

STATE OF CURRENT CONTAMINATED SEDIMENT MANAGEMENT PRACTICES

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EXECUTIVE SUMMARY

In the 1990s, the management of contaminated sediments is a complex and politically charged subject. The magnitude of the problem is continuing to be quantified and confirmed. The focus of this paper is to foster a more rigorous technical discussion and exchange on this subject by evaluating contaminated sediment projects to determine both the types of remedial goals selected for such projects and the effectiveness of the implemented remedies. Data are identified and summarized on the characteristics and size of 44 implemented projects, the remedial methods, the costs, the goals of the projects, the methods used to verify whether the goals were met, and the degree of success in meeting the goals.

The evaluation shows that the sediment remediation projects implemented to date have been small (as compared to traditional navigational dredging), costly, and difficult to implement. Furthermore, the projects typically had vaguely or inconsistently defined targets and goals, and the success of the respective projects or benefit derived from the remediation often has not been demonstrated. This finding contradicts the more scientifically grounded approach for sediment remediation emphasized in government-sponsored strategy documents. Key issues influencing contaminated sediment management are discussed, including the following:

- Application of sound science
- Identification of the proper goals and target
- Selection of remedial methods
- Verification of achievement of the goals
- Understanding of the limitations of mass removal

Key Findings

The 44 projects identified for evaluation represent the majority of the sediment remediation projects implemented in the U.S. It is noteworthy that documentation of the outcome of these projects has, in varying degrees, been incomplete and not widely disseminated. There is no central repository or clearinghouse for such information; information transfer on this subject between governmental agencies or even between regions of the USEPA does not seem to be occurring with any consistency. There is no evidence of lessons learned on prior projects being applied by regulators to subsequent projects. Particularly problematic is the availability and quality of final reports. To fill this information void, a data base was assembled using information from a wide variety of oral and written sources. Detailed descriptions of the content of this data base is provided in the paper that follows.

A variety of remedial methods are candidates depending on the severity and extent of the problem. These methods range from source control and natural recovery to full-scale remediation. These methods should be evaluated in a hierarchical approach, progressing from an evaluation of source control, then in situ methods such as natural recovery or engineered burial (capping), and finally removal and disposal using methods such as dredging or wet or dry excavation. Overriding the evaluation of remedies is the need to determine whether a proposed remedy, particularly a removal remedy, will (1) result in more harm than benefit in its implementation ("more harm than good"), (2) withstand scrutiny from a cost-benefit standpoint, and (3) achieve the identified goals.

Removal is the method of choice at the vast majority of the projects (40 of 44), despite the disruptive nature of removal and the repeated inability to achieve low cleanup levels. This propensity toward removal as a remedy is likely a follow-on to the traditional “dig it up and haul it away” approach used for soil at Superfund and other targeted sites. This approach does not translate easily to contaminated sediment; although there is a tendency on the part of regulators and other involved parties to ignore or be unaware of this fact. The differences are dramatic when sediment is involved, and these differences are worth emphasizing. They include the fact that:

- The underwater environment presents a lack of visibility and a need to manage the water phase.
- The target areas are often no longer located on the responsible party’s property; access difficulties are introduced.
- The contamination is often spread out and diffuse.
- The bottom area of most water bodies is an ecologically sensitive environment.
- The water environment mobilizes and transports contaminants back into and away from the target area during removal.
- All of the impacted sediments may not be capable of being removed, which can result in residual contaminants at the surface, sometimes at higher than original levels.

The costs for removal projects cover a wide range. Costs are highly variable due to differences in goals from project to project; differences in production (i.e., removal) rates, which are influenced by a wide variety of site-specific variables; and wide differences in disposal costs, which are influenced by disposal method and location and type of contamination and concentration.

Landfilling or containment predominates as the method of disposal. Containment (a type of landfilling) includes use of disposal ponds or nearshore confined disposal facilities (CDFs). Treatment is seldom used. Final treatment technologies have failed to make inroads as a component of sediment remediation projects primarily due to the following factors:

- An inconsistent or nonexistent track record at full-scale
- High unit costs
- The need for extensive land-based area for managing dredged material including for staging, size-reduction, dewatering, and treatment
- Concerns that regulatory-required low residual contaminant levels will not be able to be achieved.

The 22 remedial dredging projects involved relatively small volumes of sediment, certainly by navigational dredging standards. The largest remedial dredging project (at Bayou Bonfouca, Louisiana) involved removal of 169,000 cubic yards (cy). Half of the 22 projects resulted in 40,000 cy or less of sediment removal. The total volume removed for all dredging projects is 940,000 cy (rounded). This grand total, not a large total for even a single navigational dredging project, emphasizes the great difference in the character of and approach required for remedial dredging projects as compared to conventional dredging projects.

Overall costs for the remedial dredging projects ranged from \$44 to \$1,842 per cy, with a median of about \$200 to \$275 per cy. The high overall cost is due to two primary factors: low production rates and high costs for disposal. Little or no economy of scale exists. Repetitive difficulties that cause low production rates (and long implementation times), but that do not usually impede navigational dredging include the following:

- Rocks, vegetation, and debris
- Shallow water
- Floating oil

- Resuspension and associated controls
- Limited on-land water holding and treatment capacity

Dry excavation was performed predominantly in small shallow streams or ponds, amenable to dewatering. Dewatering was performed by diverting the water around the target area or draining the water body. Wet excavation was accomplished in shallow, narrow streams using excavators on the banks. Sixteen of the dry and wet excavation projects involved small volumes (i.e., 1,800 to 165,000 cy). Two larger projects, the removal of 588,000 and 450,000 cy, involved the draining of a lake and two ponds, respectively.

Overall costs for the dry/wet removal projects ranged from \$21 to \$1,500 per cy, with a median of about \$450 per cy. The high overall cost is due to the following three primary factors:

- Lower production rates than for traditional earth moving projects due to difficulties with accessibility and wet terrain
- Additional water control and handling requirements imposed for maintaining the dry condition
- High costs for disposal

Natural recovery as a remedy was selected in whole or in part for six projects. The few projects with natural recovery remedies consist of those with one of three identifiable types of conditions, namely the following:

- Lengthy rivers characterized by pervasive but diffuse contamination too extensive for a removal remedy to be feasible
- Contaminated areas of unusual aesthetic value or sensitivity or comprising dense habitat and rich feeding grounds
- Contaminated areas in a region (e.g., Washington State) that allows areas to be designated for natural recovery if recovery is predicted to occur to acceptable levels within 10 years

Selection and Achievement of Goals

The 25 largest of the 44 projects were evaluated—those targeting 10,000 cy of sediments or greater. The following key questions that are basic to any major sediment remediation project were examined:

- Was the primary remedial goal selected to achieve risk reduction, with the basis being to achieve protective levels for receptors within a specified time period?
- Was the remedial target derived from the primary remedial goal?
- Was achievement of either the remedial target or the primary remedial goal demonstrated?

Findings showed a variety of primary goals were applied to the 25 projects; for at least one-third of the 25 projects, no protective endpoint was defined by the primary goal. In these instances, the goal was simply to in effect “show progress” by reducing contaminant levels, reducing ecological impacts, or removing contaminant mass. Further, for 10 of the 25 projects, the selected sediment remedial target was not clearly tied to the primary goal. Clearly, a consistent application of sound science and careful consideration of such important principles as contaminant availability and proper goal/target selection were lacking in varying degrees. A sound scientific approach with clear goals is needed for future projects to define in advance an appropriate and beneficial goal, target, and remedy.

In response to the questions, “were goals achieved” or “will goals be achieved” the following is concluded at this time:

- Mass removal projects, by definition, achieved their goal.

- Low cleanup levels were either not achieved or were not verified at 14 of the 22 removal projects.
- No risk reduction protective endpoint goal has demonstrably been met on any project, either due to no verification sampling or no postremedy monitoring being implemented or due to monitoring still being in progress.
- Often preremedy data are limited and unsuitable for comparison with postremedy data. Often the postremedy monitoring is unscientific, opportunistic, or nonexistent. In either instance, no technically defensible measure of the success for such projects is possible.

INTRODUCTION

In the 1990s, the management of contaminated sediments is a complex and politically charged subject. The magnitude of the problem is obvious when recognizing that the U.S. Environmental Protection Agency (USEPA) estimates that 1.2 billion cubic yards (cy) of sediment (top 5 centimeters) underlying our nation's surface water is sufficiently contaminated with toxic pollutants to pose potential risks to fish, as well as to humans and wildlife who eat the fish (USEPA 1997). The 5 centimeters represents just the biologically active zone. Contamination typically extends below 5 centimeters; therefore, the 1.2 billion cy may be considered a minimum estimate. This estimate presents a daunting problem that requires thoughtful and open discussion and interchange in order to achieve successful management of these sediments.

To foster a rigorous technical discussion and exchange, this paper provides an analysis of the current state of contaminated sediment management, primarily by reviewing and evaluating contaminated sediment remediation projects implemented in the U.S. to date. A sufficient number of sediment remediation projects have been implemented to form a decade-long historical record suitable for examination. The focus of this technical paper is to evaluate the remedial goals selected for contaminated sediment projects, the degree of success in achieving these goals, and the effectiveness of implemented remedies in reducing risks to protective levels. Data are identified and summarized on the characteristics and size of 44 implemented projects, the remedial methods, the goals of the projects, the methods used to verify whether the goals were met, the degree of success in meeting the goals, and the costs.

Key issues influencing contaminated sediment management include the following, which are discussed in more detail in the subsections below:

- Application of sound science
- Identification of the proper goals and target
- Selection of remedial methods
- Verification of achievement of the goals
- Understanding of the limitations of mass removal as a target

Sound Science

Remediation goals and objectives for a specific project should be identified and applied based on sound science, an outcome emphasized in two broad-based, widely publicized strategy documents (USEPA 1998 and International Joint Commission 1997). The USEPA's strategy is designed around 14 principles, one of which states the following:

“Assessment of sediment contamination and any subsequent steps taken by the agency to reduce risks should be based on sound science and, when available, site-specific information (USEPA 1998).”

A strategy document developed by the Sediment Priority Action Committee of the Great Lakes Quality Board states the following under the heading “Lack of a Decision-Making Framework:”

“While the most urgent need in environmental management is to protect the ecosystem from further abuse, apart from source control the levels and rates of cleanup are not addressed in current sediment guidelines or criteria. Decisions to clean up contaminated sediment depend on a large number of variables, one of which is sound science. A scientific framework for evaluating the ecological significance of contaminants in sediment, however, is lacking. Local decision-making has been hampered by lack of guidance on defining quantitatively acceptable or unacceptable conditions. Also lacking is a method for

integrating a large number of environmental measurements. What is needed is a pragmatic decision-making framework that leads to the selection of ecosystem- and cost-effective options for management of contaminated sediment (International Joint Commission 1997).”

The application of sound science in a consistent manner to identify appropriate sediment remedies is one of the greatest needs and challenges facing regulators and industry, and, as discussed and shown in this paper, one that has been inconsistently realized on sediment remediation projects completed to date.

Proper Goals and Target

Identifying the target for remediation is an obvious precursor to sediment remediation efforts, but one that has often been unclear in its derivation and unfocused in its application on projects completed to date. *EPA's Contaminated Sediment Management Strategy* states the following:

“Contaminated sediments can have an impact on aquatic life by making areas uninhabitable for benthic organisms, and they can affect fish and wildlife by contributing to the bioaccumulation and biomagnification of contaminants in the food chain (Pfitezenmeyer 1975 and Reinharz 1981). . . Contaminated sediments can also pose a threat to human health when pollutants in sediments bioaccumulate in edible aquatic organisms (Puget Sound Estuary Program 1988 and Baumann 1987). There are numerous examples of cases where fish consumption advisories or bans have been issued for pollutants such as polychlorinated biphenyls (PCBs), mercury, dioxins, and Kepone because of the transfer of the pollutants into the food chain (USEPA 1997e) (USEPA 1998).”

The Sediment Priority Action Committee of the Great Lakes Quality Board states the following under the heading “Why is Contaminated Sediment a Problem:”

“The major environmental concern regarding contaminated sediment is the expression of impairment in biota, including humans. Impacts with direct links to sediment contaminants have been demonstrated for fish and benthic invertebrates. Information directly linking sediment contaminants with impacts on humans is sparse compared with other vectors such as air, water, and food. Since benthic organisms are a major food source for other ecologically and commercially important trophic levels, reductions in or changes to the benthos are of concern. As well, their uptake of persistent bioaccumulating substances and subsequent transfer to these trophic levels is also of concern (International Joint Commission 1997).”

As implied by the preceding, identifying the correct target for sediment remediation can be difficult. A direct human risk pathway may not exist. Often, the only identifiable target and intended benefit for sediment remediation is a reduction in contaminants found in fish to below a concentration judged suitable for human consumption [i.e., as set by risk assessment, by the Food and Drug Administration (FDA), or by other guidance]. The interrelationship between contaminant levels in fish and contaminant levels in sediment and water is complex and difficult to define with precision, complicating the establishment of a meaningful remediation target. Despite the complexities, remedial goals, targets, and methods must be consistent with identified risk reduction objectives; otherwise, the result will likely be ineffective, costly, and more harmful than beneficial.

Remedial Methods

A variety of remedial methods are available as described in “Remediation Methods,” ranging from source control and natural recovery to full-scale remediation depending on the severity of the problem. These methods should be evaluated in a hierarchical approach, progressing from an evaluation of source control, then in situ methods such as natural recovery or engineered burial (capping), and finally removal and disposal using methods such as dredging or wet or dry

excavation. Overriding the evaluation of remedies is the need to determine whether a proposed remedy, particularly a removal remedy, will (1) result in more harm than benefit in its implementation (“more harm than good”), (2) withstand scrutiny from a cost-benefit standpoint, and (3) achieve the identified goals.

Verifying Achievement of Goals

For removal projects, both the preremoval identification of goals and a sediment target and the postremoval verification of achievement have been haphazardly approached on many of the completed projects to date. A sound scientific approach with clear goals is needed to define what remedy is to be implemented and why. Answers should be evident for such questions as the following:

- What protection to human health or the environment or measurable improvement in fish levels or other aquatic biota is expected by achieving the target cleanup level?
- Will removal accelerate recovery?
- Is a targeted contaminant (cleanup) level a discrete value or an average? Does it apply to the top layer of sediment only (and, if so, what thickness) or to the entire vertical and horizontal extent of the target area? (For example, there is substantial evidence to demonstrate that it is only the surface sediment contaminants that are bioavailable and that control the levels in fish, not the buried contaminants.)
- What type of verification and short- or long-term monitoring program should be implemented to verify completion and measure benefit?

Limitations of Mass Removal

Contaminant mass removal (i.e., removal of a high percentage of the contaminants) is an easily defined target which at face value may seem sensible and beneficial. In fact, mass removal may produce little observable long-term benefit or risk-reduction, may result in more harm to the environment than benefit (“more harm than good”), and, as a result, may be an inefficient and even counterproductive expenditure of dollars and resources. A remedy designed solely to remove a large percentage of the mass of contamination from a targeted area may not lead to a reduction in levels in fish or other biota to the levels sought or attain risk reduction goals since the removal of sediments, particularly from previously undisturbed nearshore or other bottom areas, is logistically difficult and ecologically destructive; may bring the deeper, more contaminated sediments to the surface making them again bioavailable; may not be able to achieve the targeted low level contaminant concentrations in sediment and the water column; and accomplishes no reduction of bioavailable contaminant mass present outside of the targeted area. Nonetheless, the outcome of sediment remediation projects completed to date is frequently described in terms of amount of contaminant mass removed, sometimes as the only measure of success and with no association with risk reduction.

IN SITU REMEDIATION METHODS

Two generic approaches for the in situ (in place) remediation of contaminated sediments are summarized herein and include natural recovery and capping.

Natural Recovery

A concise description of natural recovery is contained in the report of a comprehensive study completed in 1997 by the National Research Council (NRC) under the auspices of the Marine Board to assess the nation's capability for remediating contaminated marine sediments and to identify management strategies.

“Natural recovery involves leaving the contaminated sediments in place and allowing the ongoing aquatic processes to contain, destroy, or otherwise reduce the bioavailability of the contaminants. Although no action is required to initiate or continue the process, natural recovery is considered the result of a deliberate, thoughtful decision. The same process may occur by default or as an interim approach at Superfund and other sites when cleanup is delayed by legal, technological, economic, or other barriers. Natural recovery is a viable approach if the contaminants are being buried by cleaner sediments or if ongoing processes destroy the contaminants so that contaminant transport into the overlying water column is minimal and decreases with time. . .”

“Natural recovery has been a strategy of choice at two sites,¹ including the James River in Virginia, where natural sedimentation buried sediment contaminated by Kepone, and Lake Hartwell, South Carolina (a Superfund site). In general, natural recovery is not considered a deliberate choice but is viewed as the ‘no action’ alternative in the context of the National Environmental Policy Act (NEPA) of 1969 (P.L. 91-190), which requires a complete assessment of all alternatives to proposed federal actions. Natural recovery is always a possibility if there is no need to dredge or otherwise disturb the site for the maintenance of navigation channels or for port development. . .”

The natural burial process, which is one of the cornerstones of natural recovery, is dependent on a continuing incoming source of clean sediments (e.g., from upstream flows or from tributaries) and a net deposition of these clean sediments in the target areas. Technical papers contained in Appendix C provide in-depth evaluations of natural recovery.

Capping

Once again the NRC report is quoted below, in this instance for a description of capping and some of the issues associated with capping as a remedy for contaminated sediment.

“In-place capping is the controlled, accurate placement of a clean, isolating material cover, or cap, over contaminated sediments without relocating or causing a major disruption to the original bed. Caps usually consist of natural, granular materials, such as sand, although uncontaminated mud, geosynthetic materials, and armor stone have also been used. Capping is intended to stabilize the original bed against erosion and isolate the contaminants from contact with the benthic community, thereby reducing long-term environmental damage. Capping is an engineered procedure that can be used at appropriate sites, and its success depends on the careful design, construction, and long-term maintenance of the cap (Palermo 1991a).”

¹ In fact, natural recovery has been a strategy of choice at four other sites, also, as described in “Natural Recovery Projects.”

“... Among the major benefits of in-situ capping are that it eliminates the need to move the contaminated sediments and that it promotes the in-situ isolation of the contaminants by significantly retarding their release to the benthic community.”

The in situ capping of contaminated sediment in high-energy environments is typically implemented using an engineered, multilayered cap. Multilayer cap designs typically include the following materials:

- Rocks or cobbles to serve as a top, armor layer
- Geotextile to act as a divider between layers, limit mixing of cap materials between layers, and limit intrusion of biota by bioturbation
- Sandy upper layers, which are readily placed, relatively stable, and resistant to burrowing organisms
- Fine-grained lower layers that promote binding (adsorption) with the contaminants at the sediment surface.

As explained by Cushing (1999a), there is less emphasis currently on flood flow damage to caps and more emphasis on advective forces—slow acting processes of transport through the cap and internal disruption of the cap. Early on, contaminant diffusion through the cap was the primary mechanism of concern. Now advection (by groundwater intrusion or pore water displacement) and bioturbation (burrowing organisms) are recognized as mechanisms of concern. Cap consolidation with time can squeeze pore water, which may promote transfer of contaminants through the cap.

One of the key elements that makes capping an attractive technology is that the contaminant concentration at the sediment-water interface is, in effect, eliminated, which eliminates exposure to the benthic community and subsequent contaminant uptake into fish. This end result is unlike that achieved by a removal remedy, in which low or even sometimes elevated levels of contaminants are left at the sediment surface after the removal process due to inefficiencies in the removal process and, in the case of dredging, redeposition of suspended contaminants onto the dredged surface. This end result is noted in some of the completed removal projects documented in “Project Goals.”

EX SITU (REMOVAL) METHODS

Three generic approaches for the removal of contaminated sediments for the purpose of remediation are summarized herein. These generic approaches are dredging² or wet excavation, dry excavation, and diver-assisted removal.

Dredging or Wet Excavation

Dredging or wet excavation involves the following:

- Removal of underwater sediments by a dredge or removal by use of excavating equipment positioned on a barge or on the shore
- Transportation of removed material to and placement into a temporary holding area for containment, settling of solids, and dewatering of solids
- Transportation and disposal of dewatered solids to a dedicated (local) landfill or a commercial landfill or treatment of the dewatered solids to remove, capture, and/or destroy the contaminants, followed by disposal or reuse (e.g., as fill) of the decontaminated solids

Dredging or wet excavation from a barge are both dependent on the presence of sufficient depth of water to float the dredge or barge. Both removal methods are slowed considerably by the presence of rocks, debris, wood, and vegetation, which are often present in target areas that typically have never been dredged before. Dredging, particularly hydraulic dredging, also generates large volumes of potentially contaminated water that requires management.

Dry Excavation

Dry excavation involves the following activities:

- Diverting water away from the targeted sediment area by means of rechanneling, bypass pumping, siphoning, or isolation with barriers
- Pumping the standing water out of the isolated target area
- Maintaining conditions as dry as practical in the target area by continually pumping out in-seepage and groundwater
- Removing the dry sediments with conventional excavating equipment.

The dry removed sediments may still require either additional land-based dewatering or stabilization/solidification, to be followed by landfilling or treatment and reuse. Dry excavation, by its nature, is typically limited to relatively small shallow target areas in streams or shallow lake, pond, or marsh areas of manageable size. Otherwise, the water diversion/removal logistics become prohibitive.

Diver-Assisted Removal

Diver-assisted removal involves removing sediments using a flexible suction hose connected to a land or barge-based pump; a diver is used to maneuver the suction end of the hose into the sediments. The sediments are manually loosened by the diver and suctioned through the hose and pumped into holding tanks or basins on land. Settling and dewatering follow, then disposal, or treatment and reuse. Diver-assisted removal tends to be a tedious, low-solids volume, low-efficiency operation, and, as such, is used only for very small removal projects or as an adjunct to a larger dredging project (e.g., removal around underwater obstructions).

² Dredging, by definition, is the operation of removing material, usually sediments, from underwater using floating excavators called dredges.

IMPLEMENTED SEDIMENT REMEDIATION PROJECTS

Forty-four projects have been identified that represent the great majority of the sediment remediation projects implemented in the U.S. Navigational dredging projects with a contaminated sediment component are not comparable in scope and complexity to remedial dredging projects and are not included in this total. Also, the smaller projects (less than 3,000 cy targeted) are not included unless they offer some unique feature or lesson learned. A tabular, alphabetical listing of the 44 projects is included in Table D-1. The names used to identify each project are primarily the names used by the Superfund program. For non-Superfund projects, either the name of the affected body of water is used or the name commonly used by the prevailing state agency.

Table D-1
Project Name, Water Bodies, and Type of Regulatory Action
(Sorted Alphabetically by Project Name)

Project Name	State	Bodies of Water	Type of Regulatory Action
Allied Paper/Portage Creek/Kalamazoo River—Project 1 (Bryant Mill Pond)	MI	Bryant Mill Pond, Portage Creek, Kalamazoo River	Superfund. Time-critical removal action. State-led program.
Baird & McGuire	MA	Cochato River, several tributaries	Superfund. Final. Fund-led.
Bayou Bonfouca	LA	Turning basin upstream of Lake Pontchartrain	Superfund. Final. Fund-led.
Black River	OH	Black River, Lake Erie	1985 consent decree between the USEPA and US Steel Corporation, lodged in U.S. District Court - Northern District of Ohio. The decree was issued to deal with violations of the Clean Air Act, but included several supplementary environmental requirements, one of which was the dredging of the polyaromatic hydrocarbon (PAH)-contaminated sediment.
Cherry Farm	NY	Niagara River	NY State Department of Environmental Conservation (NYSDEC) Order-on-Consent.
Convair Lagoon	CA	Shallow embayment in North San Diego Bay	Cleanup and Abatement Order with the San Diego Regional Water Quality Control Board.
Ford Outfall	MI	River Raisin, Monroe Harbor	Non-time critical removal action (NTCRA) under the Superfund Accelerated Cleanup Model (SACM). Administrative Orders on Consent (AOCs) between the potentially responsible party (PRP) and the USEPA in 1993 and 1997.
Formosa Plastics	TX	Turning basin in Lavaca Bay	Emergency response action with the Texas Water Commission and the Calhoun County Navigation District.
Fox River—Project 2 (Deposit N)	WI	Lower Fox River	Part of a Cooperative Agreement between the Fox River Group and the State of Wisconsin.
Gill Creek (DuPont)	NY	Gill Creek, Niagara River	Final; DuPont and Olin agreed to cooperate with NYSDEC in implementing the remediation program described in the <i>Gill Creek Plans and Specifications</i> (April 1992).
Gill Creek (Olin Industrial Welding Site)	NY	Gill Creek, Niagara River	NYSDEC Order-on-Consent
GM Central Foundry (Massena)	NY	St. Lawrence River, Raquette River, Turtle Creek	Superfund. Final.

Project Name	State	Bodies of Water	Type of Regulatory Action
Gould (Portland)	OR	East Doane Lake	Superfund. Final. Sediment removal and interim measure.
Grasse River—Project 1 (Hot Spot)	NY	Grasse River	EPA-led program. Interim; removal of highest PCB concentrations as NTCRA; voluntary action by PRP; agency approval.
Hooker (102 nd Street)	NY	Embayment in Niagara River	Superfund. Final.
Housatonic River—Project 1 (Hot Spot)	MA	Upper Housatonic River	Comprehensive Environmental Response, Cleanup, and Liability Act (CERCLA) 106 Administrative Order. Interim removal.
James River	VA	James River, Chesapeake Bay	Mitigation feasibility study (EPA).
Lavaca Bay	TX	Lavaca Bay, Gulf of Mexico	—
Lipari Landfill	NJ	Alcyon Lake, Chestnut Branch stream and marsh, Rabbit Run (small tributary of Chestnut Branch)	Superfund. Final.
Loring Air Force Base	ME	Greenlaw Brook Study Area: wetlands and drainage ditches, Flightline Drainage Ditch (FLDD), FLDD wetlands, East Branch of Greenlaw Brook, Nose Dock area drainage ways (north and south only), and Drainage Ditch G06. Also, Underground Transformer Site Wetland (northern portion only)	Superfund. Final.
Love Canal	NY	Black Creek, Bergholtz Creek, Cayuga Creek, Niagara River	Superfund. Final.
LTV Steel	IN	Intake Flume, Indiana Harbor Canal, Lake Michigan	Clean Water Act consent decree (1992).
Mallinckrodt Baker (formerly J.T. Baker)	NJ	Delaware River	Final.
Manistique River/Harbor	MI	Manistique River, Manistique Harbor	Final (CERCLA removal action authority); action memoranda - 10/93, 6/95 (amended 10/95 and 9/96); removal action recommendation in 8/94. Fund-led program after PRP cash out.
Marathon Battery	NY	East Foundry Cove, Marsh, and Pond; West Foundry Cove; Constitution Marsh; small cover near Cold Spring Pier in Lower Hudson River	Superfund. Final.
National Zinc	OK	Eliza Creek, Sand Creek, Caney River	State pilot project in lieu of Superfund listing, in conjunction with EPA.
Natural Gas Compressor Station	MS	Little Conehoma Creek	USEPA consent decree.
New Bedford Harbor—Project 1 (Hot Spots)	MA	Acushnet River Estuary, New Bedford Harbor (Upper Harbor)	Superfund. Interim Remedial Action. Fund-led program.
Newburgh Lake	MI	Middle Branch Rouge River, Newburgh Lake	Federal Grant. Final.

Project Name	State	Bodies of Water	Type of Regulatory Action
North Hollywood Dump	TN	Wolf River, man-made lake	Superfund. Final.
Ottawa River—Project 2 (Removal from Unnamed Tributary)	OH	Unnamed tributary, Ottawa River, Maumee Bay, Lake Erie	Partnership between the City of Toledo, Ohio EPA, USEPA, U.S. Fish and Wildlife Service, and GenCorp, Inc.
Outboard Marine	IL	Waukegan Harbor, Lake Michigan	Superfund. Final.
Pioneer Lake	OH	Pioneer Lake	Removal action funded through the U.S. Coast Guard to USEPA under the Oil Pollution Act of 1990.
Queensbury NMPC Site	NY	Upper Hudson River	NYSDEC-listed hazardous waste disposal site. State-led program.
Ruck Pond (Cedar Creek)	WI	Impoundment on Cedar Creek (tributary of Milwaukee River)	State-led (Wisconsin) program. Final.
Sangamo - Weston	SC	Twelvemile Creek, Lake Hartwell	Superfund. Final. Fund-led program.
Sheboygan River/Harbor—Project 1 (Pilot Study)	WI	Sheboygan River and Harbor (a tributary to Lake Michigan)	Superfund. Interim pilot study and removal action under Superfund.
Shiawassee River	MI	South Branch Shiawassee River	Superfund. Final. State-led program.
Tennessee Products—Project 1 (Hot Spot)	TN	Chattanooga Creek	Superfund. NTCRA.
Town Branch Creek	KY	Town Branch Creek	Franklin Circuit Court judgment. Final.
Triana/Tennessee River	AL	Two tributaries to Tennessee River	Superfund. Final.
United Heckathorn	CA	Lauritzen Channel and Parr Canal in Richmond Harbor, San Francisco Bay	Superfund. Final. Four consent decrees between EPA and PRPs approved in July 1996.
Willow Run Creek	MI	Willow Run Creek, Edison and Tyler Ponds (integral), Belleville Lake	Site proposed for the National Priority List, but not listed. The USEPA Region V Regional Decision Team approved the Willow Run Creek SACM site strategy and approved funding for an engineering evaluation/cost analysis. Agreement between USEPA and Michigan Department of Environmental Quality allows for state supervision of an approved remedial action plan under state law. The USEPA, however, approved the new Toxic Substances Control Act (TSCA) landfill. Final.
Wyckoff Co./Eagle Harbor—Project 2 (West Harbor)	WA	Eagle Harbor, Puget Sound	Final. Superfund. Preceded by enforcement actions in 1988 (AOC), 1991 (Unilateral Administrative Order), 1993 (AOC), and 1994 (consent decree).

It is noteworthy that documentation of the outcome of these projects has, in varying degrees, been incomplete and not widely disseminated. There is no central repository or clearinghouse for such information; information transfer on this subject between governmental agencies or even between regions of the USEPA does not seem to be occurring with any consistency. There is no evidence

of lessons learned on prior projects being applied by regulators to subsequent projects. Particularly problematic is the availability and quality of final reports. Although there is often extensive documentation leading up to the decision to remediate, such as generated by the remedial investigation/feasibility study process for Superfund projects, the documentation of the outcome of remediation results is often late and incomplete. There is neither consistency to the content of final reports nor any apparent adherence to a quality standard, even for Superfund projects.

To fill this information void, Applied Environmental Management; Blasland, Bouck & Lee; and the General Electric Co. have compiled a data base (Release 1.0; 1999) on completed and on-going sediment remediation projects. A wide variety of information sources were consulted. The data base contains detailed information on both the characteristics and also the planned and actual remediation work for each of the 44 implemented projects (as well as 41 other projects still in the investigation phase). Tables D-2 through D-6 summarize the target, method of remediation, size (volume removed and cost), and disposal method for each project.

Table D-2
Sediment Remediation Projects Implemented in the U.S.: Dredging/On-Site Disposal

Project	Remedial Target¹	Remediation Method	Volume Removed (cy)	Total Cost (million)	Unit Cost (\$/cy)	Disposal
Bayou Bonfouca, LA	Depth horizon (1,300 ppm PAHs)	Mechanical dredging	169,000	\$115	\$680	On-site incineration
Alcoa/Lavaca Bay, TX	Depth horizon (mercury)	Hydraulic dredging	90,000	—	—	On-site disposal ponds
Black River, OH	Depth horizon (PAHs)	Hydraulic dredging and mechanical dredging	60,000	\$5	\$83	On-site landfill
Cherry Farm, NY	Depth Horizon (20 to 50 ppm PAHs)	Hydraulic dredging	50,000	\$2.2	\$44	On-site disposal pond
N. Hollywood Dump, TN	Depth horizon (pesticides)	Hydraulic dredging	40,000	\$2.4	\$60	On-site burial in an isolated oxbow
Waukegan Harbor (Outboard Marine), IL	Depth horizon (50 ppm PCBs)	Hydraulic dredging	38,300	\$15	\$392	Nearshore CDF
Ford Outfall, MI	10 ppm PCBs	Mechanical dredging	28,500	\$5.4	\$190	On-site landfill
Gould (Portland), OR	Depth horizon (PAHs)	Hydraulic dredging	11,000	\$3	\$273	On-site landfill
Sheboygan River, WI	None ³	Hydraulic dredging, wet excavation, and capping	3,800	\$7 ²	\$1,842	On-site storage (temporary)
Grasse River, NY	None ³	Hydraulic dredging, wet excavation, and diver assisted	3,000	\$4.9	\$1,633	On-site landfill

Project	Remedial Target¹	Remediation Method	Volume Removed (cy)	Total Cost (million)	Unit Cost (\$/cy)	Disposal
Eagle (West) Harbor, WA	Various for mercury and PAHs	Mechanical dredging, wet excavation, capping, and enhanced natural recovery	3,000	\$3	\$1,000	Nearshore CDF, commercial landfill, and in situ capping
TOTAL			344,500 cy			

1 Depth horizon means a depth only was targeted designated (based on characterization data) either to remove all contaminated sediments or to reach a cleanup level, but no or only limited postdredging sampling was performed for verification.

2 Does not include disposal cost. Off-site disposal has just recently been defined for New Bedford Harbor and GM (Massena) and has not yet been implemented.

3 No designated target was defined since these were pilot (interim) removal programs; hot spots in the Sheboygan River were defined as areas greater than 686 ppm PCBs. In the Grasse River, the areal extent of the hot spot targeted was defined by a 10 ppm PCB boundary; the Fox River (Deposit N) project was strictly mass removal and demonstration testing.

Table D-3
Sediment Remediation Projects Implemented in the U.S.: Dredging/Off-Site Disposal

Project	Remedial Target¹	Remediation Method	Volume Removed (cy)	Total Cost (million)	Unit Cost (\$/cy)	Disposal
LTV Steel, IN	Depth horizon (PAHs and oils)	Hydraulic dredging and diver-assisted removal	114,000	\$12	\$105	Commercial landfill
Manistique River, MI	10 ppm PCBs	Hydraulic dredging	118,000 ²	\$25	\$212 ²	Commercial landfill
United Heckathorn, CA	0.59 ppm DDT	Mechanical dredging	108,000	>\$12	>\$111	Commercial landfill
Marathon Battery, NY	10 ppm cadmium	Hydraulic dredging and mechanical dredging; natural recovery	77,000	\$9 to \$11	\$117 to \$143	Commercial landfill
New Bedford Harbor, MA	4,000 ppm PCBs	Hydraulic dredging	14,000	\$20.1 ³	\$1,436	Commercial landfill ³
GM (Massena), NY	1 ppm PCBs	Hydraulic dredging, wet excavation, and capping	13,800	\$10 ³	\$725	Commercial landfill ³
Formosa Plastics, TX	0.5 ppm EDC	Mechanical dredging	7,000	\$1.4	\$200	Commercial landfill
Pioneer Lake, OH	Various for PAHs	Hydraulic dredging	6,600	\$2.5	\$379	Commercial landfill
Fox River, WI (Deposit N)	None ⁴	Hydraulic dredging	4,200	\$3.5	\$833	Commercial landfill
TOTAL			463,000 cy			

1 Depth horizon means a depth only was targeted designated (based on characterization data) either to remove all contaminated sediments or to reach a cleanup level, but no or only limited postdredging sampling was performed for verification.

2 Total may be biased high due to potentially inaccurate methods of measuring removed solids. In fact, the 118,000 cy reported by the USEPA at the end of 1998 has now been downgraded to 72,000 cy. If 72,000 cy is correct, the unit cost is \$347 per cy.

3 Does not include disposal cost. Off-site disposal has just recently been defined for New Bedford Harbor and GM (Massena) and has not yet been implemented.

4 No designated target was defined since these were pilot (interim) removal programs; hot spots in the Sheboygan River were defined as areas greater than 686 ppm PCBs. In the Grasse River, the areal extent of the hot spot targeted was defined by a 10 ppm PCB boundary; the Fox River (Deposit N) project was strictly mass removal and demonstration testing.

Table D-4
Sediment Remediation Projects Implemented in the U.S.: Dry/Wet Excavation - On-Site Disposal

Project	Remedial Target	How Target Established	Volume Removed	Total Cost (million)	Unit Cost (\$/cy)	Disposal
Willow Run Creek, MI	1 ppm, 7.5 ppm, or 21 ppm PCBs	Ecological modeling and State Environmental Response Act	450,000 cy	\$70	\$156	Nearby on-site landfill
Bryant Mill Pond, MI	10 ppm PCBs	Unknown	165,000 cy	\$7.5	\$45	On-site former dewatering lagoons
Lipari Landfill, NJ	Depth horizon	Human health risk assessment	163,500 cy	\$50	\$306	Some thermal desorption and beneficial reuse; some stabilization and placement
Loring AFB, ME	1 ppm PCBs, 35 to 87 ppm total PAHs	Ecological risk assessment	152,400 cy	\$13.85	\$91	On-site landfill
Hooker (102 nd Street), NY	Depth horizon and areal extent	Human health risk assessment	28,500 cy	Not available	—	On-site landfill
Gill Creek, NY (Olin Industrial Welding Site)	0.045 ppm hexachloro-cyclohexane (BHCs); 22 ppm PAHs; 0.2 ppm mercury	Based on NYSDEC Sediment Criteria	6,850 cy	\$1.4	\$204	On-site fill material
Mallinckrodt Baker, NJ (formerly J.T. Baker)	10 ppm DDT	NJDEP designated limit to define extent of hot spot removal	3,500 to 4,000 cy	\$1.2	\$320	On-site landfill
Baird & McGuire, MA	Various for arsenic, DDT, chlordane, PAHs	Human health risk assessment	1,500 cy	--	--	On-site incineration
TOTAL			971,250 to 971,750 cy			On-site landfill: 5 ¹ On-site fill: 2 ¹ Thermal treatment: 2 ¹

1 Total is more than total number of listed sites; Lipari Landfill counted twice since both thermal treatment and on-site placement were used.

Table D-5
Sediment Remediation Projects Implemented in the U.S.: Dry/Wet Excavation - Off-Site Disposal

Project	Remedial Target	How Target Established	Volume Removed	Total Cost (million)	Unit Cost (\$/cy)	Disposal
Newburgh Lake, MI	Not detected (<0.3 ppm)	Unknown	588,000 cy	\$12.0	\$20	Commercial landfill
Town Branch Creek, KY	0.1 ppm PCBs (all sediments practicable)	Circuit Court Judgment supporting KY Natural Resources and Environmental Protection Cabinet (NREPC) observations	17,000 cy (sediment and banks); 76,000 cy (floodplains)	Not available	—	Commercial landfill
Love Canal, NY	1 parts per billion (ppb) 2,3,7,8-TCDD	Centers for Disease Control (CDC) action level	31,000 cy	\$14 ¹	\$452	Commercial incineration

Project	Remedial Target	How Target Established	Volume Removed	Total Cost (million)	Unit Cost (\$/cy)	Disposal
Tennessee Products, TN	Visually identified coal tar material	—	24,100 cy	\$12	\$498	Off-site fuel source and commercial landfill
Marathon Battery, NY ²	100 ppm cadmium	Ecological risk analysis	23,000 cy	Not available	—	Commercial landfill
Ottawa River (Unnamed Trib.), OH	50 ppm PCBs	Stakeholder Negotiated Target	9,692	\$5	\$516	Commercial landfill
Gill Creek, NY (DuPont)	All sediments practicable (PCBs, PAHs)	N/A	8,020 cy	\$10 to \$14	\$1,247 to \$1,496	Commercial landfill
Ruck Pond, WI	All sediments practicable (PCBs)	N/A	7,730 cy	\$7.5	\$970	Commercial landfill
Housatonic River, MA	Depth (PCBs)	CERCLA Order for hot spot removal; final depth dictated by USEPA field decisions	6,000 cy sediment and banks	\$4.5	\$750	Commercial landfill
National Zinc, OK	1 ppm PCBs	Negotiated level in National Consent Decree	6,000 cy	—	—	Commercial landfill ³
Queensbury NMPC, NY	1 ppm PCBs	Default to Technical Feasibility	4,500 - 5,000 cy	\$3.5	\$700 to \$777	Commercial landfill
Shiawassee River, MI	10 ppm PCBs	Consent Judgment	1,805 cy	\$1.3	\$720	Commercial landfill
TOTAL			802,847 to 803,347 cy			Commercial landfill: 11 ⁴ Thermal treatment: 2 ⁴

1 Does not include disposal cost. Several years delay to determine disposal method.

2 Listed twice since both dredging and dry excavation were used.

3 Disposal plan not yet implemented; material presently stored on-site temporarily.

4 Total is more than total number of listed sites; Tennessee Products used both off-site thermal treatment and landfill disposal methods.

Table D-6
Sediment Remediation Projects Implemented in the U.S.: In Situ

Project	Remedial Target	How Target Established	Volume Removed	Total Cost (million)	Disposal
James River, VA	Levels in fish	FDA fish levels	N/A	N/A	N/A
Sangamo-Weston, SC	1 ppm PCBs	Technical feasibility, after human health risk assessment	N/A	N/A	N/A
Convair Lagoon, CA	Cover areas exceeding 4.6 ppm PCBs	Engineered cap placement (geogrid, 1 foot of crushed rock, 2 feet of sand)	5.7 acres capped	\$2.5 to \$3	In situ capping with 3 foot thick engineered cap
Triana/Tennessee River, AL	DDT levels in fish	FDA fish levels	None	\$30	Rechannelization, followed by in situ direct burial of the original tributaries

Remedial Methods Used

The types of remedial methods used at the 44 projects are summarized in Table D-7 as follows:

Table D-7
Types of Remedies Implemented for the 44 Projects

Remedy Implemented	No. of Times Used
Dredging	18
Dry excavation	15
Wet excavation	3
Combined methods	
Dredging and dry excavation	2
Dredging and capping	2
Permanent diversion/burial	1
Natural recovery	2*
Engineered capping	1

* Four others of the 44 have natural recovery as a component of the remedy.

Removal has been the method of choice at the vast majority of the projects (40 of 44), despite the disruptive nature of removal and the repeated inability to achieve low cleanup levels (see “Achievement of Goals”). This propensity toward removal as a remedy is likely a follow-on to the traditional “dig it up and haul it away” approach used for soil at Superfund and other targeted sites. This approach does not translate easily to contaminated sediment, although there is a tendency on the part of regulators and other involved parties to ignore or be unaware of this fact. The differences are dramatic when sediment is involved, and these differences are worth emphasizing. They include the fact that:

- The underwater environment presents a lack of visibility and a need to manage the water phase.
- The target areas are often no longer located on the responsible party’s property; access difficulties are introduced.
- The contamination is often spread out and diffuse.
- The bottom area of most water bodies is an ecologically sensitive environment.
- The water environment mobilizes and transports contaminants back into and away from the target area during removal.
- All of the impacted sediments may not be capable of being removed, which can result in residual contaminants at the surface, sometimes at higher than original levels.

Natural recovery as a remedy was selected in whole or in part for six projects. These are described in detail in “Natural Recovery Projects.” Engineered, multilayer caps have been constructed for only three projects; two of the three projects (GM Massena and the Sheboygan River pilot project) installed the caps in response to elevated contaminant levels remaining following a removal remedy (Cushing 1999a). Capping as a remedy is not addressed further in this technical paper.

Disposal Methods Used

Landfilling or containment predominates as the method of disposal. Containment (a type of landfilling) includes use of disposal ponds or nearshore CDFs. Treatment is seldom used. Disposal methods are summarized in Table D-8.

Table D-8
Disposal Methods Implemented for the 40 Removal Projects

Disposal Method Implemented	No. of Times Used*
Off-site commercial landfill	21
On-site landfill, ponds, or CDF	13
Off-site treatment (thermal)	2
On-site treatment (thermal)	4
Other (temporary storage; fill material)	4

* Totals more than 40 since more than one method was used on some projects.

It is interesting to note that, other than one instance of on-site incineration and some limited use of thermal desorption, on-site final treatment as a means of disposition of contaminated sediments has not been implemented for these projects. (Basic pretreatment of the dewatered sediments has been implemented at several of the projects by adding cementitious agents to solidify/stabilize the material before disposing of into a landfill.) Final treatment technologies have failed to make inroads as a component of sediment remediation projects primarily due to the following factors:

- An inconsistent or nonexistent track record at full-scale
- High unit costs
- The need for extensive land-based area for managing dredged material including for staging, size-reduction, dewatering, and treatment
- Concerns that regulatory-required low residual contaminant levels will not be able to be achieved.

Implications for Future Projects

The heavy reliance on removal and landfilling or other methods of containment is linked to the small volumes remediated to date. As future volumes targeted for removal increase substantially, the concomitant use of commercial landfills becomes cost prohibitive and subject to capacity limitations and the alternative, a large dedicated landfill, is prone to community objections and permitting difficulties. These disposal constraints remain a serious, difficult obstacle to future large-scale sediment removal projects.

Six projects³ scheduled to start remediation in the 1999-2001 period are targeting the dredging of from 200,000 to 700,000 cy. Four of the six projects will dispose of the sediments into one or more CDFs, and one will use a dedicated landfill located on the responsible party's property. All five projects are experiencing substantial delays while issues of siting, land acquisition, permitting, and construction of the disposal facilities are addressed.

Each of these projects will exceed (in volume removed) the largest remedial dredging project to date. This proactive approach and escalation in project size by the regulatory agencies is seemingly without the benefit or cognizance of lessons learned on prior, smaller projects (i.e., the agencies' actions are ahead of the science and technology).

³ Grand Calumet River (IN), Hylebos Waterway (WA), Inland Steel (IN), New Bedford Harbor (MA), Pine River (MI), and Saginaw River (MI).

SEDIMENT REMOVAL PROJECTS

Project Sizes and Characteristics

All 22 dredging projects involved relatively small volumes of sediment, certainly by navigational dredging standards. The largest dredging project involved removal of 169,000 cy (Bayou Bonfouca). Half of the 22 projects resulted in 40,000 cy or less of sediment removal. The total volume removed for all dredging projects is 940,000 cy (rounded). This grand total, not a large total for even a single navigational dredging project, emphasizes the great difference in the character of and approach required for remedial dredging projects as compared to conventional dredging projects.

Removal using conventional equipment was the norm. Specialty dredges were generally not used on the 22 dredging projects with perhaps the following three exceptions: a Cable Arm clamshell bucket used on the Ford Outfall project, a backhoe-on-a-barge custom built by Bean Dredging for the Bayou Bonfouca project, and a hydraulic Versi-Dredge used at the Gould (Portland) project. The backhoe-on-a-barge dredge is, in effect, a customized and highly instrumented clamshell dredge. The Versi-Dredge reportedly proved to be a questionable choice for the Gould project as it was continually hindered by debris and generated large volumes of water requiring management. Thus, recent claims by various public interest and governmental groups that there have been substantial advances in dredging equipment in this decade that should facilitate remedial dredging are not borne out by the projects completed to date. This fact is not surprising in that specialty dredges tend to focus only on improving limited aspects of the remedial dredging process (e.g., reducing resuspension or allowing passage of larger-size solids) and, by their nature and due to their specialized features, tend to have low production rates. Specialty dredges, with the exception of the two aforementioned clamshells, have not been demonstrated effectively for full-scale contaminated sediment removal. In addition, since many of the difficulties of remedial dredging are based on logistical and environmental constraints, these are unlikely to be overcome by the introduction of a specialty dredge, by itself.

Dry excavation was performed predominantly in small shallow streams or ponds, amenable to dewatering. Dewatering was performed by diverting the water around the targeted area or draining the pond. Wet excavation was accomplished in shallow, narrow streams using excavators on the banks. Sixteen of the dry and wet excavation projects involved small volumes (i.e., 1,800 to 165,000 cy). Two larger projects, with removals of 588,000 and 450,000 cy, involved the draining of a lake and two ponds, respectively.

Project Costs and Repetitive Difficulties

The project costs and difficulties associated with remedial dredging and dry and wet excavation are described below.

- *Remedial Dredging*

Overall costs for the dredging projects ranged from \$44 to \$1,842 per cy, with a median of about \$200 to \$275 per cy. The high overall cost is due to two primary factors: low production rates and high costs for disposal. Repetitive difficulties that cause low production rates (and long implementation times), but that do not usually impede navigational dredging include the following:

- Rocks, vegetation, and debris
- Shallow water
- Floating oil
- Resuspension and associated controls
- Limited on-land water holding and treatment capacity

A project-specific, detailed evaluation of these difficulties is contained in “Identification and Evaluation of Remedial Dredging Difficulties” (Cushing 1999b).

It can be concluded from evaluating these completed projects that the two primary determinants of cost for remedial dredging projects are dredge production rate and disposal cost. Little or no economy of scale exists (contrary to recent agency claims). Dredge production rate is dependent on the repetitive difficulties described above as well as the targeted depth or cleanup level and whether verification sampling is performed during dredging or not. Disposal cost is dependent on type of contaminant, type of disposal facility (i.e., on-site, dedicated nearby, or commercial), and distance of the disposal facility from the site. None of these variables is volume dependent. Economy of scale advantages such as longer use of temporary support facilities and water treatment facilities and possible slightly lower unit disposal costs for large volumes are small in comparison.

This conclusion was tested by plotting overall unit cost versus volume removed for the 40 completed removal projects. The plotted data (not shown) were also segregated between dedicated disposal versus commercial disposal. Other than the fact that small projects such as pilot removals of less than 10,000 cy tend to have high unit costs, no trends were discernible.

- *Dry and Wet Excavation*
Overall costs for the dry/wet removal projects ranged from \$21 to \$1,500 per cy, with a median of about \$450 per cy. The high overall cost is due to the following three primary factors:
 - Lower production rates than for traditional earth moving projects due to difficulties with accessibility and wet terrain
 - Additional water control and handling requirements imposed for maintaining the dry condition
 - High costs for disposal

Project Goals

Descriptions of setting primary goals and remedial targets and achieving those goals are provided below.

- *Setting Primary Goals and Remedial Targets*
For a sediment remediation project, one expects that there is a defined project goal or goals typically set to reduce a risk to human health or the environment to acceptable levels and a defined target for the extent of remediation in the sediment required to achieve the goal. An example of a goal is “to reduce PCB levels in fish to below the FDA limit of 2 ppm.” An example of a remedial target is “to remove PCBs in sediments to a level which will allow the fish levels to recover to less than 2 ppm.”

Table D-9 sets out the primary goals, the sediment remedial target, and the outcome for the 25 largest projects—those targeting 10,000 cy of sediments or greater. The other smaller projects (less than 10,000 cy targeted) are excluded from Table D-9. The small projects are often characterized by high contaminant concentrations in a small area or are interim actions or pilot projects, which deemphasize the incentive for extensive analysis and may legitimately encourage a common sense type approach for evaluating remediation techniques at full-scale.

Key questions that are basic to any major sediment remediation project and that have been examined critically using the information in Table D-9 include the following:

- Was the primary remedial goal selected to achieve risk reduction, with the basis being to achieve protective levels for receptors within a specified time period?

Table D-9
U.S. Sediment Remediation Projects Implemented (>10,000 cy) – Primary Goal versus Outcome

Project	Primary Goal	Basis for Primary Goal	Sediment Remedial Target	Relationship of Target to Goal	Remediation Method	Achievement of Remedial Target	Achievement of Primary Goal
Bayou Bonfouca, LA ¹ (169,000 cy)	Reduce PAH human contact risk to <10 ⁻⁴ and minimize threat to aquatic biota.	Human health risk assessment	Depth horizon to achieve <1300 ppm PAHs	Direct	Mechanical dredging followed by fill	Depth horizon achieved; no analytical verification	Likely accomplished, particularly since fill was added to the dredged areas. However, postmonitoring consists of the state annual monitoring program for water, sediment, and fish and seems hit or miss. Also, it is unclear if targeted surface PAH levels were achieved since a sediment contact and swimming advisory is still in effect due to PAHs in sediment samples exceeding EPA guideline values, but not verified.
Manistique River, MI ¹ (118,000 cy)	Reduce PCB in fish levels, reduce carcinogenic and noncarcinogenic risks to <10 ⁻⁴ and <1, respectively, except for high-end subsistence and some high-end recreational exposure from fish consumption.	Human health risk assessment	10 ppm PCBs	Default level after using biota to sediment accumulation factor (BSAF) factor to estimate a target sediment level, then increasing the estimate to 10 ppm PCBs, which EPA justified based on cleanup levels at other EPA projects, the likelihood of achieving <10 ppm, and future natural burial	Mechanical dredging	In progress; consistent achievement of 10 ppm or less proving difficult	Too soon to tell. Remediation still in progress in Year 5. No postmonitoring program defined as of yet.
LTV Steel, IN ¹ (114,000 cy)	Remove all oil-contaminated sediments from a 3500-foot manmade intake channel.	Clean Water Act Consent Decree	Depth horizon (removal down to original bottom)	Direct	Hydraulic dredging and diver-assisted removal	Depth horizon achieved; no analytical verification	Likely accomplished, but not verified.
United Heckathorn, CA ¹ (108,000 cy)	Achieve EPA marine chronic water quality criteria of 1 parts per trillion (ppt) DDT; achieve human health surface water criteria of 0.6 ppt DDT; achieve the National Academy of Sciences (NAS) action levels for DDT in fish to protect fish-eating birds.	Ecological risk assessment	Remove all "young bay mud" to achieve <0.59 ppm DDT.	Indirect (calculated in the ecological risk assessment)	Mechanical dredging	Depth horizon (penetration into "old bay mud") achieved; 20 samples for chemical analysis collected from top 6 inches of final dredged surface for informational purposes (several exceeded 0.59 ppb DDT)	Too soon to tell; postmonitoring in progress.
Marathon Battery, NY ¹ (77,000 cy)	Eliminate adverse ecological impacts by achieving 100 ppm cadmium in sediment in East Foundry Cove (EFC) Marsh and 10 ppm cadmium in other areas; allow natural recovery in over 300 acres of adjacent cove/marsh.	Ecological assessment based on "weight of evidence," bioassay tests, and comparison with ambient water quality standards	Remove top 1 foot of sediment in areas targeting 10 ppm cadmium; remove to <100 ppm cadmium in EFC marsh; allow natural recovery in over 300 acres.	None other than 95% cadmium mass removal predicted	Hydraulic and mechanical dredging; dry excavation	Removed more than top 1 foot; decided to take verification samples for analysis in some areas; achieved an average of 25 ppm cadmium in EFC Marsh; achieved an average of <10 ppm cadmium in EFC and near pier	Postmonitoring in progress. Two years of reported results are inconclusive.

Project	Primary Goal	Basis for Primary Goal	Sediment Remedial Target	Relationship of Target to Goal	Remediation Method	Achievement of Remedial Target	Achievement of Primary Goal
Black River, OH ¹ (60,000 cy)	Remove all PAH- and metal-contaminated sediments.	Clean Air Act Consent Decree	Depth horizon (removal down to "hard bottom" or "bedrock")	Direct	Hydraulic and mechanical dredging	Depth horizon achieved; no analytical verification	Likely accomplished, but not verified.
Cherry Farm, NY ¹ (Niagara River) (50,000 cy)	Reduce PAH-related risks to benthic aquatic life and fish.	Ecological and biotoxicity testing; literature review for ecotoxicity of PAHs	Depth horizons based on characterization data to achieve 20 ppm PAHs in the top 1 foot; 50 ppm PAHs below 1 foot	Vague; target levels set by negotiation and by comparing prevailing PAH levels to upstream background levels	Hydraulic dredging	Achieved depth horizons based on bathymetry; no analytical verification	Unknown; postmonitoring program being negotiated.
N. Hollywood Dump, TN ¹ (40-acre lake) (40,000 cy)	Restore the pesticide-contaminated fishery in the lake so that it is suitable for human consumption.	Human health risk assessment	Remove or isolate pesticide-contaminated surface sediments.	Direct	Fish harvesting first, then part hydraulic dredging/part direct burial	Achieved	Too soon to tell; long-term bi-annual fish and sediment sampling in progress.
Outboard Marine, IL (Waukegan Harbor) ¹ (38,300 cy)	Eliminate PCB flux from the harbor into Lake Michigan.	Hydrodynamic modeling	50 ppm PCBs in the harbor; 500 ppm PCBs in Slip #3	Direct for the harbor; unknown for the 500 ppm target in Slip #3	Hydraulic dredging	Unknown. No analytical verification. Dredged to a predefined depth in the harbor to the reportedly uncontaminated sand layer.	Unknown. Some limited analysis of surface samples at undefined locations in the harbor over four years after dredging exhibited 3 to 9 ppm PCBs. PCB levels in harbor fish are trending downward.
Ford Outfall, MI (River Raisin) ¹ (28,500 cy)	Reduce PCB levels in fish.	Risk analysis by EPA	10 ppm PCBs after removal down to the native clay layer	Direct	Hydraulic dredging	Partially achieved. Removal to refusal was accomplished. Verification by field test kits, then 14 samples (one per quadrant) for laboratory analysis; seven quadrants had insufficient sediment to collect; four quadrants exhibited 0.5 to 7 ppm PCBs; three quadrants exhibited 12 to 20 ppm PCBs.	Unknown. No formal postmonitoring program identified. Results of fish samples and caged fish studies from a monitoring program performed by MI Department of Environmental Quality are not yet available. Two postmonitoring sediment core samples from the dredged area exhibited 60 and 110 ppm PCBs.
New Bedford Harbor, MA ¹ (14,000 cy)	Remove PCB mass at an optimum "residual concentration to volume removed" ratio and reduce PCB flux to the water column (interim measure).	Mass removal calculations; flux modeling studies conducted by PRPs; water column data	4,000 ppm PCBs in five acres of hot spots	Direct	Hydraulic dredging	Achieved based on a limited number of verification samples (15 composite samples ranging from 67 to 2,068 ppm PCBs)	Achieved mass removal. Water column data postdredging (if collected) not obtained. PCBs in surface sediment samples in the Upper Harbor increased 32% on average, following hot spot dredging.
GM (Massena), NY ¹ (13,800 cy)	Reduce PCB levels in fish.	Human health risk assessment	Achieve 1 ppm PCBs and remove as much sediment as technically feasible.	Vague; 0.1 ppm PCBs desired, but 1 ppm selected based on technical feasibility	Hydraulic dredging	Not achieved. Average residual PCB levels at completion in six dredged quadrants across 11 acres ranged from 3 to 27 ppm with a maximum of 90 ppm	Two annual postdredging fish monitoring programs completed. No discernible trends other than a slight increase in fish PCB concentration in Year 2 versus Year 1.

Project	Primary Goal	Basis for Primary Goal	Sediment Remedial Target	Relationship of Target to Goal	Remediation Method	Achievement of Remedial Target	Achievement of Primary Goal
Gould (Portland), OR ¹ (11,000 cy)	Vague; apparently protect from direct contact risk and remove lead-contaminated surface (0 to 2 feet) sediments that exceed the extraction procedure (EP) toxicity concentration.	Applicable or relevant and appropriate requirement (ARAR)	5 ppm lead	Not identified	Hydraulic dredging followed by filling in the 3.1 acre lake	Achieved based on verification sampling	Apparently achieved.
Newburgh Lake, MI ² (599,800 cy)	Restore 105-acre lake depth and restore fishery.	Not identified	Depth horizon which will both restore depth and remove the detectable PCBs	Direct	Dry excavation supplemented by hydraulic dredging in undrained bypass channel through the lake	Depth horizon achieved; no analytical verification	Achieved, but no analytical verification. Fish harvested and restocked. Postmonitoring not identified.
Willow Run Creek, MI ² (450,000 cy)	Eliminate adverse ecological impacts.	Ecological assessment based on ecological ingestion modeling, then feasibility and compliance with MI Environmental Response Act 307	Removal to 21 ppm or 1 ppm PCBs below waterline depending on locale; removal to 21 ppm or 2.3 ppm PCBs above waterline	Direct	Dry excavation	Achieved based on verification sampling	Unknown. No formal postmonitoring is planned.
Lipari Landfill, NJ ² (154,000 cy)	Reduce human health risk from direct contact with or air exposure to targeted VOCs to below 10 ⁻⁶ .	Human health risk assessment	Depth horizon 6 inches into the underlying Kirkwood Clay layer to achieve nondetect for bis(2-chloro-ethyl)ether	Direct	Dry excavation	Depth horizon achieved except in areas where no Kirkwood Clay was encountered, in which instances excavated 18 inches below a level extrapolated from adjacent contiguous clay layers no analytical verification.	Apparently achieved, particularly since clean fill was also placed. No postmonitoring identified.
Bryant Mill Pond, MI (Kalamazoo River) ² (165,000 cy)	Mitigate the public health threat posed by direct human and wildlife contact and mitigate threats posed to aquatic life and wildlife by ongoing releases (i.e., source control) to the Kalamazoo River.	Ecological risk assessment along with direct observation of continuing releases by erosion and sloughing from banks	10 ppm PCBs	Unknown	Dry excavation	Reportedly achieved based on verification sampling. Sample results not obtained or reviewed.	Unknown and probably too early to tell since removal was just completed (June 1999). However, as stated in the Action Memorandum, "the nature of the removal is, however, expected to minimize the need for postremoval site control, at least in the Bryant Mill Pond area."
Loring AFB, ME ² (162,000 cy)	Reduce human health risk to below 10 ⁻⁶ and below a hazard index of 1 and eliminate adverse ecological impacts.	Human health and ecological risk assessments	Various for specific contaminants (e.g., 1 ppm Aroclor 1260, 35 ppm total PAHs)	Direct	Dry excavation	Apparently achieved based on verification sampling for PCBs and less rigorous testing for five other indicator compounds	Too soon to tell. A long-term environmental and wetlands monitoring plan was finalized in late 1998.
Love Canal, NY ² (31,000 cy)	Reduce human health risk from direct contact and from fish consumption.	Evaluation of various health advisories for dioxin from multiple sources such as NY Department of Health, Canadian agencies, and FDA	1 ppb 2,3,7,8-TCDD (CDC action level)	Direct	Dry excavation	No details obtained	Probably achieved, but no details obtained.

Project	Primary Goal	Basis for Primary Goal	Sediment Remedial Target	Relationship of Target to Goal	Remediation Method	Achievement of Remedial Target	Achievement of Primary Goal
Hooker (102 nd Street), NY ² (28,500 cy)	Vague; apparently reduce risk from fish ingestion to below 10 ⁻⁴ to 10 ⁻⁶ and a hazard index of 1 and reduce water concentrations to below state water quality standards.	Human health risk assessment and environmental endangerment assessment	Remove out to a "clean" boundary line and to a depth horizon dictated by characterization data	Vague	Dry excavation	Areal and depth horizon achieved; no analytical verification	Too soon to tell. One foot of fill added to remediated areas. No postmonitoring identified.
Tennessee Products, TN ² (24,100 cy)	Remove visual coal tar material from several thousand feet of the creek (interim measure).	Nontime critical removal action	Remove all visual coal tar material	Direct	Dry excavation	Achieved. Visual confirmation only.	Achieved. Visual confirmation only.
Town Branch Creek, KY ² (17,000 cy)	Reduce PCB in fish levels to <2 ppm FDA limit.	State environmental agency evaluation and Circuit Court Judgment	0.1 ppm PCBs	Direct	Dry excavation	Achieved sediment removal to extent practical but not always 0.1 ppm in 30% of 3.5 miles of creek so far. Work on remaining 2.5 miles on hold pending resolution of access issues.	Too soon to tell. Postmonitoring planned after all of remediation is completed.
Triana/Tennessee River, AL ² (no removal)	Reduce DDT in fish levels to <5 ppm FDA limit.	Negotiated agreement and Consent Decree to restore the fishery	Rechannelization and direct burial of the two isolated tributaries (2.5 miles) containing an estimated 93% of the DDT mass	Vague, basically a "try it and see what happens" approach	Stream diversion, direct burial, and some natural recovery	Achieved	Substantial progress. One target species reached the 5 ppm standard in the 10-year attainment period, two species did not but they exhibit 80 to 90% DDT reductions in the 10 years. Annual monitoring continuing.
James River, VA ³ (no removal)	Allow natural recovery of fish and biota to below FDA limit for Kepone (0.3 ppm in fish and 0.4 ppm in blue crabs).	Technical impracticability of achieving FDA limits in fish by remediation	None	N/A	Natural recovery	N/A	Natural burial by clean sediments is continuing to decrease the bioavailability of Kepone. Crab/oyster Kepone levels dropped from 0.8 to 0.1-0.2 ppm from 1976 through 1985. The commercial fishing ban was lifted in 1988; only a subsistence fish eating advisory remains.
Sangamo-Weston, SC ³ (no removal)	Reduce PCB in fish levels to <2 ppm FDA limit by natural recovery.	Technical impracticability of achieving risk-based concentrations in fish by remediation; existence of an ARAR (the FDA limit); and the voluntary nature of fish consumption	1 ppm PCBs	Default level, per the Record of Decision: "The time for two to eight year old largemouth bass to achieve 2 ppm for the range of sediment cleanup goals was compared to a baseline. It was determined that fish PCB levels decline at about the same rate regardless of sediment cleanup goal. Therefore, 1 ppm was selected based on technical feasibility..."	Natural recovery; modeling predicts 2 ppm levels in fish will be reached by 2004	Too soon to tell	Too soon to tell. Annual monitoring in progress. No reports yet available for review.

- 1 True dredging projects
- 2 Dry excavation projects
- 3 Natural recovery projects

- Was the remedial target derived from the primary remedial goal?
- Was achievement of either the remedial target or the primary remedial goal demonstrated?

The primary goal for the 25 projects (22 removal projects and three nonremoval projects) listed in Table D-9 can be broken down into six categories in Table D-10 (below).

Table D-10
Primary Goal Breakdown from Table D-9

Primary Goal	No. of Projects
Reduce human health risk to below 10^{-4} to 10^{-6}	5
Reduce contaminant levels in fish to below FDA limits	5
Reduce contaminant levels in fish	4
Reduce or eliminate adverse ecological impacts, generally or specifically	6
Eliminate contaminant flux (source control)	1
Remove contaminant mass	4

An analysis of the basis for these goals and their scientific soundness is beyond the scope of this paper. However, two things stand out after an examination of Table D-10. First is the variety of primary goals. On the one hand, this variety can be attributed to the complexity and unique features at each site. On the other hand, it is symptomatic of the confusion surrounding the subject of sediment remediation and the absence, in many instances, of sound science. Second is the fact that for at least one-third of the projects, no protective endpoint was defined by the primary goal. The goal was simply to, in effect, “show progress” by reducing contaminant levels, reducing adverse ecological impacts, or removing contaminant mass.

A further examination of Table D-9 shows that for 10 of the 25 projects, the sediment remedial target was not clearly tied to the primary goal. Also, for the 16 projects for which a numerical contaminant cleanup level was identified, in no instance was a distinction made as to whether the cleanup level represented a discrete target value or an average. In only one instance (Cherry Farm) was a distinction made that the cleanup level was variable with depth. Finally, for 10 of the 22 removal projects, no verification sampling was performed to document residual contaminant levels in sediment after removal. For four additional projects, verification sampling was performed during and following removal, but the targeted sediment cleanup level was not consistently achieved.

Clearly, a consistent application of sound science and careful consideration of such important principles as contaminant availability and proper goal/target selection were lacking in varying degrees in these projects.

- *Achievement of Goals*

To identify whether goals and remedial targets were achieved for the 25 projects in Table D-9 is a daunting task. A fundamental difficulty is that 20 of the 25 projects were implemented in the 1995 to 1999 time period. Accordingly, to the extent that postremedy monitoring is being performed for these 20 projects, time has been short for identifying and reporting achievement of protective endpoints or even verifiable improvements to the water body or to aquatic biota. A second fundamental difficulty is an absence of consistency in approach from one project to the other, making generalized findings and observations difficult to identify. Finally, a third fundamental difficulty is that a lack of anticipation and preplanning for postremedy monitoring seems to characterize many of the projects. For many projects, baseline sediment, water, and

aquatic biota conditions were not established with the specific intent of comparing to postremedy monitoring data. It appears for many projects that removal was the paramount goal and that demonstration of substantial improvement or measurable benefit by postremedy monitoring was either an afterthought or not considered at all. For example, for nine of the 25 projects, no formal postremedy monitoring is being performed. For six other of the 25 projects, postremedy monitoring is (or will be) being performed in accordance with a monitoring plan prepared after the remedy was implemented.

In response to the questions, “were goals achieved” or “will goals be achieved” the following can be concluded at this time:

- Mass removal projects, by definition, achieved their goal.
- Low cleanup levels were either not achieved or were not verified at 14 of the 22 removal projects.
- No risk reduction protective endpoint goal has demonstrably been met, either due to no verification sampling or no postremedy monitoring being implemented or due to monitoring still being in progress.
- Often preremedy data are limited and unsuitable for comparison with postremedy data. Often the postremedy monitoring is unscientific, opportunistic, or nonexistent. In either instance, no technically defensible measure of the success for such projects is possible.

To focus this issue, an effective and concise description of the importance of effective monitoring for documenting environmental benefit from sediment remedial projects is contained in the *New Bedford Harbor Long-Term Monitoring Assessment Report: Baseline Sampling* (USEPA 1996) as follows:

“Because . . . sites can be quite different, both with respect to types of contaminants (e.g., PCBs, metals, dioxins) and physical characteristics (e.g., land, streams, estuaries), there is no all-encompassing monitoring blueprint. However, certain elements are characteristic of any well-designed monitoring effort. First, specific environmental goals must be clearly articulated and understood prior to designing an effective monitoring program. Second, the monitoring program should provide the information necessary for managers and/or scientists to make site-specific assessments of whether or not the goals were attained. Finally, the experimental design should be both statistically rigorous to allow for quantitative assessments and flexible enough to accommodate changes over time (USEPA 1996).”

NATURAL RECOVERY PROJECTS

Natural recovery has been the sole remedy for two projects and is part of the remedy for four other projects. A capsule summary of the characteristics, objectives, and status of the projects follows.

Natural Recovery Remedies

For two projects, one an 81-mile stretch of the James River (Virginia) and the other 24 miles of creek and a 56,000-acre lake at Sangamo-Weston (South Carolina), remedial dredging was judged infeasible. The affected length of river and total acreage was extensive in both instances, and contaminant concentrations in sediments were relatively low and diffuse. A natural recovery approach in the form of slow burial of contaminated river sediments by incoming clean sediments was successful enough for the James River to allow the commercial fishing advisory to be lifted in 1988—13 years after the removal of the upstream source of contamination. At Sangamo-Weston, fate and transport modeling predicts recovery of largemouth bass to less than the FDA limit of 2 ppm PCBs within 12 years (2004).

- *James River (Virginia)*
All major components of the 81-mile long James River estuary were contaminated with Kepone (a chlorinated pesticide) including sediments, water column, biota, and small mammals. The subsequent distribution of Kepone in sediment was not controlled by the point source, but by estuary hydrodynamics such as circulation and reflux action. Based on data from the early 1990s, the highest Kepone concentrations occurred in a near field zone within 10 miles of the upstream source (12 ppm maximum) and at the freshwater/saltwater interface zone called the “turbidity maximum zone,” nine to 31 miles from the upstream source. Average main channel concentrations were 20 to 193 ppb Kepone.

In 1980, State officials decided dredging would do more harm than good by stirring up the Kepone. Additionally, there was no viable option for disposal of the potentially enormous quantities of Kepone-contaminated sediment. The decision was to allow slow burial of river sediments by natural sedimentation; allow natural recovery of fish and biota; and allow maintenance dredging of the main channel. A six-year moratorium on maintenance dredging was lifted in 1982, allowing disposal of dredge spoils on the flanks of the river bottom adjacent to the dredged channel. Crab/oyster Kepone levels dropped from 0.8 to a 0.1 to 0.2 ppm range from 1976 to 1985. The commercial fishing ban was lifted in 1988; only a subsistence fish eating advisory remains in place.

- *Sangamo-Weston (South Carolina)*
Twelvemile Creek flows 24 miles into Hartwell Lake. Hartwell Lake is a man-made reservoir constructed by the U.S. Army Corps of Engineers from 1955 to 1963. The maximum depth of the lake is 50 feet. Approximately 80 tributaries flow into Twelvemile Creek, and there are three masonry impoundments. The average daily creek flow is 198 cubic feet per second (cfs), with a historical daily range from 30 to 5,360 cfs. Sediment PCB concentrations in contaminated areas of the Twelvemile Creek are typically in the 1 to 3 ppm range at the surface and slightly higher in deeper sediments. Portions of the seven-mile long Twelvemile Creek Arm, a separate depositional stretch, exhibited PCBs up to 61 ppm. Maximum PCB concentrations measured in 1991/92 in sediment core samples from the upper section of Lake Hartwell exhibited concentrations of 5 to 11 ppm. PCB contamination in sediment in the lower part of the lake is typically below 1 ppm. The affected area covers approximately 730 acres with a total estimated volume of 4,722,000 cy of sediment at greater than 1 ppm PCBs.

A carcinogenic risk-based approach was evaluated by determining the concentration levels in largemouth bass that would result in acceptable risk to anglers through ingestion of fish.

Utilizing EPA risk assessment methods, a fish tissue concentration of 0.036 ppm was identified as the 10^{-4} risk level. The risk-based fish cleanup goal of 0.036 ppm was determined by the EPA to be technically impracticable. As a result, the FDA safe tolerance level of 2 ppm PCBs was selected by the EPA as the target in fish based on technical feasibility.

The EPA and the public rejected remedies associated with the removal, treatment, and disposal of the estimated 4.7 million cy of PCB-contaminated sediment that is spread over approximately 730 acres due to cost (\$500 million minimum). The EPA also rejected alternatives that involved aggressive engineering controls to contain or remove and dispose of PCB-contaminated sediment as too costly (\$30 to \$50 million) and not providing significant overall risk reduction. Firm public opposition also caused the EPA to reject installation of a fishery isolation barrier (fence) to prohibit movement of migratory fish into or out of the most contaminated areas of Lake Hartwell.

In 1994, natural recovery supplemented by institutional controls was selected as the only remedy. A cleanup level of 1 ppm PCBs was judged technically infeasible to achieve. Natural recovery to below FDA action levels was predicted by modeling to occur in largemouth bass within 12 years (from 1992).

Natural recovery is in-progress along with a continuation of the fish advisory, annual monitoring, and controls on the periodic flushing of sediments from behind three impoundments. Annual sediment (20 locations) and fish monitoring (six stations) are being performed for 15 years minimum. PCB data trends will be used to support decisions to modify the fish advisory. Annual monitoring reports have not yet been obtained and evaluated by the author.

Partial Natural Recovery Remedies

At four projects, Marathon Battery (New York), Eagle (West) Harbor (Washington), Triana/Tennessee River (Alabama), and Baird and McGuire (Massachusetts), natural recovery is a component of the remedy.

- *Marathon Battery (New York)*
At Marathon Battery, which has a total of 540 acres of cadmium-contaminated backwaters, coves, and marshes adjacent to the Hudson River, about 300 acres were targeted for natural recovery. Natural recovery was selected since the EPA judged that removal would cause more harm than good and slow burial by deposition of clean sediments was expected to occur following remediation of the adjacent targeted areas. Long-term monitoring is underway, including the collection of groundwater, surface water, sediment, and biological samples semiannually (from 1996 to 2000) and annually thereafter. Data have not been obtained and evaluated by the author.
- *Eagle (West) Harbor (Washington)*
At Eagle (West) Harbor, enhanced natural recovery (thin layer capping with sand) was the remedy for a six-acre target area containing low levels of mercury. Other areas of the harbor are expected to recover naturally without resorting to remediation. These areas are being monitored over a ten-year period to confirm or deny that natural recovery has occurred sufficiently for "minor adverse effects contaminant levels" to be achieved.
- *Triana/Tennessee River (Alabama)*
At the Triana/Tennessee River site, eight miles of tributaries with DDT contamination, Reaches B and C, were targeted for natural recovery following completion of remediation in Reach A. The remedy in Reach A, which contained an estimated 93% of the mass of DDT in the system, was permanent stream diversion, then isolation of 2.5 miles of tributary by direct burial. As stated in the decision document for that site:

“Following completion of remedial action in Reach A, the sediments in Reaches B and C should, through natural deposition, be covered by clean, upstream sediments and therefore be isolated from the aquatic environment. Thus, direct exposure of fish to DDT-containing sediments in these two reaches should diminish over time.”

Remediation was completed in 1987. The PRP had ten years following remediation to demonstrate achievement of the performance standard of 5 ppm DDT in the fillets of three species of fish to satisfy the Consent Decree and declare the remediation successful. Largemouth bass recently reached the standard; channel catfish and smallmouth buffalo did not (although 80 to 90% DDT concentration reductions were observed). An extension was proposed the USEPA in September 1998, extending the attainment periods for these two species by five and ten more years, respectively. It is not clear from data available what the current conditions are in Reaches B and C and their relative contribution to the recovery.

- *Baird & McGuire (Massachusetts)*

At the Baird & McGuire site, removal of about 1,500 cy of sediments from the shallow, narrow Cochato River was completed by wet excavation from the banks in 1995. Contaminants of most concern in sediments were chlordane and DDT. A large area of the river, as well as associated ponds and wetlands, with an estimated 18,600 cy of contaminated sediments, was selected for no action by the EPA based on a “more harm than good” finding. The EPA reasoned as follows in the 1989 Record of Decision:

“Because of the sensitivity of aquatic organisms to the Site contaminants, a much larger area of the Cochato River, as well as associated ponds and wetlands, would require remediation to completely eliminate the potential long-term risks to aquatic organisms in the river. . . . Approximately an additional 18,600 cy of sediment would be excavated and treated to address these potential chronic risks to biota. . . . the EPA assessed whether or not the adverse environmental impacts associated with the excavation of these areas would be greater than the benefits of removing contaminated sediments. These downstream areas include forested and shrub swamp. Without complete remediation of these areas, the potential exists for a long-term threat to the organisms that inhabit the area. However, excavation of these downstream contaminated sediments for treatment would require extensive clearing and grubbing operations, which would disrupt the habitat and feeding grounds of a wide variety of wildlife in the area.”

Further, “EPA considered the advantages and disadvantages of the options for remediation of these downstream sediments. EPA believes that the benefits obtained by excavating the additional 18,600 cy of sediments are outweighed by the adverse environmental impacts associated with extremely disruptive excavation. Therefore, the EPA has decided that no action shall be taken for the sediments beyond Union Street for the protection of long term environmental risks in this area. EPA will include long term monitoring of these areas on an annual basis.”

Although natural recovery is implied by this agency position it is not specifically stated as a goal. Monitoring data have not yet been obtained and evaluated by the author.

Key Findings for Natural Recovery Projects

Projects with natural recovery remedies are still relatively few and consist of those with one of three identifiable types of conditions, namely the following:

- Lengthy rivers (1) characterized by pervasive but diffuse contamination, (2) with affected sediments too extensive for a removal remedy to be feasible, and (3) with demonstrated modeling or other data that suggest that fish contaminant levels will reduce to acceptable levels over time by natural recovery (the slow burial of contaminants by incoming clean sediments, which makes the contaminants less and less bioavailable). This is the case with the James River and Sangamo-Weston projects.
- Contaminated areas of unusual aesthetic value or sensitivity or comprising dense habitat and rich feeding grounds for which disruption by attempted removal of the contaminants would constitute “more harm than good.” This is the case for sectors of the Marathon Battery, Triana/Tennessee River, and Baird & McGuire projects. For each of these projects, removal of contaminated adjacent source areas was a necessary first step in order to allow the natural recovery to occur in the sensitive areas. Data are not yet available to evaluate the success of this approach at these three projects.
- A policy approach (Washington State and EPA Region X) that allows contaminated site areas to be designated natural recovery areas if mathematical modeling predicts recovery to minimum contaminant levels within ten years without resort to remediation. Such areas are subject only to long-term monitoring. Certain areas of Eagle (West) Harbor are in this category.

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