Mobile Containment and Cleanup for Subsurface Contaminated Sediment Remediation

Final Report 05-06a
December 2005

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Mobile Containment and Cleanup for Subsurface Contaminated Sediment Remediation

Final Report

Prepared for the

New York State Energy Research and Development Authority

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NYSERDA Report 05-06a | NYSERDA 4452 | December 2005

NOTICE

ABSTRACT

This report describes the results of a four-year effort to develop an advanced and more protective approach to subaqueous contaminated sediment removal. The technology (Mobile Containment Technology) is based on the concept of controlled dredging within the confines of a specially fabricated Mobile Containment Vessel. The subject vessel, which can be deployed at a cleanup site, contains vertical barrier walls in the form of sheet piles that can be lowered from the vessel to set up a secure containment area from which sediment dispersed during the dredging process cannot escape. A Mobile Water Treatment Vessel provides for the post-dredging cleanup of the containment area after dredging is completed. The containment of dispersed sediment and the post-dredge cleanup operation can be expected to reduce residual contamination to levels that cannot be achieved if dredging alone is employed as the remediation option.

KEY WORDS

Subaqueous contaminated sediment
Cleanup
Remediation
Dredging
Cleanup goals
Containment area
Residual fluff layer

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SUMMARY

Nationwide, as a result of decades of waste discharges resulting from human activity, concentration levels of contaminants, in many of our lakes, rivers, and coastal sediments, have reached levels that are adversely impacting the fish and wildlife sustained by these waterways. Some of these contaminants pose special risk because of their potential, after ingestion by organisms that dwell in the sediment, to bio-accumulate and amplify their concentrations in higher organisms as they are transferred up the food chain to fish and ultimately humans. Contamination present in many species of fish have reached levels where fish-consumption advisories and, in some cases, fish-consumption bans have been put into effect by regulatory agencies. These advisories and bans are necessary to reduce contaminant uptake by humans as a result of human fish-consumption.

In addition to the health risks, the presence of contaminants in subaqueous sediments is a significant economic problem. The negative economic consequences resulting from the presence of these sediments have already been felt by commercial fishing, recreational businesses, and local property owners, living along these waterways, whose property values have been adversely impacted.

To resolve this problem, Federal, State and Local governmental agencies, through regulatory and in some instances enforcement actions, have proceeded with both the planning and implementation of sediment remediation projects. When contaminant types and concentration levels are such that sediment removal is deemed necessary, dredging technology has been selected as the preferred remediation strategy. Dredging technology involves the use of mechanical or clamshell buckets and hydraulic or vacuum dredges to extract the sediment from the waterway. The basic approach is similar to navigational dredging operations that are designed to deepen shipping and boating channels.

The cost of dredging using conventional dredging technology is predictable when the area and depth of excavation or cut are well defined and accurately specified. Under such circumstances, the cost of sediment removal, such as removal of the top two feet of sediment, can be fairly well estimated. In contaminated sediment remediation dredging projects, where the target goal is defined in terms of a residual level of contaminant concentration in the final strata however, the cost to attain the target is not apparent. Engineers and planners cannot readily predict nor estimate the ultimate quantity of sediment that needs to be removed, nor the number of dredge passes needed to meet a particular concentration-based clean up standard. Under such conditions the final cleanup cost can exceed the original project cost estimate several times over. Additional cost may also be incurred, if extra care is specified to control the dispersion and migration of destabilized sediments resulting from dredging operations.

In addition, and perhaps even more problematic, is the fact that when low residual contaminant concentration levels for selected contaminants (e.g., PCBs) are specified as the required remediation goal, recent field data suggest that these low levels may not be achievable even after numerous dredging passes. The realization that low residual contamination goals being specified may be beyond the reach of current dredging technology raises serious questions about the whether clean-up projects that employ conventional dredging technology can successfully return a contaminated waterway to a healthy condition. If this is the case, and if the residual levels of contamination left behind will continue to impact these waterways after the cleanup is completed, then new approaches that either supplement, complement or replace existing strategies are needed.

Recognizing the limitations of current dredging technology, Seaway Environmental Technologies, Inc. of Greenport, New York, during the period from 2001 through 2004 undertook the development of a new supporting technology to complement and improve the effectiveness and efficiency of conventional dredging operations. This new technology is referred to as Mobile Containment Technology. The primary objective of this effort was to develop a technology that could

- Capture and collect contaminated sediment particles that are destabilized and/or dispersed during dredging operations,

- Reduce the need for multiple dredging passes at a dredge site to achieve lower residual concentrations,

- Provide for controlled capping of the dredge site, and

- Permit controlled monitoring of both the sediment and the water column at the dredge site to ensure that cleanup goals have been achieved.

Mobile Containment Technology achieves the above objectives by employing a specially designed containment vessel inside which dredging occurs. The containment vessel is equipped with the means to lower a vertical barrier around the contaminated area to prevent dispersed sediment particles from leaving the dredge site. A mobile water treatment vessel, working with the containment vessel, provides the means to pump and treat water from the containment area and remove residual contamination from the sediment-water interface that is left behind by the dredging process. The containment vessel provides a secure boundary inside which clean capping material, if needed, can be accurately placed. Sampling of sediment and water quality inside the containment area can be undertaken to ensure that target goals are achieved before the containment vessel is redeployed to a new location.

The decision to employ Mobile Containment Technology in a site cleanup will be dependent on the cost of deploying the technology versus the enhanced benefits that the technology brings to the cleanup, compared to the costs and benefits of conventional dredging technology. The results of such an analysis indicate that Mobile Containment Technology will improve the quality of the cleanup and increase the probability that target goals will be achieved. It will provide a defined closure point to a cleanup, eliminating the unpredictability of effort and cost associated with attempts to achieve concentration-based cleanup standards using conventional dredging technology; and will reduce future liability associated with dispersed and residual levels of contamination. The cost of employing the technology in many instances will result in lower overall project costs when compared to conventional technology costs, resulting in both increased benefit and reduced cost.

Instances and situations where the enhanced benefits of the technology can be fully realized include cleanup sites where

1. High levels of contamination (hot spots) are present and conventional dredging can be expected to yield relatively high levels of residual contamination,

2. Capping is included as part of the cleanup plan,

3. Debris fields are present, where conventional dredging can be expected to induce a large degree of sediment dispersion,

4. Sensitive downstream receptors such as water supply intakes and fish breeding areas are present,

5. Alternative containment strategies cannot be deployed (e.g., areas of high current), and where

6. Controlled verification testing is deemed necessary to ensure a satisfactory cleanup.

The main body of this report provides a more detailed description of the subject technology, which was developed by a team of engineers and scientists under contract with the New York State Energy Research and Development Authority (NYSERDA) and the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET). The primary objective of this effort was to proceed through system design pilot operation and the design and fabrication of a prototype system for water-based system operation and testing. Preliminary design and pilot operations were undertaken in 2001 and 2002, and a prototype vessel was constructed at Cedar Beach in Southold, New York and operated and tested from February 2003 to November 2003. Mobile Containment and Mobile Water Treatment are presently being marketed (for licensing and commercial use) by Seaway Environmental Technologies, Inc. (www.seawaytech.com).

Section 1

BACKGROUND

During the last quarter of the 20th century, the environmental and health risks resulting from decades of hazardous material discharge and dumping into the environment led to the passage of the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA), more commonly referred to as Superfund. While Superfund was designed to address both land-based and subaqueous contamination, initial remediation activities focused on land-based contamination. Innovative land-based technologies were developed for excavating, disposing, capping, containing, and treating runoff, leachate, and emissions associated with these cleanups.

Subaqueous remediation activities lagged. The increased complexity, the significantly higher remediation costs, and the absence of public awareness of the magnitude of the problem were all contributing factors. Only when the link between contaminants present in subaqueous sediments and the bio-magnification of these contaminants to higher organisms in the food web was firmly established, was significant public pressure brought to bear on regulatory agencies, through the political process, to initiate activity. In spite of the magnitude of the subaqueous contamination problem, cleanup activity and the corresponding development of new, innovative methods to respond to the unique challenges of remediating contaminated sediments in a subaqueous environment, have proceeded at a slow pace.

For those projects that have entered the planning and implementation stage, four remediation strategies are typically considered. These include 1) natural recovery or attenuation, 2) in-situ capping, 3) in-situ treatment, and 4) sediment removal. Natural attenuation is an option that assumes that no actions are needed and the sediment quality will improve as the contaminants degrade or are physically encapsulated with time. In-situ capping employs a strategy that leaves the contaminated sediments (or at least some of the contaminated sediments) in place, but covers the sediment with a cap to prevent or minimize the transfer of the contaminants in the sediment to the aquatic environment. In-situ treatment is a strategy that employs methods that would accelerate the degradation or encapsulation of contaminants by introducing treatment reagents to the sediment to promote controlled treatment. Removal employs a strategy that extracts the contaminated sediment from the waterway and disposes of the sediment in a secure location (e.g. landfill). The most commonly selected “removal” strategy for subaqueous contaminated sediment cleanup is dredging. Dredging employs clamshell buckets or hydraulic dredges to remove the sediment from the waterway. A more detailed discussion of dredging technology is presented in Section 2. The general environmental dredging operation is very similar to the operations used in navigation dredging (i.e., channel deepening), which is a technology that has been around for well over a century.

Environmental dredging operations, however, differ from navigation dredging operations in two major areas. The first major area is the extra concern associated with dispersion and spreading of contaminants from the dredge location to downgradient or adjacent locations that are not contaminated. The second major area is the primary objective of the cleanup. For environmental dredging the primary objective is not simply the removal of bulk sediment to deepen a channel, but the reduction of contamination in the subaqueous sediments to environmentally sustainable levels.

As far as dispersion and spreading of contamination is concerned, dredging technology cannot help but destabilize the subaqueous sediments during digging and raking operations. As a result, some form of containment to prevent the spread of contaminated sediment is needed. Current containment strategies are presented in Section 2. With respect to contaminant removal, while dredging technology is well suited for the removal of bulk sediments (e.g., removal of the top 3 foot layer), it was never intended as a technology to reduce residual sediment contamination concentrations to low levels. The probability that it can achieve low levels of residual contamination required for many of the contaminants encountered in subaqueous sediments is not very high (see discussion below). Dredging, as a contaminated sediment removal technology, serves primarily as a default technology, since few if any practical alternatives are available or have been developed to take its place.

Recent data suggest that there is significant uncertainty as to whether dredging alone can adequately remediate subaqueous contaminated sediment sites. A recent USEPA study, which provided post-dredging contamination data at seven polychlorinated biphenyl (PCB) contaminated sediment sites where dredging was employed as the remediation technology and where sufficient data were available to evaluate the results (USEPA, 2004a), showed PCB reduction at all sites, but not one achieved average residual PCB concentrations in the sediment of less than one ppm after dredging, even after multiple dredging passes.[1] One ppm (or less) is an approximate concentration level that many PCB cleanup projects are presently targeting as the desired post-cleanup level of residual contamination for risk reduction. Concern associated with the expected efficiency of cleanup resulting from dredging technology is presently acknowledged by many experts involved in dredging remediation activity and is presently the subject of serious concern (Bridges et al., 2005 and Doody et al., 2005). Billions of dollars will be expended over the coming years on remediation projects with little assurance that cleanup goals will be achieved

Problems associated with dredging begin with the site survey, which defines the spatial limits of the cleanup. This includes both the vertical cut and lateral boundaries of the project. These spatial limits are for the most part an interpolative estimate of the true extent of the contamination in the waterway, and will,

[1] The seven sites included two sites in the St. Lawrence River (General Motors and Reynolds Metal), New Bedford Harbor, Cumberland Bay, two locations on the Fox River, and one on the Grasse River. Reported average residual concentrations at these seven locations ranged from 2 to 80 ppm.

unless grossly overestimated, contribute to the probability that residual contamination will be present after the cleanup is completed. During the dredging process itself, higher levels of contamination that are located below the sediment-water interface can expected to be transferred to the sediment-water interface. In addition, destabilized contaminated sediment particles that are dispersed during dredging will either resettle in the cleanup area or migrate from the site to adjacent locations. The result is that during the dredging process continual disturbances associated with mixing and settling will occur at the water-sediment interface, further increasing the probability that residual contamination will be present after the cleanup is completed.

While the aforementioned considerations are recognized as dredge-limiting problems, the development of new approaches to mitigate these issues has received little attention. The absence of research and development into new remediation approaches to address these issues is not unexpected. The development of new technology and particularly the development of “new remediation equipment technology” in the field of contaminant sediment remediation have been painstakingly slow. This is because research in this area requires the development and use of heavy equipment, which can rarely be conducted in a university setting where most research activity is centered. Few dredging contractors have the resources to undertake research activities or engage in the development of new equipment, and government agencies have been slow to respond to the residual contamination issues and to provide resources to investigate new remediation strategies.

This report provides a description of the development of a new technology designed to provide advanced containment and cleanup operations for environmental dredging projects. The technology was developed over a four-year period and culminated in the construction of a field prototype that was successfully tested at Cedar Beach, in Southold, Long Island. The system developed is referred to as Mobile Containment Technology. Support for its development was provided by the New York State Energy Research and Development Authority, the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET), the National Oceanic and Atmospheric Administration (NOAA), the Pall Corporation, Cornell Cooperative Extension of Suffolk County, Marine Division, and the New York State Canal Corporation. The technology was developed by Chesner Engineering, P.C. and Melrose Marine Service, Inc. It is described in detail by three U.S. Patents[2] and is being marketed under a third party company, Seaway Environmental Technologies, Inc.

The report is divided into six subsequent sections that provide an overview of current containment technology approaches (Section 2), a description of Mobile Containment Technology and how it works

[2] U.S. Patent No. 6,637,135 B2, Contaminated Sediment Removal Vessel; U.S. Patent No. 6,640,470 B2, Contaminated Sediment Remediation Vessel; and U.S. Patent No. 6,613,232 B2, Mobile Floating Water Treatment Vessel.

(Section 3), a description of post-dredging cleanup methods (Section 4), a discussion of capping issues (Section 5), a description of advanced containment options associated with Mobile Containment Technology (Section 6), and a review of cost-benefit considerations associated with the subject technology (Section 7).

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Section 2

CURRENT DREDGING AND CONTAINMENT TECHNOLOGY

Current dredging methods can be divided into two general categories. They include mechanical dredging and hydraulic or vacuum dredging. The fundamental difference between these categories is the equipment used and ultimately the form in which the sediments are removed.

Mechanical dredging operations make use of clamshell buckets to remove the sediments. Clamshell buckets, shown in Figure 2-1, are lowered to the bottom of waterways where they scoop the sediments, capturing and bringing to the surface the bottom sediments as well as the water entrapped within the bucket. Mechanical (i.e., clamshell-bucket) dredging results in the collection of sediment with a relatively low liquid to solid ratio (i.e., relatively little water is entrained in the sediments) compared to hydraulic dredging operations. Some clamshell buckets have openings that drain the free water entrapped within the bucket to reduce the water collected with the sediment.[3]

Figure 2-1. Clamshell Buckets

Hydraulic or vacuum type dredges agitate the bottom channel to dislodge the sediment, and pump (vacuum) the sediment from the waterway. This agitation is accomplished with augers or cutterheads shown in Figure 2-2. In hydraulic dredging operations the sediment is transported as a slurry with water acting as the transport medium (see floating pipeline in Figure 2-2). This results in a water-sediment mix with a high liquid to solid ratio. The sediment in the slurry must later be segregated from the water carrier. This is typically accomplished using large impoundment areas where the sediment is extracted by settling and the water (effluent) is returned to the originating waterway.

[3] This is a highly questionable practice when contaminated sediments are being dredged since contaminated drainage is released back into the waterway.

Figure 2-2. Hydraulic Cutterheads and Horizontal Augers

The problem with both mechanical and hydraulic dredging operations is that by nature they must penetrate, displace, and rake the bottom sediment in order to extract the sediment from the waterway. As noted in Section 1, such operations destroy the stability of the sediment structure at the sediment-water interface. These destabilized sediments are more susceptible to dispersion and migration than the original pre-dredged sediments. In mechanical dredging operations, sediment dispersal is further induced when buckets are intentionally drained to reduce the water content of the collected sediments, when leakage occurs due to inadequate bucket sealing mechanisms, or when debris gets caught in the buckets, as shown in Figure 2-3. These latter issues are particular problems in debris fields where the presence of wood debris, metal debris, or large boulders will interfere with bucket operations.

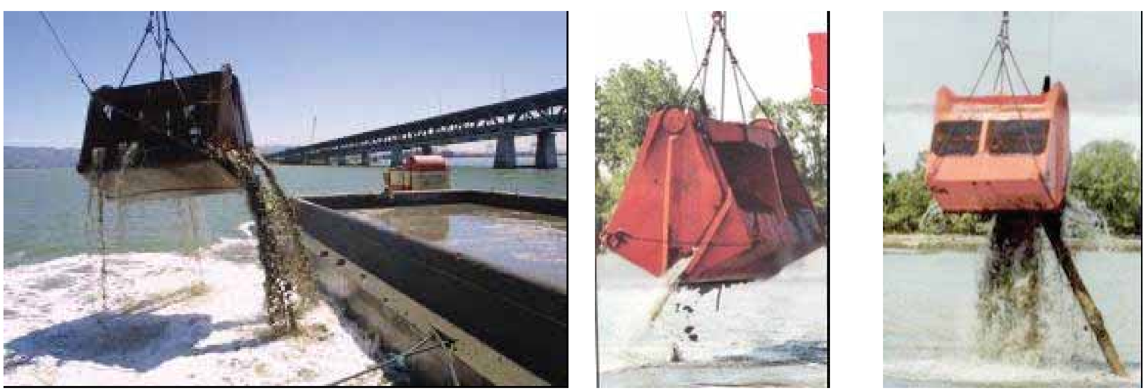

Figure 2-3. Leaky Clamshell Buckets

Hydraulic dredging operations offer the advantage of a vacuum system that can assist in capturing some resuspended solids during bottom scouring operations, but the energy imparted to the sediment by hydraulic dredging cutterheads, which is intended to break up the cohesive forces that bond the soil (so that the sediment can be sucked into the vacuum head), can be expected in most instances to exceed the vacuum energy available to capture these soil particles. The loss of soil particles that are ejected from the zone of vacuum head influence is compounded by the presence of currents in the waterway that act to sweep away the particles during these operations. Hydraulic dredging operations are limited by vacuum head clogging problems and can only be effectively employed in areas in which the sediments have low levels of debris. Since hydraulic dredging operations generate large volumes of water, which carry the sediments, the sediments must be withdrawn from the water and the carrier-water treated prior to discharge. As a result, hydraulic dredging operations are further limited to areas where large impoundment areas exist or can be made available to collect and hold the water for treatment.

Sediment destabilization during contaminated sediment dredging operations is a special concern since the most destabilized sediments can be expected to be the fine, light, organic-rich particles. These are the sediment particles that typically carry the highest levels of contaminant concentrations.

Physical barriers have been employed during environmental dredging operations to isolate the area of dredging and contain contaminated particulates that are dispersed into the water column during the excavation process. Two of the more common approaches include silt curtains and fixed steel sheet piles.

Silt curtains, shown in Figure 2-4, are flexible, canvas sheets that are deployed by attaching heavy ballast materials to the bottom of the fabric and buoyant floats to the top to hold the curtain in a vertical configuration. Silt curtains, however, can only be used in quiescent waterways. Locations with high currents (in excess of 0.5 knots) can disrupt and force silt curtain movement, similar to the manner in which a wind blows a sail, causing the silt curtain to dislocate and migrate in the direction of the current.

Figure 2-4. Silt Curtains

Fixed steel sheet piles, shown in Figure 2-5, provide an alternative to silt curtains. If designed properly they can withstand significantly higher currents than silt curtains. Fixed sheet pile barriers require the installation of fixed posts and “soldier-beams” in the waterway to support the structure. Sheets must be properly imbedded into the subsurface (vibrated or driven into the sediment) to ensure the sheet pile structure withstand the hydraulic forces (e.g., waves and currents). A fixed sheet pile containment barrier is an immobile barrier, which in most cases will surround all equipment inside the containment area for the duration of the project.

Figure 2-5. Fixed Sheet Piles

The most notable deficiency associated with both silt curtain and fixed sheet pile containment systems is that the containment is "temporary." Once the bottom sediments are destabilized, the sediment particles are mobile and can readily migrate downstream after the silt curtains and/or fixed sheet piles are removed. This raises a serious question as to the overall effectiveness of such systems in preventing contaminated sediment migration.

Section 3

MOBILE CONTAINMENT TECHNOLOGY

Mobile Containment Technology introduces a new approach that provides for improved containment and cleanup during dredging operations. It is designed to incorporate the mobility of silt curtains, providing the means to deploy and redeploy the system to suit the needs of the cleanup site, coupled with the stability of the fixed sheet piles allowing containment to occur in areas with high currents. It introduces the concept of containment area cleanup that provides for the removal of residual contamination left behind in the water column and at the sediment-water interface by the dredging process, increasing the efficiency of the cleanup. It also allows for a more controlled certification process to ensure that cleanup standards have been achieved. Containment area cleanup and cleanup area certification are discussed in greater detail in Section 4.

Improved containment is provided by establishing a secure area inside which dredging occurs. Containment area cleanup is provided by collecting the dispersed and settled contaminants that are retained within the containment area. A secure area is established by use of a specially designed containment vessel that is comprised of floating sectional deck barges that are deployed in a rectangular configuration. Sheet piles that are attached to the inner hull of the barges are lowered from the barge deck to the bottom of the waterway. This results in the formation of a pen-like area. Dredging takes place inside this area. Simplified illustrations of the containment vessel are shown in Figure 3-1.

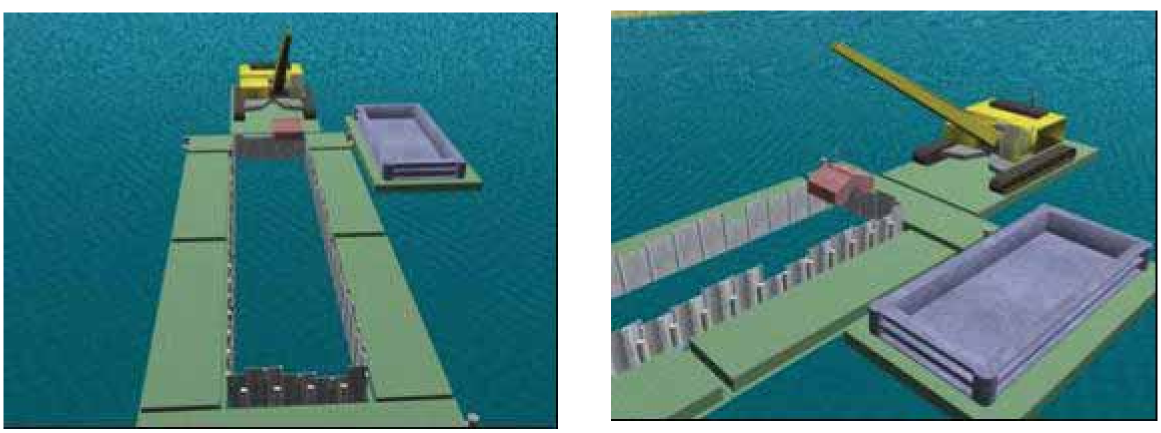

Figure 3-1. Mobile Containment Vessels Deployed

A submerged view underneath the sectional barges illustrating sheet pile penetration into the bottom sediments is illustrated in Figure 3-2. The result is an enclosed containment barrier that prevents the migration of dispersed sediments.

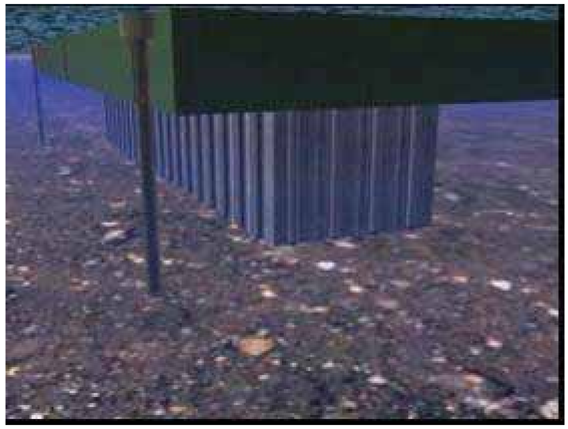

Figure 3-2. Submerged View of Containment Barrier

Figure 3-3 presents two photographs showing deployment of a demonstration containment vessel that was fabricated and tested by Seaway Environmental Technologies, Inc. at Cedar Beach in Southold, Long Island in the fall of 2003. The photographs show the sectional barges being deployed from a shore-side location into the test waterway (i.e., creek). After the initial deployment of the barges, the barges are connected together with a barge pinning system. Once the barges are pinned together, a specially designed sheet pile support structure is connected to the inner hull of the barges. This sheet pile support structure is designed to hold the sheet piles against the inner hull of the vessel, as shown in Figure 3-4, while permitting the sheets to freely slide up and down during deployment and redeployment. A detailed drawing of the specially designed support structure is shown in Figure 3-5 and described in detail elsewhere.[4]

Figure 3-3. Sectional Barge Shore-side Deployment

Since the containment vessel is mobile, it can be continually shifted during a dredging operation from one location to the next. Additionally, for larger dredging operations, multiple containment vessels can be deployed at a job site, resulting in greater dredging productivity. Multiple vessel deployment provides the

[4] U.S. Patent No. 6,637,135B2, Contaminated Sediment Removal Vessel.

means for one crane or excavator to shift from one containment vessel to the next, increasing its overall operating time. The concept of multiple containment vessel deployment is illustrated in Figure 3-6.

Figure 3-4. Connected Barges with Sheet Deployment

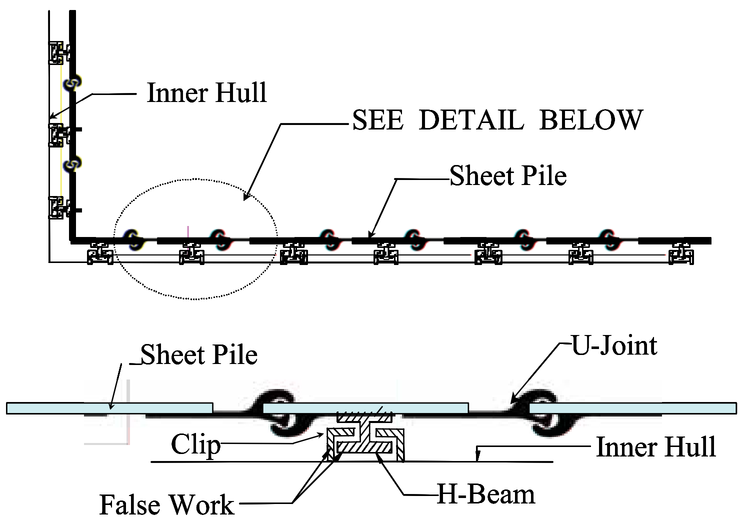

Figure 3-5. Support Structure System Details

To simplify the task of deploying and redeploying the containment vessel during a cleanup operation, a specially designed sheet lifting and sheet pile pin locking system was developed to ease the task of raising and lowering the sheets and locking them in place. Photographs of the specially designed lifting angle and locking pins are shown in Figure 3-7.

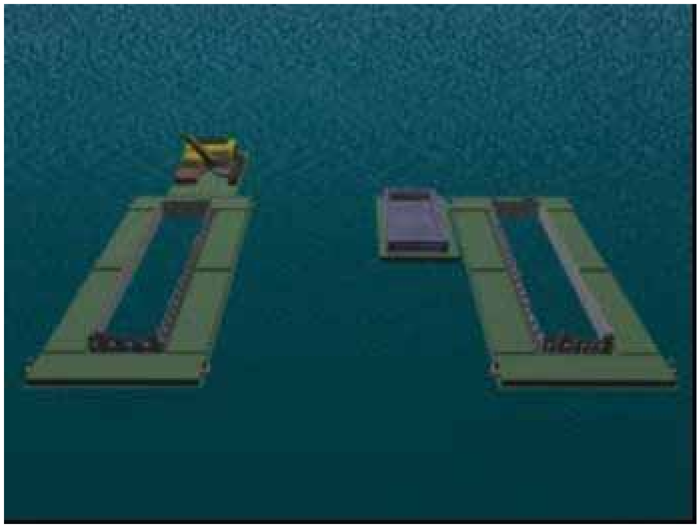

Figure 3-6. Multiple Containment Vessel Deployment

Figure 3-7. Sheet Deployment

Section 4

CONTAINMENT ZONE CLEANUP AND CERTIFICATION

During traditional or conventional dredging operations, as noted in Section 1, the bottom sediments are destabilized and residual contamination is left behind, free to remain or migrate from the dredge site. While the Mobile Containment Vessel prevents the immediate migration of contaminants from the dredge area, it does not by itself provide adequate cleanup. This is because once the containment barrier is removed, the unstable sediments would be free to remain as residual contamination or migrate from the dredge site.

A basic problem with silt curtains and fixed sheet piles deployment strategies is the assumption that by themselves they are effective containment barriers. At best they provide for temporary containment of dispersed particles. The destabilized particles, particularly the low specific gravity particles that likely contain the highest contaminant concentrations will remain unstable and subject to migration well after the dredging process has been completed and these containment barriers have been removed.

To remove destabilized, contaminated particles present in the containment area during and after dredging operations are completed, Mobile Containment Technology employs a Mobile Water Treatment Vessel.[5] This treatment vessel is a floating package water treatment plant that removes contaminated particulate matter that is captured in the containment area. Contaminated particles (or solids) are collected and removed by pumping water from the containment area into the treatment plant and discharging the treated effluent into the ambient water outside the containment area.

Although numerous treatment strategies are available to ensure a high degree of particulate removal, membrane filtration technology was selected as the preferred treatment strategy. This technology, which can remove all particulate matter less than one micron in size, provides for the removal of essentially all suspended solids present in the water prior to discharge.[6] This is extremely important since the smallest particles, due to their large surface area, likely contain the greatest concentration of contaminants. A photograph showing the deployment of a membrane filtration system supplied by the Pall Corporation for the Cedar Beach prototype system is presented in Figure 4-1. Effluent discharged from the plant is shown in the photograph. An alternative view of the filtration plant can be seen on the left side of the left photograph in Figure 4-2.

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[5] U.S. Patent No. 6,613,232 B2, Mobile Floating Water Treatment Vessel.

[6] This is because minus 0.45 micron particles are categorized as soluble in standard laboratory analyses. If soluble contaminants are determined to be problematic, an activated carbon unit can be added for tertiary treatment.

Figure 4-1. Mobile Water Filtration Plant
(Membrane Treatment provided by the Pall Corporation)

The right photograph in Figure 4-2 shows a settling tank that is used to pre-treat the incoming flow prior to entering the membrane treatment facility. Backwash and reject from the membrane plant is returned to this settling tank, where all solids removed from the water are collected for disposal.

Figure 4-2. Mobile Water Filtration Plant
(Membrane Treatment and Pre-Settling Tank)

Effluent exiting the water plant contains no measurable suspended solids. Beakers of influent and effluent water are illustrated in Figure 4-3.

While one of the more pronounced effects of dredging, as previously noted, is the destabilization and dispersion of particulates into the water column, differential settling of the dispersed particulates will occur whereby the heavier particles resettle rapidly, while the lighter (i.e., low specific gravity) particulates remain in the water column for longer periods of time. Based on field experience and observations made during pilot and prototype demonstration activities most particles that are suspended during dredging operations resettle to the bottom of the waterway within a 6 to 12-hour period. These particles, however, are in an unconsolidated and unstable form. As a result, to effectively clean up a containment area after dredging is completed, the bottom of the containment area must be cleaned.

Figure 4-3. Mobile Water Filtration Plant Results (Influent Water On Left and Effluent on Right)

This cleanup is accomplished with the use of a specially designed cutter-less vacuum head, which is deployed from the Mobile Water Treatment Vessel. The vacuum head is deployed from a boom that can extend the vacuum head to the bottom of the waterway, to vacuum up the loose and unstable sediments that resettle to the bottom of the containment area. Since the sediment particles are in an unconsolidated and unstable form, they will readily be picked-up by the vacuum head without the need for re-disturbing the sediments below the sediment-water interface. A photograph of the cutter-less vacuum head is shown in Figure 4-4. A flange connection on the vacuum head provides the means to connect the head to a flexible pipe so that vacuumed flow can be transported to the Mobile Water Treatment Vessel for the removal of contaminated particulate matter. An overall schematic of the Mobile Containment Vessel deployed with a Mobile Water Treatment Vessel is shown in Figure 4-5.

The sequencing of mobile containment and post-dredging cleanup operations offers an opportunity to sample and test the post-cleanup sediments and contained water quality in a manner that affords additional quality control over the cleanup process. After dredging and post-cleanup is completed and before the containment vessel is relocated, the collection and testing of sediments and water quality within the contained area can provide on-site information as to whether the containment area has been adequately remediated. If the site has not been adequately cleaned, additional dredging, vacuuming, or capping operations (see Section 5) can be employed in the contained area to provide the necessary remedial activities. After the operation is satisfactorily completed, the contained area can be “certified” as completed. This on-site certification process avoids the problem of having to remobilize equipment and return to the site after dredging is completed if the site is not adequately cleaned.

Figure 4-4. Cutter-less Vacuum Head

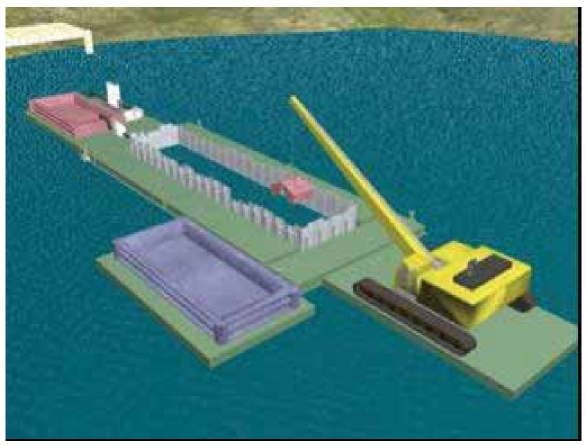

Figure 4-5. Mobile Containment Vessel and Mobile Water Treatment Vessel Deployment

The combined effect of containment, cleanup, and post-cleanup certification is a unique advantage of Mobile Containment Technology. It provides a degree of process control not afforded by current dredging and containment practices.

Section 5

CONTAINMENT AREA CAPPING

The likelihood that any dredging activity will leave behind a clean, uncontaminated residual sediment is remote. Depending upon the target cleanup criteria and the desire to provide a clean surface sediment layer for benthic organism recolonization, the capping of the dredged cleanup area may be needed. Some remediation projects are already including capping as an option if target goals cannot be achieved after multiple dredging passes (USEPA, 2004b).

The development of advanced engineering capping systems to improve the stability and containment properties of subaqueous caps are being developed for subaqueous contaminated sediment applications (Palermo, 1998). Some advanced engineered cap concepts include the placement of multiple layers of materials with different densities and sizes (e.g., a multi-layered cap). A typical multi-layered cap might contain a lower silty, fine-grained layer that allows the cap to bind strongly with the contaminants in the underlying sediment bed, an upper sandy layer that may be more resistant to the colonization efforts of burrowing organisms, and an upper armoring layer or a protective layer that might consist of coarser stone. More recently, the concept of reactive caps has been introduced (SERDP, 2004). Reactive caps are special capping materials that consist of or contain amendments that can react with, absorb, or physically prevent the migration of the contaminant through the cap. While capping, at least in theory, may provide a highly viable alternative to dredging, there is a significant gap between theory and practical application, particularly as it relates to capping-material delivery and placement technology. In practice a cap will only be as good as its delivery and placement system.

Current capping placement technology can be divided into two general categories: 1) mechanical placement (surficial broadcasting with clamshell buckets and surface dumping with split-hull barges); and 2) hydraulic placement (slurry delivery with pressurized pumping or gravity tremie). None of these approaches are particularly effective in delivering material(s) continuously to a target location, placing the material(s) cap in precise layers, or preventing disruption of the subsurface (and the resultant dispersion of contaminants) during cap placement.

The placement of capping material inside of a post-dredged containment area, illustrated in the schematic shown in Figure 5-1, provides an improved system for applying a controlled, easy-to-monitor cap. It ensures that the capping material does not migrate from the dredge location with currents and prevents the release of disbursed sediments resulting from cap deployment from the cleanup location. Capping inside a containment area provides an additional advantage if sediment cuts are deep, since the capping material can be used to fill in the cut, preventing the collapse of exterior sediment walls into the excavated containment area after the sheet piles are removed and the containment vessel is redeployed.

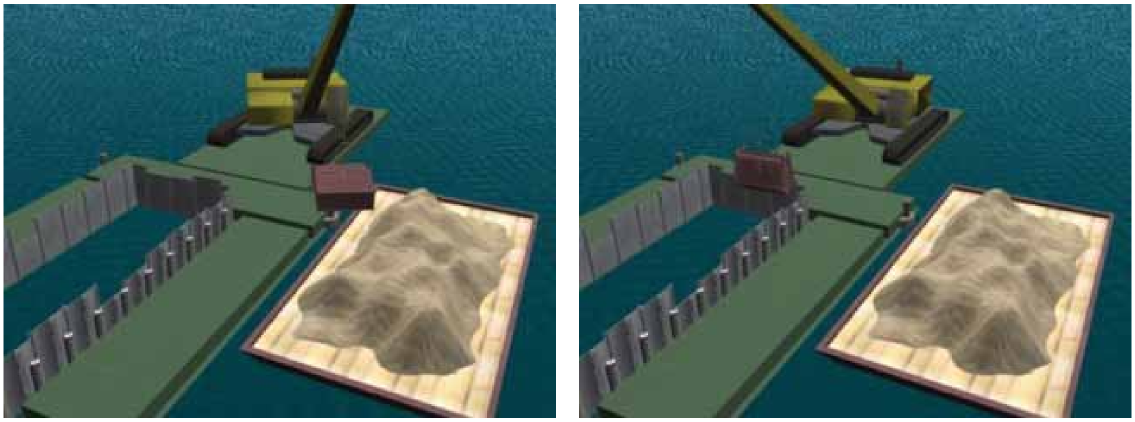

Figure 5-1. Capping Operation

Section 6

ADVANCED CONTAINMENT

Mobile Containment Technology can provide an advanced containment option that enables the containment of not only particulate contamination, but also liquid and soluble contamination that might be released during dredging operations. This advanced containment option is referred to as "low-pressure control zone technology." Low-pressure control zone technology works by lowering the elevation in the containment area to levels that are less than that in the ambient water outside the containment area. Only a small measurable differential in elevation between the containment area and ambient water level outside the containment area is needed. By lowering the water elevation inside the containment area, the pressure (elevation-head) in the containment area is effectively lower than the pressure (elevation head) of the surrounding water. This prevents the flow of water out of the containment area, sealing all soluble and particulate contamination inside the containment area or control zone.

To achieve a measurable difference in elevation between the water level surrounding the containment area and the water level inside the containment area, it is necessary to pump water out of the containment area at a rate that exceeds the inflow of water into the containment area. Flow into the containment area will occur due to the migration of water under the sheets or through the sheet pile joints.

Water passing under the sheet pile will be minimized if the sheet piles are firmly embedded into the bottom sediment. Sheet pile joints, however, are highly porous openings through which water can readily flow. The joints themselves are u-shaped edges that run the length of the vertical sides of each sheet pile. The u-shapes provide an interlocking configuration so that the sheets can be vertically aligned, standing side-to-side. To minimize the flow of water through the sheet pile joints, a special sheet pile sealing system design was developed. The patented joint seal consists of a sealing tube that uses a specially designed connecting shroud that straddles the joint between each adjoining sheet pile. A top view of a u-joint and the connecting shroud straddling the joint is shown in the left photograph in Figure 6-1. A side view of the shroud aligned vertically along adjoining sheet piles is shown in the right photograph in Figure 6-1.

The sealing tube is a flexible tube that fits into the void between the shroud and sheet pile (see Figures 6-2 and 6-3). When the sealing tube is pressurized, it expands into the joint, cutting off the flow of water through the joints. Pressurization occurs by filling the sealing tube with water through a water-fill cap. Photographs of the sealing tubes, deployed on the mobile containment demonstration vessel, are shown in Figure 6-2. To evacuate water from the sealing tube, pressurized air is introduced into the sealing tube through an air-fill port, which drives the water out of the tube through a water-fill cap. A photograph of the water-fill cap and air-fill port situated on the top of the sealing tube is shown in Figure 6-3.

Figure 6-1. Connecting Shroud

A decreased reduction in water rate migration through and under the sheet piles makes it possible to effect a difference in elevation between the water level inside and outside the containment area at a reasonable pumping rate.[7] Water pumped from the containment area to maintain a differential elevation between the water levels inside and outside the containment area is transported to the mobile water treatment vessel, which is deployed during this operation.

By maintaining a low-pressure zone inside the containment area and by continually routing the pumped water through the mobile water treatment vessel, a high degree of treatment (i.e., due to multiple containment area turnover) of the water column inside the containment area is provided. This water column treatment followed by bottom vacuuming, described in Section 4, provides for an extremely aggressive cleanup of residual contamination present in the containment area, providing for the most secure cleanup technology of a contaminated site currently available.

[7] Based on demonstration vessel testing, a pumping rate of 250 gpm would be capable of maintaining a 3- to 6-inch elevation differential.

Figure 6-2. Sealing Tubes Deployed

Figure 6-3. Sealing Tube Cap and Air-Fill Port

Section 7

COST-BENEFIT EVALUATION

While the environmental benefits of employing Mobile Containment Technology to provide a more efficient (i.e., lower post-cleanup residual sediment contaminant concentration) and controlled (i.e., reduced contaminant migration from the dredge site) cleanup are readily apparent, the magnitude of the cost and the benefits of employing the technology are not. The decision to employ Mobile Containment Technology in a site cleanup will be dependent on the costs of deploying the technology versus the enhanced benefits that the technology brings to the cleanup compared to the costs and benefits of conventional dredging technology.

The benefits of any remediation technology or approach can be defined in terms of the potential for the respective technology or approach to achieve the target cleanup goal(s). As previously noted, in Section 1 of the report, there is significant uncertainty as to whether conventional dredging technology alone can achieve concentration-based target cleanup goals. The problem begins with the inherent error associated with the site survey that defines the spatial limits (i.e., vertical and lateral) of the cleanup and is compounded by the destabilization, mixing and dispersion of sediments that accompany dredging operations. As a result there is a low probability that conventional dredging alone can achieve low residual levels of contamination for many contaminants (e.g., PCBs). To increase the probability of success in achieving such goals alternative, supplementary and/or complimentary systems are needed. The cost benefit evaluation then becomes an analysis of the cost of the alternative, supplementary and/or complimentary system in terms of its enhanced benefit. The cost-benefit evaluation presented in Section 7 for Mobile Containment Technology is intended to address this issue.

The results of the analysis presented below argues that Mobile Containment Technology can improve the quality of the cleanup operation, and thereby increase the probability that target goals will be achieved. The use of Mobile Containment Technology embodies a new approach to environmental subaqueous clean-up campaigns that allows for reaching a defined closure point to a cleanup in a stepwise manner, eliminating the unpredictability of effort and cost associated with repetitive attempts to achieve concentration-based cleanup standards using conventional dredging technology; and reduces future liability associated with dispersed and residual levels of contamination. The cost of employing the technology in many instances is expected to result in lower overall project costs when compared to conventional technology costs, resulting in both increased benefit and reduced cost. An analysis of the cost of Mobile Containment Technology can best be undertaken by defining the equipment and operational costs of deploying the technology on a cleanup site and comparing the relative cost of this deployment to the overall cost of a conventional cleanup.

There is a scarcity of documented contaminated sediment cleanup cost data available in the literature. Nonetheless, it is known that the cost of contaminated sediment removal has historically been at least one to two orders of magnitude greater than navigational dredging costs.[8] Contaminated sediment removal costs are also known to be increasing due to the imposition of greater regulatory control on cleanup operations and an increase in supporting activity requirements. Some of the more notable cost items associated with a cleanup include: 1) sediment excavation operations, 2) sediment handling and dewatering, 3) sediment transportation, 4) sediment disposal, 5) contaminant containment activities, 6) field monitoring, 7) engineering support services, and 8) public interface activities. In addition, while not a direct cost item, the defined cleanup specifications, as will be shown, is perhaps the most significant of all factors, since it can affect most of the cost items listed above.

Probably the most comprehensive information available on subaqueous sediment site cleanup costs has been compiled by the General Electric Corporation (GE) in an on-line database (MCSS, 2004). This database provides a review of activities at over 100 sites in the U.S. that have undertaken some form of subaqueous contaminated sediment removal and/or capping. The cost data presented in this database is expressed as a composite cost in terms of dollars per cubic yard. Although cost data is not available for all the sites, and where data is provided it is not consistent from site to site with respect to the level of detail, the available information does provide a means to examine the general magnitude of the costs, the relative costs and range of costs encountered in prior cleanup projects. To undertake such an examination, data from 23 locations were selected for statistical analysis.[9] A listing of the selected sites and their respective cost data are presented in Table 7-1.

Most notable in the Table 7-1 data is the large variability in reported cost, which includes a range of costs from $110 to $1670 per cubic yard, with a population average and standard deviation of $510 and $414 per cubic yard, respectively. The median value of the data set is $375 per cubic yard. Although differences in remediation costs from site to site can be expected to vary depending on site conditions, the magnitude of the observed variability, reported in Table 7-1, which includes an order of magnitude difference in the range of costs and a coefficient of variation (CV)[10] 0f 87 percent, would not be expected.

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[8] Navigation dredging costs are most dependent on the cost of sediment disposal and have ranged in the past from less than $5 per cubic yard (where the sediment is deposited in water-based disposal sites) to approximately $50 per cubic yard (where the sediment must be disposed in upland sites). Contaminated sediment cleanup costs have historically been well above $100 per cubic yard.

[9] Twenty-three sites that were included in the analysis were those sites for which cost data were available and which were deemed to be typical of most cleanup activities (i.e., did not include extraordinary activities such as sediment incineration or special on-site disposal of sediment, which would tend to skew costs in a high or low direction).

[10] CV (expressed as percent) = 100 x (Std Dev)/(Average)

Some differences in the reported costs could be due to the size of the cleanup project operation, where economies of scale tend to reduce costs when costs are expressed in unit terms, such as dollars per cubic yard, however the magnitude of the observed differences are greater than would be anticipated. Alternatively, differences in the selected excavation, and sediment handling, transportation and disposal strategies between projects might account for the observed differences. Again however, the differences in costs are too widespread, particularly the high end costs, for this to be the case. It is also possible that differences could be due to the fact that major components of cost data for individual sites were omitted in the database, however this too is unlikely.

Table 7-1. GE Database: Cost Per Cubic Yard[1]

1.	Site ID	$/yd^3
	Cumberland Bay	174
	Lake Capri	345
	Ford Outfall	198
	Formosa Plastics	200
	Fox River 1a	396
	Fox River 1b	230
	Fox River 2	525
	Gill Creek	1500
	GM (Massena)	920
	Gould	273
	Grasse River	1670
	Housatonic	750
	Koppers	700
	Lipari Landfill	306
	LTV Steel	110
	Malingkrodt Baker	375
	Marathon Battery	128
	Ottawa Project 2	516
	Outboard Marine	300
	Reynolds Metal (Massena)	468
	Ruck Pond	970
	Tennessee Product	450
	Velsicol 2	223
2.	Statistics	$/yd^3
	Average	510
	Std Dev	414
	Median	375
	High	1670
	Low	110
	Number	23

[1] See Reference MCSS, 2004.

As previously noted, the imposition of increasingly stringent cleanup requirements can affect project costs and can do so in a manner that may not be fully recognizable at the beginning of the project. Two such requirements include more stringent target cleanup goals and more stringent containment requirements. As an example, sediment excavation goals are typically defined in one of two ways. Traditionally the goal has been defined in terms of mass sediment removal (e.g., cubic yards).[11] More recently however, target sediment removal goals are being defined in terms of residual sediment contaminant concentration. Differences in project costs resulting from the two sets of differing goals can be profound. In the former (i.e., traditional) case, the quantity of sediment to be removed and the number of excavation passes required to achieve the goal are predictable. The excavation portion of the project can proceed in a manner that is similar to a navigation-dredging project. In the latter case however, the quantity of sediment to be removed and the number of excavation passes required to achieve the target goal are not readily predictable.[12]

Insofar as containment requirements are concerned, such requirements and costs can vary from site to site depending on site conditions, as outlined in Section 2. Perhaps more important than the differences in containment approaches however, is the affect containment efficiency can have on the rate of sediment excavation. For example, during project activities if high sediment resuspension rates are encountered, regulatory agencies tend to impose excavation rate restrictions to reduce the rate of particulate dispersion. The result of this excavation rate reduction translates directly into a direct increase in project costs. These costs are not readily predictable at the beginning of the project.

While sufficient information in the MCSS database was not available to fully verify that the high end costs presented in Table 7-1 were all attributable to more stringent target cleanup goals and containment standards, it is known that some of the higher costs projects, (e.g., GM Massena at $920 per cubic yard), have required multiple cleanup passes and encountered difficulties in achieving target cleanup goals.

Given the wide range of cost data presented in Table 7-1, it is difficult to define what a “typical” remediation project might cost (in terms of dollars per cubic yard). A “typical” remediation project in this case would be one in which target goals and containment specifications are achieved using conventional dredging technology. Based on the existing data and the experience of the authors, the median value of $375 per cubic yard was selected by the authors as a best estimate of the expected cost of a “typical” subaqueous sediment remediation project.[13] If a “typical” remediation project can be expected to cost $375

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[11] This quantity is determined by specifying the excavation of a defined vertical layer of sediment over a defined area (e.g., 3 ft over 5 acres)

[12] This is because the number of excavation passes required to achieve the target cleanup goal is unknown. In such cases some projects are considering a combination of multiple passes plus capping if target goals are not achieved. In addition, recent data (as outlined in Section 1) suggest that dredging technology alone may be incapable of achieving low residual contamination goals.

[13] Typical, in a statistical sense, meaning the median value where 50 percent available remediation cost data were above this value and 50 percent below.

per cubic yards, then when more stringent requirements are imposed on a project and the project is "atypical" (e.g., low residual concentration levels and stringent containment requirements), higher costs would be expected. The data presented in Table 7-1 suggest that the higher costs that could be encountered when conventional technology is used in an attempt to achieve more stringent requirements could be two to three times as great as "typical" project costs.

If target goals cannot be achieved with conventional dredging technology alone, then new systems, such as Mobile Containment Technology, are needed to improve the quality of the cleanup. Since employing Mobile Containment Technology to complement conventional dredging operations requires the use of additional equipment and supporting operations, as described in Sections 3, 4, 5, and 6, the cost-benefit evaluation of using Mobile Containment Technology should be based on the analysis of the relative cost and benefits associated with Mobile Containment versus the costs and benefits presently experienced using conventional technology.

To provide such an analysis, a sample project and cost calculation for the deployment of containment and treatment vessels on a job site is presented in Table 7-2. The sample project, presented in Table 7-2, depicts a cleanup activity where it is determined that a 7.35-acre area with contaminated sediment would be best undertaken with the use of Mobile Containment Technology to achieve the necessary containment and site cleanup objectives.

In the example given, the depth of contamination in this 7.35-acre area is 3 ft. For design purposes, one containment vessel with a complimentary water treatment vessel is planned to support the dredging operation. The containment vessel will encompass a containment area that is 70 ft long and 70 ft wide, and the supporting water treatment plant will have the capability of treating 500 gallons per minute (gpm) of containment area water. A three-shift operation is assumed and the operational schedule presented in Table 7-2, Item 3 is planned. The operational schedule is presented in terms of Day, Shift (i.e., 3, 8-hr. shifts per day) and Activity. The activities included in the schedule, shown in Item 3, include sheet deployment (2 shifts), excavating (1-shift), zone settling (1 shift), area vacuuming (1 shift), sediment testing and analysis (2 shifts), lifting sheets and redeployment (2 shifts). The planned containment cycle, as shown in Table 7-2, Item 3, is three days. This means that a containment vessel shifts positions every three days.

The estimated cost of mobile containment for the given example is approximately $70 per cubic yard. For a "typical" remediation project where the best estimate of the cleanup cost is assumed to be $375 per cubic yard, the mobile containment portion of the cost amounts to approximately 20 percent of the total project cost. For a "typical" remediation project, as defined above, if the cleanup goal(s) can be achieved without the deployment of Mobile Containment Technology, then this cost is not warranted. However at locations where a "typical" project cannot be anticipated, this 20 percent increase in project cost is a relatively small amount when viewed against the backdrop of multiple cost increases and unsuccessful attempts that have been associated with conventional technology efforts to achieve target cleanup goals.

Table 7-2. Sample Cost Calculation

1. Site Conditions
   - Contaminated Sediment Area: 7.35 acres
   - Depth of Contamination: 3 ft

2. Deployment Plan
   - One 70 ft x 70 ft Containment Vessel
   - One 500 gpm Water Treatment Vessel

3. Containment Cycle (3 days, 3 shifts/day)

Day	Shift	Activity
1	A	Sheet deployment
	B	Sheet deployment
	C	Sediment Excavation
2	A	Zone settling
	B	Area vacuuming
	C	Sediment and water testing
3	A	Testing results
	B	Sheet extraction
	C	Sheet extraction and repositioning

4. Cost Estimates

Mobilization and Demobilization	$60,000
Containment Vessel	$400,000
Treatment Vessel	$550,000
Tug Boat Support	$600,000
Service Barge Support	$350,000
Containment Vessel Crew	$400,000
Water Treatment Vessel Crew	$200,000
	$2,500,000

5. Containment Cost Summary

Containment Cost	$2,500,000
Quantity Excavated (yd^3)	35,556
Cost per cubic yard	$70.31

There are numerous locations where “atypical” cleanup sites will be encountered and the benefits of Mobile Containment can be employed to improve the probability of achieving target cleanup goals and control the magnitude of unanticipated project costs. Examples of such locations include areas where:

1. Levels of contamination are very high (hot spots), and containment activity is likely to reduce dredging rates;

2. Capping is included as part of a combined dredging-cleanup strategy;

3. Debris fields are present and containment activity is likely to reduce dredging rates;
4. Sensitive downstream receptors (e.g., water supply intake) are present and containment activity will be necessary to prevent contamination from spreading;
5. Other containment strategies cannot be deployed (areas of high currents);
6. Low target residual concentration levels have been established as the cleanup specification and more efficient and controlled cleanup is required; and
7. On-site certification is considered important to reduce future cleanup liability.

For sites with the above conditions, the risk of escalating costs can be reduced, the cleanup of the site can be improved, and the long-term liability associated the presence of residual and dispersed contamination can be mitigated by use of Mobile Containment Technology.

REFERENCES

MCSS Database, 2004. Major Contaminated Sites Database Release 5.0, General Electric Corporation, hudsoninformation.com/MCSS/download.htm, September 2004.

National Research Council, Sedimentation Control to Reduce Maintenance Dredging of Navigational Facilities in Estuaries. Report and Symposium Proceeding, Washington, DC, National Academy Press, 1987.

Palermo, M., S. Maynard, J. Miller, and D. Reible, Guidance for In-situ Subaqueous Capping of Contaminated Sediments, EPA 905-B96-004, Great Lakes National Program Office, Chicago, IL, 1998.

Strategic Environmental Research and Development Program (SERDP), Final Report. Expert Panel Workshop on Research and Development Needs for the In-Situ Management of Contaminated Sediments, Department of Defense, Arlington, VA, October 2004.

Third International Conference on Remediation of Contaminated Sediments, Remedy Effectiveness: How Do We Make Risk Management Decisions, Bridges, T.S and Apitz, S.E. Battelle, New Orleans, Jan. 24-27, 2005.

Third International Conference on Remediation of Contaminated Sediments, Remedy Effectiveness: How Do We Make Risk Management Decisions, Doody, J.P. and Crystal, M. Battelle, New Orleans, Jan. 24-27, 2005.United States Environmental Protection Agency (USEPA), Case Studies of Environmental Dredging Projects, Vol. 5, USEPA, Region 2, April 2004a.

United States Environmental Protection Agency (USEPA), Statement of the Engineering Performance Standards for Dredging, Volume I, USEPA, Region 2, April 2004b.

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Mobile Containment and Cleanup for Subsurface Contaminated Sediment Remediation

Final Report 05-06a

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