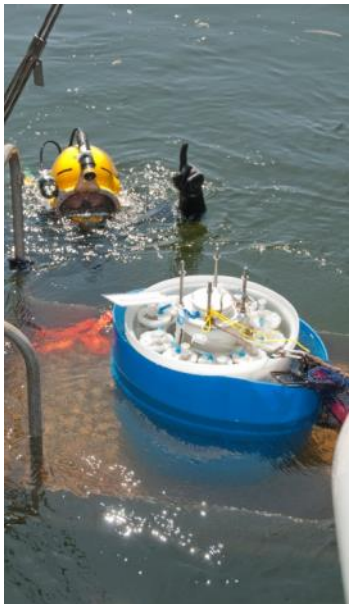
Remedial Action under CERCLA as part of the Record of Decision for site clean up

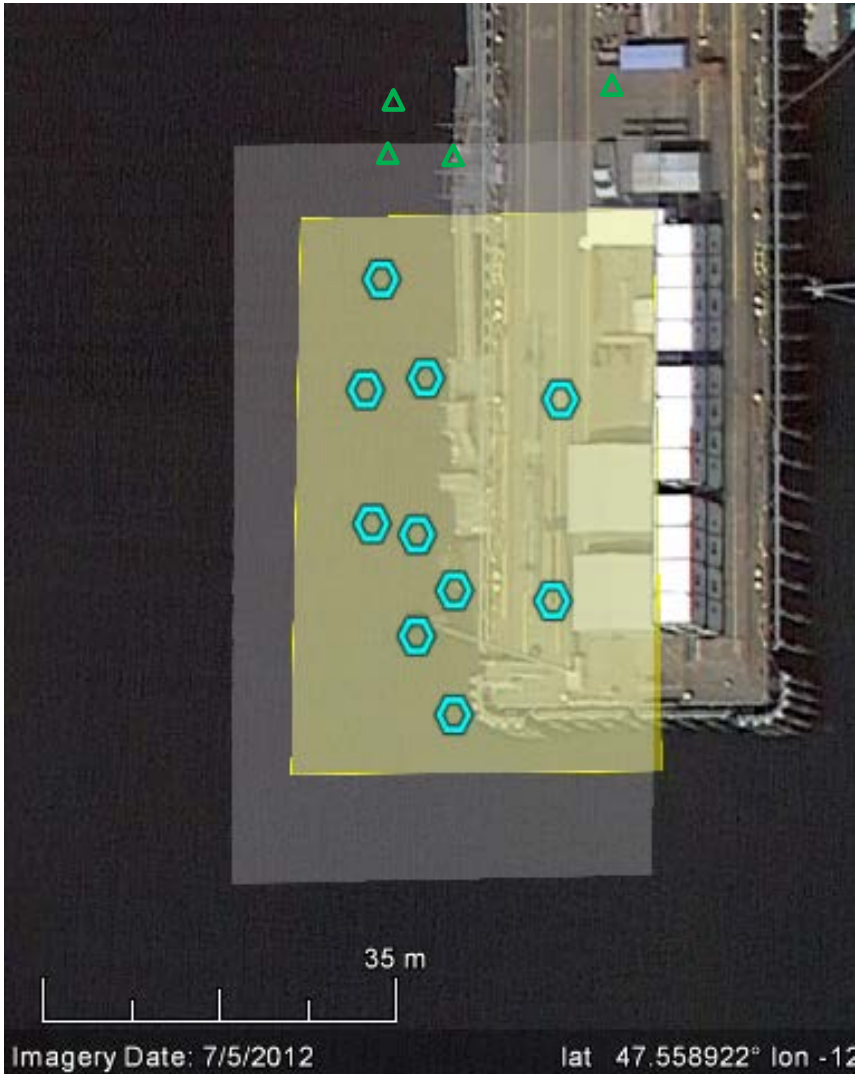


Monitoring for Baseline and T=10 months

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 – solid phase micro extraction (SPME)
  - 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

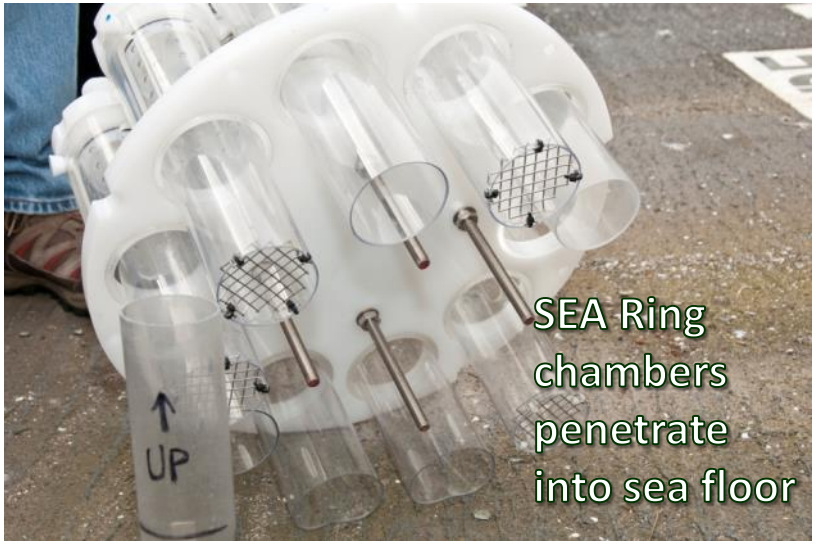




Amendment Target Area
SPI Monitoring
SEA Ring Chamber
Reference Site

Sediment
Ecotoxicity
Assessment

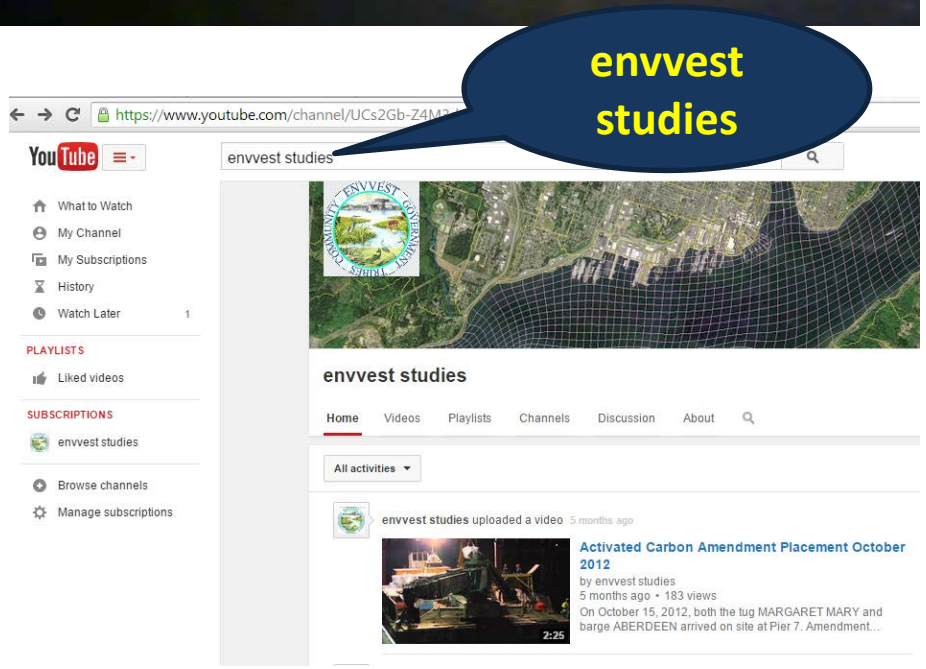
SEA Ring




Preparing SEA Ring
Water Quality and Passive Samplers
Worms and Clams


SEA Ring on Bottom
Diver inspecting SEA Ring prior to retrieval
Flashing blue light indicates circulation pump OK
Chambers intact and covered with sea life


Recovering SEA Ring
Worms, clams, benthic community
Passive samplers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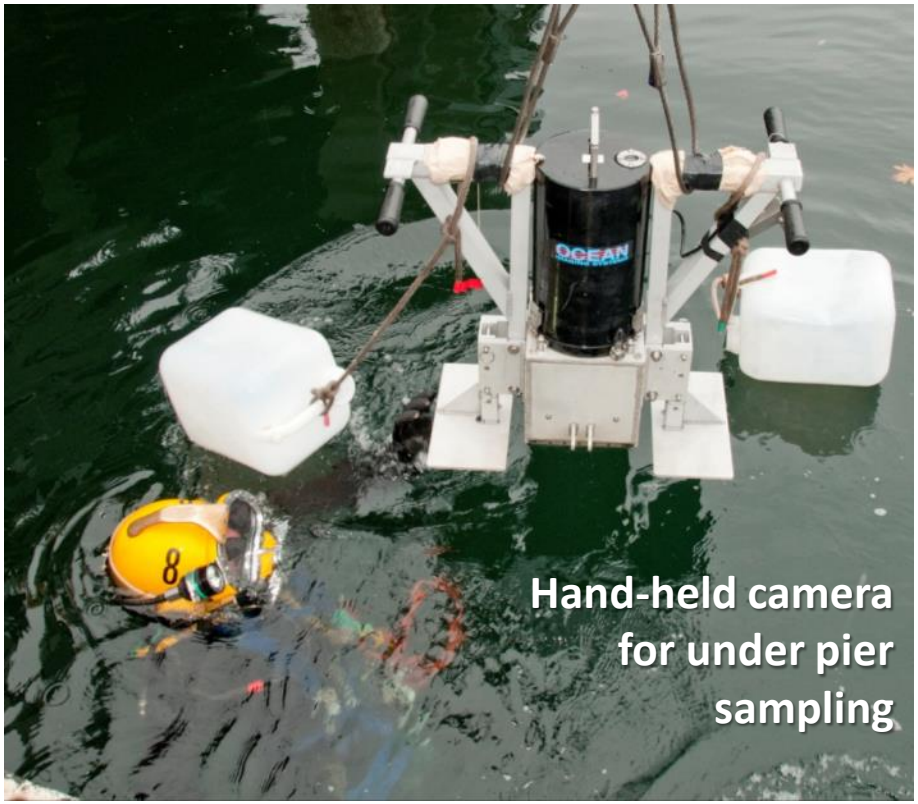
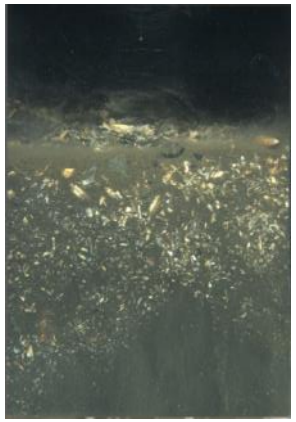
https://www.youtube.com/channel/UCs2Gb-Z4M3
YouTube
envvest studies
What to Watch
My Channel
My Subscriptions
History
Watch Later 1
PLAYLISTS
Liked videos
SUBSCRIPTIONS
envvest studies
Browse channels
Manage subscriptions
envvest studies
Home
Videos
Playlists
Channels
Discussion
About
All activities
envvest studies uploaded a video 5 months ago
Activated Carbon Amendment Placement October 2012
by envvest studies
5 months ago • 183 views
On October 15, 2012, both the tug MARGARET MARY and barge ABERDEEN arrived on site at Pier 7. Amendment...
2:25

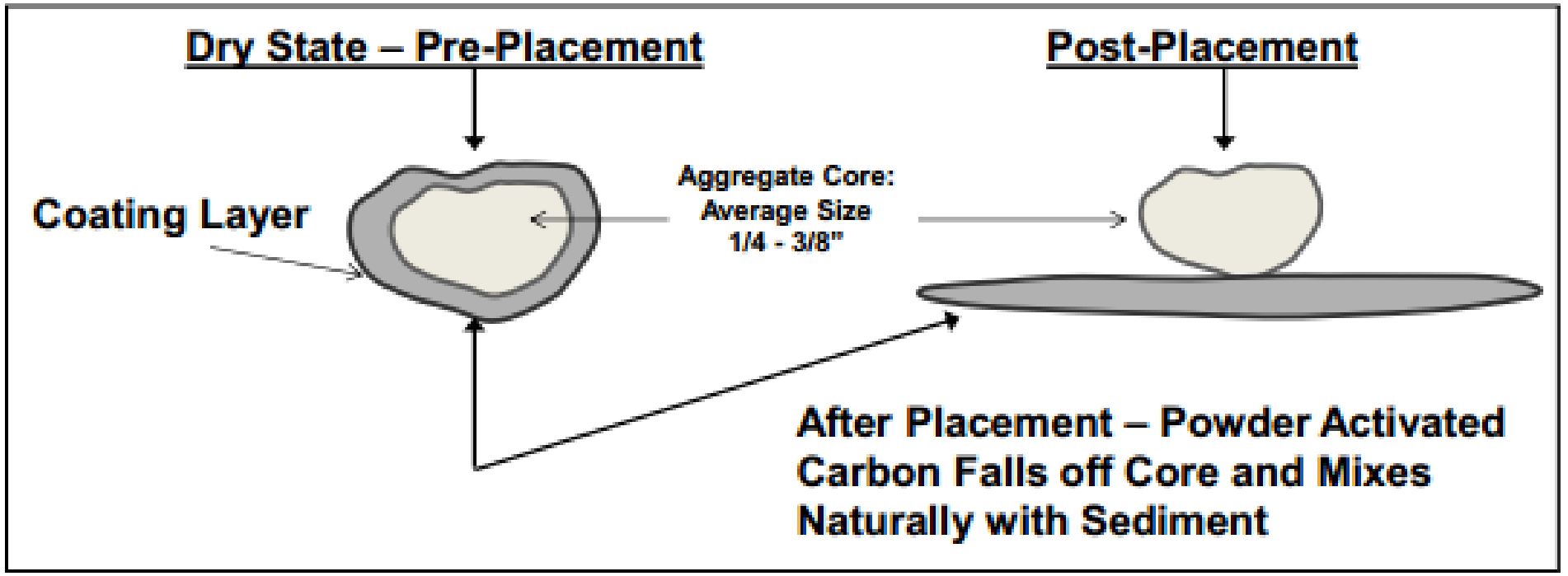
Sediment Profile Imaging (SPI) Camera



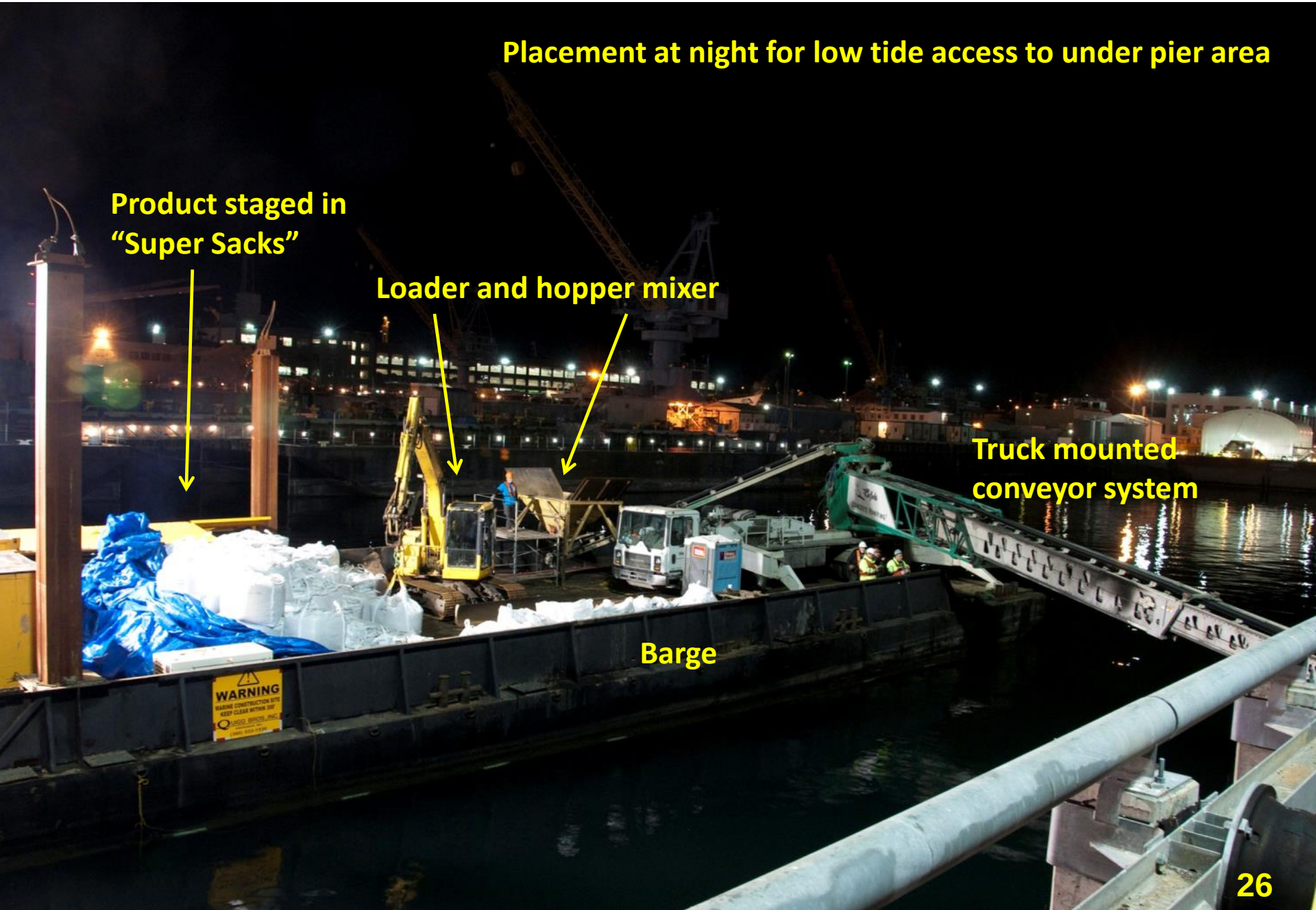
Sediment Profile Images



AquaGate+PAC™ Composite Aggregate



Product Staging and Placement

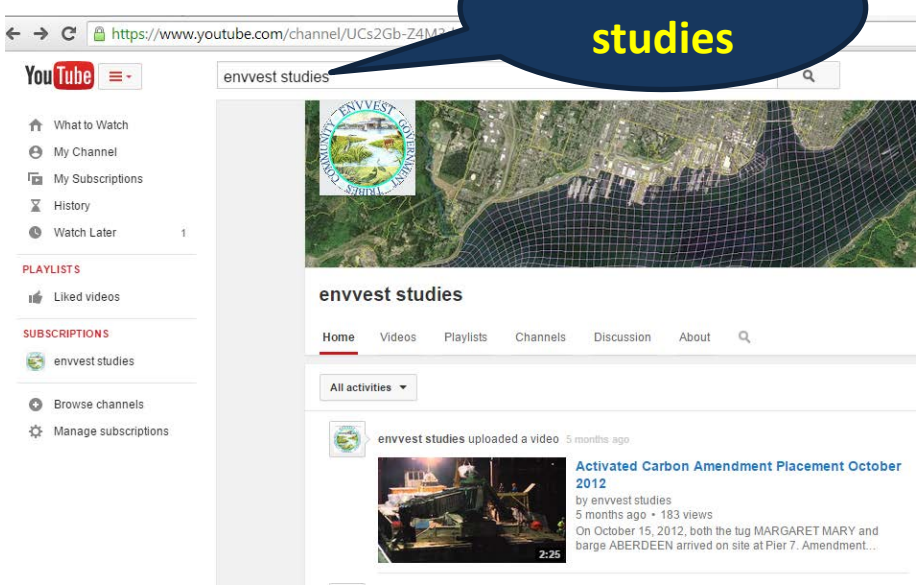


Product Placement
Berthing Area
Under Pier

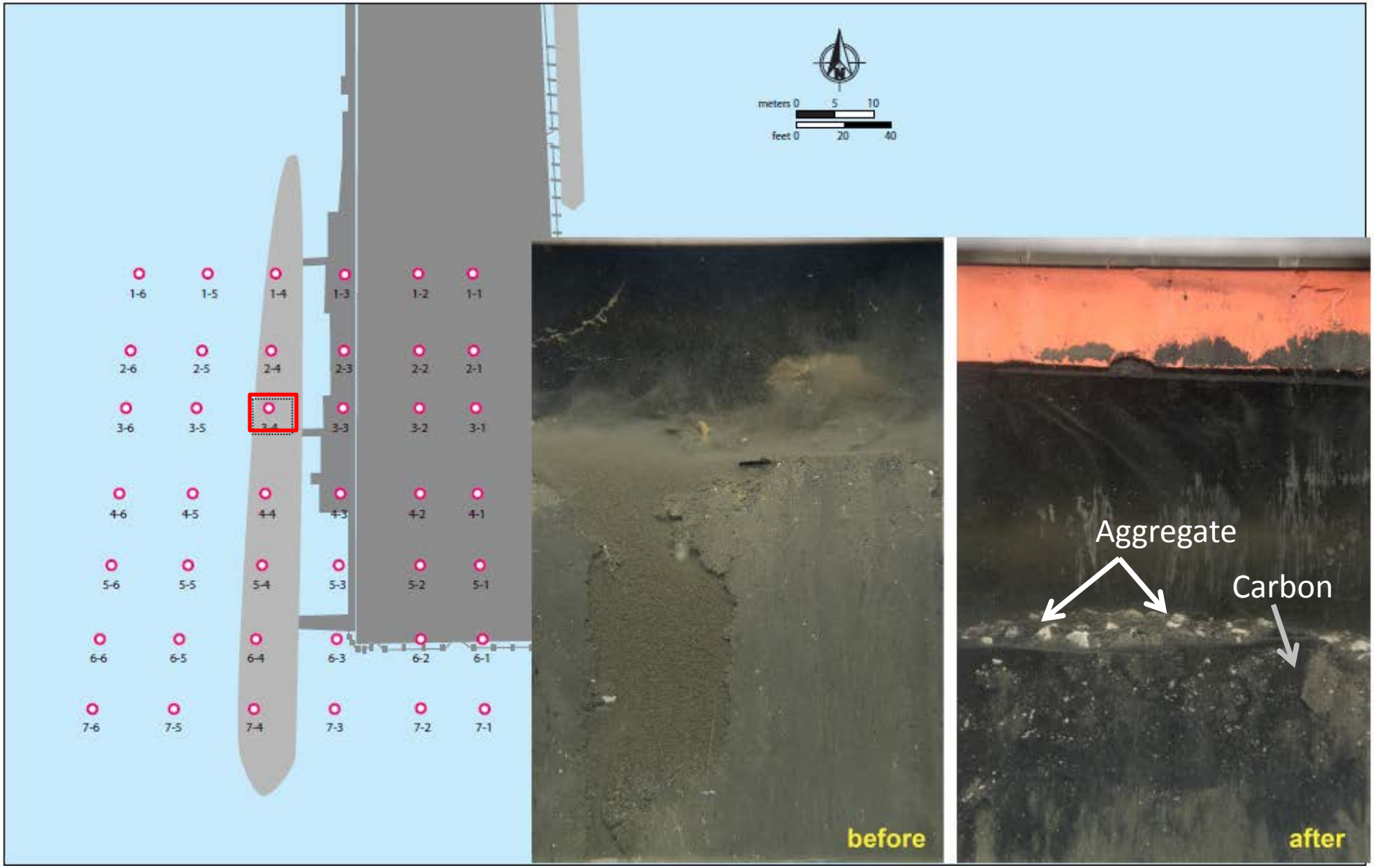
Water Column During Placement:
Diver in water column as product is released at the line
Diver follows product down
Diver watches product settle on the bottom

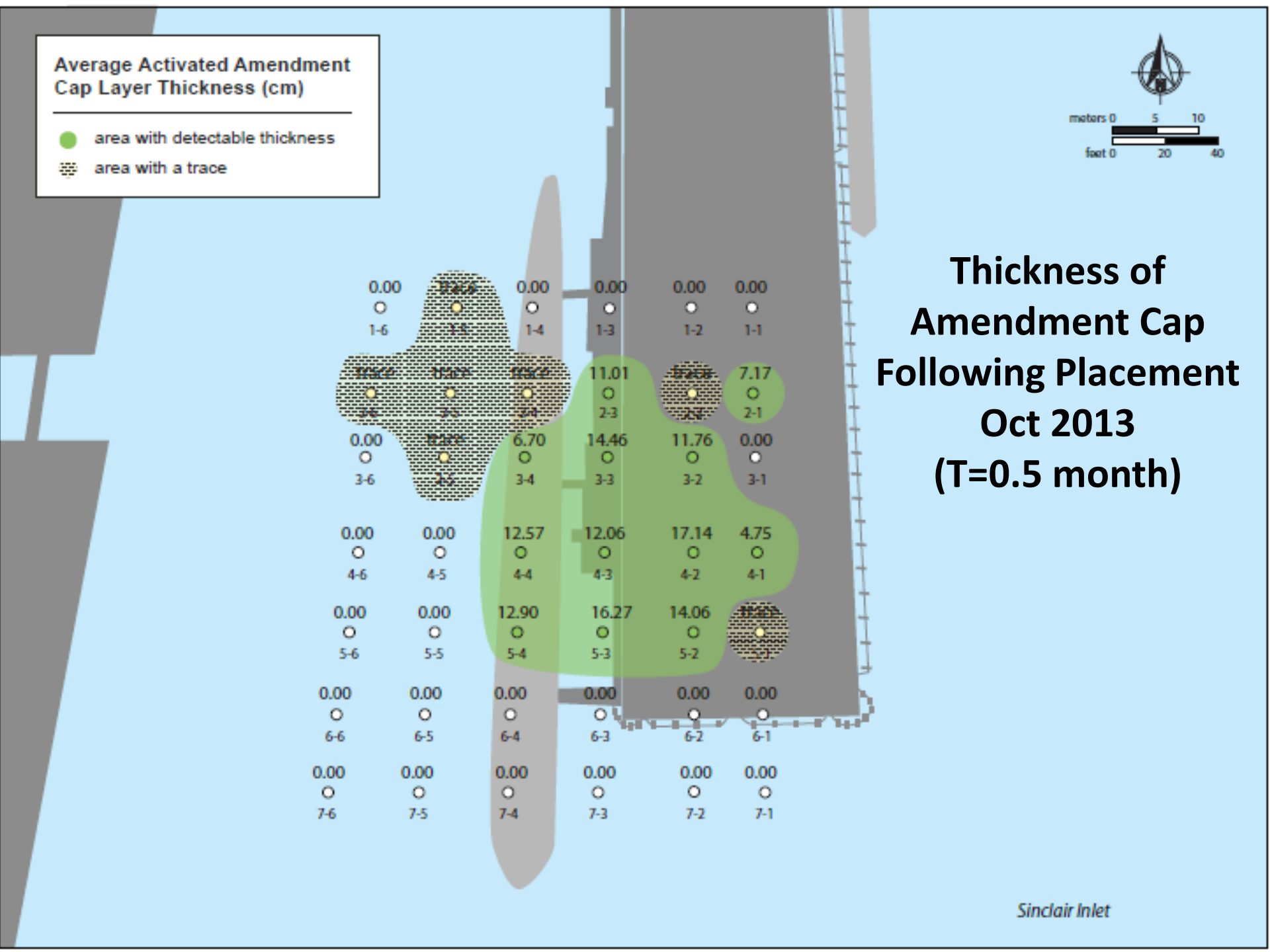
Bottom Following Placement
Diver surveys transect from area with no product
Through berthing area to under pier with product
Crabs, fish, other marine life, and sloping bathymetry visible

envvest studies



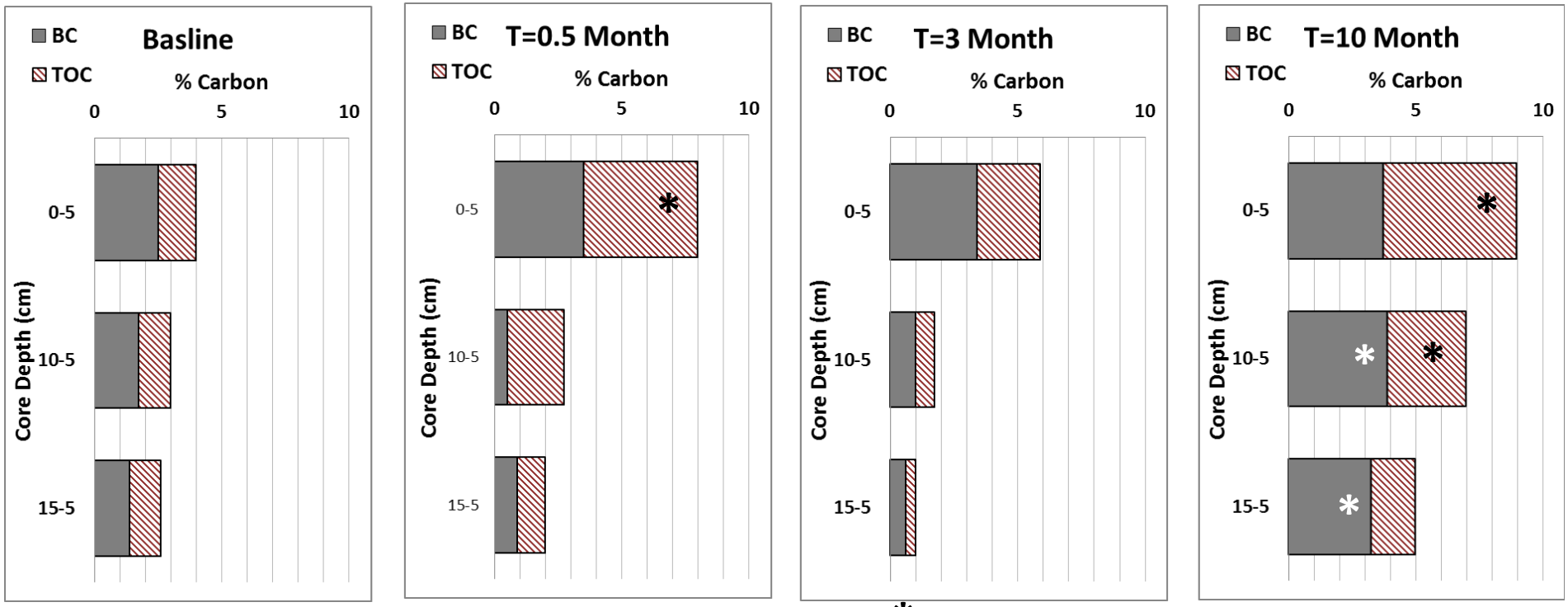
Sediment Profile from SPI camera





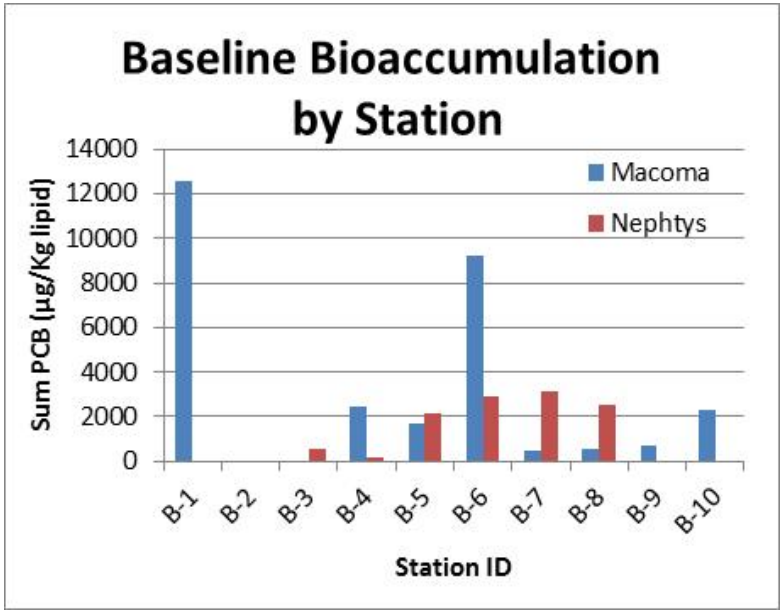
Thickness of Amendment Cap Following Placement Oct 2013 (T=0.5 month)

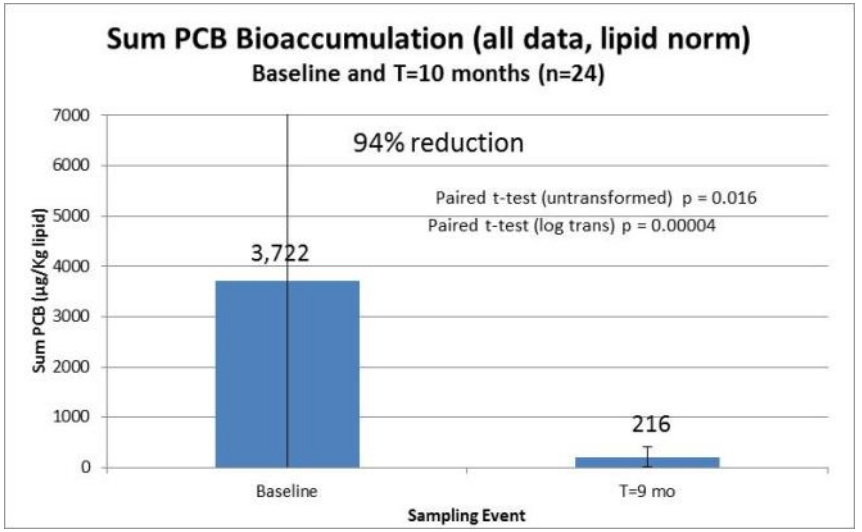
Average Black Carbon (BC) and Total Organic Carbon (TOC) measured in Sediment Cores

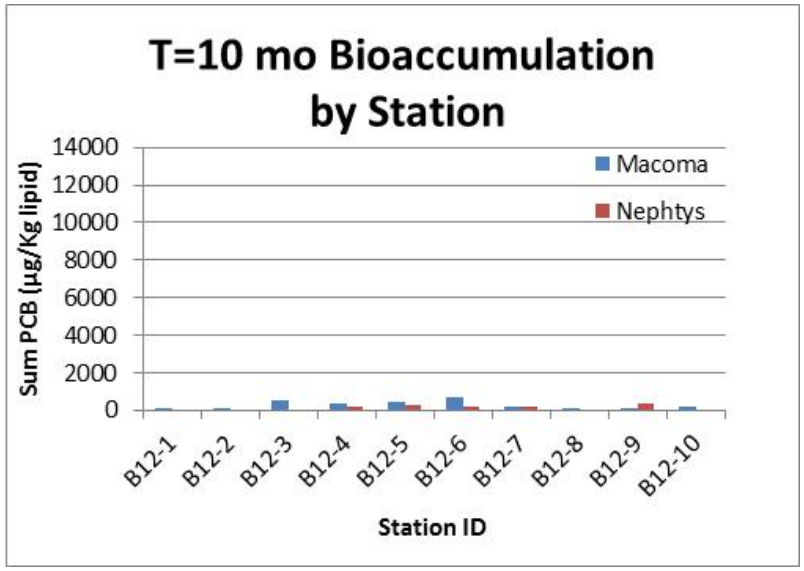


- Measurements confirm increase in carbon content in sediment
  - Expected increase in carbon following installation; ~2x increase in surficial (0-5 cm) layers from 4% to 8% TOC.
  - At 10-mo there appears to be an increase in carbon at deeper levels.
  - Variability across site; look at trends not mass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

In Situ Bioaccumulation in Clams and Worms



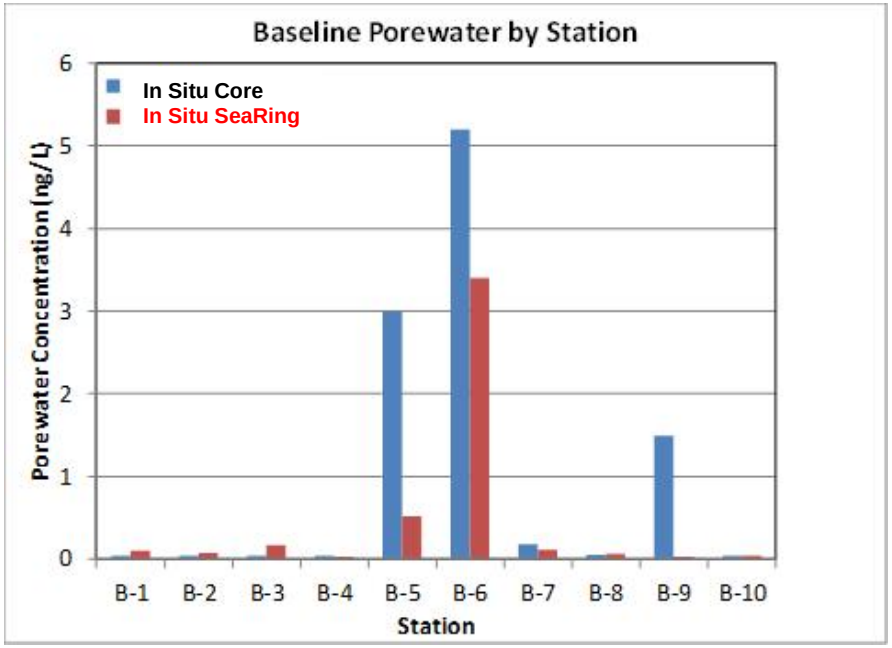


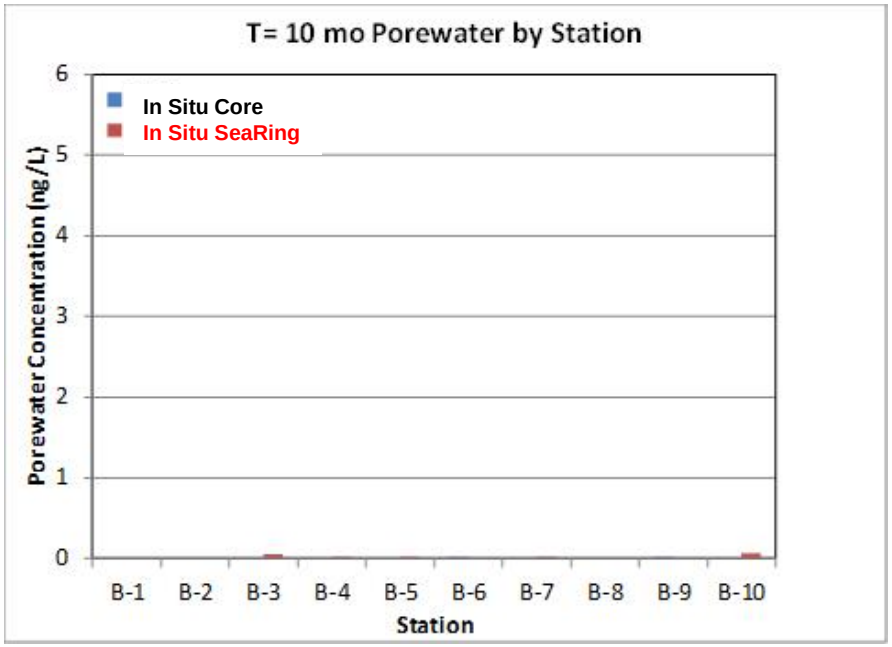


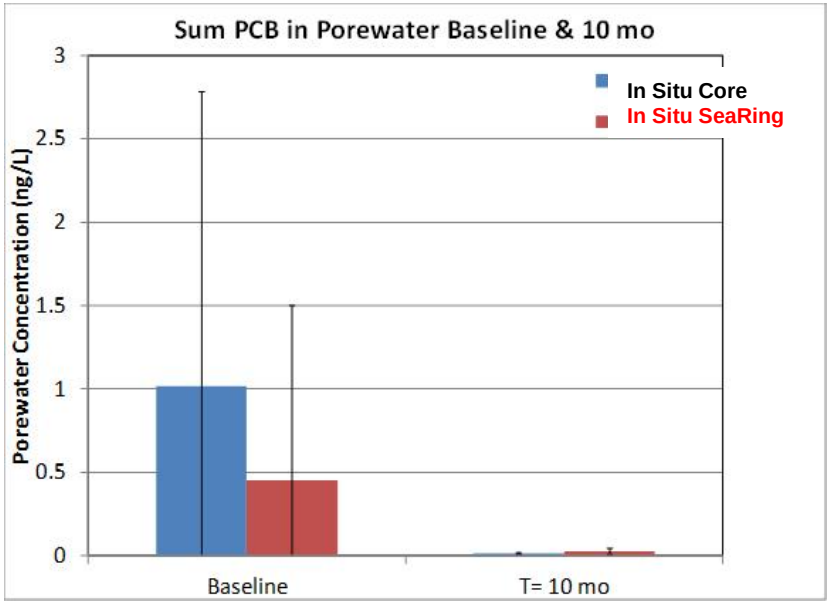
Significant reduction (~90%) in PCB bioavailability to sediment invertebrates

- 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

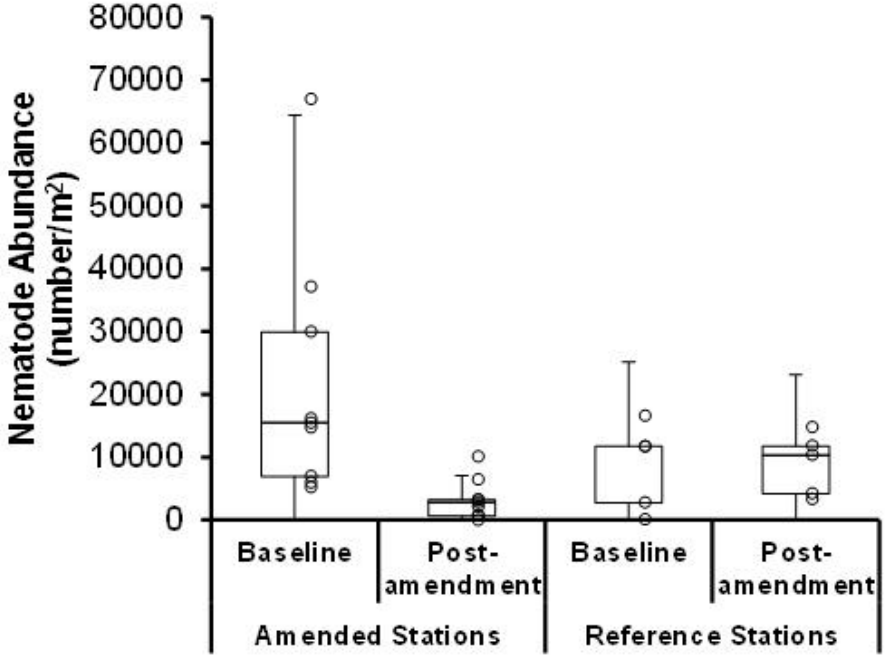


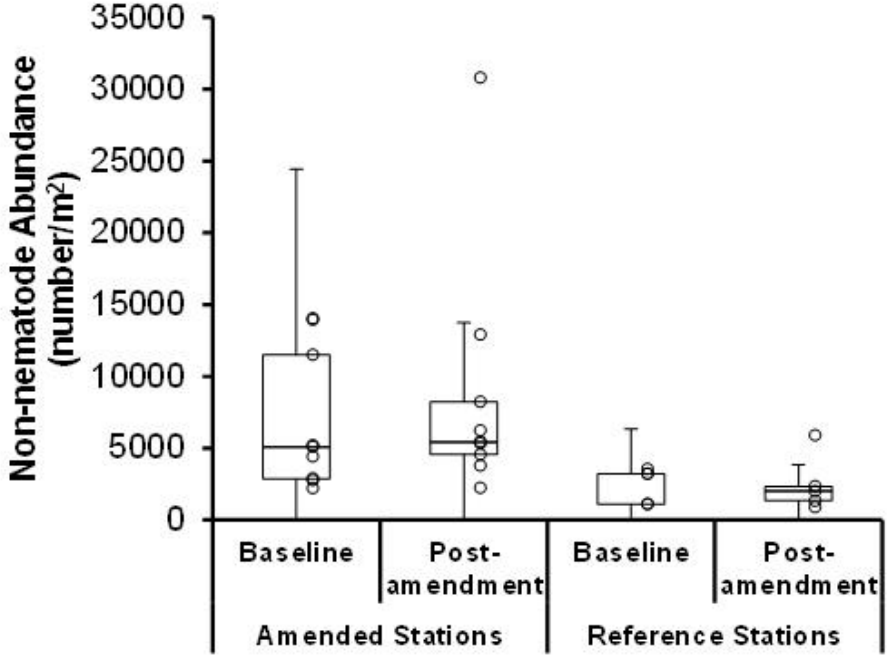




- **Similar reduction (~95-99%) in PCBs in porewater as observed in invertebrate tissues**
  - Concurrence with reduction observed in the initial lab study.
  - Sum of detected PCB congeners for both SPME exposures (in situ SeaRing and in situ cores) used during Baseline and T=10-mo post-remedy.
  - 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)

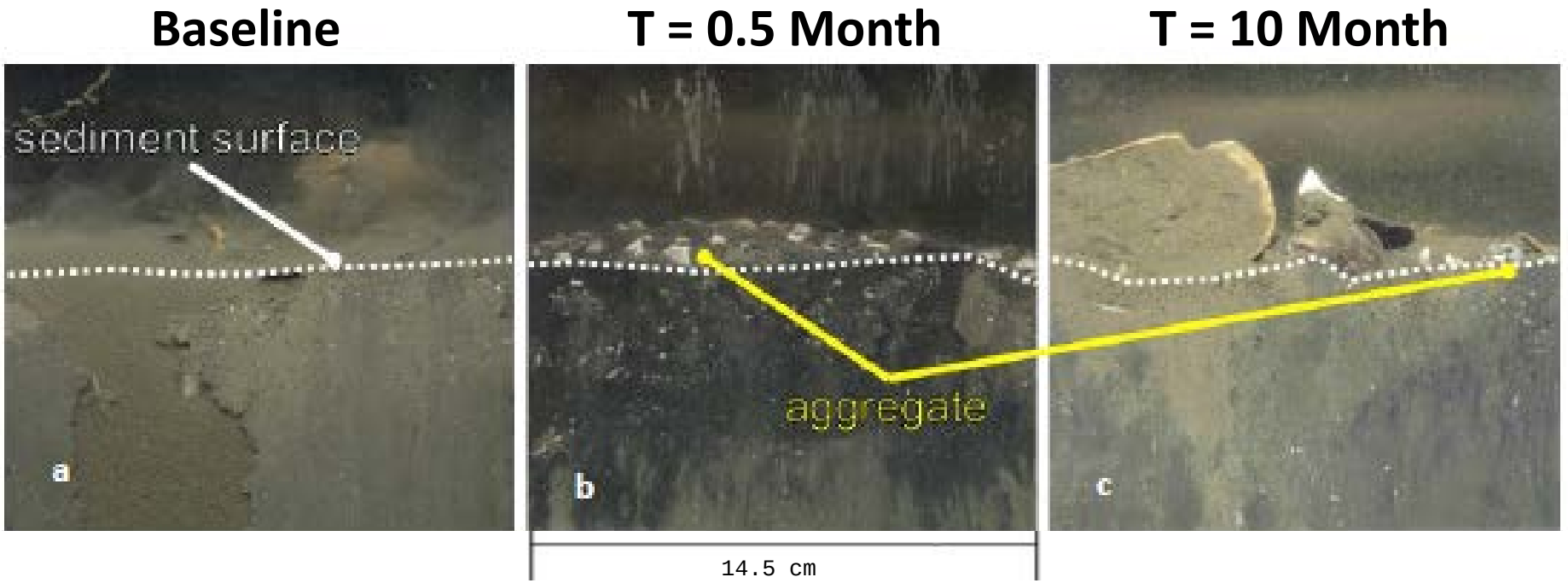




Slight shifts in community structure observed

- 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.

Sediment Profile Images at a Representative Site



- AquaGate + PAC™ particles on sea bottom
- Activated Carbon released from carrier granules
- At 10 months Activated Carbon was being reworked into underlying sediment

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 for AC Demo Project

- 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

Take Home Message

Need to know if our actions are working, if we are addressing the most urgent and important problems, and whether we are getting the "biggest bang for the buck".

Robust monitoring is required to track status and trends and assess the effectiveness of management actions.

References

Chadwick, D.B. Kirtay, V., Rosen, G. Johnston, R.K., Conder, J. Grover, M., Webb, R., Collins, J., Germano, J., and Helland, B., 2014. Short-Term Performance of an Activated Carbon Amendment to Reduce PCB Bioavailability at an Active Naval Shipyard. Interim Report – Project ER-201131, Submitted to Environmental Security Technology Certification Program, August 2014. http://www.mesodat.org/Public/Pier7/Docs/ER-201131_InterimReportFinal_2014_08_22.pdf

Envvest Studies, 2014. YouTube Videos. https://www.youtube.com/channel/UCs2Gb-Z4M3dcghzqxLaLpeg

Ghosh, Upal , Richard G. Luthy, Gerard Cornelissen, David Werner, Charles A. Menzie, 2011. Environ. Sci. Technol. In-situ sorbent amendments: A new direction in contaminated sediment management. Feature Article, 45, 1163–1168. http://pubs.acs.org/doi/full/10.1021/es102694h

Johnston, R.K. Rosen G.H., J.M. Brandenberger, E.W. Mollerstuen, J.M. Young, and B. Beckwith, 2011. Monitoring water, sediment, and biota to assess protection of beneficial uses for Sinclair Inlet. Proceedings of the Salish Sea Ecosystems Conference 2011, Vancouver, BC, Canada http://www.verney.ca/assets/O2AProceedings_Johnston.pdf

Johnston, R.K., V. Kirtay, D.B. Chadwick, G.H. Rosen, J.M. Guerrero, J. Collins, C. Ortega, R. Webb, R. May, J. Germano, D. Browning, E. Beaver, M. Wicklein, J. Pittz, D.E. Leisle, L. Doyle, and L. Hsu, 2013. "B-024 Installing an Activated-Carbon Sediment Amendment at the Puget Sound Naval Shipyard and Intermediate Maintenance Facility, Bremerton, WA." In proceedings of the Seventh International Conference on Remediation of Contaminated Sediments (Dallas, TX; February 4–7, 2013). ISBN 978-0-9819730-6-7, ©2013 Battelle Memorial Institute, Columbus, OH. http://www.mesodat.org/Public/Pier7/Docs/SedConf2013_Johnston_B-024_Paper.pdf

Johnston, R.K., Jill Brandenberger, Li-Jung Kuo, Carolyn Suslick, Eric Mollerstuen, Eric Beckley, 2014. Mussel Watch monitoring to assess status, tends, and continuous process improvement of environmental protection and restoration initiatives for Sinclair and Dyes Inlets, Liberty Bay, and Port Orchard, Rich and Agate Passages of the Puget Sound, WA. Proceedings of the 2014 Salish Sea Ecosystems Conference, April 30 – May 2, 2014, Seattle, WA. http://www.wwu.edu/salishseaconference/ https://event.crowdcompass.com/ssec2014/activity/kmuGu3CxPZ

Johnston, RK, D.B. Chadwick, V. Kirtay, G.H. Rosen, , J. Guerrero, J. Germano, J. Conder, and C. Stransky. 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. Proceedings of the 2014 Salish Sea Ecosystems Conference, April 30 – May 2, 2014, Seattle, WA. http://www.wwu.edu/salishseaconference/ https://event.crowdcompass.com/ssec2014/activity/Iqh5qziisJ

Kimbrough, K. L., W. E. Johnson, G. G. Lauenstein, J. D. Christensen and D. A. Apeti. 2008. An Assessment of Two Decades of Contaminant Monitoring in the Nation's Coastal Zone. Silver Spring, MD. NOAA Technical Memorandum NOS NCCOS 74. 105 pp. http://ccma.nos.noaa.gov/publications/MWTwoDecades.pdf

Space and Naval Warfare Systems Center Pacific, 2014. Pier 7 Activated Carbon Demonstration Project. http://www.mesodat.org/Public/Pier7/Index.htm