# Analysis of Recontamination of Completed Sediment Remedial Projects

**_Steven C. Nadeau_** (snadeau@honigman.com) (Honigman Miller Schwartz and Cohn LLP, Detroit, Michigan, USA)
**_Merton M. Skaggs, Jr., P.E._** (mmsnsl@aol.com) (InDepth Environmental Associates, Inc., Southlake, Texas, USA)

**ABSTRACT:** A number of sediment remedial projects have been completed in recent years. Many of these projects were not followed up with post-remedial monitoring. Few studies have been published which have attempted to ascertain whether the initial results achieved through remediation will be maintained over the long term. Twenty completed sediment remediation projects, which included both dredging and capping remedies, have been identified as having become recontaminated after remedial construction. These findings underscore the importance of the strong directive in USEPA's contaminated sediments strategy and guidance to confirm that sources have been controlled prior to embarking on dredging or other sediment management alternatives.

## INTRODUCTION

A survey of recently completed contaminated sediment remedial actions identified a total of twenty sites in which sediment had become recontaminated. The locations of these sites reflect widely varying geomorphic and geographical settings. The sites included freshwater as well as estuarine locations, and did not appear to exhibit geographical centralization. The initial remedial responses at these sites included dredging, subaqueous capping, and combined remedies employing both of these remedial responses. The factors behind the sites' respective recontamination are site-specific, but some common features appear to exist among these sites.

A large inventory of contaminated sediment sites have been, and are continuing to be, identified within the United States. U.S. Environmental Protection Agency's (USEPA's) *Contaminated Sediment Management Strategy* estimates that approximately 10% of the sediment underlying the nation's surface water is impacted with levels of contaminants that pose potential risks to fish and humans who eat fish (USEPA 1998). Describing the sources of the contaminants present in such sediments, USEPA (1998) reported these materials arise "from discharges from industrial waste and sewage; storm water runoff from waste dumps, city streets, and farms; air pollutants contained in rainwater; contaminants in ground water; discharges to surface water; and from natural sources."

USEPA (2004b) identified ninety-six watersheds as containing areas of probable concern (APCs) for sediment contamination. Specific sites located both within and outside of these identified APCs are progressing through the remedial assessment process, with remedies being selected and implemented at an increasing rate. Remediation of these contaminated sediment sites will represent a very large commitment of available remediation resources, both in the aggregate (SMWG 1999) as well as on the basis of the individual site remedies (USEPA 2002a, USEPA 2002c).

The successful remediation of such contaminated sediment sites requires that effective management techniques be employed to manage a site's contaminated sediment inventory. USEPA and USACE recently sponsored an expert dialog on how to evaluate and select active remedial alternatives that will properly manage the "4-Rs" ("Risks", "Resuspension", "Residuals", and "Releases") of contaminated sediment remediation. The findings of this study indicate that a fifth "R" is very important in the success of sediment remedial actions – a careful assessment of the steps necessary to prevent "Recontamination" and an effective implementation of those steps.

Through much of the past decade, the USEPA has advanced its understanding of the scope and extent of the contaminated sediment problem in this country. It has twice issued reports to Congress on the nature and incidence of contaminated sediments (USEPA 1997, USEPA 2004b). Through its written strategy, contaminated sediment management principles, and remedial guidance documents, the USEPA has repeatedly emphasized the importance of ensuring that sediment remedies will be effective by controlling potential recontamination sources.

In its *Contaminated Sediment Management Strategy* (1998), the USEPA stated that "before initiating any remediation, active or natural, it is important that point and nonpoint sources of contamination be identified and controlled." Specific point sources that were listed as potential contaminant sources were "municipal treatment plants, combined sewer overflows (CSOs), storm water discharges from municipal and industrial facilities, direct industrial discharges of process waste, runoff and leachate from hazardous and solid waste sites, agricultural runoff, runoff from mining operations, runoff from industrial manufacturing and storage sites, atmospheric deposition of contaminants, and contaminated groundwater discharges to surface water."

The *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (USEPA 2002b) restates this concern but with more specificity. The document offers eleven risk management principles that project managers should consider in planning, selecting, and implementing contaminated sediment site remedies. First among these Principles was "Control Sources Early." As early in the process as possible, the project manager is to identify all direct and indirect continuing sources of significant contamination. An assessment is to follow to identify which of these continuing sources can be controlled and by what mechanisms. Finally, site managers are to evaluate the potential for recontamination as part of the process of selecting a response action, and to include source control measures as part of the site remedy.

The USEPA's rationale on the importance of evaluating and avoiding sediment site recontamination was further developed in its *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA 2005). Site managers were advised to factor the potential for recontamination into the remedy selection process, through steps such as the inclusion of source control measures. This Guidance emphasizes that phasing may be useful when the effectiveness of source control is in doubt. This Guidance concluded, "By knowing the effectiveness of source control prior to implementing sediment cleanups, the risk of having to revisit recontaminated areas is greatly reduced."

## UNIVERSE OF SITES IDENTIFIED

Available online and public information sources were reviewed to identify sites at which contaminated sediment remedial measures had been implemented, and then at which recontamination was reported afterwards. Sites reviewed included ones incorporating either dredging or capping response actions, or combined dredging-capping response measures. It should be noted that the geographic distribution of the twenty sites which were identified as meeting these criteria is likely a function of the degree of attention, if any, given to post-remedial sampling. The mix and number of recontamination sites will undoubtedly change and expand as more post-remedial sampling is conducted at future CERCLA sites, based on the Guidance's directives to do so.

**TABLE 1. Sediment sites with reported recontamination.**

| Site | Response Measure(s) | Recontamination Information | References |
|---|---|---|---|
| Anacostia River, DC | 2004 Cap | 2006 Urban sources, upstream sources | USEPA 2006 |
| Bloomington, IN (3 creeks) | 1987 Sediment Removal | 1992 All sources unclear – point source discharge included | ATSDR 1992 |
| Bremerton Naval Complex, WA | 2000 Dredge | 2000 Losses from CAD placement | SPI 2002, DNO 2002 |
| Convair Lagoon, CA | 1998 Cap | 2002 Public storm drain discharges | Zeng 2002, Carlisle 2002 |
| Denny Way Site, WA | 1990 Cap | 1993 CSO point source discharges | Palermo 2002, NRC 2001, Romberg 2005, WDNR 2002 |
| Duwamish Norfolk CSO, WA | 1999 Dredge-Cap | 2001 CSO point source discharges; unremediated adjacent contaminated sediment | WDE 2003, USEPA 2003 |
| Duwamish River Diagonal, WA | 2004 Dredge | 2005 Sewage system discharges | SPI 2005 |
| Eagle Harbor Site, WA | 1994 Cap | 1999 "Surface sources", "offsite sources" | USEPA 1999, Palermo 2002 |
| Ford Outfall/River Raisin, MI | 1997 Dredge | 2001 Unremediated upstream sediments and/or upland sources; sediments sloughed from adjacent navigational channel | Cieniewski 2003, Bergeron 2000, Cleland 2000, Cleland 2001<br>Weston 2004 |
| Fox River SMU 56/57, WI | 2000 Dredge-cap | 2005 1.2-1.5 m of new impacted sediment deposited in five years | AE 2006 |
| Housatonic River, MA | 2002 Dredge-Cap | 2005 Upstream sediments, CSO and SSO point source discharges | BG 2005 |
| Lauritzen Canal, CA | 1996 Dredge-Cap | 1998 Undetected point source(s); incomplete remediation near margins of site | USEPA 2001, Weston 2002, USEPA 2004a |
| Long Beach North Energy Island Borrow Pit (NEIBP), CA | 2001 Cap | 2004 "Deposition from the surrounding harbor" | USACE 2005 |
| Pier 51 Ferry Terminal, WA | 1989 Cap | 1990 PAHs due to pile pulling; metals from "new sediment deposition" | HSRC |
| Pier 53-55, WA | 1992 Cap | 2002 Prop wash resuspension near edges; PAHs due to pile removal | Romberg 2005 |
| Pier 64-65, WA | 1994 Cap | 2002 Piling repair work released creosote | Romberg 2005 |
| Puget Sound Naval Shipyard Pier D, WA | 1994 Dredge | 1998 Suspected resuspension of sediments from outside response area | RETEC 2002 |
| Sitcum Waterway/ Nearshore Tideflats, WA | 1993 Dredge | 2002 "Continued source input from recent sediment deposition or off-loading activities" | RETEC 2002 |
| St. Clair Shores, MI | 2002 Dredge | 2003 Sewer pipe discharges | TMD 2006 |
| Thea Foss Waterway, WA | 2002 Dredge-Cap | 2006 City storm drain discharges | TNT 2006a, TNT 2006b |

The twenty sites listed in Table 1 represent a variety of site conditions and remedial response measures. About two-thirds of the sites are located in tidally influenced water bodies, and the remaining sites are located in flowing freshwater bodies. Eight of these sites employed subaqueous caps as the primary response action, seven of them employed dredging, and the five remaining sites used both dredging and capping elements in their response actions.

USEPA's sediment guidance documents (1998, 2002b, 2005) and other sources (Spadaro 2006) have described the types of sources that may lead to the recontamination of sediment sites. These types of sources generally are summarized in the following manner:

- Point Sources – public sources such as CSOs, storm sewer outfalls (SSOs), and municipal sewage treatment plants, and industrial discharges.
- Sediment Sources – including upstream sources, unremediated nearby sediments.
- Runoff Sources – runoff from industrial manufacturing and storage sites, erosion of stream bank and/or adjacent upland soils, mining sites runoff, agricultural runoff.
- Other Sources – atmospheric deposition, contaminated groundwater advection, spills

The available information was reviewed to attempt to characterize the source(s) of recontamination at the sites identified in Table 1. Differing levels of information were available on these sites, but in all cases, at least some indication existed of the type(s) of source that led to the recontamination. In some cases, more than one type of source contributed to the recontamination of the site.

Point Sources were identified as the source of the recontamination at fifty percent of the twenty sites reviewed. Dominant among this group were CSO and other public storm water discharge sources. Point Source discharges from industrial sources were notably absent from this group of sites, although it is possible (perhaps likely) that such sources may have been unidentified upstream contributors to the CSO and public storm drain systems.

The category of Runoff Sources also contributed recontamination at forty percent of the sites (8 of 20). This category was likely artificially expanded somewhat by the way data were managed in this study. If the recontamination at a site were attributed to general sources such as "recent sediment deposition", "from the surrounding harbor", "upland sources", etc., the site was included with the Runoff Sources. It is likely that some of these upland stormwaters, for example, are discharged to the water body through storm sewers. Unless the information source identified specific CSO(s) or SSO(s), the site would have been classified as a Runoff Source site.

Approximately forty percent of the identified sites had some portion of their recontamination attributed to Sediment Sources – the relocation of unremediated nearby sediments into the response area that defined the specific site. The Sediment Source group includes sites where the response action addressed only a portion of the affected sediments, and then the unremediated sediments subsequently moved into the area previously addressed.

The recontamination of three sites (seventeen percent) included processes outside those described above. None of the twenty sites reviewed were reported to have become recontaminated due to contaminated groundwater advection, mining site impact, or agricultural runoff.

## CASE EXAMPLES

Examples are presented for the purpose of demonstrating the recontamination mechanism concepts described above.

**Anacostia River**. The Anacostia River is a freshwater tidal system draining portions of Maryland and the District of Columbia. Historic industrial, municipal, and military activities resulted in potentially hazardous levels of PAHs, PCBs, metals, and other contaminants in the sediments. An innovative “active cap” was constructed at this site in 2004 to provide preliminary design information.

The sediments covered by the active cap are located near to and downstream of an active CSO. Monitoring results after 18 months indicated that the cap remedial element was efficiently containing the targeted contaminated sediments. However, new sediments containing elevated PAHs are accumulating on top of the cap. These “new” contaminants are related to the urban sources in the area, and to the relocation of unremediated sediments present elsewhere in the waterway (USEPA 2006).

**Ford Outfall.** In 1997, Ford completed a sediment remediation project, dredging approximately 20,600 cubic meters ($m^3$) of PCB Aroclor 1248-contaminated sediment from a depositional area adjacent to its Monroe, Michigan facility, located on the banks of the Raisin River. At the same time, substantial upland remedial work was undertaken, including the removal of contaminated in-plant sewer material to eliminate the potential for on-going releases (Cieniawski 2003) as well as extensive soil removal. Dredging was successful in removing sediment down to the bedrock in most quadrants. Barely enough sediment remained in the other quadrants to even recover a sample, but the results of that limited residual sampling confirmed that the cleanup level had been achieved. In contrast, sampling by USEPA (GLNPO) four years post-dredging in 2001 revealed that the sediment in the dredged area had redeposited to a thickness of approximately 33 centimeters and was impacted almost exclusively (43/44 samples) by a different Aroclor – 1242, which is typically associated with the paper industry. Substantial unremediated upstream sediment and land soil sources upstream from the dredged area remained post-dredging, including a former paper mill on the riverbank, which had numerous Aroclor 1242 detections in soil and drainage ditches. (Weston 2004)

**Convair Lagoon.** Convair Lagoon is a 4-hectare embayment in North San Diego Bay. A 2.3-hectare area within the lagoon, contaminated with PCBs, was remediated in 1998 through the application of a robust subaqueous cap. By 2002, PCBs had been detected in newly deposited sediments present on top of the cap. PCBs were identified in adjacent public storm drain systems (Carlisle 2002).

**St. Clair Shores.** The St. Clair Shores site involves the Lange and Revere canals, which connect to Lake St. Clair. PCB contaminated sediments were removed from these waterways by dredging during 2002-2003. Subsequent testing found a recurrence of elevated concentrations of PCBs in site sediments. These PCBs were attributed to an adjacent public storm water sewer. Source controls were implemented on this sewer, and approximately 500 meters of the waterways were then redredged (TMD 2006).

**Lauritzen Canal.** The Lauritzen Canal was the site of United Heckathorn, a pesticide-formulating firm which processed DDT, dieldrin, and other products. This tidally influenced marine site is located off San Francisco Bay. Site releases impacted sediments in the adjacent waterway. In 1996-1997, approximately 82,000 $m^3$ of contaminated sediments were removed by dredging, and then an average 30-cm thick sand cap was applied across the site. Capping alone was performed in portions of the site beneath docks and around pile structures where dredging access was poor. Initial post-construction testing indicated a high degree of remedial success (Weston 2002).

Additional testing conducted in 1998 and 1999 indicated that the site had become recontaminated with DDT (USEPA 2001). The source of the recontamination materials were initially thought to be from slumping and erosion from undredged areas beneath docks and around pilings. Noting the presence of a public storm drain and the potential for abandoned outfalls hidden by site conditions, in late 2001, a source identification study was undertaken to identify potential sources of DDT to the Lauritzen Canal. Testing revealed very high levels of DDT to be present in waters being discharged from an embankment outfall only visible at low tide, and it was sealed off (USEPA 2004a). Thus, this site is one in which two sources of recontamination are reported -- the movement of unremediated sediments and the outfall point source.

**Thea Foss Waterway.** The Thea Foss Waterway is a 2,440-meter long tidal marine waterway located in Tacoma, Washington. Response actions starting in 2002 included the dredging removal of 400,000 $m^3$ of sediments, plus the application of 8.5 hectares of subaqueous cap. Testing conducted during 2005 found elevated levels of di(2-ethylhexyl) phthalate to be present in the remediated areas. The recontamination is attributed to contamination present in waters being discharged from two 2.4 meter city storm drains (TNT 2006a, TNT 2006b).

## DISCUSSION

The overall circumstances and sources that led to recontamination at these twenty sites provide an understanding of some of the difficulties faced in complex urban sediment site remediation. USEPA's Contaminated Sediment Remediation Guidance (USEPA 2005) calls for similar post-construction monitoring for "evidence of recontamination", regardless of whether dredging, capping or monitored natural recovery remedies have been selected. However, all of the site remedies reviewed in this study were selected and constructed before this Guidance was finalized. In the past, sediment dredging has sometimes been considered to be a more "permanent" remedial response, which means that post-construction monitoring may not have been in place to detect recontamination. In contrast, robust post-remedial monitoring requirements have been included at sites in which capping is a component. Therefore, follow-up data are more available at previously capped sites.

As the data in Table 1 show, this group of twenty sites all became recontaminated, at least in part, relatively rapidly after the completion of remedial actions. The observed recontamination events in this study group do not constitute failure of the initial remedial action. However, it appears that incomplete or no assessments were made prior to remedy selection of the risks associated with potential recontamination at the site or the risks which might result if these continuing sources go unaddressed for a long time period. Additionally, some of the response actions, such as at the Anacostia River, were constructed at locations where source control was known to be incomplete and evolving. Such sites are important to consider because they add to the understanding of the importance of urban sources in site recontamination, but they should not be considered remedy "failures" since their source control elements were known to be incomplete.

Many types of potential sediment recontamination sources are reported in guidance and studies, but recontamination due to Point Sources dominated this study group. Ten of these sites (50%) had recontamination attributed to Point Sources. At these sites, all ten of the identified point source discharges were associated with public CSOs and SSOs.

These ten Point Source recontamination sites were all located in urban areas. USEPA's (2004b) recent sediment source inventory identified 96 watershed "areas of probable concern" (APC) for sediment contamination. A review of these 96 APCs shows that they generally correspond to urban/population centers. Nine of the ten Point Source recontamination sites from this study are located within APCs identified by USEPA (2004b).

"Urban Slobber" is a term that is sometimes used to describe such discharges "…from pet waste to brake lining to pesticides to everything we spill, spit, and drop on the ground." (SWRCB 2004) An internet search of this term found the state regulatory authorities in at least five states are using this term to describe urban wet weather discharges. USEPA's *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (2005) describes urban storm water runoff to be a "potential continuing source of contamination that could impact a remedy", and the results of this study confirms USEPA's conclusion. When sediment response actions are planned in areas receiving urban discharges, the project managers should take steps to ensure the effectiveness of source control(s) prior to implementing sediment cleanups.

Post-remediation site recontamination seemed unrelated to the remedial technology employed at the sites reviewed in this study. Contaminated sediments were capped at eight of these sites, dredging was used at seven sites, and dredge-cap combination remedies were used at six sites. These results suggest that dredging response actions may not be more "permanent" than capping or blended remedies, if sources are not controlled.

## CONCLUSIONS

This survey of completed sediment response actions identified twenty sites at which recontamination has been reported. USEPA's sediment strategy, policies, and guidance have consistently directed attention to steps to take to avoid this problem. However, the existence of these recontaminated sites suggests that the risk of recontamination is significant enough to merit greater attention in the site investigation and remedy selection stages.

From the available information, recontamination is most likely to arise from uncontrolled Point Sources and/or incomplete remediation in the adjacent/upstream areas of the waterbody. To avoid recontamination due to Point Sources, careful study is necessary to understand them, and their control must be of an equal or greater priority than the sediment response action itself. USEPA's (2002b) "Control Sources Early" sediment management principle should be implemented, using the phasing and strategies described in the Guidance (USEPA 2005).

The Point Sources identified as recontamination sources in ten of the sites reviewed were related to public discharge systems such as CSOs and SSOs. The effluent from industrial Point Sources did not seem to be a factor in these recontamination cases, but such sources may be important upstream contributors to the public discharges.

Eight sites were identified at which recontamination arose as a product of incomplete remediation. In these sites, contaminated sediment from outside the response area entered the response area through resuspension, etc. and recontaminated it. One important lesson from these projects is to avoid remediating single or discrete locations (especially downstream locations) out of a larger area until/unless the project manager has a carefully developed an understanding of the way upstream and/or adjacent locations will affect the longevity of any environmental benefits that might be expected.

In sum, the mandate to "Control Sources Early" (USEPA 2002b), as reiterated in the Guidance (USEPA 2005), should be carefully adhered to while addressing future contaminated Sediment sites.

**ACKNOWLEDGMENTS**

A portion of the work and research underlying this paper was performed with financial support from Tierra Solutions, Inc.

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