Best Practices and Lessons Learned from 25 Years of PCB Assessment and Remediation on the Waterfront

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April 11, 2024

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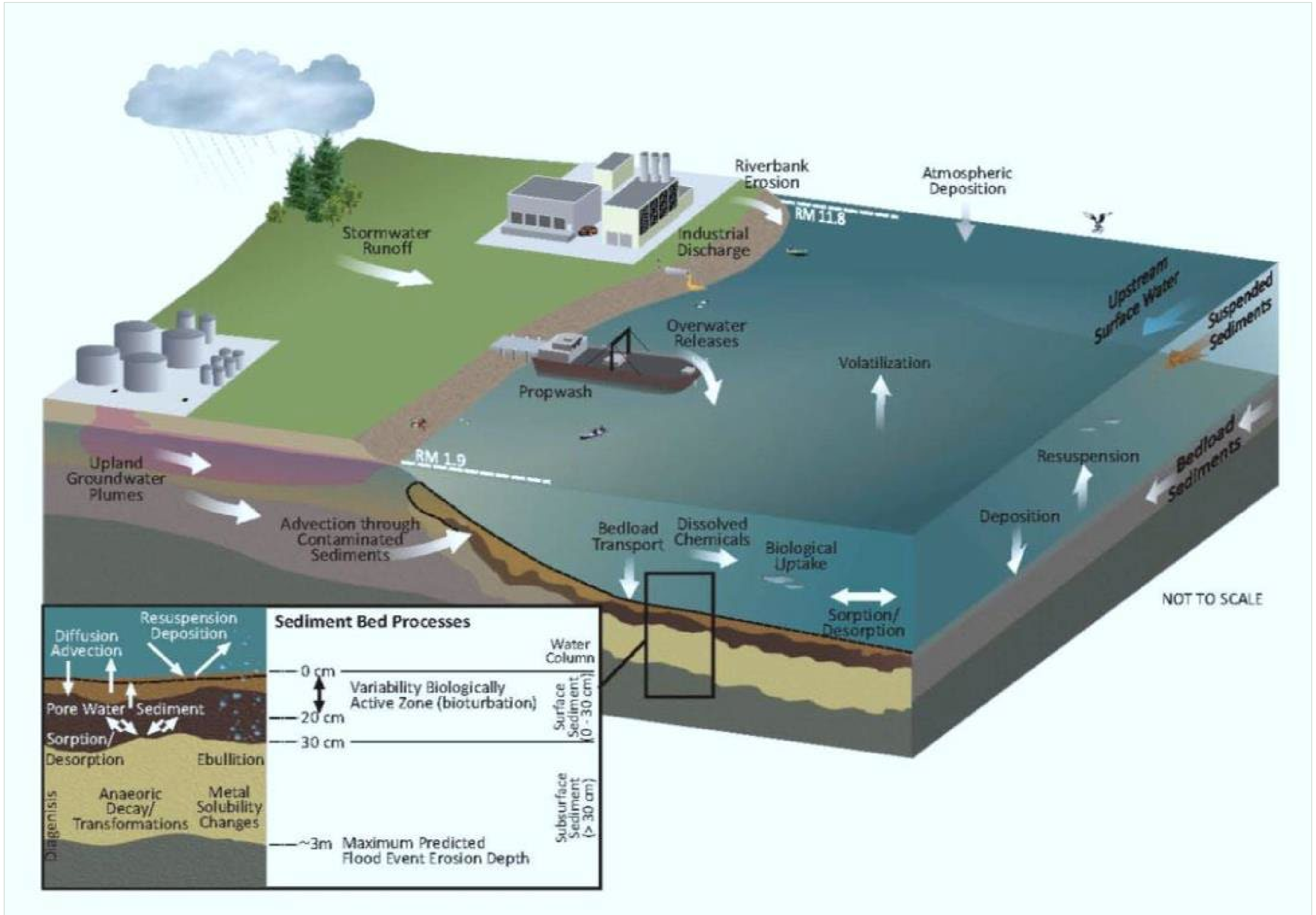
Outline

- Background on PCBs in aquatic environments
- Investigation approaches
- Remediation approaches
- Case study examples
- Summary

Background

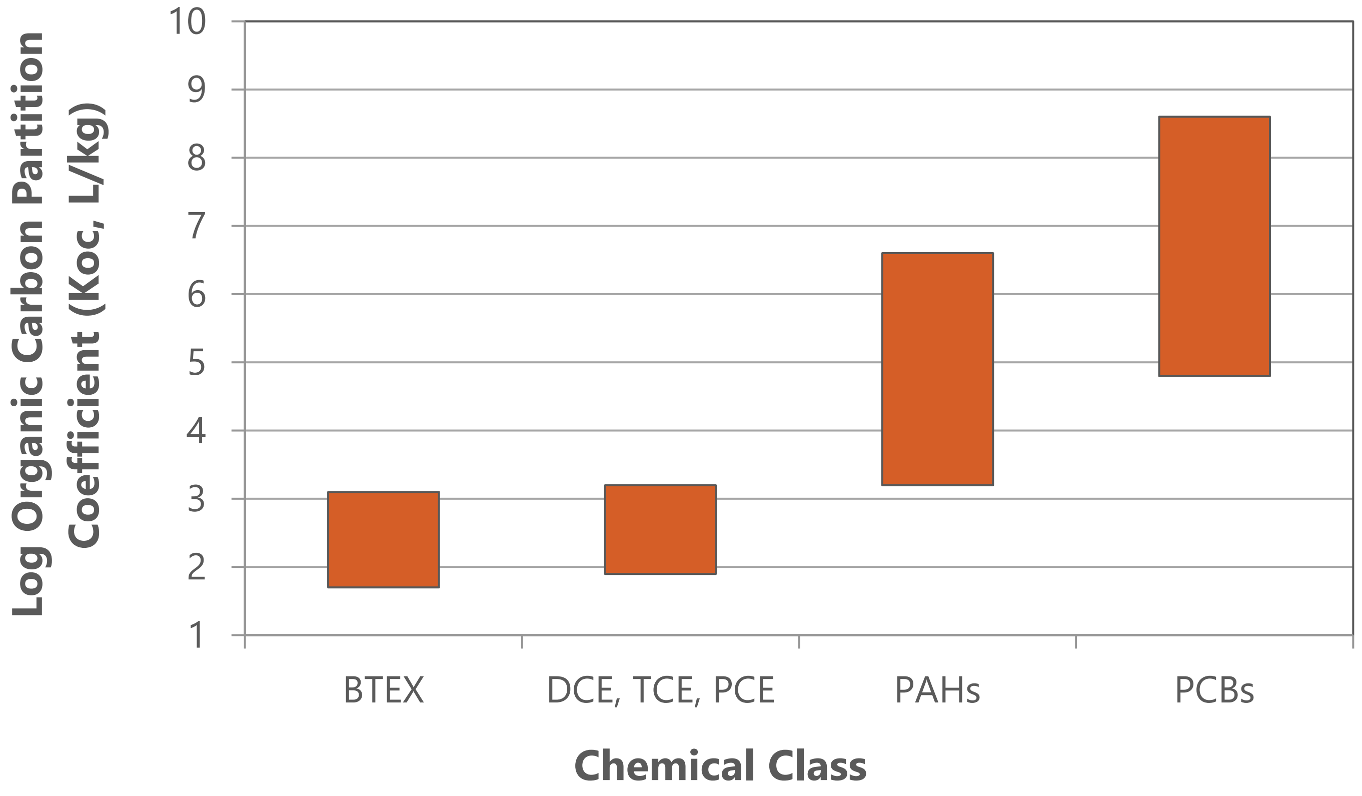
Background—Pathways

- Multiple pathways by which PCBs can enter a surface water body



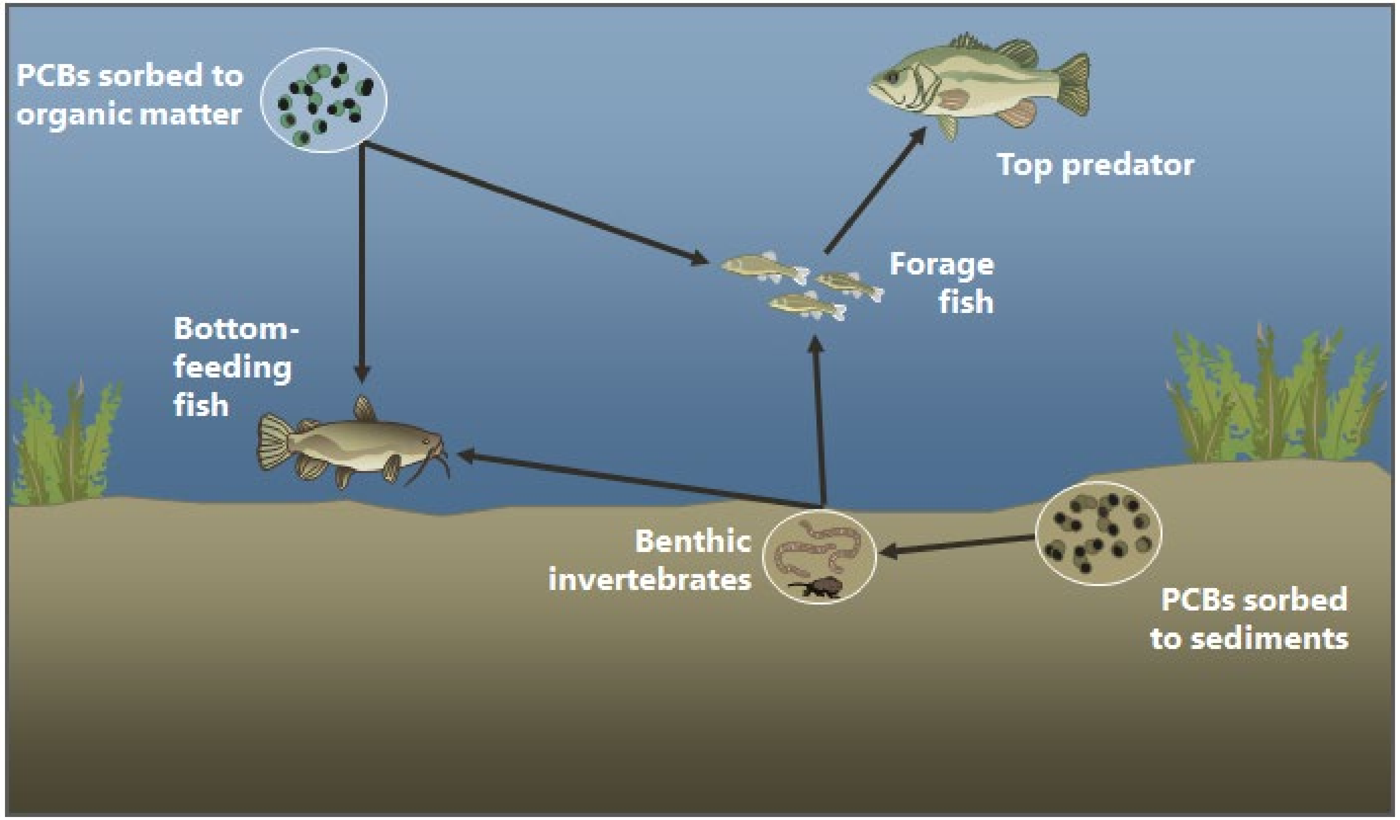
Background—Key PCB Properties

- Sorb strongly to soils and sediments
  - Organic carbon fraction
- Little to no degradation in the environment
- Bioaccumulative



Implications for Aquatic Environment

- Part per trillion (ng/L) levels in surface water can give rise to:
  - Part per billion or part per million (µg/kg or mg/kg) levels in particulate matter
  - Part per million (mg/kg) levels in biota
    - Levels increase by trophic level in the food web



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PCB Cleanup Levels for Aquatic Sediment Typically Much More Stringent Than Those for Upland Soil

Agency or Site	Upland Cleanup Level (mg/kg)	Aquatic Cleanup Level (mg/kg)
Delaware DNREC (Screening Levels for Ecological Receptors)	40	0.04 to 0.06
Housatonic River, MA (Site-specific Risk-based Values)	4.6 to 115 (recreational) 169 to 242 (utility worker)	1.5 (short-term fish tissue) 0.064 (long-term fish tissue)
Sheboygan Harbor and River, MI (Project-specific Values)	10	0.5

- Cleanup costs can be driven by aquatic portion of a site, even if it contains a relatively small fraction of the total PCB mass released

>15 million cubic yards dredged
>$10 billion spent (2022 dollars)

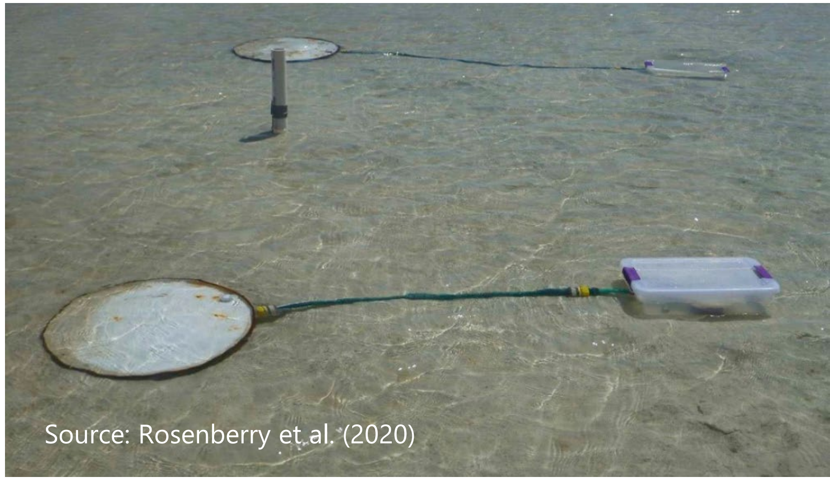
Sediment PCB Cleanup Sites

1. Cedar Creek, WI	8. Field Brook/Ashtabula River, OH	15. Mirror Lake, DE	22. River Raisin, MI
2. Commencement Bay, WA	9. Fox River ,WI	16. Onondaga Lake, NY	23. Sangamo Weston/Lake Hartwell, SC
3. Columbia Slough, OR	10. Grasse River, NY	17. Ottawa River, OH	24. San Diego Bay, CA
4. Cumberland Bay, NY	11. Housatonic River, MA	18. Passaic River, NJ	25. Sheboygan River and Harbor, WI
5. Duwamish Waterway, WA	12. Hudson River, NY	19. Pearl Harbor, HI	26. Sinclair Inlet/Bremerton Naval Shipyard, WA
6. East Waterway, WA	13. Kalamazoo River, MI	20. Portland Harbor, OR	27. Town Branch Creek/Mud River, KY
7. Elliott Bay, WA	14. Manistique River and Harbor, MI	21. Puget Sound, WA	28. Waukegan Harbor, IL

Investigation Approaches

Aquatic PCB Investigation

- Multi-media approach is almost always needed; some require specialized sampling techniques
  - PCB sampling media
    - Soil, sediment, porewater
    - Surface water
    - Biota (e.g., fish tissue)
  - Other types of data collection
    - Surface water elevations, flows, velocities
    - Groundwater/surface water interactions
    - Sediment deposition and erosion



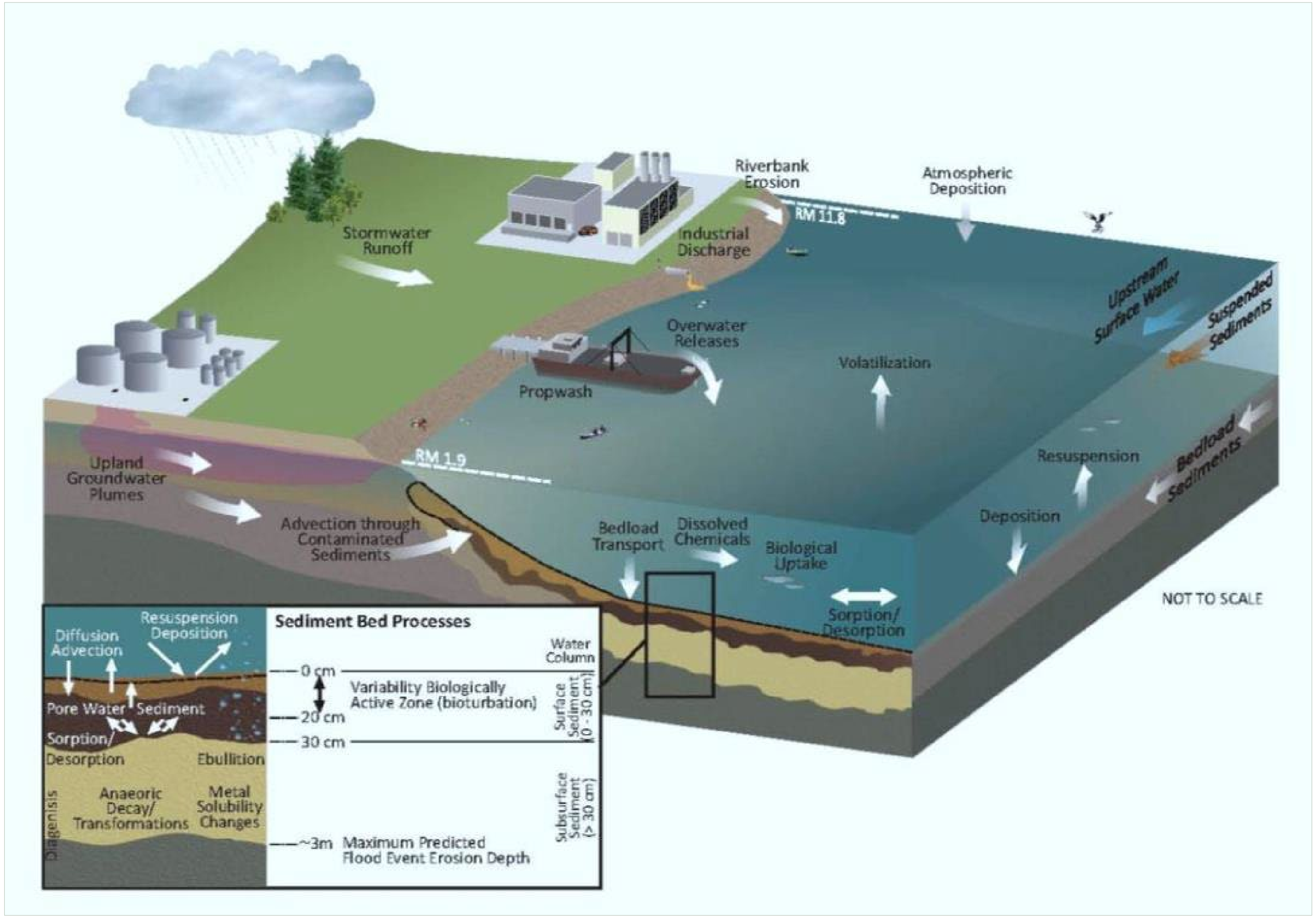
Source: Rosenberry et.al. (2020)

Understanding Sources and Pathways is Key

- Multiple source pathways usually present
  - Contemporary may be different than historical
- Sediment/water exchange processes can be an important driver
  - Erosion/deposition
  - Dissolved phase exchange (seepage and diffusion)
- Multiple routes of bioaccumulation are possible
  - Fish uptake tied to sediment bed (benthic)
  - Fish uptake tied to water column (pelagic)
  - Combination

Conceptual Site Model (CSM)

- A robust CSM is needed to inform development of remedial approaches
- Requires multiple lines of evidence based on empirical datasets
  - Mathematical modeling often used to integrate data and help fill temporal and spatial gaps in data



Remediation Approaches

Remedial Technologies

- Numerous technologies, but most often three main approaches
  - Removal (dredging)
  - Containment (capping, including with amendments)
  - Monitored natural recovery (MNR)

Hydraulic Placement of Cap Material

Mechanical Dredging

Remedial Approaches

- Each technology has its pros and cons
- Site remedies very often consist of combinations of technologies, such as:
  - Dredging to accommodate a cap
  - Removal in most heavily contaminated areas, with capping and MNR in other areas

Contaminated Sediment Remediation Guidance for Hazardous Waste Sites

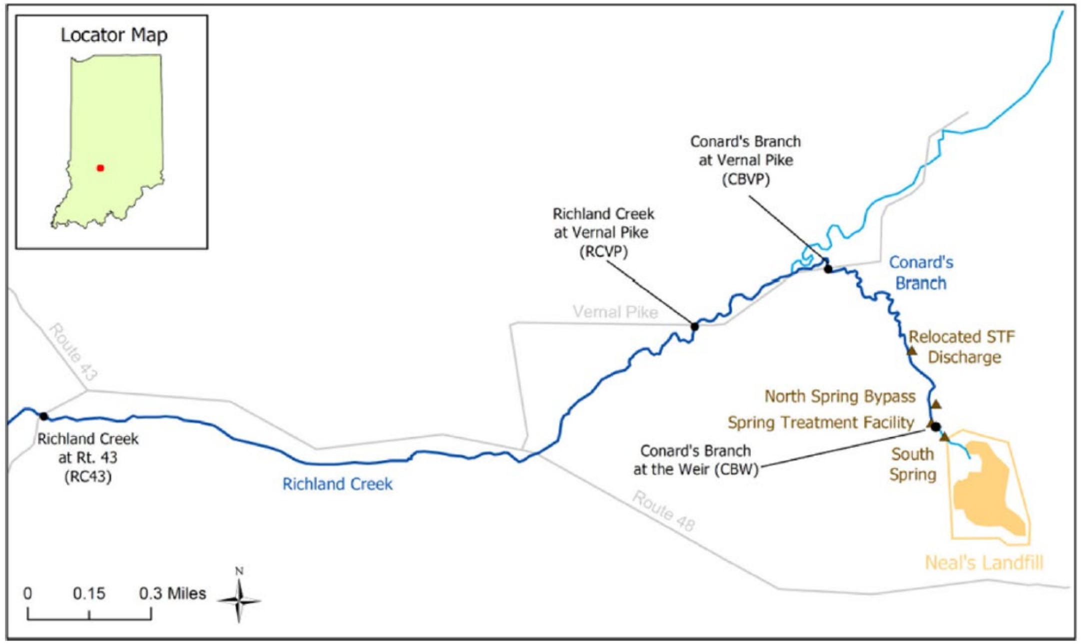
Source: USEPA (2005)

Case Studies

Case Study Examples

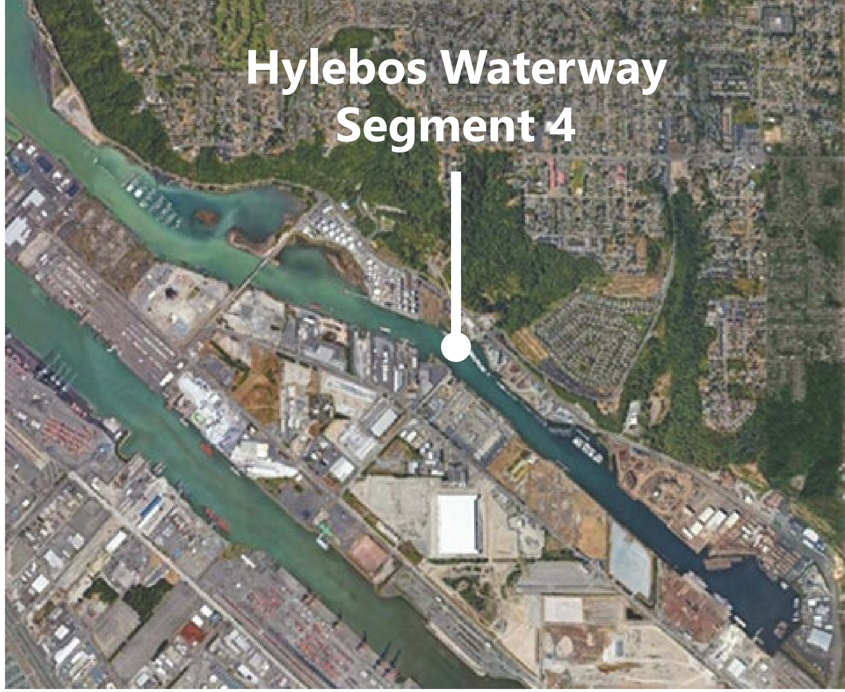
- Puget Sound, Washington
  - Hylebos Waterway and Sinclair Inlet

- Conard's Branch and Richland Creek, Indiana



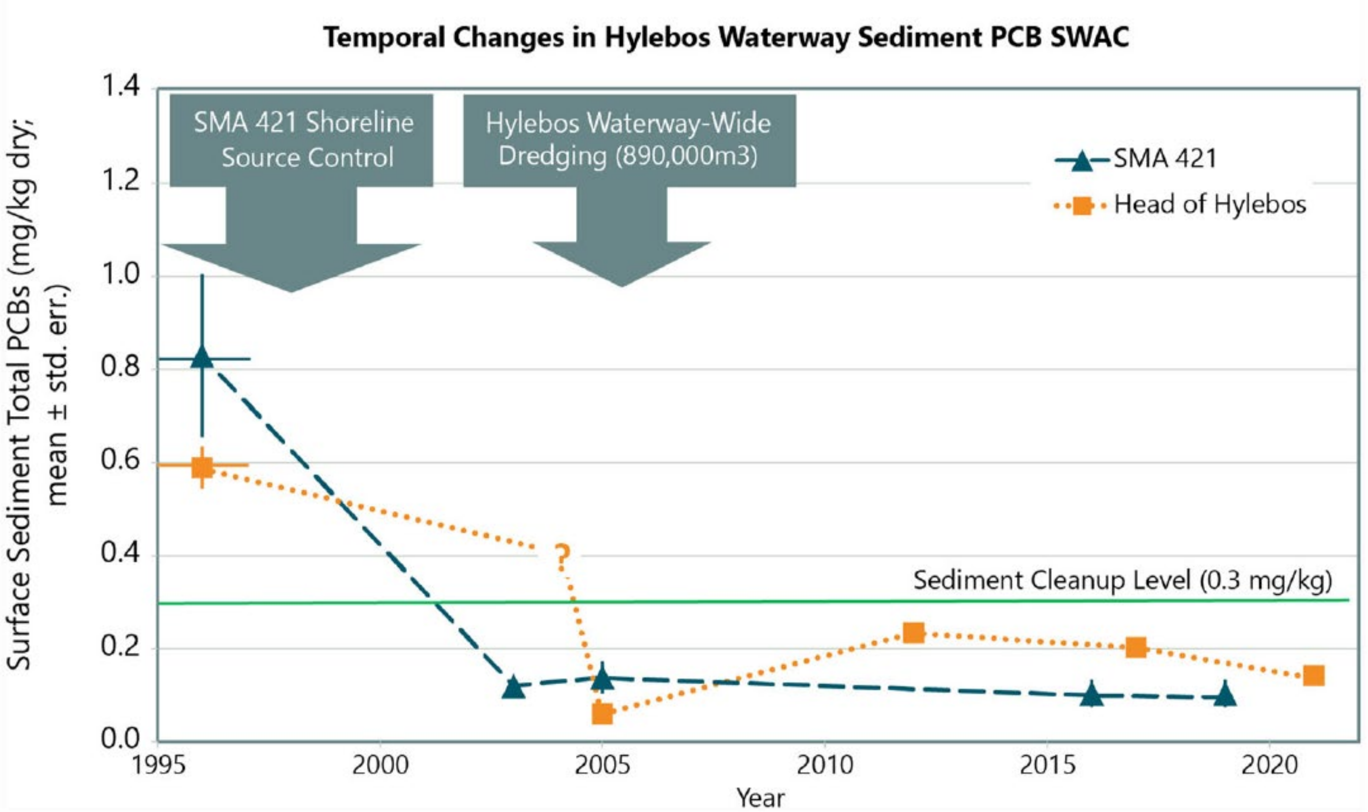
Hylebos Waterway, Washington

- Part of Commencement Bay Site
- Numerous historical PCB sources
  - Extensive wastewater/stormwater controls and upland/shoreline cleanup actions: 1985 to 1999
  - Source control verified in 2001
- Sediment remediation: 2001 to 2006
  - 24 acres dredged (1,500,000 cy)
  - 8 acres monitored natural recovery
  - 3 acres capped



Hylebos Waterway Segment 4 Sediment Monitoring

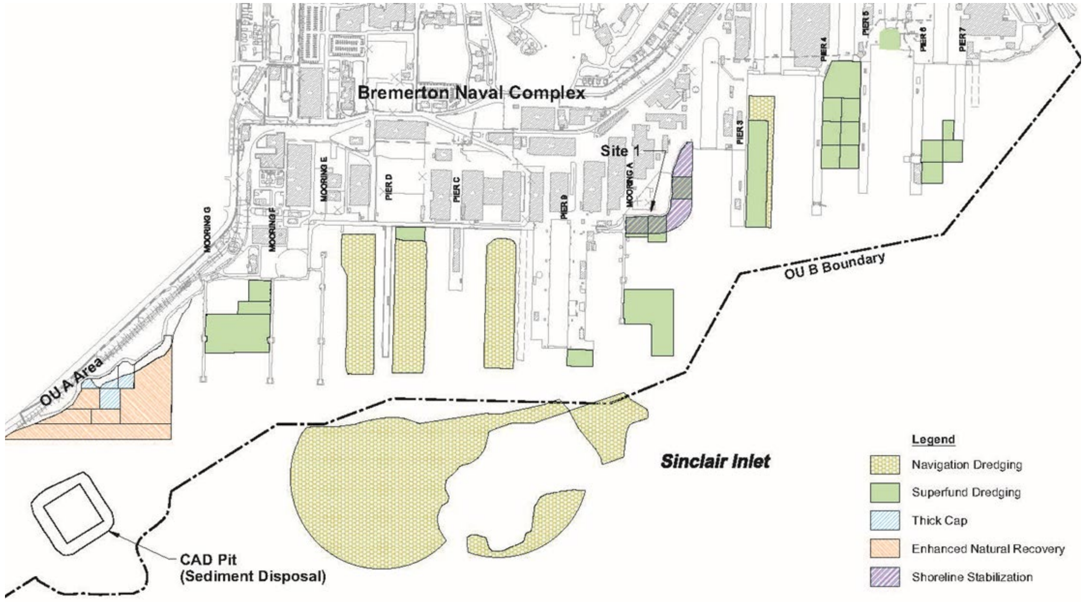
- 1999 remediation of larger shoreline PCB source
- Offshore surface sediment recovered faster than expected
- Source control most effective reducing sediment PCB levels



Source: Patmont and Healy (2024)

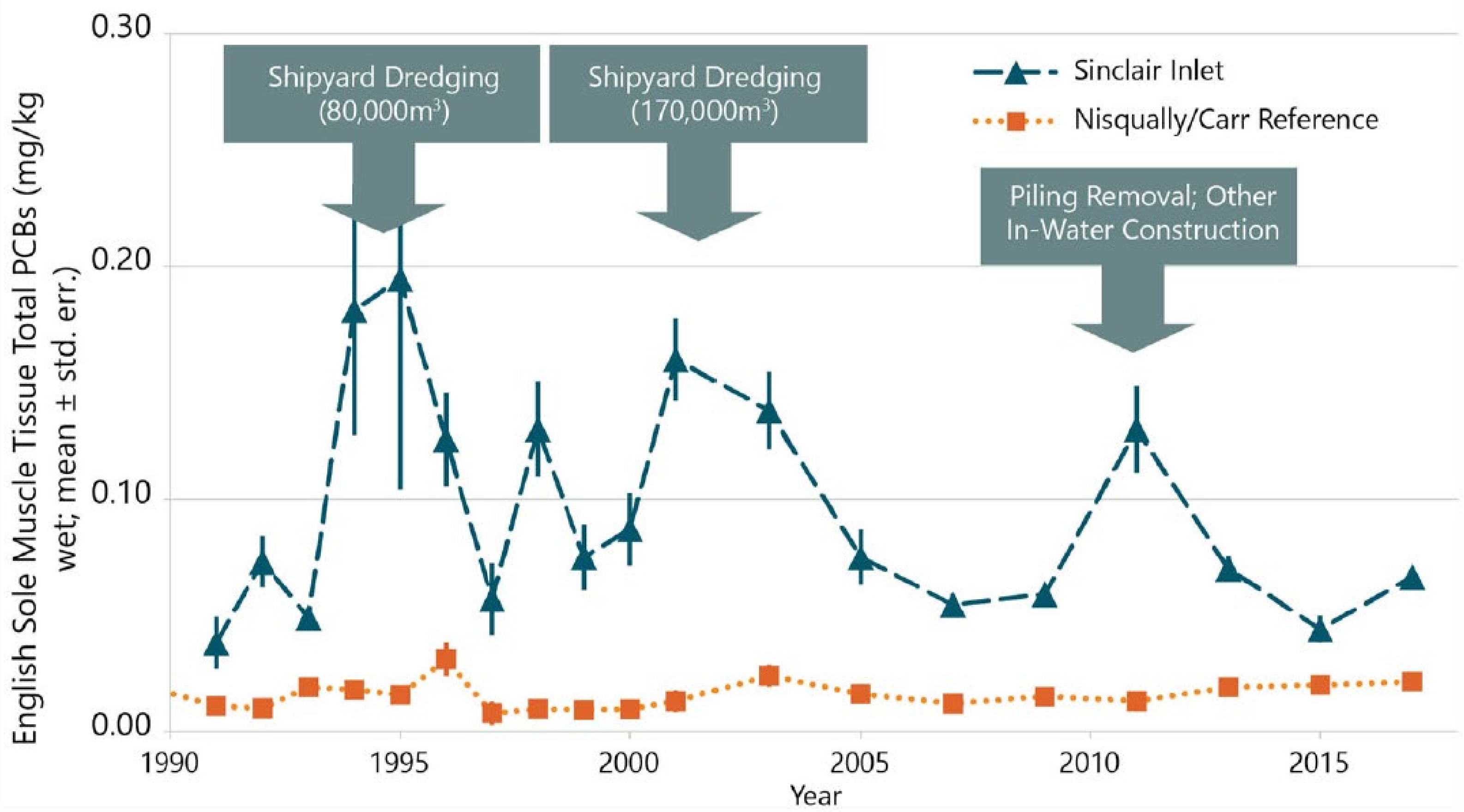
Sinclair Inlet, Washington

- Numerous historical shipyard PCB sources
  - Continuous process improvements and upland cleanup actions beginning in 1992
- Navigation dredging in 1994/1995
- Navigation/Superfund actions in 2000/2001
  - 32 acres dredged (225,000 cy)
  - 13 acres capped or sand covered
- Shipyard infrastructure projects in 2011
- Fish tissue sampling: 1991 to 2017



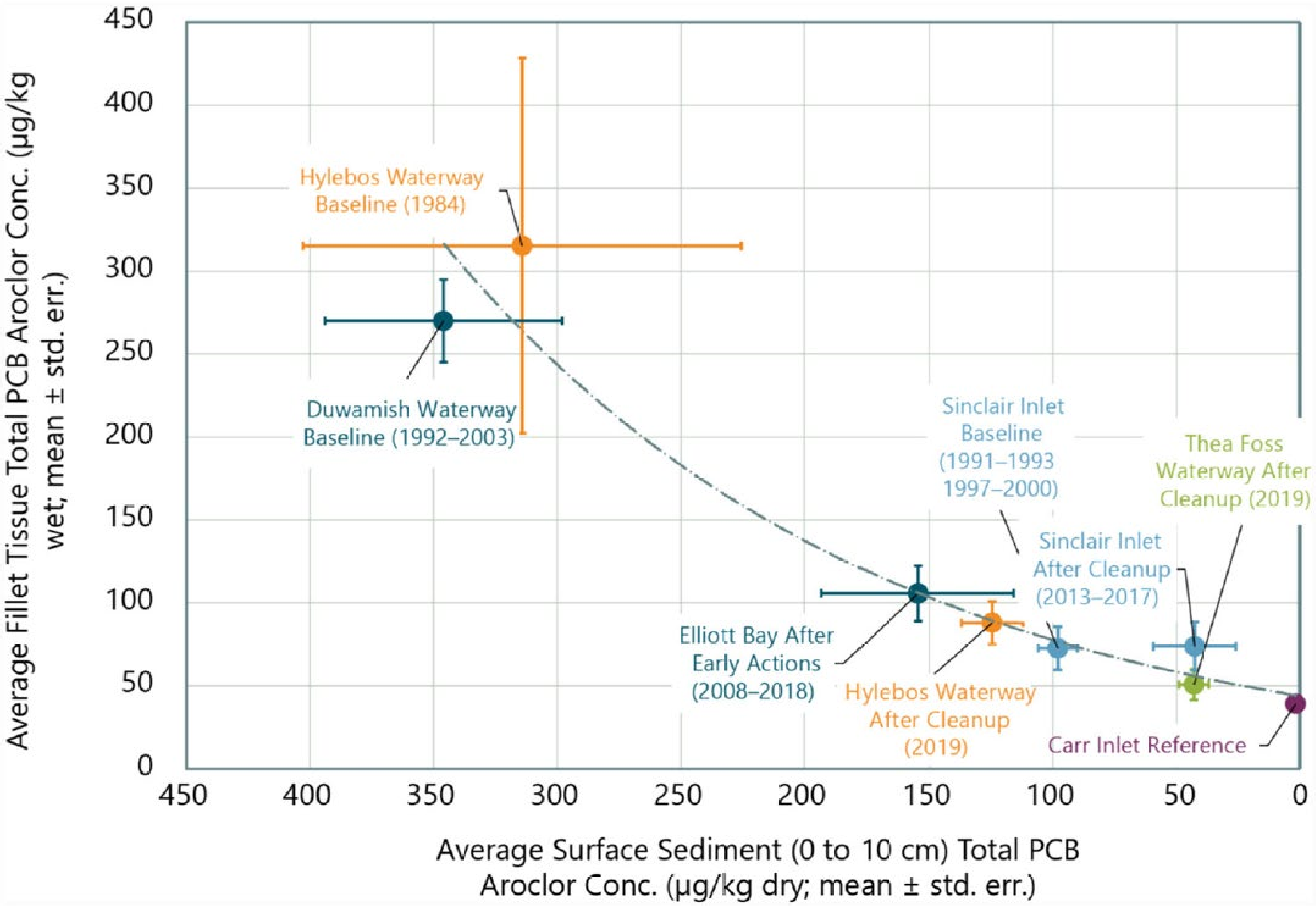
Sinclair Inlet Remedy Effectiveness Monitoring

- Tissue peaks associated with in-water construction releases
- Little net change in tissue PCB levels over 26 years



Source: Patmont and Healy (2024)

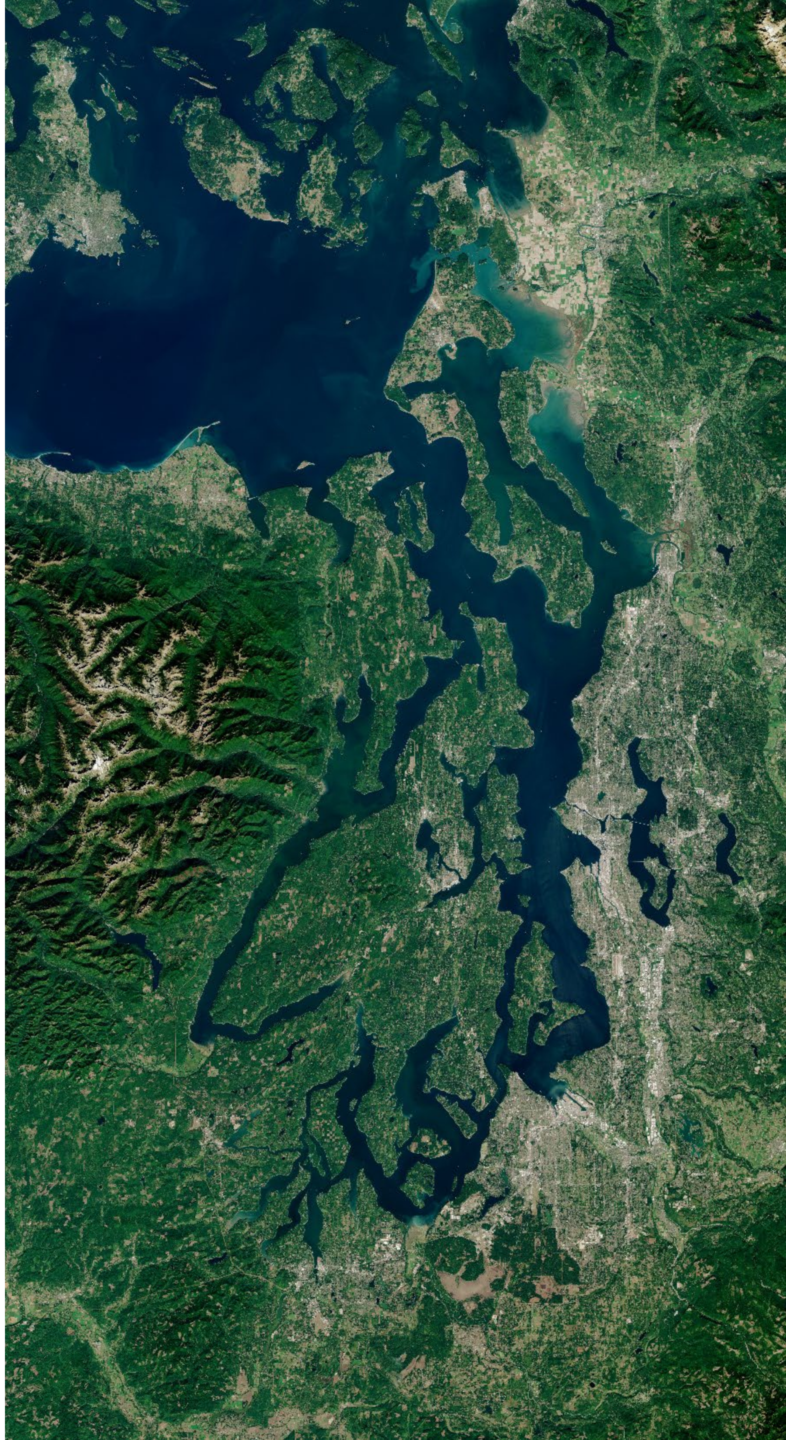
Puget Sound Remedy Effectiveness Monitoring



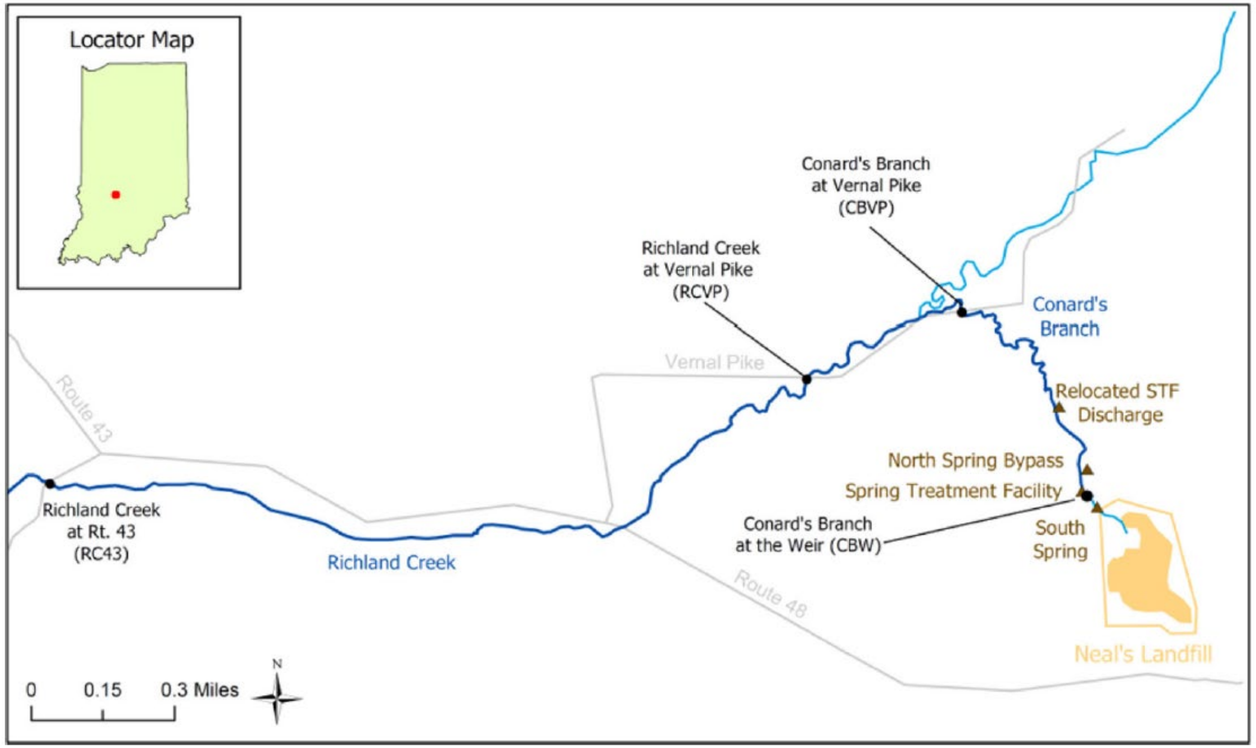
Source: Patmont and Healy (2024)

Puget Sound PCB Recovery Lessons Learned

- Diminishing linkages between surface sediment and fish tissue at lower PCB levels
  - Non-sediment factors such as water column exposures become predominant
- Source control and natural recovery have generally been more effective than remediation
  - Particularly after higher PCB sediments are addressed
  - Dynamic/rapid equilibrium of surface sediment
  - Unavoidable short-term dredging releases



Conard’s Branch and Richland Creek, Indiana

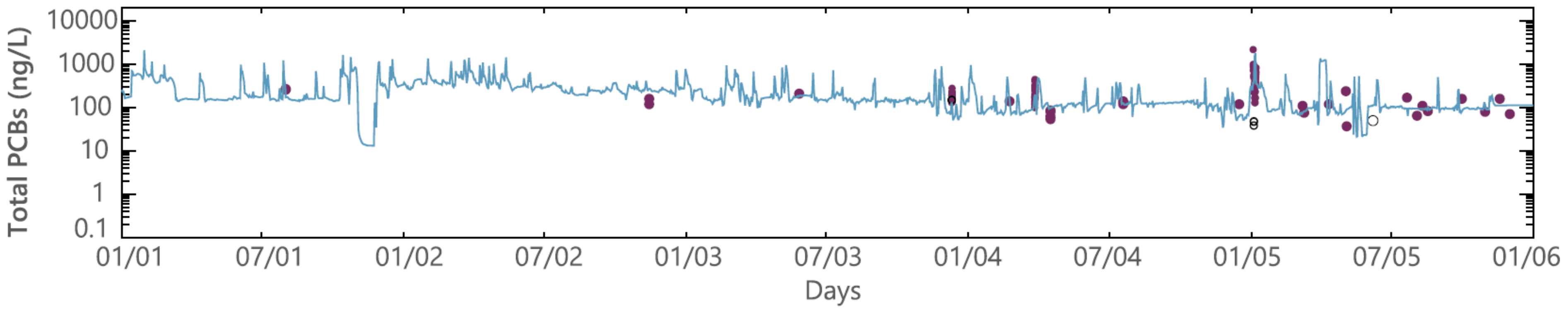


Source: Glaser et al. (2021)

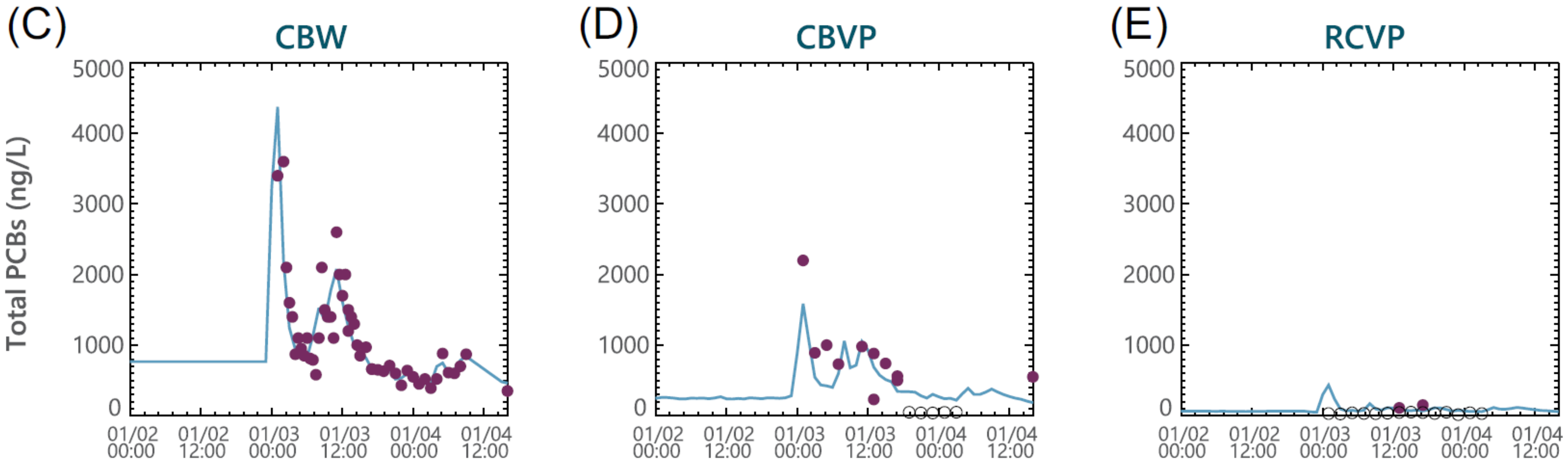
- Small spring-fed streams impacted by landfill with PCB-containing materials
- Elevated PCB concentrations in springs, especially during storms
- PCBs in fish tissue resulted in risk
- Contemplated remedies early in project focused on capturing and treating storm flows
- Commenced study of sources to evaluate remedial approach

Extensive Monitoring and Modeling of PCB in Streams and Feeding Springs

Long-Term



Storm Events



Source: Glaser et al. (2021)

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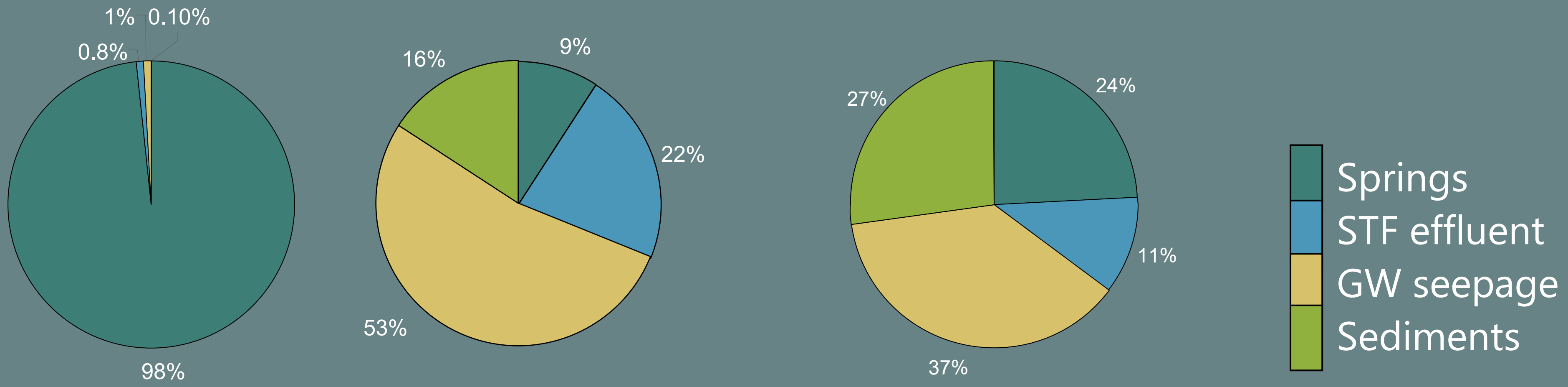
Extensive Evaluations of PCB Sources Based on Data Evaluation and Modeling

Sources to Water Column

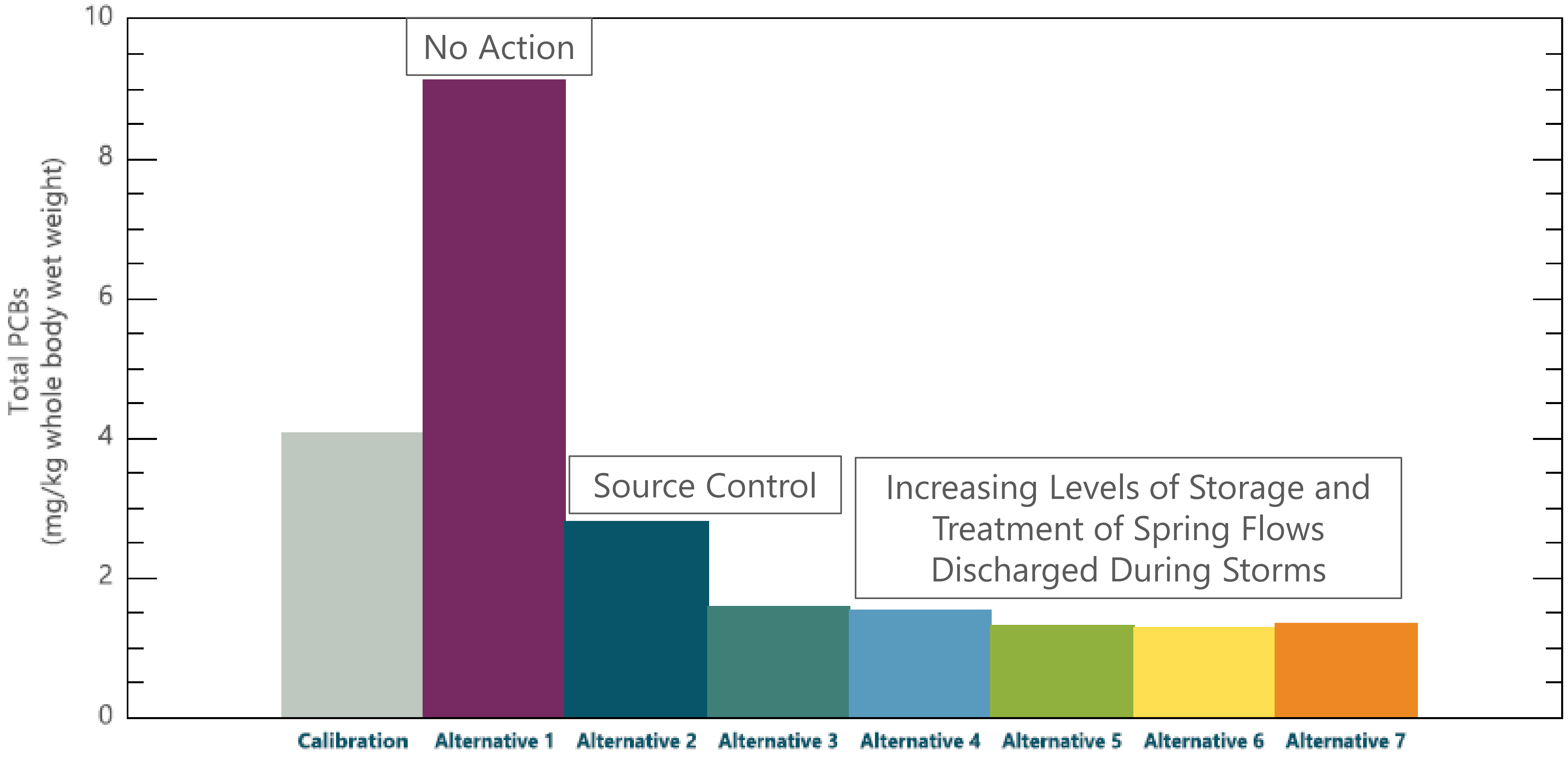
Sources to Fish



Storm flows

Base flows

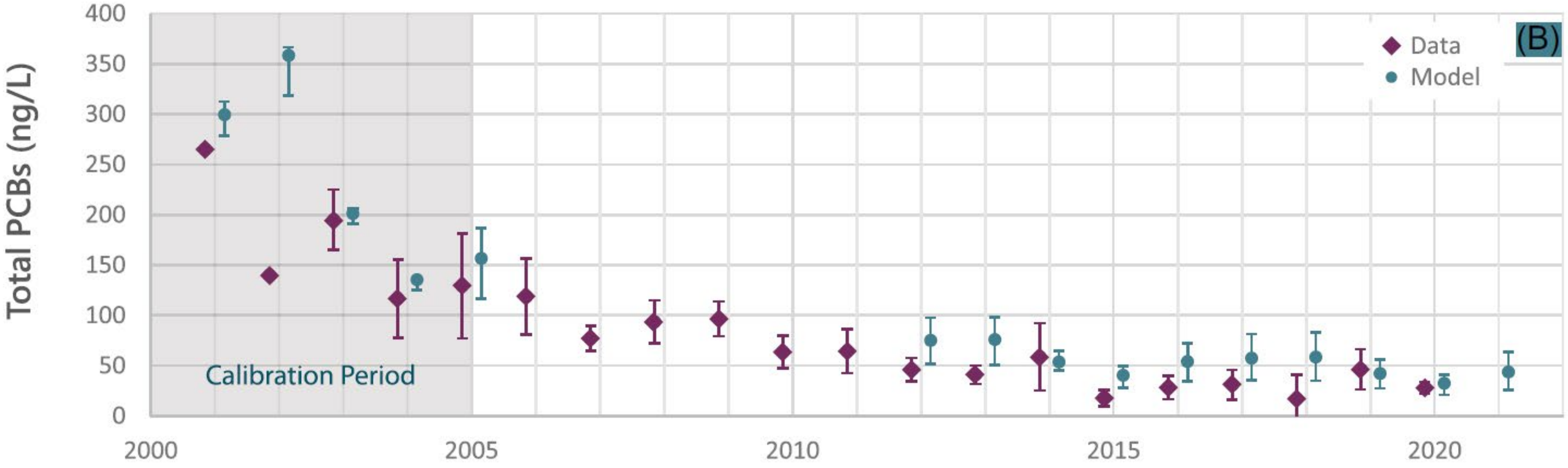
Source Control-Based Remedial Alternatives Found to Provide Largest Incremental Benefit



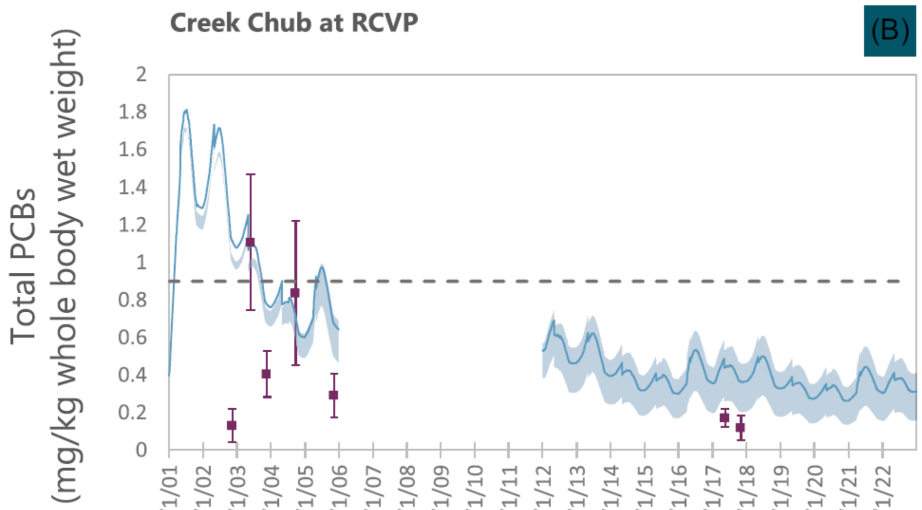
Source: Glaser et al. (2021)

Post-Remedy Monitoring Consistent with Predicted Reductions and Led to Site Closure

Surface Water



Fish



Source: Glaser et al. (2021)

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Conard’s Branch and Richland Creek Lessons Learned

- Robust data set to understand sources is valuable to support CSM and remedial decision making
  - Multiple pathways (springs, sediments)
  - Under differing conditions (base flow versus storm flow)
  - Routes of fish uptake
- Detailed quantitative comparisons of remedial alternatives based on robust CSM can lead to selection of most cost-effective remedy
- Robust post-monitoring data useful to confirm expectations

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Key Takeaways

- Unique properties of PCBs result in the aquatic portions of a site often driving risks and remediation costs
- Develop sound CSM that links PCBs in the aquatic food web to the predominant source pathway(s)
- Source control is key for successful remediation
- Alternate remedial approaches such as sediment capping can perform better and cost far less than presumptive remedies such as sediment dredging

Questions?

Photo by Bill Rhodes

Citations

- Glaser, D., K. Russell, J. Rhea, W. Ku, D. Reidy, and R. Cepko, 2021. "Model-Supported Decision-Making at a Contaminated Sediment Site: Post-Audit and Site Closure." *Integrated Environmental Assessment and Management*. Published November 2021. DOI: 10.1002/ieam.4556.
- Patmont, C. and Healy, R., 2024. "Puget Sound sediment cleanup remedy effectiveness retrospective." *Integrated Environmental Assessment and Management* 2024(00:1–11). https://doi.org/10.1002/ieam.4890
- Rosenberry, D.O., C. Duque, and D.R. Lee, 2020. "History and Evolution of Seepage Meters for Quantifying Flow Between Groundwater and Surface Water: Part 1 – Freshwater Settings." *Earth Science Reviews* 204(103167). DOI: 10.1016/j.earscirev.2020.103167.
- USEPA, 2005. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*. Office of Solid Waste and Emergency Services. EPA-540-R-05-012, OSWER9355.0-85. December 2005.