Benefits of Less Intrusive Remediation Alternatives; A review of Case Studies in Oak Ridge, Tennessee – 15482

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ABSTRACT

Various alternative cleanup strategies have been utilized at Department of Energy facilities in Oak Ridge, Tennessee to avoid costly and potentially ineffective removal of contaminants in soil and sediments, transportation by truck, and long-term storage in landfills. One such example is a remedial decision in the 1990s to not conduct large-scale removal of PCB-contaminated sediments from a large downstream reservoir, and instead implement sediment disturbance controls and monitoring requirements. Monitoring results suggest the decision was a good one with PCB concentrations in fish decreasing substantially over the last 20 years, presumably due to recent cleaner sediments overlying historical sediment layers. At the East Tennessee Technology Park an innovative remediation strategy was developed to reduce human and ecological risks associated with a PCB-contaminated pond, while also enhancing the site's natural resources. Termed the "Ecological Management and Enhancement" strategy, this remediation option provided an alternative approach to more conventional pond remediation options like sediment and soil removal, draining and capping, and point source/discharge actions. The basic premise of this option is that ecological management, including fish and wildlife management and vegetation management, can interrupt the contaminant exposure pathways that lead to ecological or human receptors. Recent monitoring results have demonstrated both risk reduction and increased natural resource value. Currently under investigation is the use of watershed management approaches that may help ameliorate mercury methylation and bioaccumulation in East Fork Poplar Creek. There is increased recognition that mercury source reduction alone will not achieve the human health risk target level in fish in the downstream environment, where water chemistry and ecological processes are conducive to mercury methylation. Additionally, significant losses in natural resource values are anticipated if major soil and sediment source removal activities are implemented. The Oak Ridge experience suggests that alternative approaches to the conventional "muck and truck" options to sediment contamination are worth pursuing in some cases. Taking advantage of natural attenuation processes and/or implementing less intrusive water and ecological manipulations could be especially advantageous at contaminated sites where there are multiple or complex sources that are difficult to remediate, conventional source removal is costly, the contaminant of concern is highly bioaccumulative, or where natural resource values could be preserved or enhanced.

INTRODUCTION

Sediments at some locations downstream of Department of Energy (DOE) facilities in Oak Ridge, Tennessee contain elevated concentrations of PCBs, mercury, and other metals as a result of legacy releases from the DOE facilities in the 1940s and 1950s. Mercury and PCBs are problematic because they are bioaccumulative contaminants that are found in fish at levels exceeding human and ecological risk thresholds. The DOE Oak Ridge facilities and offsite waters were designated a CERCLA site in 1989, after which remedial investigations and feasibility studies were initiated to assess risk and to evaluate remedial options within watershed-defined cleanup units.

Bioaccumulative contaminants in sediments in large bodies of water, or in flowing systems, provide special challenges for effective cleanup. Conventional "muck and truck" methods involving dredging and removal of sediments to a landfill can be costly and potentially ineffective, in that contaminated sediments can be diffuse and continue to result in significant contaminant concentrations in fish. Aquatic systems with continued low level source inputs can also recontaminate downstream remediated areas. It has long been recognized that scientifically defensible and technically sound approaches that stabilize wastes in-place and reduce risks is essential.

This paper provides a "case study" of three separate contaminated water bodies near Oak Ridge, Tennessee, including a reservoir, a pond, and stream, where less conventional and less intrusive remedial options were chosen or proposed. The benefits as well as the challenges of alternative cleanup strategies are explored through an examination of current monitoring trends.

SITE DESCRIPTION

In Oak Ridge, DOE and its predecessor agencies have had an energy and national security mission for over sixty years that has resulted in legacy contaminated areas within the Oak Ridge Reservation (ORR) and offsite. Offsite contamination is primarily related to contaminated downstream waters, including sediments, surface water, and fish. The remediation strategy for the contaminated sites on the ORR is based on a watershed management approach, defined here as an integrated, holistic approach to restore and protect ecosystems and to protect human health by focusing on hydrologically defined drainage basins. The Clinch River bounds the ORR on three sides; all ORR creek drainages ultimately flow into the Clinch River (Figure 1). The primary pathway for contaminant migration is via facility storm drains and soil erosion to surface water, which then flows off-site.

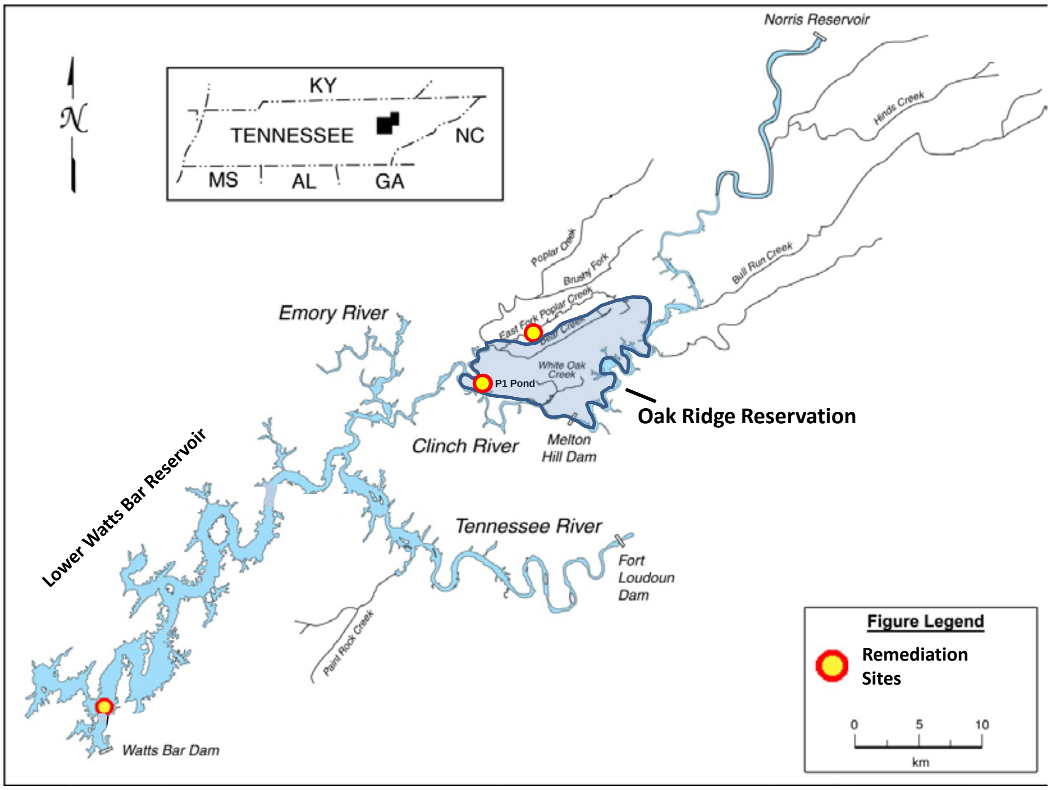


Figure 1. Location of three remediation sites where contaminated sediments have not been removed: Lower Watts Bar Reservoir, the P1 Pond, and East Fork Poplar Creek.

In this paper, we examine remedial decisions to leave existing contaminants in place and a range of selected controls to limit human and ecological risks. Three remediation sites (or watershed units) are evaluated:

1) Lower Watts Bar Reservoir (LWBR), where institutional controls were implemented to decrease PCB exposures to recreational fisherman,

2) East Tennessee Technology Park (ETTP) Ponds Action. Focus here is on the “P1 Pond” (one of three contaminated ponds at ETTP), where an innovative strategy called the “Ecological Management and Enhancement” action was chosen to reduce risk and enhance habitat value, and

3) Lower East Fork Poplar Creek, where research and technology development approaches are ongoing to examine remedial options for mercury cleanup that do not involve large-scale sediment removals.

The timeline of remedial decision-making and a general summary of the actions associated with each site are summarized in Table 1. The primary risk drivers for all three watersheds are associated with fish ingestion, by both humans and wildlife.

Table 1. Three water bodies where in-place remedial options were implemented or proposed.

Watershed Unit	Water body	CERCLA Decision	Primary risks	Response action to reduce risks	Required Monitoring?
Lower Watts Bar Reservoir	38 miles of large river/reservoir	Record of Decision 1995	Exposure to PCBs from fish ingestion, exposure to metals in deep sediments	Institutional controls by fish consumption advisory, limit sediment disturbance	Yes
ETTP Ponds	Three small, (<25 acre) impoundments	Removal Action 1997, 2007	Exposure to PCBs from fish ingestion	Ecological management and enhancement alternative, controlled access	Yes
Lower East Fork Poplar Creek	15 miles of stream	Record of Decision 1995, Floodplain only;	Exposure to mercury from fish ingestion	Many abatement actions taken at headwater facility. Future decision to address in-stream mercury. State has posted stream no consumption of fish	Yes

For LWBR, the primary action was to implement institutional controls including preventing exposure to contaminated sediment (via an interagency working group); limiting fish ingestion through issuance of fish consumption advisories, and annual monitoring to evaluate changes in contaminant levels. Performance monitoring for LWBR, and the upstream sections including the Clinch River/Poplar Creek, has primarily focused on contaminant trending in fish to address the requirement for annual monitoring to detect changes in contaminant levels or mobility.

For the P1 Pond ecological manipulation actions were implemented in an attempt to reduce human and ecological risks. Contaminated sediments, which were thought to be the main source of PCBs to fish, were left in place. The ecological management actions provided a lower cost alternative approach to more conventional pond remediation options like sediment removal, draining and capping, and point source/discharge actions. The basic premise of this option is that ecological manipulations can interrupt the contaminant exposure pathways that lead to ecological or human receptors (Figure 2). The focus of the contaminant pathway interdiction is at the higher food chain level, in contrast to conventional options where interdiction is at the soil or sediment source level. An additional goal of the action was to enhance the pond environment, providing substantial natural resource benefits over the long term. Since the non-time-critical removal action was implemented in 2007, monitoring of PCBs in fish and natural resource values have been conducted to evaluate remedial performance.

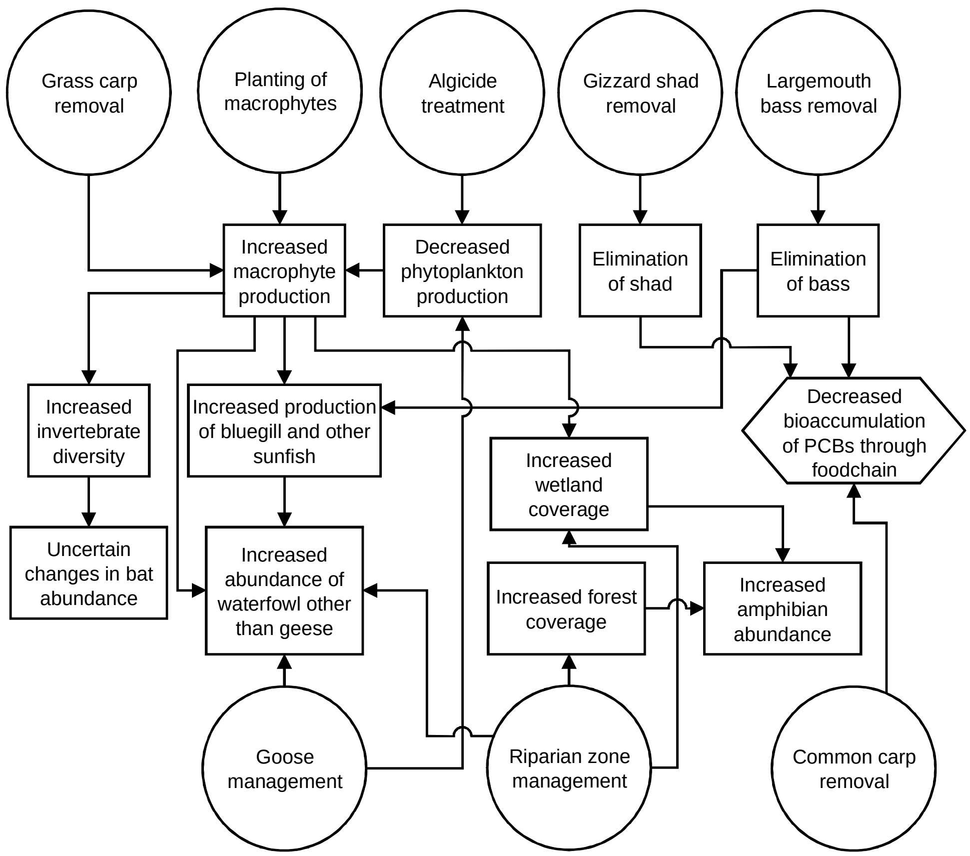


Figure. 2. A conceptual model depicting structural and process changes to the P1 Pond under the Ecological Management and Enhancement alternative. Circles represent management actions, rectangles are states, and hexagons are processes.

For LEFPC where mercury concentrations exceed regulatory limits for surface water and fish, abatement and remedial actions to date have centered on storm drain cleanouts and treatment actions at the industrial facility at the creek's headwaters, and a soil removal action in the LEFPC floodplain. Potential future actions in the downstream sections of the watershed will depend in part on the success of a planned additional treatment action at the facility, a more detailed assessment of sources and processes in the watershed, and the development of technologies that may provide benefits relative to remedial effectiveness and cost. Mercury speciation and transport and fate processes in the environment are complex, and actions to date have not had their desired effect downstream. For LEFPC, research and technology development activities designed to address the mercury problem are currently underway.

DISCUSSION

Biological monitoring data collected over many years at the three remediation sites provides a valuable measure of the benefits and challenges associated with using in-place remediation options. Following is a summary of performance monitoring results.

Lower Watts Bar Reservoir (LWBR)

Performance monitoring in LWBR has primarily focused on requirements to evaluate changes in fish contaminant levels. These trending results are directly related to the ROD requirement that monitoring of water, sediment, and biota be continued to determine if there is a change in the currently calculated risk that would pose a threat to human health and/or the environment. The ROD indicated that the response action (namely, monitoring of contaminant levels or mobility) was considered applicable to reducing ecological risk.

Monitoring results indicate that PCB concentration in LWBR in 2014 averaged 0.13 µg/g in channel catfish (Fig. 3). Regulatory guidance and human health risk levels have varied widely for PCBs, depending on the regulatory program and the assumptions used in the risk analysis. Although historically fish advisories were considered when fish fillets were in the 0.8 to 1 µg/g range (thus current concentrations are far less than fish advisory limits), the current target concentration for Watts Bar Reservoir is 0.02 mg/kg in fish fillet. The fish PCB concentrations in LWBR are still above this concentration. The good news is that the current levels are substantially lower than the concentrations observed in the 1980s and 1990s when the advisories were first issued (Figure 3).

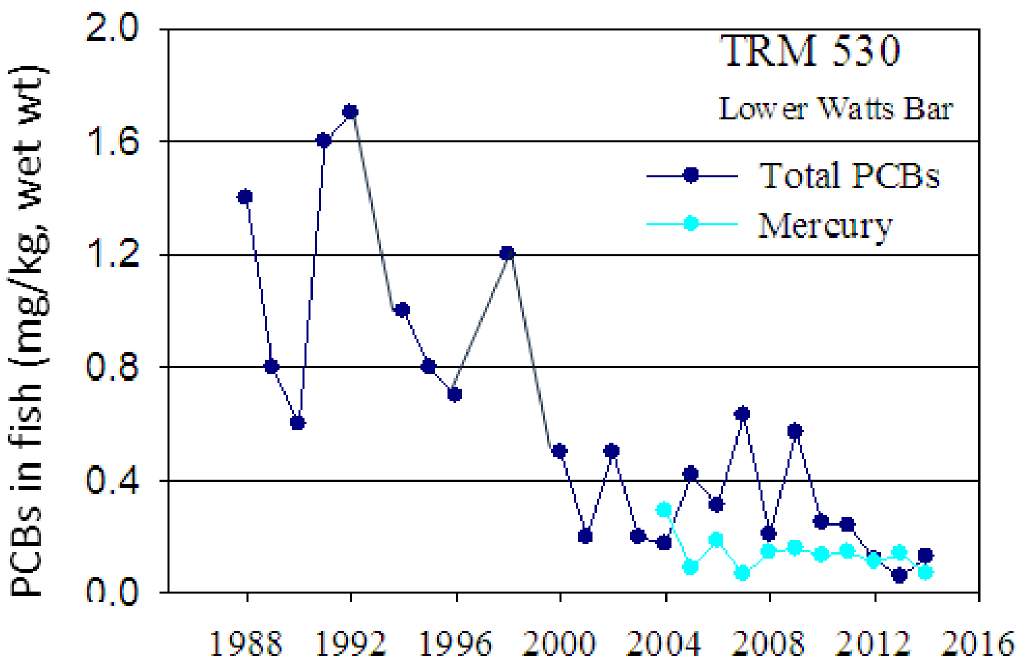


Fig. 3. Average PCB concentrations in channel catfish from Clinch River/Poplar Creek and LWBR sites, 1986–2014.

Mercury concentrations in fish from LWBR are also low, averaging equal to or less than 0.16 µg/g depending on species (Fig. 3). This level is less than the EPA recommended AWQC of 0.3 µg/g mercury in fish. Mercury concentrations in the 0.2 µg/g range are typical of largemouth bass and channel catfish in Tennessee reservoirs.

The significant decreases in fish contaminant concentrations is thought to be due to decreases in PCB use and release from industrial facilities, and highly contaminated sediments layers being overlain with cleaner sediments over time in the deep downstream reservoir.

The P1 Pond

A summary of the monitoring results for the P1 Pond highlighting pre-action conditions, remedial actions taken, and current status in 2014 is provided in Table 2. The good news is the human health target goal of 1 ppm PCBs in fish was achieved two years in a row. Whole body fish still exceed the 2 ppm goal, but overall trends are downward, and PCB concentrations in fish are substantially lower than pre-action. Challenges in managing the fish population do not appear to date to be negatively affecting bioaccumulation. Further, many of the habitat enhancement measures, including vegetation enhancement, wildlife benefits, and water quality improvements, have been highly successful.

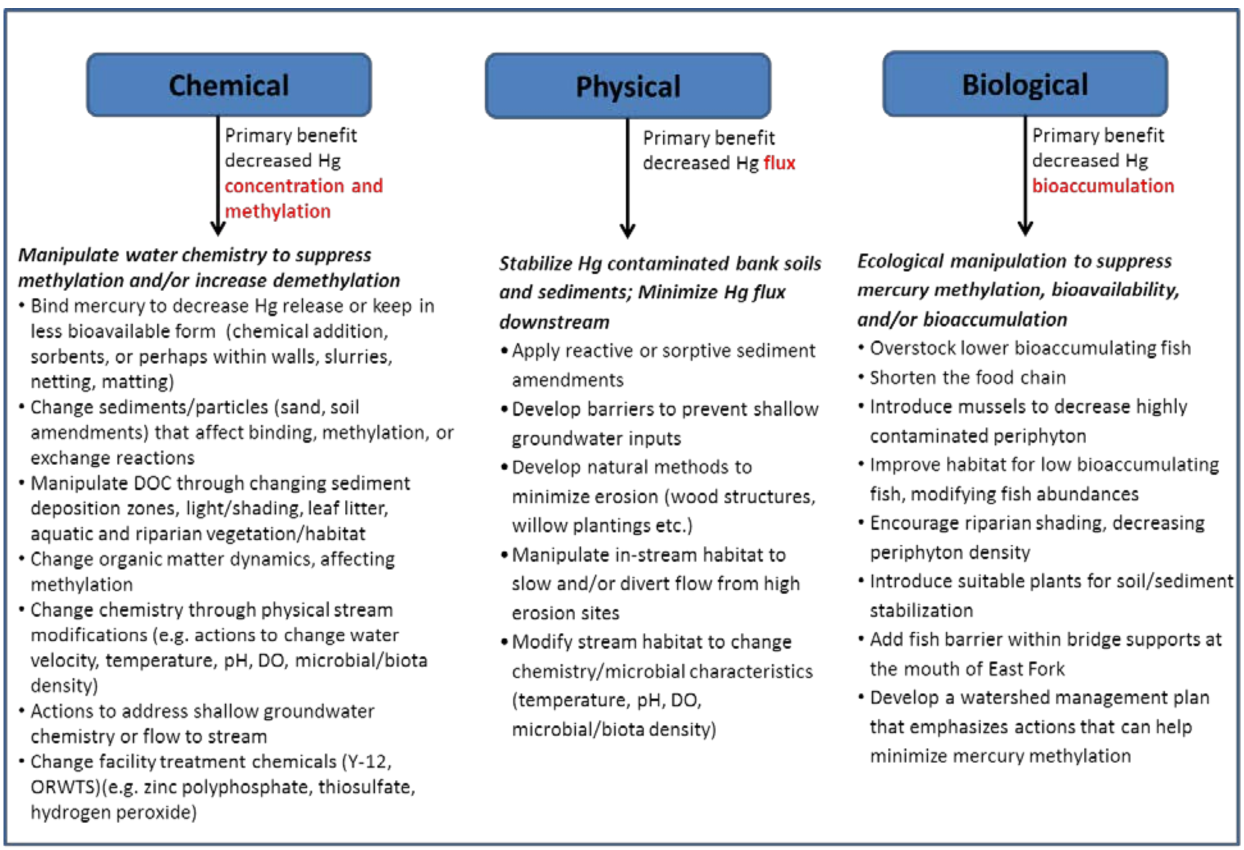
Table 2. Summary of pre-action conditions, remedial actions taken, and current status in 2014

Pond Attribute	Pre-action	Actions (2009–2011)	Current status
PCBs in biota	PCBs high in fish and clams. Bass especially high in PCBs	FISH MANAGEMENT: convert to community dominated by low bioaccumulators	PCB concentrations in sunfish fillet have hit the target goal < 1 ppm for two years in a row.
Fish community	Large number of grass carp and other undesirables (80%)	FISH MANAGEMENT: remove grass carp that eat vegetation; remove undesirable species; stock desirable species	• No grass carp, and very few common carp and buffalo • Bluegill populations are generally higher than pre-action, which was desired • Since the weir breach, undesirable species such as largemouth bass and shad have reproduced
Plant community	No aquatic emergent vegetation	PLANT MANAGEMENT: add stabilizing soil and plant native vegetation (70,000 specimens in 2009, 5,000 in 2010, 3,000 in 2011)	>90% plant cover in summer. Lotus coverage across the pond increased in 2014
	Poor riparian habitat	Improve riparian zones to limit goose use, prevent erosion	No obvious erosion; native species are dominant
Wildlife	High goose population contributes to poor water quality	WILDLIFE MANAGEMENT: remove or harass geese and other herbivores; riparian habitat less suitable for geese	Geese now in low numbers; other waterfowl observations are higher post-action
Water quality	High suspended algae, poor water clarity	WATER QUALITY CHANGES: use no algaecide; remove geese, add plants, and modify riparian habitat	Substantial improvement in water clarity and quality between pre- and post-remediation

Lower East Fork Poplar Creek (LEFPC)

Actions have yet to be applied within the stream environment to address mercury contamination in LEFPC. This is in part due to remedial prioritization which focuses on upstream actions first, and an adaptive management approach that will take advantage of current and future research in LEFPC to better inform remedial decision-making. Recently, a broad-based watershed approach to research and technology development has been proposed to address the LEFPC mercury issue, that includes investigations of (1) potential landscape-scale source control, including soil and groundwater; (2) in-stream sediment and surface water manipulation; and (3) ecological manipulation (Fig. 4). These three domains (source, methylation, food chain) are the primary major factors that control mercury levels in fish. A focus of future technology development will be on those tools and strategies that can interrupt the mercury transport, methylation, and bioaccumulation processes in LEFPC. An underpinning aspect of this research is the desire to avoid large-scale removal of downstream soils and sediments that would be environmentally disruptive, costly, and potentially ineffective in achieving desired remediation goals. The watershed approach is advocated because it considers all the contributing factors that affect mercury transformations in the complex LEFPC environment, and may provide opportunities for managing and restoring the system for natural resource benefit and water quality enhancement.

Figure 4. Watershed scale approach to LEFPC technology development that focuses on the potential use of chemical, physical, and biological actions to limit mercury concentration, flux, and bioaccumulation.



CONCLUSIONS

Bioaccumulative contaminants in sediments in large bodies of water, or in flowing systems, provide special challenges for effective cleanup. Large-scale dredging and landfill burial can be extremely costly, environmentally destructive, and may not achieve risk reduction. Long desired are scientifically defensible and technically sound approaches that stabilize wastes in-place and reduce risks. This paper provides a brief introduction to three separate contaminated water bodies near Oak Ridge, Tennessee, where less conventional and less intrusive remedial options were chosen or proposed. After multiple years of monitoring, the remedial decisions to not conduct large-scale sediment removals or capping at two sites appear to be good decisions, as PCB concentrations in fish continue to decline. For LWBR, the secondary PCB sources in sediments may be overlain with cleaner sediments that have been deposited over the last 20 years. At the P1 Pond, planted vegetation may be stabilizing sediments, and changes in food chain structure may be limiting PCB uptake. In LEFPC, a watershed approach to the mercury issue, that avoids large-scale sediment and soil removal but considers water chemistry and ecological manipulations, is advocated. All three of these aquatic systems share system-level traits that suggest that taking advantage of natural attenuation processes and/or implementing less intrusive water and ecological manipulations could be advantageous. Less intrusive cleanup options should be considered at contaminated sites where there are multiple or complex sources that are difficult to remediate, conventional source removal is costly, the contaminant of concern is highly bioaccumulative, and/or where natural resource values could be preserved or enhanced.

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