AGENDA

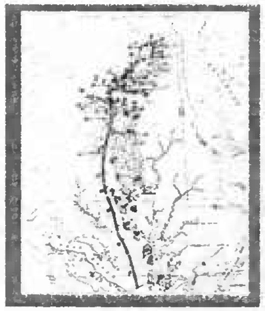
INNOVATIVE AND BENEFICIAL USE OF DREDGED MATERIAL ADVISORY COUNCIL MEETING

SEAGIRT MARINE TERMINAL
THURSDAY, JULY 27, 2000
10:00 a.m. – 2:00 p.m.

Facilitator:	Frank Hamons, Manager Harbor Development
Greetings, Introductions and Overview of Legislative Charge	Kathleen Broadwater, Director Planning & Business Development
Overview of the Port of Baltimore Dredging Needs	Frank Hamons, Manager Harbor Development
Review of the Innovative Use Industry	Maryland Environmental Service: Wayne Young, Beneficial and Innovative Overview Use Steve Storms, Review of Selected Technologies for Innovative Use Cece Donovan, Ongoing Agricultural Land Application Investigation
Design, Development and Project Status of the State's RFP for Innovative Uses	Frank Hamons, Manager Harbor Development
Open Discussion	
Scheduling Next Meeting	

Development, Review & Consideration of Alternatives for Placement of Dredged Material

Maryland
Port
Administration



1976
Hart-Miller Island EIS

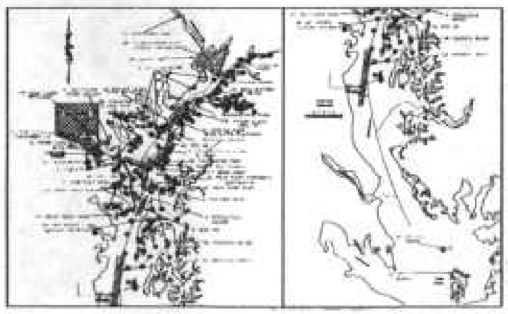
<u>70</u> Alternatives

1989
Master Plan

<u>475</u> Sites

1991
Governor's Task Force

1992 **MPA Dredging Needs and Placement Options Program**



Over <u>75</u> Sites and Concepts

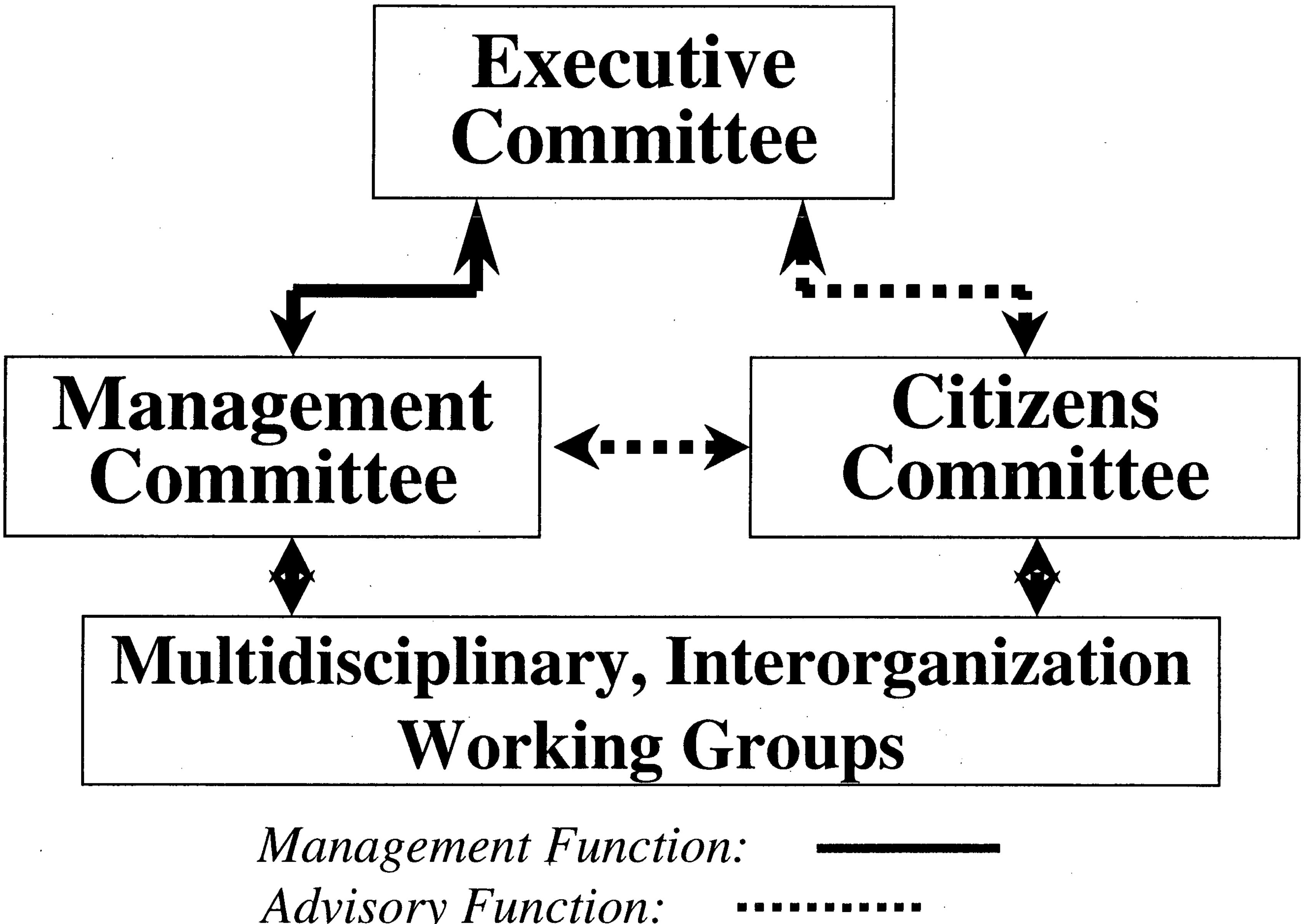
Over <u>40</u> Beneficial Use Sites and Concepts

1996 **Governor's Strategic Plan for Dredged Material Management**

- Containment facilities (2 projects)
- Expand Pooles Is. Open Water (2 sites)
- Beneficial Use (1 large-scale project)
- New Open Water (3 options)
- Island Placement Site (8 options)

Future

Dredging Needs and Placement Options Program Structure



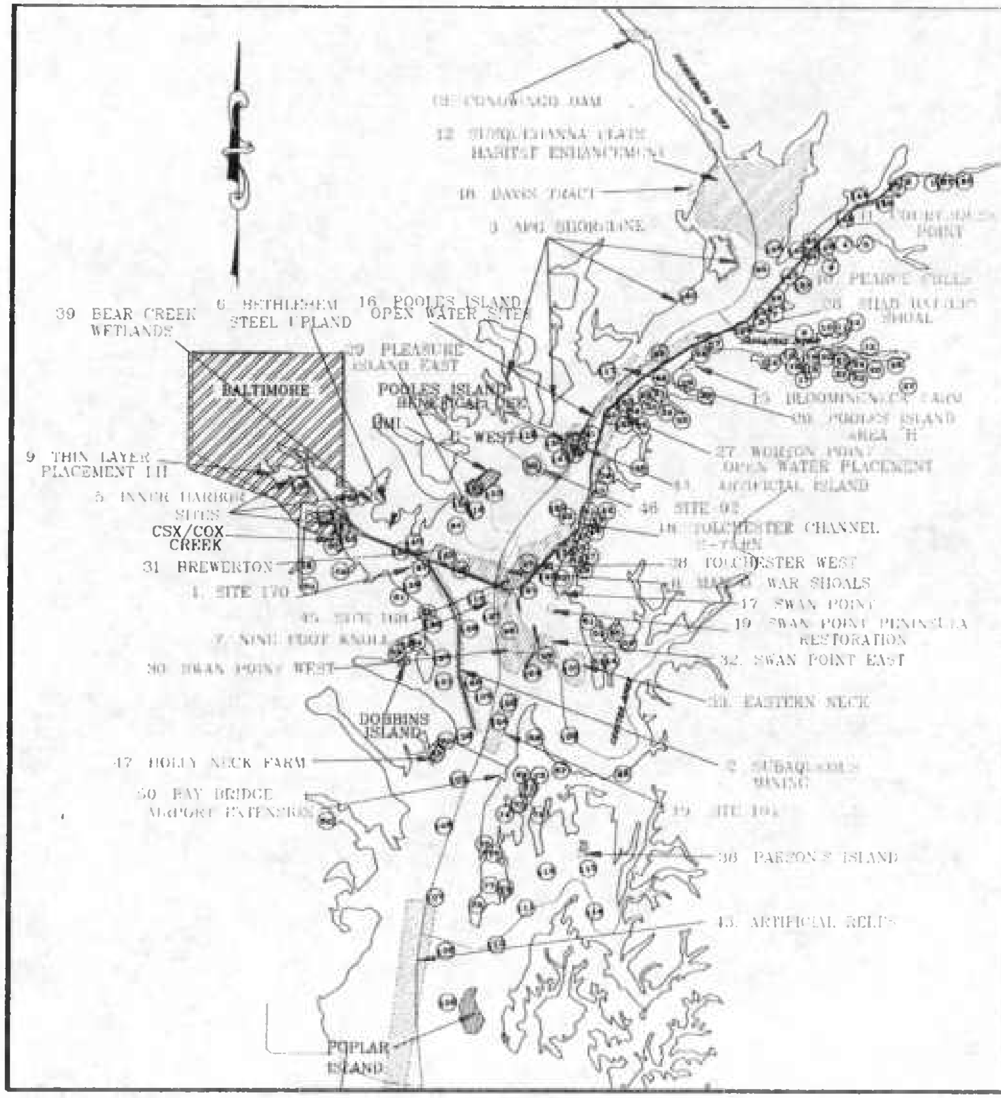
What Options Have Been Considered in Forming the State's Plan?

- Beneficial use options (examples)
  - Bodkin Island
  - Dobbins Island
  - Sparrows Point
  - Worton Point
  - APG, Spry Island
  - Eastern Neck
  - Parsons Island
  - Holly Neck Farm
  - Davis Tract
  - Barren Island
  - Smith Island
- Innovative Use / Recycling
- Open-water sites (examples)
  - Worton Point area
  - Site 171
  - Deep Trough
  - various other locations
- Upland placement
- Quarry reclamation
- Mine reclamation
- Remediation of contaminated sediments
- Ocean placement

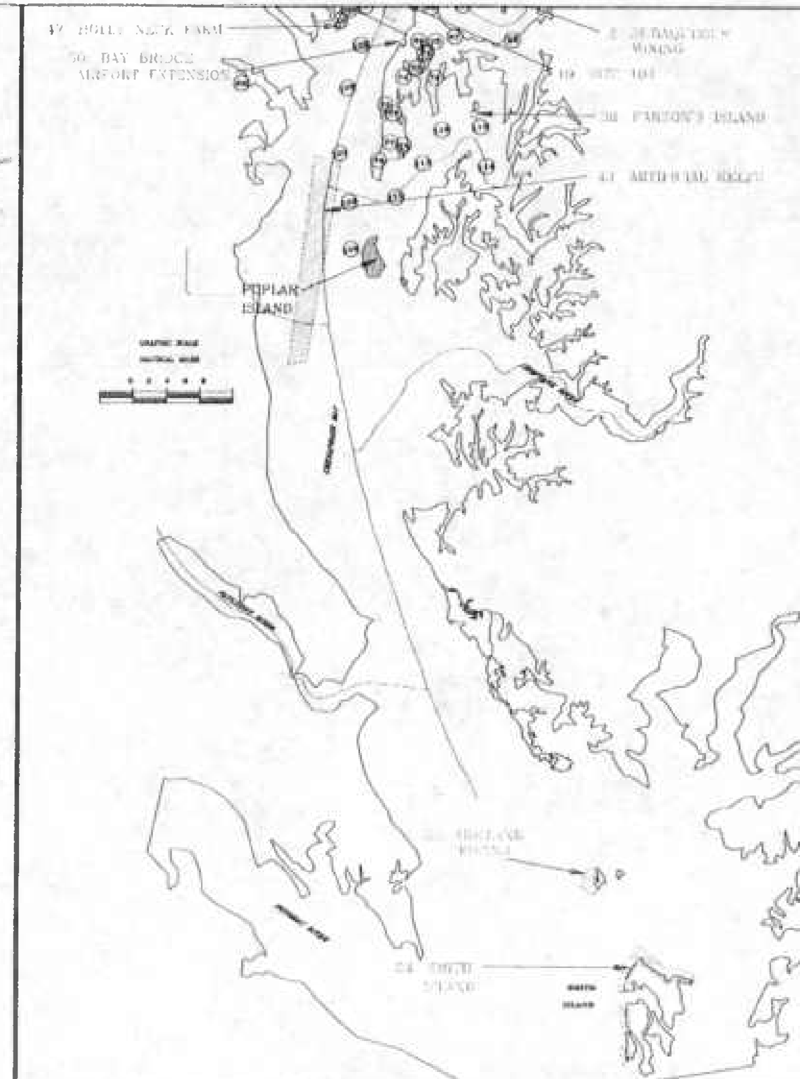
from **1992**

MPA Dredging Needs and Placement Options Program *(DNPOP)*

Master Plan "Listed" and DNPOP Options



above Bay Bridge



below Bay Bridge

MPA Applied Research: Innovative Use
University of Maryland
U.S. Department of Agriculture

MPA Dredging Needs and Placement Options Program

Beneficial Use Options

Over 40 sites and concepts (e.g., soil products)

The Technical and Economic Feasibility
of Producing Beneficial Products
from Baltimore Harbor Dredged Spoil

Maryland Environmental Service
Annapolis, Maryland

Elbridge M. Smith, P.E.
Senior Project Engineer

Walter R. Niessen, P.E.
Project Manager

28 March 1974

Prepared by
Roy F. Weston, Inc.
Environmental
Scientists and Engineers
West Chester, Pennsylvania

W.O. 1086-01

MAS D. MCKEWEN
DIRECTOR

REED W. McDONAGH
DEPUTY DIRECTOR

STATE OF MARYLAND
DEPARTMENT OF NATURAL RESOURCES
MARYLAND ENVIRONMENTAL SERVICE
TAWES STATE OFFICE BUILDING
ANNAPOLIS 21401

Phone 301-267-5351

September 23, 1974

To Whom It May Concern:

I am happy to send you a copy of the Maryland Environmental Service report "The Technical and Economic Feasibility of Producing Beneficial Products from Baltimore Harbor Dredged Spoil", which was prepared for us by Roy F. Weston Associates.

The report indicates that manufacture of a lightweight ceramic building material similar to pumice rock is technically feasible. The report also provides estimates of the cost of the process and the marketability of the product. It concludes that some but not all of the dredge spoil from dredging Baltimore Harbor channel could be disposed of by this alternative. In this regard, I would like to point out that the estimate of spoil volume is now 120 million cubic yards over the next 10 years rather than the 100 million cubic yards over the next 10 years as shown in this report.

The report was managed jointly by the planning and solid waste services of MES. I would like to acknowledge also the interest and cooperation of the Water Resources Administration and Maryland Geological Survey, and the interest of the many citizens whose comments in part stimulated this work. A limited number of additional copies are available upon request from MES by contacting either William Sloan, 201/267-5355 or Cliff Willey, 301/267-5666.

Sincerely,

Thomas D. McKewen

Thomas D. McKewen
Director

TDM:WS:am

SUMMARY

Dredging projects planned for the Baltimore Harbor area over the next 20 to 25 years are expected to produce about 100 million cubic yards of spoil. Disposal of this material is a serious environmental problem. A diked containment area in Chesapeake Bay has been proposed for the disposal of dredged spoil.

In recent months it was recognized by the Water Resources Administration and the Maryland Environmental Service, both of the Maryland Department of Natural Resources, and by many private citizens and environmental groups, that dredge spoil might be processed into a brick or aggregate material for use as a construction material. Numerous comments to this effect were made in the public review of the draft Environmental Impact Statement for the diked disposal site. In line with its responsibility for regional solid waste planning in the State, the Maryland Environmental Service contracted with Roy F. Weston, Inc. to investigate the feasibility of producing a useful and salable product from the spoil as a whole or partial alternative to a diked disposal area.

In addition to the demands for dredge spoil disposal, the Baltimore area is faced with an increasingly serious solid waste disposal problem. The study therefore was to investigate also the feasibility and economics of using solid waste and waste oil as fuel for the production process.

The Weston program included a study of available data on beneficial use of harbor spoil, and a sampling and bench-scale testing program directed at developing a useful product. Review of the available data indicated that little had been done, either in the private or in the public sector, to explore the possibility of recovering or manufacturing useful products from dredged spoil.

The program identified a number of possible products (natural aggregate, synthetic aggregate, lime, bricks and related products, and mineral or rock wool), but after the results of the sampling and experimental program were analyzed, the only viable product apparently attainable from Baltimore Harbor dredged spoil was synthetic aggregate.

The synthetic aggregate considered technically feasible and with sufficient market potential was a structural-grade lightweight aggregate. All the other products which initially appeared to hold some promise were found to be unfeasible, for a variety of technical and/or economic reasons.

The proposed system for manufacture of a lightweight aggregate might involve another beneficial usage of waste material, in that a substantial portion of the process heat requirements might be met by burning refuse and reprocessed waste oil generated and collected in the Baltimore region.

The principal conclusions evolving from the present study are:

1. A lightweight aggregate comparable in quality to competitive products could be produced from Baltimore Harbor spoil, and no major technological breakthroughs appear necessary to achieve commercialization.

2. Product-marketing limitations would prevent utilization of all the spoil at the planned dredging rate, thus requiring the provision of an interim storage site. However, this site would require no more than 51 million cubic yards, half the ultimate capacity of the proposed diked disposal complex.

3. Manufacture of lightweight aggregate could use about 1,600 tons per day of refuse to supply part of the processing heat requirements and about 600 barrels per day of reclaimed oil for the remainder.

4. If reasonable market penetration can be realized by the proposed plant, the market should be able to take 1,500 tons per day of lightweight aggregate at the outset, about 3,000 tons per day starting with Year 6, and about 4,500 tons per day in Year 11.

5. Capital investment is estimated at $60,000,000 for the initial 1,500-TPD plant, with an increment of about $60,000,000 for each future expansion of the same size.

6. Discounted cash flow analysis indicates that the project might be self-supporting if a return on investment of 9% for a non-profit (i.e., non tax-paying) operator and 12% for a private-sector operator were

realized. The latter figure is marginal for a commercial venture of this risk and magnitude, but it could be compensated for by such measures as development of more efficient spoil-recovery techniques and use of dunnage and discarded tires as fuels. The return on investment, however, involves a number of assumptions on the economics of solid waste disposal as well as on dredge spoil conversion.

These conclusions are based on a limited feasibility study and require verification. The next steps in such a verification, after further study of the economics of variations of the basic process described in this report, would be a more extensive testing and experimental program, and preliminary design of the production facility.

Offprint

WESTERN DREDGING ASSOCIATION
(A Non-Profit Professional Organization)

Journal of Dredging Engineering

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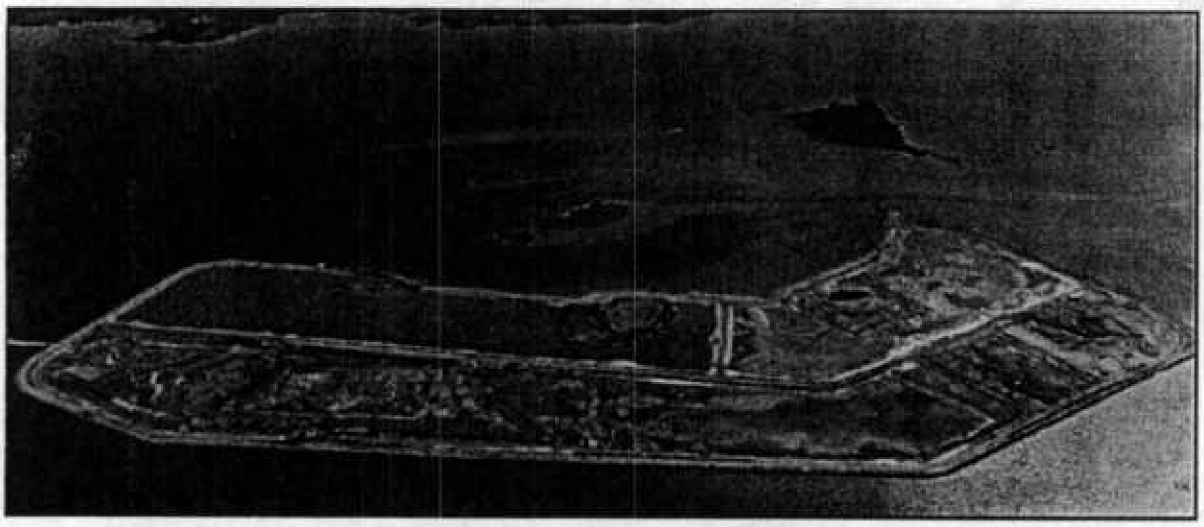

Poplar Island Restoration Project, Chesapeake Bay, Maryland

IN THIS ISSUE

Beneficial Uses of Dredged Material in the Upper Chesapeake Bay —
FL Hamons and W. Young 1

Beneficial Use of Dredged Material in the Rock Island District — MD Cox 25

Notes for Contributors 41

BENEFICIAL USES OF DREDGED MATERIAL IN THE UPPER CHESAPEAKE BAY

Frank L. Hamons[1] and Wayne Young[2]

ABSTRACT

The use of dredged estuarine sediments has been widely advocated in Maryland as a natural resource for island restoration, marsh creation and enhancement, and shoreline stabilization, and as an economic resource for making marketable products, thereby providing a solution for dredged material management that would also help enhance the Chesapeake Bay ecosystem. About 3.5 million cubic yards of sediments are dredged each year from the approach channels in the Bay serving the Port of Baltimore and Chesapeake and Delaware Canal. Most of these sediments are suitable for beneficial use as either a natural or economic resource. The Maryland Port Administration, with technical assistance from the Maryland Environmental Service, has been working to establish beneficial use as a meaningful component of dredged material management for the Port of Baltimore. But, moving from concept to application has been impeded by various environmental, social and economic factors, to the extent that only one large-scale project has been implemented as part of Maryland's strategy for dredged material management. Linking the beneficial use concept to a specific geographic location has focused attention on tradeoffs that worked against acceptability of most projects in the upper Bay. Habitat conversion from one form to another, including restoration to a prior condition, has been a significant obstacle, especially with respect to fisheries habitat. Institutional and social factors have also affected the State's ability to advance beneficial use projects. This paper discusses the past and ongoing efforts to apply the beneficial use concept in the upper Chesapeake Bay. Beneficial aspects of the multi-objective Hart-Miller Island Dredged Material Containment Facility are discussed.

INTRODUCTION

Historically, the Chesapeake Bay has experienced a considerable reduction in the acreage of islands and marshes as the result of erosion and inundation from a relative rise in sea level. For example, Spry Island and Sharps Island disappeared and are now fishing reefs. Poplar Island has eroded from about 1,400 acres in the 1670s to under 5 acres today (Leatherman et al., 1995; MES, 1994a,b). Within the watershed, vast quantities of sediments are constantly eroded, transported and deposited in the upper Bay including the shipping channels. Every year, approximately 5 to 6 million cubic yards of sediments are dredged to maintain the Port of Baltimore's navigation infrastructure in Maryland, Delaware and Virginia. Each year, over 3.5 million cubic yards of sediments are dredged from the upper Bay approach channels to Baltimore Harbor and the

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Chesapeake and Delaware (C&D) Canal. Traditionally, these sediments were placed in open water areas near the channels that were dredged. Virtually all of this material is potentially suitable for use as a natural resource to achieve environmental benefits while at the same time providing for final deposition of the dredged sediments. On face value, beneficial use is an approach that is very alluring, providing an apparent opportunity for mutual cooperation among dredging and environmental interests. Over the past 20 years, concern about the Bay's environmental health helped stimulate opposition to the open-water placement of clean dredged material. Except for modest open-water placement near Pooles Island in the northern upper Bay, the Maryland Port Administration (MPA), as local sponsor, and the Philadelphia and Baltimore Districts of the U.S. Army Corps of Engineers (USACE) were not able to establish alternative open-water placement sites. As a result, at least 2 million cubic yards of clean dredged material were placed annually in the Hart-Miller Island Dredged Material Containment Facility (DMCF).

The possibility of using dredged material beneficially rather than disposing of it as a byproduct of dredging has gained broad-based conceptual support as an alternative to traditional open-water placement in the Chesapeake Bay. Using sediments as a resource is not new to the Bay. Practical application was introduced to the lower and middle Bay as early as the mid-1970s by the USACE through a few small-scale marsh restoration and oyster reef creation projects (Garbarino et al., 1994; NRC, 1994). Expanding from small-scale to large-scale application was proposed as a way to resolve the port's placement needs in a manner that would contribute to Bay restoration efforts and overcome longstanding controversy about dredged material management.

The MPA has sponsored intense planning since the early 1980s to resolve the port's placement needs, including consideration of beneficial use. This effort lead to the State's 1996 Strategic Plan for dredged material management, which includes the 1110-acre restoration of Poplar Island (MDOT, 1996, 1998). Yet, moving from concept to practical application has proven difficult despite the efforts of the MPA and the many federal, state and interest group participants in the MPA-sponsored Dredging Needs and Placement Options Program (DNPOP). Linking the beneficial use concept to specific sites focuses attention on site-specific environmental, social and economic tradeoffs that, in most cases, work individually or collectively against project acceptability. Conversion of habitat from one form to another, especially fisheries habitat, has been a major factor in determining whether or not the environmental value that would be gained would in turn justify modifications to existing site conditions.

THE STATE'S DREDGED MATERIAL PLANNING PROCESS

The MPA uses a 20-year, forward-looking planning window for managing dredged material. The port's dredging need over the next 20 years is about 110 million cubic yards, of which 80 million cubic yards is for maintenance; the remaining quantity is for new work to enhance safety and to maintain and improve port competitiveness. Planning data are continually updated to reflect changes in actual or projected dredging needs. The long-term planning approach allows for consideration of the magnitude of the dredging need; dredging needs beyond the 20-year window; time needed to advance placement projects from concept through implementation; prospective environmental conditions; changes in technology (for dredging, placement, ships, and intermodal transportation); and, associated implications to dredged material management, port infrastructure requirements and port competitiveness. A longer planning horizon moves beyond what can be reasonably managed, except for implementation of options that begin within the 20-year window.

The State is implementing its strategic plan. The plan will provide over twenty years of placement capacity if all elements are successfully implemented at planned capacity, thereby providing a resource needed to maintain the port's navigation safety and competitive status. By taking a strong leadership, planning, design and coordination role at State expense, the State has been able to proceed with implementation in coordination with the U.S. Army Corps of Engineers but on a schedule that is independent of the early phases of the federal planning process for placement projects. This approach has overcome institutional factors that typically result in extended time periods of moving individual projects from concept to completion. Dike raising to extend the service life of the Hart-Miller Island DMCF has already been completed. The State role has expedited implementation of the Poplar Island restoration project, two open-water placement options, renovation and reactivation of a previously used containment facility, and initial investigation of a large-scale island containment in the upper Bay.

The Master Plan Initiative

Since the early 1980s, many traditional and non-traditional placement options were identified but few were supported. During the mid-1980's, 475 options were considered in the development of a draft Master Plan sponsored by the MPA (MPA, 1990). Extensive interorganizational and public involvement was purposefully included in the consensus-based planning process. The process incorporated lessons learned from the planning of the Hart-Miller Island DMCF and also included the introduction of additional alternatives, as required. It was thought that the Master Plan initiative would result in sufficient placement alternatives, thereby precluding the need for expansion of the Hart-Miller DMCF once filled to capacity in the early to mid-1990s, depending upon the ability to dewater and consolidated placed sediments. Upon closure, each cell is to be converted for recreational use and creation of wildlife habitat (Hamons, 1988).

Use of the deepest relic feature of the old bed of the Susquehanna River south of the Chesapeake Bay Bridge and north of Bloody Point on Kent Island, referred to as the "Deep Trough," emerged as a primary candidate for open-water placement. Preliminary analysis and field work determined that the area could potentially be used without causing significant environmental impacts (Versar, 1989, 1990). However, strong opposition arose from the public and environmental interest groups, and the Maryland General Assembly enacted a statute that prohibits the open-water disposal of dredged material in the legally defined Deep Trough.

The draft Master Plan was overtaken by events. A short summary report was published. A draft technical report was not published, but has been used as a resource for ongoing dredged material management planning (MPA, 1990). The lack of alternative placement sites compelled placement of large quantities of clean dredged material into the MPA's Hart-Miller Island DMCF, the State's only repository for contaminated dredged material. The facility's capacity was prematurely exhausted, necessitating raising of its dike system in 1988 (Hamons, 1988; NRC, 1994, 1997; Hamons et al., 1997).

The Governor's 1991 Task Force

With Hart-Miller Island nearly filled, Governor William Donald Schaefer appointed a task force to develop a consensus-based dredged material management plan for near-term and long-term solutions to the dredging and placement needs. The Governor's 1991 Task Force brought a panoply of state and federal agency representatives and environmental and public interest groups into a cooperative problem-solving effort in a manner similar to the Master Plan process. A consensus-based, multi-faceted approach covering a full range of placement categories was developed and recommended (MDOT, 1991). There seemed to be ample potential for beneficial use projects using dredged sediments, considering the loss of islands and marshes to physical forces at work in the Bay. The beneficial use of dredged material was recommended and emphasized as a principal element of both near- and long-term solutions. Subsequently, the planning focus was shifted to beneficial use in what can be characterized as a great and continuing experiment in shifting from a traditional to nontraditional paradigm for the management of dredged material. As discussed in later sections, the experiment has had a unique result: so far, the beneficial use concept has been capable of limited implementation on grand scale in the upper Chesapeake Bay.

Dredging Needs and Placement Options Program

The MPA and the Maryland Environmental Service (MES), an independent state environmental agency which operates the Hart-Miller Island DMCF for the MPA, collaborated in 1992 to develop the DNPOP program as the vehicle for implementing the Task Force recommendations. A multi-disciplinary, multi-organization approach with broad governmental, public and environmental interest group involvement was implemented. The MPA-sponsored program is facilitated at the technical level by MES. Executive, Management, and Citizen's Committees guide the planning process. The Executive and Management Committees are supported by information and analysis from working groups and advice from the Citizen's Committee. This approach provides for coordination at all levels of government and citizen interest.

The ongoing DNPOP program drew on the results of the earlier planning efforts as an information resource to aid the planning process. Participants initiated their planning activities by focusing on identifying and evaluating beneficial use opportunities. Over thirty-five beneficial use options have been considered since 1992 (Figure 1). The first phase of "Bay Enhancement" planning identified twenty near-term options for expedited investigation:

- restoration of Dobbins Island in the Magothy River;
- conversion of poor bay bottom at Sparrows Point to create marsh and upland habitat;
- conversion of shallow water bottom to create upland, intertidal marsh and freshwater habitat at Worton Point and prevent further erosion of a high bluff;
- restoration of Poplar Island at the mouth of Eastern Bay; and

- restoration of islands and creation and enhancement of marsh habitat at Aberdeen Proving Ground—sixteen options in the vicinity of Pooles Island and Gunpowder Neck.

Various area-specific and site-specific working groups were formed to provide technical support and advice. The Bay Enhancement Phase II Working Group was formed to develop mid-term and long-term placement options. This entire effort was characterized by extensive multi-disciplinary, multi-organization cooperative planning and assessment activities. An interdisciplinary, multi-party planning process with substantial opportunities for public participation has been a hallmark of the planning process for dredged material management for the Port of Baltimore beginning in the early 1980s.

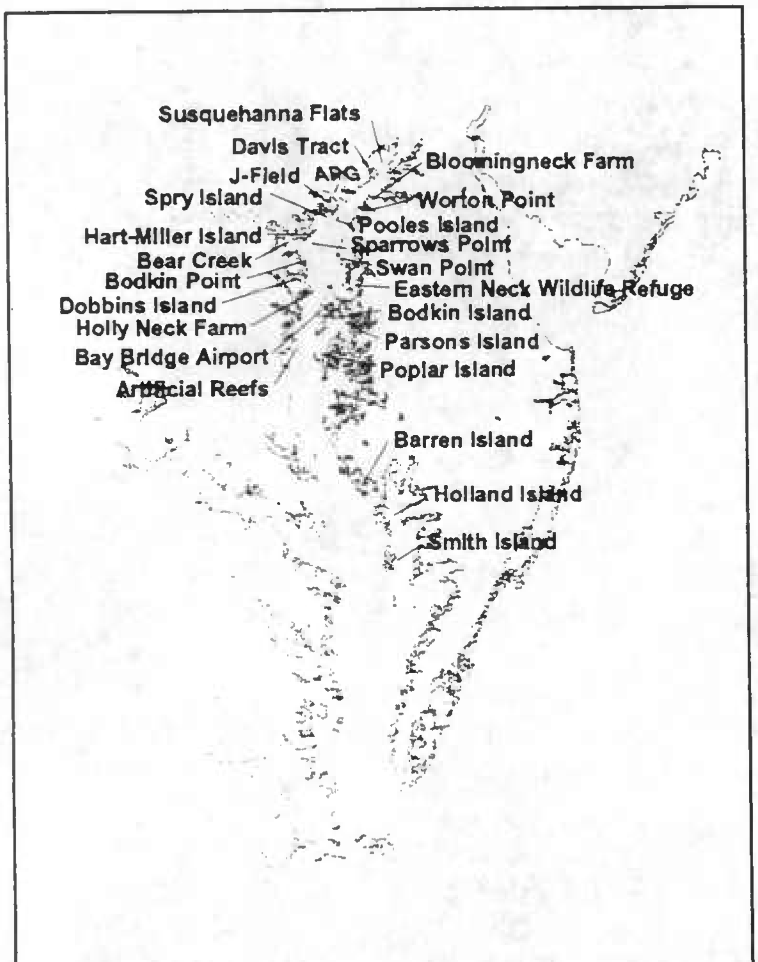

Figure 1. General locations of beneficial use projects that have been considered by the DNPOP program. Also shown is the location of Bodkin Island.

During the first half of 1995, all of the Bay Enhancement Phase I placement options, except the restoration of Poplar Island, had been determined to be either not feasible or incapable of implementation. Most of the Phase I options did not prove to be good candidates for implementation, potential environmental benefits not withstanding. In general, the linking of the beneficial use concept to a specific location resulted in identification of location-specific environmental tradeoffs. These tradeoffs usually involved the conversion of habitat from one form to another, typically at the expense of fisheries habitat.

Habitat conversion worked against project endorsement by state and federal resource agencies and other interested parties including watermen, environmental and community groups. Only the Poplar Island environmental restoration project received the institutional and popular support necessary to advance from prefeasibility studies to construction (which began in mid-1998). In this one case, the added environmental value was sufficient to balance the conversion of habitat from one form to another while the large scale of planned placements (38 million cubic yards) kept the unit cost per cubic-yard-placed within affordable limits.

Despite the dredging need and widespread interest in finding a solution to the placement problem, a broad-consensus on specific placement options was elusive. Lack of support for specific beneficial use projects was associated with:

- adverse perceptions about dredging, dredged material and material placement;
- concerns and fears about the environmental quality of dredged sediments and their potential effects;
- environmental tradeoffs that are associated with virtually all placement options;
- social tradeoffs associated with some options;
- competing environmental missions and interests of the various interested parties; and
- the typically high cost of non-traditional placement options.

By mid-1995, with Poplar Island construction still several years in the future, urgent action to provide near-term placement capacity became imperative. The Hart-Miller Island DMCF was predicted to be filled in 1996 and the small-scale Pooles Island open-water sites had only an estimated two years of placement potential remaining.

STATE OF MARYLAND'S STRATEGY FOR DREDGED MATERIAL MANAGEMENT

The inability to broadly implement beneficial use options precipitated urgent planning by DNPOP participants in the first half of 1995 to avoid a dredging crisis that would have otherwise occurred during the winter of 1996-1997. A multi-faceted plan was developed which combined traditional, non-traditional and innovative management solutions into a balanced strategy for resolving near-term placement deficits while also providing long-term capacity. The State's strategy was formally announced by Maryland Governor Parris Glendening in September 1996. The objective is to provide 20-years or more of placement capacity for deep-draft channel dredging requirements in Maryland waters. The approach is reminiscent of the 1991 Task Force recommendations in that the State's plan called for a balanced program by type of placement, location and cost.

State Strategy for Dredged Material Management

The main features of the State's strategy included:

- raising the elevation of the north cell dike system at the Hart-Miller Island DMCF (along with accelerated development of the facility's south cell for recreational and wildlife uses);
- construction of the Poplar Island restoration project;
- renovation and reactivation of a previously used containment site in Baltimore Harbor;

- additional small-scale and large-scale open-water placement in conjunction with voluntary funding of the State's oyster recovery program by the MPA; and

- development of a large placement island in the upper Bay with a beneficial use component.

The cooperating State of Maryland Departments and Federal agencies prepared and signed a Statement of Cooperation to implement the strategy, subject to applicable rules, regulations and institutional regulatory responsibilities. Implementation of the full strategy is well underway.

The DNPOP program remains operative to assist in implementing the strategic plan and to find and screen supplemental placement options including beneficial use. The MPA also is sponsoring applied research into the potential for using suitable sediments in farming operations. The research is being managed by MES and performed by research facilities of the U.S. Department of Agriculture and the University of Maryland. The MPA has also acted on its announced interest in the use of dredged material as an economic resource. A preliminary review of available technologies and techniques was performed by MES for the MPA, and the MPA has initiated a procurement process for an innovative use system.

Implementation of the State's Strategy

The Hart-Miller Island DMCF north cell dike system was raised a second time in 1997 as the first component of the State's strategy. The objective was to provide additional capacity over the next 10-years (Hamons et al., 1997; NRC, 1997). Conceptual planning for the South Cell habitat development of Hart-Miller Island was performed by the Baltimore District for the Maryland Department of Natural Resources (MDNR) with support from the MPA and technical support by MES. The MPA sponsored the planting of vegetative test plots in the cell in order to generate field data to support the planting of vegetation upon cell development. Baltimore County sponsored construction of a beach stabilization and nourishment project at the MDNR State Park along the western side of the containment facility.

Two new, small-scale, open-water placement sites near Pooles Island were designated for use by the Philadelphia District. In February 1999, the Baltimore District released a draft Environmental Impact Statement for reactivation of a previously used open-water placement site for large-scale placement immediately north of the Chesapeake Bay Bridge. The MPA is currently completing a prefeasibility investigation for the upper Bay island placement site component of the State's plan. Each of these activities has been supported by interdisciplinary, multi-party technical working groups which have included participation by watermen, charter boat captains, and sports fishermen who participate on the DNPOP Citizen's Committee. Although all participants do not necessarily favor individual options, they nevertheless have worked cooperatively to achieve the best possible overall results.

BENEFICIAL USE CASE SUMMARIES

Over 35 beneficial use options have been screened for technical feasibility, environmental effects, and prospective costs (Figure 1). Selected options are summarized in this section to highlight important considerations that have affected project planning and capability for implementation. Also reviewed are beneficial aspects of the Hart-Miller Island DMCF.

Island Restoration

Under the DNPOP program, restoration of island habitat became an early avenue for beneficial use planning because of the reduction and loss of island habitat at various locations in the northern half of the Chesapeake Bay estuary. It was thought that there would be broad-based support for such restorations, and that this would facilitate planning, design, funding and implementation. This planning assumption proved to be inaccurate for most proposed projects.

Dobbins Island, a small remnant island in the Magothy River north of Annapolis, was one of the first sites proposed for restoration. The island remnant consists of a narrow, high and eroding sediment bank with woody vegetation. Eroded sediments affect water quality in the general vicinity of the island. Placement of several hundred thousand cubic yards of clean dredged material inside of a dike system to expand the island's upland acreage, prevent further erosion, and create marsh habitat was suggested but was ultimately found to be impractical. Shallow water habitat surrounding the island remnant would be converted. Concern about the effect on wind patterns was raised by individuals who race sailboats in the lower Magothy River. It was also determined that the potential placement capacity was insufficient to make a meaningful contribution to the Port's dredging needs. Further, the shallow depths at the entrance to the river made barge access impractical. The distance from most dredging sites made hydraulic pipelines impractical. There was also lack of consensus regarding environmental effects. Although a small-scale beneficial use project at Dobbins Island might prove feasible, the site was found unsuitable for a port-related project.

Aberdeen Proving Ground (APG) has been frequently advocated by many individuals as an appropriate location for the placement of dredged material. On face value, APG would seem to be an appropriate location for multiple beneficial use projects. This U.S. Army post covers about 72,000 acres along the western shoreline in the northern upper Bay. The post's eastern boundary is near to and directly accessible from the western approach channels to the C&D Canal. About 40,000 acres of the post consist of open water. The remaining area consists of about 15,000 acres of wetlands and 17,000 acres of terrestrial habitat and developed areas. The post has over 55 major tenants and extensive military activities including research and development, many of which are classified.

Since its inception, the DNPOP program has focused considerable attention on the potential of APG. A multi-disciplinary working group was formed to help investigate possible beneficial use options at APG. A combination of sixteen sites and configurations was developed, a number of which involved island enhancements and restorations. None of the options have proven capable of implementation due to lack of consensus and environmental impacts resulting from a combination of resource conflicts, chemical contamination, presence of unexploded ordnance (UXO), conflict with military missions, and limited capacity. The difficulties associated with projects at APG are illustrated by several of the island restoration and enhancement placement options that have been proposed.

One early proposal was restoration of Spry Island which had been lost to erosion. The site is now a shoal at the mouth of the Gunpowder River. Although inside of the APG boundary, the shoal is adjacent to the southern boundary and is outside of existing active military ranges at the Army post. Because the shoal has become fisheries habitat, its restoration to upland and marsh habitat was not supported by resource agencies with fisheries management responsibilities. The shoal is used for commercial fishing by Maryland watermen who also objected to conversion of the existing habitat for island restoration purposes (MES, 1994a). Restoration of Spry Island proved incapable of obtaining the broad-based support necessary for implementation.

Pooles Island was also proposed as a location for beneficial use projects (MES, 1994a). Initially, six options were proposed but were not capable of implementation because of environmental tradeoffs. Three containment island configurations in the Pooles Island area, including one that would connect to the island, are under consideration as candidates for the island containment component of the State's strategic plan. The containment island component includes incorporation of beneficial use to an extent yet to be determined.

Beneficial use projects in the vicinity of Pooles Island within the APG boundary have been opposed by APG because of: significant environmental value of the island and surrounding waters in their present state; active use of the island and vicinity for military missions; the presence of UXO; and, the fact that large portions of the post, including Pooles Island and all of the Edgewater Peninsula and Gunpowder Neck, are listed as Superfund sites under CERCLA.

Pooles Island is a relatively large island located in the middle of the northern upper Bay. The island is mostly wooded, but also has freshwater wetlands and ponds between its northern and southern sections. The ponds are used heavily by migratory waterfowl. The southern portion of the island is home for a large heron rookery that typically has about 1630 active nests each year. The island is also populated by deer and other wildlife. The Bay bottom immediately east and west of island contains a variety of physical conditions, some of which is considered important fisheries habitat by natural resource agencies and sport and charter boat fishing interests. There is an historic lighthouse on the northwest side and an underwater wreck west of the island. Because the background erosion rate is minimal with some accretion, the existing island habitat is not considered threatened.

The UXO issue is currently a showstopper for all potential beneficial use projects at the facility. The significance of this issue became apparent while DNPOP planners and resource agency participants were attempting to advance a small-scale shoreline protection and enhancement project at "J-Field" along the tip of Gunpowder Neck immediately west of Pooles Island. APG representatives estimate that between three and thirty million rounds of UXO are located throughout and immediately outside of the APG boundary. There is no national standard for the remediation of UXO. Therefore, the worst case situation would be removal and disposal at substantial cost. The technology for locating UXO at underwater locations is limited and removal is difficult and dangerous. With respect to beneficial use, the lack of a remediation standard means that if a marsh creation were undertaken to encapsulate an area, the marsh would have to be excavated to get to possible UXO should removal and disposal become the remediation standard.

Another complicating factor is that there is no definitive legal precedent regarding liability for UXO contaminated areas and remediation. Therefore, a representative of EPA Region 3 advised that one must assume the worst case situation with respect to liability, which is that any involvement whatsoever could lead to designation as a potential responsible party for any remediation that might subsequently be required. Thus, beneficial use within the entire APG controlled area is institutionally constrained indefinitely.

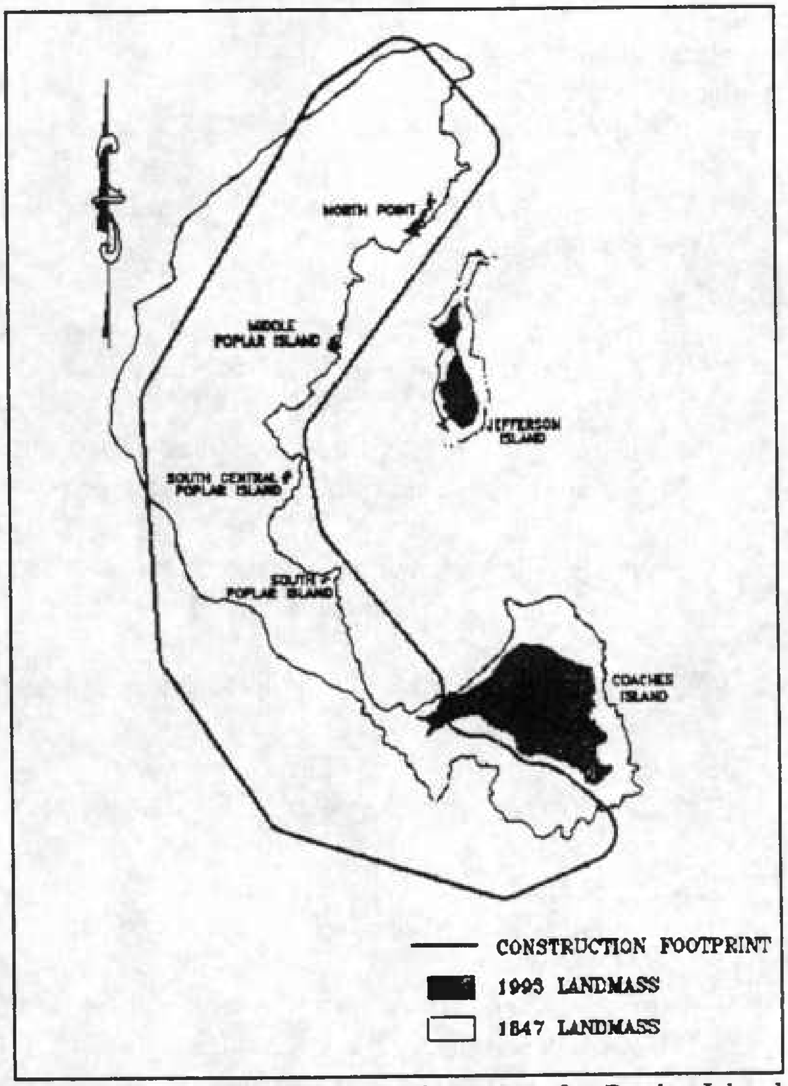

Figure 2. Plan view of general concept for Poplar Island restoration. The dike alignment was adjusted to a small extent from that shown to accommodate site-specific conditions.

Poplar Island in Talbot County at the mouth of Eastern Bay is the site of the only beneficial use option within the DNPOP program that has obtained the support needed to advance from concept to implementation. The island experienced rapid erosion over the past 50 years after suffering multiple breaches during a major episodic storm. Ownership of the remnants was obtained for the State through a real estate transaction. In 1993, MES obtained a grant from the Environmental Protection Agency (EPA) Chesapeake Bay Program and a matching cost share from the MPA to install obsolete barges as a temporary breakwater around Middle Poplar Island, preserving valuable nesting habitat until the remaining islets could be incorporated into the full-scale restoration project. The EPA Chesapeake Bay Program, through its Living Resources Subcommittee, provided several additional grants to assist with project planning and installation of rock reefs for fisheries habitat.

The first phase of the project consisting of 640 acres of uplands and wetlands is under construction by the Baltimore District, U.S. Army Corps of Engineers (USACE), as a beneficial use project under terms of Section 204 of the Water Resources Development Act of 1992. The MPA is the local sponsor. Construction of the first phase is nearing completion. Authorization and funding for the second phase have been obtained by the Baltimore District and the MPA. The contracting process for the second phase of the project was in progress during Spring 2000, with an award expected in time to begin construction during the last half of the year. Each phase will hold approximately 19 million cubic yards of clean dredged sediments.

The planning and design for the Poplar Island restoration was accomplished in a total of 7 years, a significant reduction in the time frame for similar federal navigation-related projects (Fulford, 1994; MES, 1994b; Mohan and Urso, 1997). The accelerated schedule was made possible by:

- the prospect of imminent loss of valuable habitat which helped motivate consensus about the project;
- the local sponsor's assumption of reconnaissance, feasibility assessments, planning, engineering, design and environmental studies;
- integration of multi-organizational, interdisciplinary working group support into the planning and design activities as a component of the DNPOP program;
- the opening of new areas for commercial clamming by MDNR to offset a loss of clam beds within the prospective island restoration footprint;
- special Congressional funding authorization as a Section 204 project in excess of annual funding caps;
- concurrent performance of NEPA documentation by the Baltimore District; and
- expedited approval of final design by the Baltimore District once the restoration was authorized as a federal Section 204 project.

Of particular importance is the fact that although most of the island's historical footprint had been converted to shallow water habitat, this habitat had not yet achieved high environmental value for fisheries. The involvement of all interested parties in the process was also very important to consensus building and to achieving "ownership" of the solution by the panoply of participants. Overall, all parties concluded that restoration would achieve substantially greater environmental value for the Bay ecosystem than would be allowing complete loss of the islands to erosion. Impacts that would occur to a small, localized clam fishery were accommodated by MDNR through the opening of other areas for commercial clamming.

Another important factor is funding. There is limited federal funding for beneficial use projects, either under Section 204 or as the least cost placement option for channel dredging projects. Section 204 has an annual cap of $15 million in total for all projects. Further, Section 204 has typically not been funded to this level and the funds are competed for on a national basis. The first phase of the Poplar Island restoration, the northern half of the project, is estimated to cost about $46 million. It consists of 640 acres that will be configured into an upland cell on the west and two wetland cells on the east.

Section 204 funding is obviously not sufficient to enable large-scale beneficial use projects as a practical component of dredged material management projects. Either special funding as a Section 204 project or specific authorization as a navigation project through a Water Resources Development Act would be needed. In the case of Poplar Island, the Maryland Congressional Delegation recognized the value of the restoration project and was able to coordinate a funding authorization in excess of the annual cap on Section 204 funding. Considering the costs of large-scale beneficial use projects and interest in them in other port regions, competition for federal funding is likely to remain high.

Island Protection and Enhancement

Small and modest-scale protection and enhancement projects have been proposed for some existing islands. For example, a non-port-related beneficial use project has been designed to expand habitat at Bodkin Island using dredged material from small federal navigation projects (Maynord, et al., 1991). However, small-scale island protection and enhancement projects such as those shown in Table 1 have not been practical for implementation to help resolve the port's dredged material placement needs. Reasons include one or a combination of the following factors: limited placement potential; environmental effects; cost of planning, design, environmental documentation, construction, and transportation; the level of effort and resources required to develop multiple placement options.

Table 1. Island Protection and Restoration Options

Location	Characterization	Evaluation
Eastern Neck Island National Wildlife Refuge	National Wildlife Refuge Prior small-scale beneficial use project using segmented breakwaters and sandy dredged material to protect eroding shoreline and create shallow water habitat.	Placement potential limited to about 50,000 cubic yards without significantly altering the character of existing habitat. Small placement potential relative to Port dredging need.
Parsons Island (privately owned) (Figure 3)	100-acre island in agricultural use. Eroding at a rate of about 2 acres per year. Eroded material believed to adversely impact nearby oyster beds. Owner interest in preserving habitat for migratory waterfowl.	Potential to double acreage to 200 yards. Submerged aquatic vegetation surrounding island would be impacted. Potential for between 1 to 3.5 million cubic yards of placement.
Barren Island	Prior modest-scale beneficial use projects to protect eroding shoreline. Site is up to 60 miles down bay from channels.	Placement potential for marsh creation is 500,000 cubic yards. High transportation costs and small placement potential relative to dredging need.
Holland Island (privately owned)	85-acre island used primarily for recreation. Size at time of early settlement was 260 acres. Site is up to 60-70 miles down bay from channels.	Potential for modest to large-scale beneficial use project. High transportation and construction costs.
Smith Island (state and private lands)	Historic fishing community. Significant losses of habitat due to erosion and relative sea-level rise. Site is 65-75 miles down bay from channels.	Potential for modest to large-scale beneficial use project. Fine grained sediments not well suited for raising island elevation, although suitable for marsh creation and enhancement. High transportation and construction costs.

When additional transportation and construction costs of perhaps as much as $10-25 dollars or more per cubic yard are compared to the large-scale dredging need, it becomes apparent that shifting to down-bay beneficial use projects could add tens to hundreds of millions of dollars in placement costs relative to upper Bay options. Considering how the Army Corps of Engineers calculates local cost share responsibilities and the technical feasibility of open-water placement sites relatively near the channels being dredged, the increased transportation costs may have to be borne by the State. Nevertheless, the options shown in Table 1 were considered and are still possible options for supplemental dredging needs, along with several other potential options that have been suggested.

Shoreline Stabilization and Enhancement

Small-scale through large-scale shoreline protection and enhancement projects have been proposed for various upper Bay locations (Figures 1 and 3). None have been practical and capable of implementation. Impediments to implementation have been related to limited placement potential; environmental effects; cost of design, environmental documentation, construction, and transportation; lack of consensus; institutional constraints; or a combination of these factors. The smaller projects typically were not suitable because of a combination of limited capacity and adverse environmental effects. Two large-scale projects were proposed but have not been capable of implementation.

Figure 3. Field evaluation of Parsons Island by MPA, MES and U.S. Fish and Wildlife Service team as a possible site for an island restoration project. *(W. Young, MES)*

Sparrows Point is located on the north side of Baltimore's Outer Harbor. The existing shoreline is upland composed of slag materials from operations by the Bethlehem Steel Corporation

(Figure 4). The bottom in the area is very soft and of marginal value for fisheries. A beneficial use project of about 300 acres with a placement potential of ten million cubic yards was proposed in 1992. The project was to consist of a breakwater to create productive wildlife habitat including aquatic and intertidal wetlands, high marsh, and upland nesting areas. The proposed project was also envisioned as providing aesthetic relief for the entrance to the harbor.

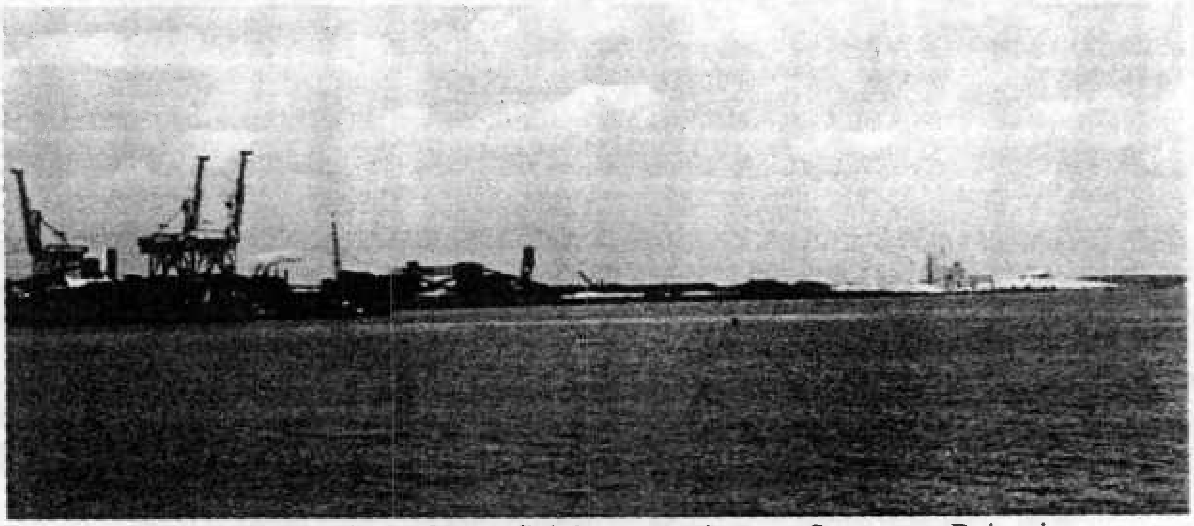

Figure 4. Proposed location of beneficial use project at Sparrows Point in center of picture. *(W. Young, MES)*

Preliminary engineering determined that a project was feasible, although bottom conditions might necessitate "floating" the dike on top of geotextile fabric. An assessment determined that the area's biological productivity is similar to that of other areas inside the harbor, but less productive than the Bay (MES, 1995b). However, inasmuch as a closed dike system was required, implementation was considered by some to be institutionally constrained by a State law that prohibited construction of a containment site within five miles of the Hart-Miller-Pleasure Island Chain. This law had been enacted in response to citizen opposition to construction of the Hart-Miller Island DMCF in Baltimore County and fears that an additional containment facility might be constructed in the county.

The Sparrows Point concept was presented to local citizens. Citizen support for the beneficial use project and for a revision to the law was not obtained. Local citizens expressed anger at the past filling of open-water areas by the steel mill and strongly objected to the conversion of any additional open-water areas, regardless of the potential environmental benefits.

Worton Point in Kent County was proposed in 1992 as the site for a 200-acre beneficial use project with a potential capacity of about eight million cubic yards for clean dredged sediments. The concept consisted of preventing erosion and creating important habitat through construction of an armored dike system, and filling to create fastland, tidal wetlands, upland and freshwater ponds. The point is wholly owned by one landowner. It is immediately south but outside of the northern portion of the upper Bay, which has been designated as a rockfish spawning area. The point consists of eroding cliffs that are adversely affecting water quality in the area (Figure 5).

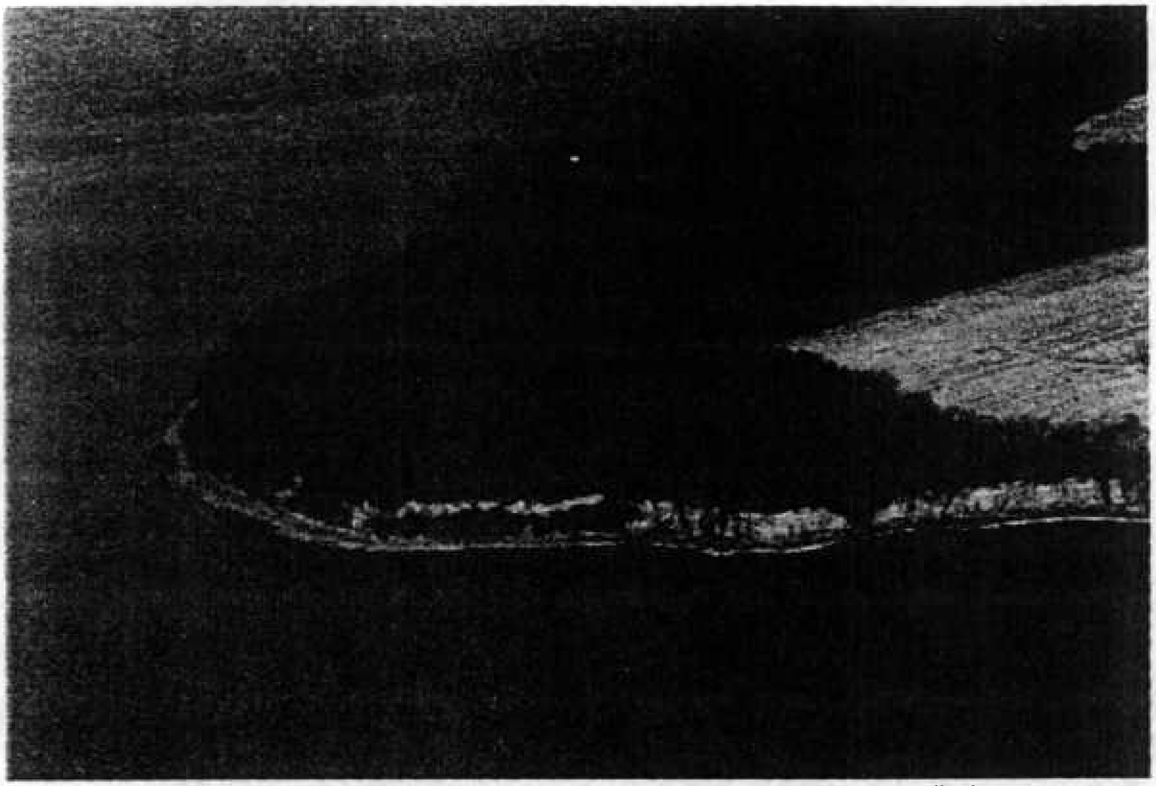

Figure 5. Proposed site of marsh and upland creation at Worton Point to prevent shore erosion. *(T. Banta, MES)*

Extensive multiparty, interdisciplinary working group planning and evaluation were performed including involvement by engineers contracted by the property owner. Issues included conversion of shallow water habitat, potential impacts to a small, seasonal recreational fishery, and potential effects on upwelling from a nearby deep hole considered beneficial to rockfish foraging. However, no fatal flaws were identified. Despite these environmental tradeoffs, the potential habitat benefits were considered sufficient to merit detailed investigation (MES, 1994a). The Philadelphia District, USACE, prepared a plan of action for a reconnaissance study. An assessment of finfish data was prepared (MES, 1996). In response to a request for a right of entry for the purpose of performing geotechnical and groundwater investigations, the landowner unexpectedly withdrew support in 1995, ostensibly over environmental concerns. Repeated efforts to obtain the landowner's cooperation have not been successful. Technical feasibility remains uncertain.

Hart-Miller Island Multiple-Use Project

The Hart-Miller Island DMCF is typically thought of only as a confined disposal facility. It is in fact a multiple-use project that already has provided substantial environmental and recreational benefits. As part of original agreements upon establishment of the complex, the State is committed to converting the containment cells for use by wildlife and for recreation once the cells are filled. As part of the official response to the dike raising in 1996, the Maryland General Assembly enacted a statute turning the State's commitment into binding requirements.

Environmental and Economic Contributions. The original dike system reunited and protected the remnants of Hart and Miller Islands. A recreational beach was constructed between the remnants and the western dike (Figure 6). The dike system has provided shelter for a constructed beach and helped preserve shallow water habitat surrounding the remnants and the island habitat that remained at the time of construction. It has also provided physical protection for the shorelands to the west from wind-generated waves and winter storms as well as protection from the movement of large ice floes during cold winters. In contrast to the incorrect characterization of the containment cells as wastelands by some individuals, the complex provides important habitat for shorebirds and migratory waterfowl. There is habitat suitable for seasonal and year-

Figure 6. West side of Hart-Miller Island during the summer boating season. Recreational beach protected by segmented breakwaters shown in center of picture. *(L. D. Heath, MES)*

round use by a variety of species. The remnant islands are used by small mammals and birds. Ospreys establish nests around the complex. Commercial crabbers fish the area on the east side of the facility. Commercial pound nets have been placed in the vicinity of Miller Island during the Fall.

Containment Cell as Interim Habitat. The containment facility's north cell (active) and south cell (filled) have, in effect, served as "interim" wildlife habitat even while in use for dredged material management. Human access to the cells is limited to dredged material management. Food sources have been replenished annually through the placement of dredged sediments. The sediments contain benthic organisms that attract large numbers of birds during fall through spring migrations. Since 1977, over 268 different species have been observed and documented in and around Hart-Miller Island by bird watchers from the Maryland Ornithological Society. Ducks use the cells as breeding and nursery habitat.

Recreation. The island remnants and beach have been a State Park since the creation of the facility in the mid-1980s. Since that time, the sheltered cove between the former island remnants, constructed sandy beach, vegetated low dunes, upland and wetland habitats, and upland recreational wooded areas have attracted thousands of boaters, recreational fishermen, crabbers, picnickers, sunbathers and bird watchers. Additional recreational facilities have added to the park's attraction as a boater destination and recreation site. Improvements include a comfort station with showers, an observation tower, a park office and multi-use building, a deck with picnic tables overlooking the woodlands and wetlands, a boardwalk to and from the beach, and primitive campsites. The comfort stations have incorporated self-composting toilets as an environmental attribute. The beach was recently stabilized, protected and nourished through the construction of segmented breakwaters, rip rap to protect portions of Miller Island, and nourishment using sand dredged from a nearby channel that was stored at the containment facility for this purpose (Figure 6). The beach improvements were sponsored by Baltimore County. MES provided on-site construction management support. Although the park attracts recreational users most of the year, the principal recreational use occurs from late Spring through early Fall. During peak weekend periods, up to 1,200 pleasure boats have been observed at the island. Up to 70,000 individuals and 3,100 overnight campers have visited the park annually during peak years.

USE OF DREDGED MATERIAL AS AN ECONOMIC RESOURCE

During the search for suitable placement options, there have been frequent inquires regarding the potential for the "recycling" of dredged material from the Bay to beneficial uses. The MPA has desired to include innovative uses in the DNPOP program since its initiation, with the objective of using dredged sediments as both a natural and economic resource. Initially, the MPA established a long-term goal to develop a capability to recycle up to 500,000 cubic yards of sediments annually. Subsequently, the MPA expressed interest in achieving a capability in ten years to recycle up to 2 million cubic yards of dredged material each year, insofar as practicable and cost competitive with other dredged material management options. Although a formidable goal, the current advancement in technologies for innovative management of the dredged material stream suggests that economic use of sediments on a large-scale may by achievable within the next decade.

Landfill Applications

In 1995, the MPA and MES conducted a field trial to assess the technical and economic feasibility of using selected dredged material in the construction of a landfill cell. Although most material received by the Hart-Miller Island DMCF consists of fine silts and clays, sandy material is occasionally received and stockpiled. About 14,500 cubic yards of clean sandy material was mechanically excavated from one of the stockpiles. The material was barged to Easton, Maryland. The material was offloaded and trucked to the Midshore Regional Solid Waste Facility owned and operated by MES for four counties. The material was placed on top of a geotextile liner during cell construction. The cost of excavation, multiple rehandling and transportation was about $14 per cubic yard, not including the initial cost of dredging, placement and stockpiling. The approach was not cost-competitive with other sources of suitable construction materials on the Eastern Shore, although the field trial was technically successful (MES, 1995a).

Turning Mud into a Cash Crop

Clean dredged sediments have been placed on farmland in various locations around the country. After weathering of the sediments and sometimes the application of amendments such as lime, the lands have been returned to active agricultural use. In some cases, such as in New Jersey along the Delaware River near Camden, lowlands along the river have been filled and subsequently farmed. In one case, a farmer "hayed" phragmites and fed it to his cattle (Landin, 1997). Farm application of clean dredged material has occurred for many years in Maryland, albeit on a small scale, and is typically associated with maintenance and improvement of federal and county small boat channels and private marinas. Generally, several acres of land with riparian access are leased from a farmer. Compensation is typically per-cubic-yard placed plus preparation of the soils for crops. The topsoil is scraped off and formed into a berm to hold hydraulically placed clean sediments in thin lifts of 1 to 2 feet to enable natural dewatering. The topsoil in the berms is then bulldozed back over the acreage. Soil amendments such as lime are often added. The topsoil, soil amendments and sediments are mechanically tilled and blended. and the acreage is returned to active farming (Duff and Corletta, 1997).

Although the concept of farm application has been applied for many years, there is little documentation to guide future applications. However, the fact that there is considerable farmland reasonably accessible from the upper Chesapeake Bay, the concept of returning suitable sediments to farms could aid in the dredging of ship channels while helping offset the longstanding effects of soil erosion from upland locations. The MPA is sponsoring applied research into the farm application of clean sediments from approach channels in Maryland waters. The research includes identifying which soil amendments might be needed and crop suitability. This research is being managed by MES for the MPA. Field research is being performed by the University of Maryland, College of Agriculture, Wye Research and Education Center (Wye). Technical analysis is being performed by U.S. Department of Agriculture - Agricultural Research Service - Beltsville Agricultural Research Center (USDA). Bench scale testing is being performed at the Wye facility to collect and assess leachate and soil quality changes over time from both untreated and amended sediments. Germination and production of various crops are also being studied. The results of the bench testing will be used to assess geophysical conditions that would be suitable for farm application. The results will also be used in the planned planting, monitoring and analysis of field test plots at the Wye facility. USDA is also doing bench-scale testing focusing on industrial and agricultural residuals which could potentially be combined with dredged material to make a value-added agricultural product. Both research facilities are performing literature searches and reviews.

Although we believe that there is significant potential for farmland use of clean dredged sediments at suitable locations, obtaining public support for farm application will require considerable coordination and demonstration of suitability. For example, a private venture, Creative Environmental Solutions, attempted to acquire and use several Eastern Shore farms very near the Bay for the placement of clean dredged material. The concept was to adapt the small acreage approach described in this section to a larger scale with multi-year placements along with aesthetic landscaping and annual planting of suitable crops that might provide interim habitat and help with dewatering. Stiff opposition was encountered from nearby residents and citizens who considered the approach a threat to their quality of life and property values. Dredged material was also inaccurately characterized as sewage sludge. The proposal was ultimately withdrawn.

Innovative Use of Clean and Contaminated Sediments

The MPA has for many years been interested in the potential beneficial use (sometimes referred to as "beneficial reuse") of clean and contaminated sediments for innovative commercial applications. The MPA issued a Request for Proposals (RFP) in December 1999 for establishment of an innovative use system at the Cox Creek containment facility, located in the harbor area, that is being renovated and reactivated. The MPA is hopeful that "perpetual" capacity might be achieved in the future by using the containment facility as a receiving site and the adjoining upland property as a processing site for the production of environmentally suitable marketable products and end uses from contaminated and clean dredged sediments. Products and end uses and any waste streams from the innovative use system would need to comply with applicable regulatory criteria. A phased approach from bench tests through full-scale production is included in the RFP. MES is providing planning and technical support to the MPA for this activity, drawing on certain experience from the agency's environmental services and waste management service area, including the processing and marketing of recyclable materials.

The innovative use of dredged material on a large scale may or may not prove to be a near-term solution. However, technological developments suggest that innovative uses have the potential to become practical and cost-competitive to some extent over the next decade. Issues for consideration include:

- availability and suitability of technology;
- processing requirements;
- capability to produce environmentally sound products and end uses;
- capability to minimize or avoid waste streams, and associated regulatory requirements;
- availability and capability for contracting proprietary or patented technology and processes;
- marketability of products including possible competition for existing markets and market creation;
- public and consumer acceptance of products and end uses, especially for products produced from contaminated sediments;

- innovative use potential relative to dredged material management need; and
- cost-effectiveness.

Ultimately, innovative use will only become successful if the products using dredged sediment can be cost-effectively marketed or otherwise used in an environmentally appropriate manner, regardless of how well the various technologies may perform.

LESSONS LEARNED

Much has been learned through the identification, screening and assessment of a full range of placement options, especially beneficial use opportunities. The lessons and insights gained serve as the context for determining the practicality, technical feasibility, cost-effectiveness, and environmental acceptability of beneficial use in the upper Bay insofar as habitat development, enhancement, and restoration are concerned. These lessons and insights may also be adaptable to beneficial use planning in other areas, depending upon local conditions.

Scale of Dredging Need is Fundamental to an Effective Strategy

Recognition of the scale of the dredging need is a key to effective strategic planning. A continuing large-scale dredging need necessitates a large-scale solution, a long-term planning horizon, and economies of scale. It has been our experience that if the problem-solving for the dredging need is viewed over the short rather than long term, then small-scale projects with limited capacity and typically high costs often appear to be more attractive than they are relative to actual placement needs. The considerable effort that is required to plan, design and permit small-scale beneficial use projects can approach the level of effort required for large-capacity projects without the corresponding economies of scale. This does not mean that small-scale projects do not have a role. Options with limited capacity can potentially help, for example, to satisfy increased placement needs in certain years. However, small-scale beneficial use projects have not been sufficient to resolve the overall placement needs either in terms of capacity or cost effectiveness.

Evaluation of Placement Options Needs to be Balanced with Available Resources

It is not practical nor are the resources available to conduct full-scale or even prefeasibility assessments for every possible option. Interdisciplinary screening criteria should be applied to assess each option's potential and to determine if there are any apparent showstoppers. Work can then be focused on the more promising options, conserving and optimizing available resources. However, sufficient information needs to be developed in order to support the consideration of alternatives required as part of the National Environmental Policy Act (NEPA) process for projects that would result in a major federal action.

Information Sharing is Essential to Planning and Implementation

Search and screening efforts need to be documented sufficiently to demonstrate the competence and thoroughness of the planning process. The results need to be disseminated to all interested parties, the public and the news media to insure that accurate information is available. The sharing of information needs to begin early in the planning process and continue through implementation.

Information sharing does not necessarily mean a lack of controversy. For example, the DNPOP program has broad-based involvement with the panoply of interested parties. However, it has not been possible to achieve a consensus on all options. Public opposition to specific upper Bay placement options, including beneficial use, has often taken the form of challenges to the adequacy of the search for other alternatives. Yet, over 500 options have been considered since the mid-1980s. Nevertheless, an effective information-sharing program has been essential to maintaining cooperative working relationships despite differing perspectives.

Funding Insufficient to Rely Exclusively on Beneficial Use

Insufficient dedicated resources are available to enable exclusive reliance on beneficial use projects for a large-scale dredging need. These options are usually more expensive than traditional placement actions. Beneficial use option costs should include construction, habitat development and site maintenance costs in addition to transportation and environmental monitoring costs. In many cases, the locations with the best potential for a habitat restoration or enhancement project are far removed from the channels to be dredged. Incremental costs that exceed the federal cost share relative to the "base plan" for each project often become the responsibility of the local sponsor. With respect to the Port of Baltimore, incremental costs for distant sites are estimated to be on the order of hundreds of millions of dollars over the operational lifetime of such sites.

Section 204 federal funding for beneficial use projects is capped annually at $15 million per year. Except for special Congressional funding arrangements for Poplar Island, which has a projected construction cost of over $70 million, Section 204 has not been fully funded. Certain calculated risks were assumed by the State in undertaking the planning of the island restoration project. Although federal participation and the level funding was initially uncertain for Poplar Island, it was believed that some level of federal participation was inevitable because of the project's environmental benefits. During the planning process, State officials coordinated with the USACE and the State's Congressional Delegation to obtain federal sponsorship and full project funding. The overwhelming environmental benefits of restoring Poplar Island motivated broad institutional support. Without these benefits, obtaining exceptional federal funding support would have been most difficult. Even with the environmental benefits, the Maryland General Assembly raised concern about the prospective costs of the project.

Institutional Constraints can Preclude Beneficial Use

The planning and implementation of beneficial use projects can be complicated by institutional barriers or constraints. For example, construction of a dike to hold material in place for the marsh creation proposed for Sparrows Point appears to some to be prohibited by the State statute that precludes construction of a containment within five miles of the Hart-Miller-Pleasure Island Chain. Planning must consider the institutional situation and the potential for institutional factors to delay or preclude certain otherwise feasible placement options. A candid assessment is needed to determine if there is reasonable expectation for relaxation, waivers, or removal of institutional constraints. If not, then options so constrained may be best eliminated from further consideration or put on hold until such time that institutional conditions favor revisiting the option. It may nevertheless be necessary for the USACE to consider such options in order to comply with NEPA.

Beneficial Use does not Guarantee Acceptability

The fact that a project proposes to use dredged sediments beneficially does not guarantee acceptability. Although the beneficial use concept has broad conceptual support, each proposal must be evaluated on its own merits. Some areas or regions may be better suited for beneficial use projects than others. Early consideration needs to focus on site-specific conditions or circumstances that could affect project acceptability. In this regard, a multi-party, interdisciplinary planning process with outreach to interested and affected parties is essential.

SUMMARY

Beneficial use opportunities are more limited than originally thought for the upper Chesapeake Bay. Both natural and economic resource applications are needed for beneficial use to make a meaningful contribution due to the scale of the dredging need. Shifting to beneficial use projects does not alleviate the issues, problems and concerns associated with finding suitable placement options. Strong conceptual support for beneficial use does not automatically extend to individual projects. Expanding the beneficial use concept from small-scale demonstrations to a principal role in solving dredged material placement needs has been impeded by various environmental, institutional, social and economic factors. Although many environmentally oriented projects have been proposed, only the planned large-scale restoration of Poplar Island has obtained sufficient institutional and public support and the State and Federal funding necessary to enable implementation. Limited Federal funds for beneficial use projects are competed for nationally. Beneficial use does not offer a comprehensive solution for the upper Bay in the foreseeable future. Economic use of dredged material has yet to be proven as a practical alternative on a meaningful scale for the Chesapeake Bay region, although efforts to do this are in progress.

This paper was revised from the original paper by Hamons and Young (1999). It contains updated information about several beneficial use options, minor editorial corrections for completeness, accuracy and clarity, and has been reformatted from the previously published version. The views expressed in this paper are those of the authors and do not necessarily reflect those of the Maryland Port Administration or the Maryland Environmental Service.

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Planning Issues for Innovative Use Applications

The innovative use of dredged material on a large scale may or may not prove to be a near-term solution. However, technological developments suggest that innovative uses have the potential to become practical and cost-competitive to some extent over the next decade. Issues for consideration include:

- availability and suitability of technology;
- processing requirements;
- capability to produce environmentally sound products and end uses;
- capability to minimize or avoid waste streams, and associated regulatory requirements;
- availability and capability for contracting proprietary or patented technology and processes;
- marketability of products including possible competition for existing markets and market creation;
- public and consumer acceptance of products and end uses, especially for products produced from contaminated sediments;
- innovative use potential relative to dredged material management need; and
- cost-effectiveness.

Ultimately, innovative use will only become successful if the products or process outputs using dredged sediment as a resource can be cost-effectively marketed or otherwise used in an environmentally appropriate manner, regardless of how well the various technologies may perform.

Potential Technologies and End Uses

There following are the general categories of technologies that have been considered nationally and internationally for innovative use applications.

- Bioremediation
- Chemical treatment
- Direct application
- Photocatalytic degradation
- Phytoremediation
- Soil amendments
- Soil manufacturing
- Soil washing
- Solidification
- Solvent extraction
- Stabilization
- Thermal desorption
- Vitrification
- Other technologies

The following are the general categories of potential end uses:

- Direct upland applications with or without treatment (e.g., recycling to farmland)
- Habitat creation, enhancement and restoration
- Reclamation (e.g., brownfields, strip mines)
- Manufactured products
- Other end uses or applications

Research Initiatives

Most research and development into the innovative use of dredged material has been directly related to initiatives intended to find solutions for the remediation of contaminated sediments. Development of pretreatment and treatment technologies have involved both low through high-technology solutions. Inasmuch as the national focus has been predominantly on contaminated sediments, the applications that have been tested have tended towards higher technologies. Technologies that have been investigated include:

- **thermal destruction technologies** (incineration, pyrolysis, high-pressure oxidation, and vitrification);

- **thermal desorption technologies** (high-temperature thermal processor, low-temperature thermal treatment system, proprietary thermal desorption systems, desorption and vaporization extraction systems, low-temperature thermal aeration systems, and anaerobic thermal processor systems);

- **immobilization technologies, extraction technologies** (including soil washing);

- **chemical treatment technologies** (chelation processes, dechlorination processes, chemical dehalogenation treatment, base-catalyzed dechlorination, ultrasonically assisted detoxification, oxidation processes, and chemical and biological treatment); and

- **bioremediation technologies** (bioslurry processes, contained land treatment systems, composting, and contained treatment facilities).

In general, research and testing have found that pyrolysis, oxidation, and bioslurry processes have performed within acceptable limits for both silts and clays, and soil washing, solvent extraction, composting, and contained treatment facility processes have performed within acceptable limits for silts.

Innovative Use Technologies for Dredged Material

Technologically, there have been significant advances in the technological capability to produce products and innovative end uses from dredged marine and estuarine sediments. Technologies and techniques that are under development include:

- the manufacturing and blending to create soil products
- soil washing
- conversion into lightweight construction aggregates
- use in landfill construction
- production of construction grade cements
- forming cementious products for mine reclamation
- manufacture of bricks
- production of commercial tiles
- manufactured material using waste products such as automobile shredder byproduct and dredged sediments to produce structural and non-structural fill

Most of the aforementioned applications have been targeted towards contaminated sediments, primarily because these are the more difficult of dredged sediments for which to secure final deposition. Other applications, such as farm applications, are intended to use suitable, uncontaminated dredged. Transforming these approaches into practicable applications requires that the technology be capable of adaptation to local sediment conditions, a particular need for contaminated sediments.

For example, innovative uses would include the concept of applying dredged sediments to farmlands, with or without the subsequent addition of amendments. Indeed, this concept has been used in small-scale farm applications in Maryland and elsewhere. Although reported to be successful, there currently is limited data to support general application in agriculture. Both the Army Corps of Engineers and MPA are conducting applied research into potential soil applications. Applied research and development into the innovative use of dredged sediments is also being pursued elsewhere, including applications for New Jersey waters in the New York Harbor area. This latter research involves federal funding through the Water Resources Development Acts of 1990, 1992 and 1996 as well as, over $100 million in funding from the State of New Jersey in an effort to advance from concept to practical application.

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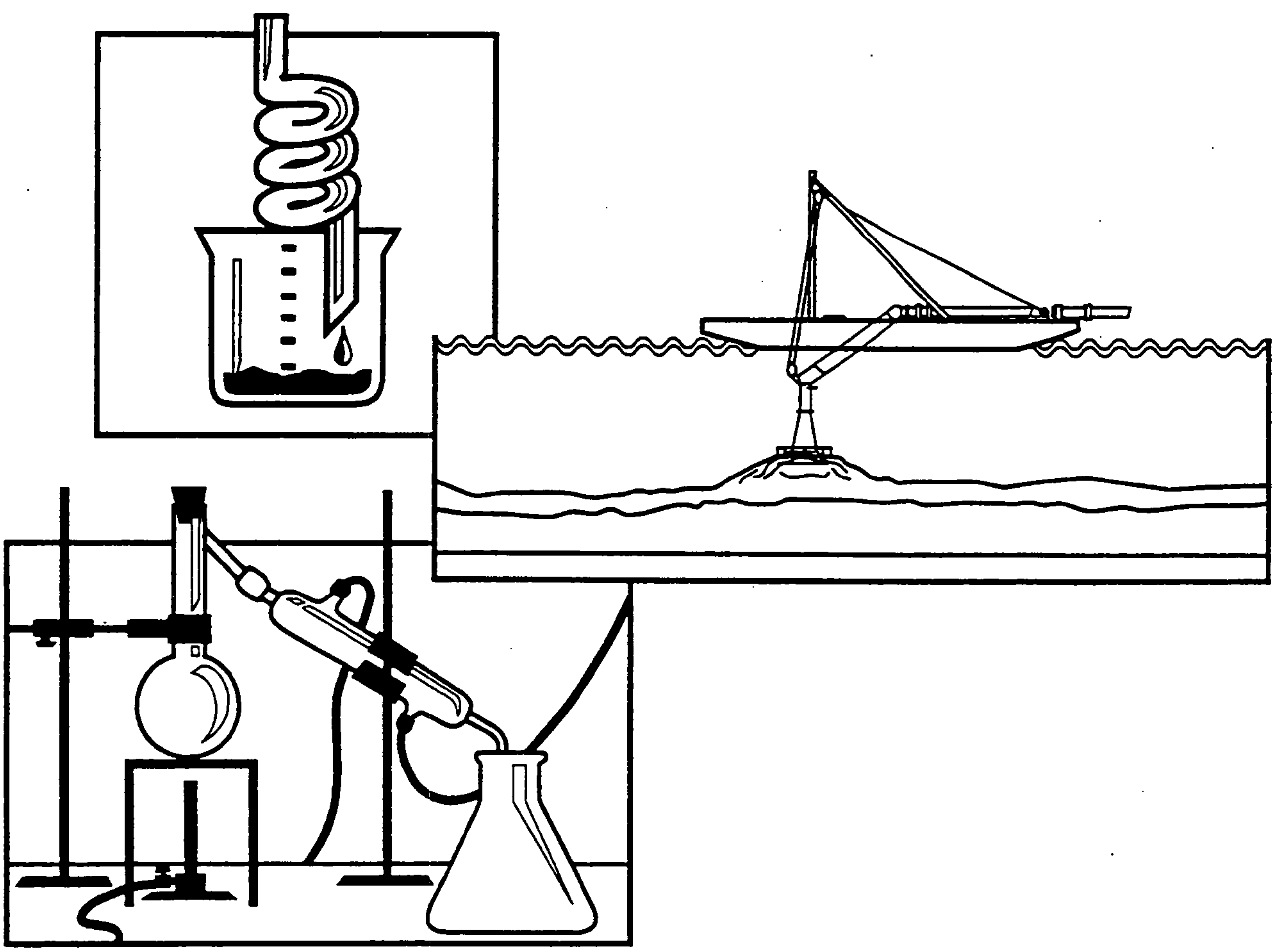

Integrated Sediment Decontamination for the New York/New Jersey Harbor

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Abstract

Disposal of dredged material taken from the New York/New Jersey (NY/NJ) Harbor is problematic because of the presence of inorganic and organic contaminants that under revised testing criteria render it unsuitable for return to the ocean or for beneficial reuse. Decontamination of the dredged material followed by beneficial reuse is one attractive component of the comprehensive dredged material management plan being developed by the U.S. Army Corps of Engineers, New York District. A demonstration program to validate decontamination processes and to bring them into full-scale use in the NY/NJ Harbor is now in progress. Tests of selected technologies have been completed at the bench-scale and pilot-scale (2-15 m^3) levels. Procedures for demonstration testing on scales from 750 m^3 to 75,000 m^3 are being developed with the goal of producing a usable decontamination system by the end of 1999. The overall project goals and present status of the project are reviewed here.

Introduction

The Port of New York and New Jersey requires dredging approximately 4,000,000 m^3 of sediment each year from navigational channels and from many different types of public and private berthing areas. At this time the fraction of dredged material that can be disposed of in the coastal Atlantic Ocean at the Historic Area Remediation Site (HARS) represents perhaps 25% of the total. Other disposal options must be chosen for the bulk of the material. One option or component to dredged material management is to decontaminate the sediments and put the treated material to a beneficial reuse (1).

The cleanup goal is clearly achievable from a purely technical standpoint and has already been demonstrated in many soil remediation projects. However, in the Port there are additional factors to consider in the actual creation of a decontamination processing option. The facility must be large enough for handling and stockpiling an enormous amount of material (some fraction of the total yearly dredging volume) that arrives at highly irregular time intervals throughout the year, and it must do so with a treatment cost which can be borne by the various customers in the Port. The minimal costs for dredging followed by unrestricted ocean disposal can be in the range from $6 to $12 per m^3. Additional costs that can be borne presently by the larger of the Port customers are estimated to be no more than $35 per m^3. A cost decrease is needed to keep the Port viable and competitive for the future. Thus, there is a strong impetus for the development of beneficial reuses which can generate a revenue stream that can be combined with a tipping fee of the magnitude just mentioned to give the foundation for an economically viable business.

In addition, there is need for substantial capital funding for decontamination infrastructure construction. The largest volume of dredged material is generated by the U.S. Army Corps of Engineers and the Port Authority of New York/New Jersey. Under present contract procedures, it is impossible to provide assurances of long-term streams of materials to a vendor and/or facility capable of decontaminating the dredged material. This makes the development of a business difficult using private funding alone since the risks to potential investors is very high. Thus, in the long term, the use of innovative public-private partnership arrangements may be necessary at the inception of individual enterprises.

The purpose of this report is to summarize, from a technical and practical standpoint alone, the work that is in progress in the Harbor of New York and New Jersey, as called for under the Water Resources Development Acts (WRDA) of 1992 and 1996. This project is aimed at development and construction of a large-scale decontamination facility as part of a stable long-term solution to the handling of dredged material in the region. Earlier summaries have been given by Stern et al. (2) and Jones et al. (3). Cost considerations will be presented elsewhere (4).

Project Components

There are many components contained in a project designed to produce an operating facility for dredged material processing and decontamination. There are also many different research, university, and industrial sector institutions working on tasks that relate to the needs of the project. However, in general, there is no pathway for coordinating and integrating the data and results produced into a systems package that is useful for meeting specific decontamination goals for a range of sediment contaminants. As a result, the present work has components that span a range of research and development activities from relatively basic science to applied engineering and business activities. Some of the key components that are needed in producing an operational treatment facility are:

- Treatment train development
  - Selection and testing of treatment technologies
  - Pretreatment (physical separation/dewatering)
  - Facility siting
  - Facility design and construction
  - Technology and facility permitting
- Fundamentals
  - Sediment toxicity identification evaluations
  - Toxicity testing of post-treated material
  - 3-D visualization of contaminant distributions to assist in making dredging decisions
  - Environmental and human health risk assessment. This includes risks from the material and from operation of the decontamination procedures.
  - End-use criteria. How clean is clean?
- Operational requirements
  - Public outreach
  - Business development for beneficial reuse products
  - Develop cost- and profit-sharing public-private partnerships for operation of the facility

Characteristics of NY/NJ Harbor Dredged Material

The physical characteristics of the sediments found in the Port are generally very fine-grained silts and clays (80-95%) with a small fraction of larger grain sizes and large-size debris. The total organic content of Harbor sediments ranges from 3-10%. The bulk material has the consistency of a black mayonnaise or gel. The solids content of the dredged material is 30% to 40% when obtained using a conventional clam-shell bucket dredge. The NY/NJ Harbor estuarine salinity ranges from 1.5 to 28 parts per thousand. The concentrations of major contaminants and metals found in dredged material from Newtown Creek, NY, are shown in Table 1. This is of interest in considering possible pathways for beneficial reuse as manufactured soil, cement, or glass.

Inorganic contaminants include heavy metals such as cadmium, mercury, lead, arsenic, and chromium. Organic compounds include dioxins and furans, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), petroleum hydrocarbons, and chlorinated pesticides and herbicides. Generally, the material is chemically stable and is found to pass the toxicity characteristic leaching program (TCLP) for testing the leachability of contaminants. The concentrations found in Newton Creek sediments are not high enough to warrant classification as hazardous materials, but are sufficient to cause them to fail bioaccumulation and toxicity tests required prior to ocean disposal and specifications for soil cleanup levels in New York and New Jersey. Contaminant concentrations found in Newtown Creek, NY, and in Port Newark, NJ, sediments are also compared to several soil criteria for the States of New York and New Jersey in Table 1. These chemicals are characteristic of a historically used, heavily industrialized urban port.

Results of Bench- and Pilot-scale Testing Programs

Technologies that have been tested have fallen into those that are carried out (1) at ambient or at least low temperatures, (2) intermediate temperatures that do not destroy the organic constituents, and (3) high temperatures above the decomposition point of the organic compounds. The wide variety of contaminants and differing concentration levels make it plausible to search for technologies that can be applied to specific concentration levels. In addition, the low-temperature technologies may be more acceptable to the local and regulatory communities and they may be easier to permit. The

Table 1. Contaminant Concentrations of Untreated As-Dredged NY/NJ Harbor Sediments (Dry Weight)

Contaminant	Newtown Creek (Bench)	Newtown Creek (Pilot)	Port Newark	NJ Non-Resid.[1]	NJ Resid.[2]	NY Resid.[3]
2,3,7,8 TCDD (ppt)	42	81	66	—	—	—
OCDD (ppt)	17,463	38,881	5560	—	—	—
TCDD/TCDF TEQ (ppt)	518	1570	109	—	—	—
Total PCBs (ppm)[4]	1.55	1.78	0.141	2	0.49	1
Anthracene (ppb)	3702	1074	167	10,000	10,000	50,000
Benzo(a)anthracene (ppb)	4484	8970	283	4000	900	224
Chrysene (ppb)	4564	9973	365	40,000	9000	400
Total PAHs (ppb)[4]	113,000	130,000	30,000	—	n/a[5]	396,500
Arsenic (ppm)	33	42	15	20	20	7.5
Cadmium (ppm)	37	47	6	100	1	1
Chromium (ppm)	376	432	171	—	—	10
Copper (ppm)	1171	1410	212	600	600	25
Lead (ppm)	617	631	300	600	400	SB[6]
Mercury (ppm) total	1.3	3.7	2.2	270	14	0.1
Zinc (ppm)	1725	2070	526	1500	1500	20

[1] NJ Department of Environmental Protection. Non-residential soil, direct contact. J.J.A.C. 7:26D, revised 7/11/96.
[2] NJ Department of Environmental Protection. Residential soil, direct contact. J.J.A.C. 7:26D, revised 7/11/96.
[3] NY Department of Environmental Conservation. Recommended soil cleanup objectives. HWR-94-046 (Revised). January 24, 1994.
[4] See Reference 12.
[5] n/a = not available.
[6] SB = Site background.

higher temperature technologies may be more applicable to the most contaminated sediments that are found outside of navigational channel and depositional areas. These areas may lend themselves to "Hot Spot" remediation. High temperature technologies may well produce beneficial use products that have higher resale values. Examples of the technologies that fit each sediment contamination category are:

- Low contamination. Solidification/stabilization, manufactured soil, and phytoremediation. U.S. Army Corps of Engineers (5)
- Low-to-medium contamination. Sediment washing and chemical extraction. BioGenesis Enterprises Inc. (6)
- Medium contamination. Solvent Extraction. Metcalf & Eddy, Inc. (7)
- High contamination. High-temperature rotary kiln. Institute of Gas Technology (8)
- High contamination. High-temperature plasma torch. Westinghouse Electric Corporation, Science & Technology Center (9)

Taken together these technologies form the basis of an integrated "treatment train" for the management of contaminated dredged material from the Port of NY/NJ or other locations worldwide.

U.S. Army Corps of Engineers

The simplest approach to decontamination is the preparation of a manufactured soil using dredged material. The advantages of this method include relatively low cost and easy implementation with no need for complex capital equipment or dewatering of the material. The disadvantages are that establishing growth of cover plants may be difficult since degradation of some compounds may be slow, and trophic transfer issues could restrict use as a topsoil since removal of contaminants is an *in-situ* process that proceeds slowly and needs long-term monitoring.

The soil is produced by mixing the sediment with a cellulose material such as wood chips, sawdust, or yard-waste compost, cow manure or sewage sludge, and lime and fertilizer as needed. Specific mixtures that were tested contained dredged material, sawdust or yard waste, and cow manure. The tests showed that the optimum dredged material concentration was about 30% of the soil mixture by weight, thus giving an overall reduction in contaminant concentrations through dilution. These concentrations are compared to New York and New Jersey standards for residential and industrial soil cleanup standards in Table 2. It was found that some of the contaminant concentrations exceeded the soil cleanup criteria. Hence, a decontamination procedure may be advisable for producing a soil meeting state standards. The suitability of the soil for growth of different plant species was tested for tomato, marigold, rye grass and vinca. The soil was most suitable for the growth of rye grass.

BioGenesis

A schematic diagram of the sediment-washing equipment of BioGenesis is shown in Figure 1. The first step in the process is to use surfactants combined with a water jet to break up agglomerates and solubilize hydrocarbons coating the individual sediment grains. The second step combines a chelating agent and high-velocity water jet that further strip organic coatings from the particles and remove metals sorbed to the base materials. The water-solid mixture is then passed through a cavitation-oxidation unit to break up the organic components, followed by steps to separate the processed solids from the water which contains the remains of the contaminants. The water is processed to meet standards required for disposal at wastewater treatment plants. The testing program to date has been confined to study of the contaminant reduction efficiency. Results obtained for reduction of PAHs and metals in one experiment are shown in Table 3. These values are compared to the standards for soil cleanup given by NY and NJ. Similar values have been obtained for other contaminants.

The bench-scale experimental results indicate that it is possible to expect reductions that exceed 90% in a single pass through the apparatus. Results found from sequential passes through the system have been encouraging and make it plausible to think that further improvements in the system efficiency can be attained. The next step would be testing on a pilot-scale level of up to 1000 yd^3. The final product can be combined with the manufactured soil approach of the Corps of Engineers to produce a material suitable for unrestricted use as long as the dredged material contamination can be reduced to acceptable levels consistent with those mentioned above.

Table 2. Summary of Results for U.S. Army Corps of Engineers Waterways Experiment Station Bench-scale Manufactured Soil Demonstration: 30% Dredged Material, 50% Sawdust, 10% Cow Manure

Contaminant	As Dredged	Man. Soil 30% As Dredged	Percent Reduction	NJ Non-Resid.[1]	NJ Resid.[2]	NY Resid.[3]
2,3,7,8 TCDD (ppt)	41.5	15.2	63.4	—	—	—
OCDD (ppt)	17463	5290	69.7	—	—	—
TCDD/TCDF TEQ (ppt)	518	182	64.9	—	—	—
Total PCBs (ppm)[4]	1.22	0.782	68.0	2	0.49	1
Anthracene (ppb)	3700	1590	57.0	10,000	10,000	50,000
Benzo(a)anthracene (ppb)	4480	3130	30.1	4	900	224
Chrysene (ppb)	4560	3720	18.4	40	9000	400
Total PAHs (ppb)[4]	57,900	35,800	38.2	—	n/a[5]	396,500
Arsenic (ppm)	33.5	12.5	62.7	20	20	7.5
Cadmium (ppm)	3.0	7.9	78.6	100	1	1
Chromium (ppm)	377	140	62.9	—	—	10
Copper (ppm)	1172	393	66.5	600	600	25
Lead (ppm)	617	331	46.4	600	400	SB[6]
Mercury (ppm) total	1.29	—	—	270	14	0.1
Zinc (ppm)	1725	514	70.2	1500	1500	20

[1] NJ Department of Environmental Protection. Non-residential soil, direct contact. J.J.A.C. 7:26D, revised 7/11/96.
[2] NJ Department of Environmental Protection. Residential soil, direct contact. J.J.A.C. 7:26D, revised 7/11/96.
[3] NY Department of Environmental Conservation. Recommended soil cleanup objectives. HWR-94-046 (Revised). January 24, 1994.
[4] See Reference 12.
[5] n/a = not available.
[6] SB = Site background.

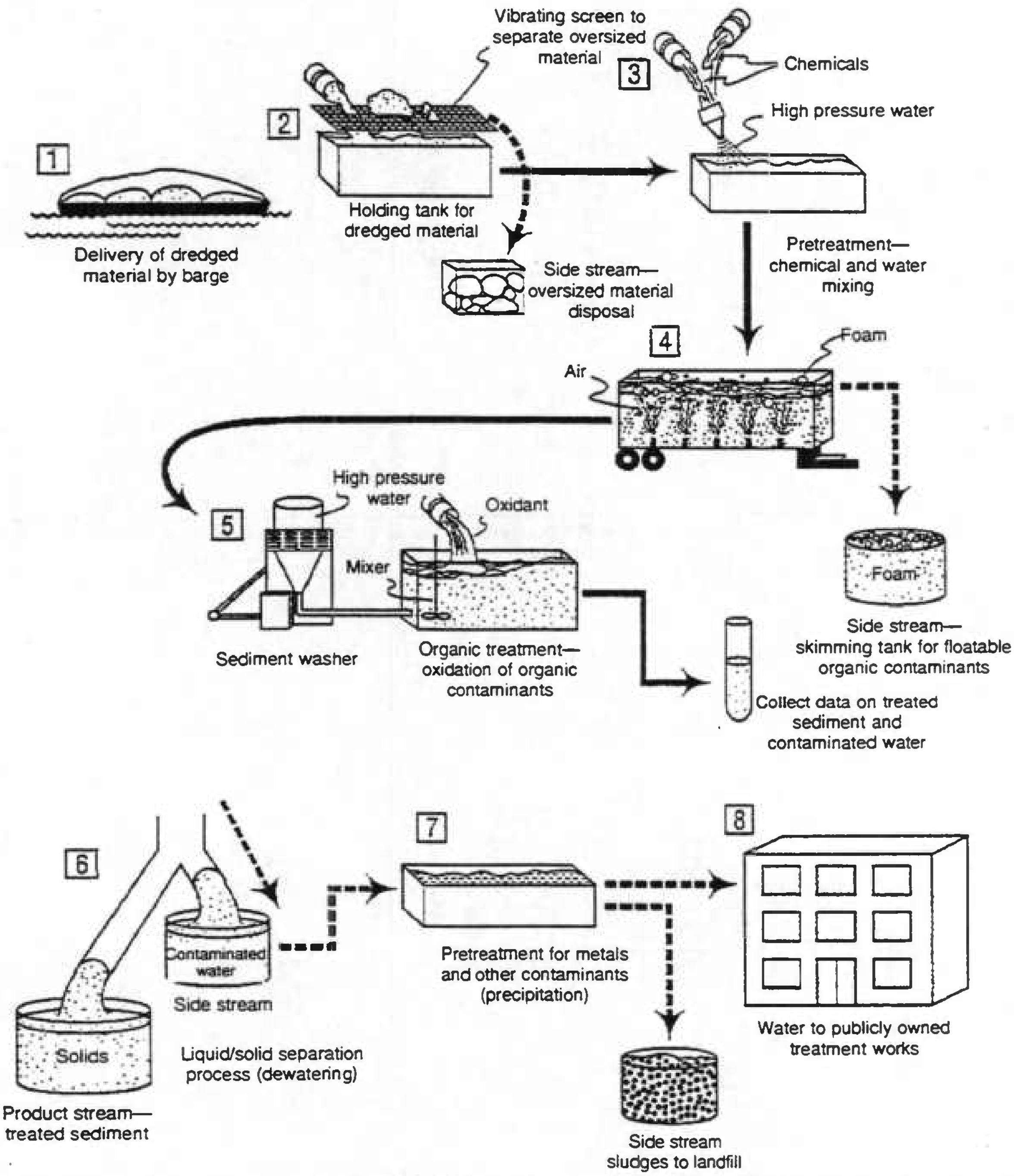

Figure 1. Schematic diagram showing the steps in the sediment washing and chemical extraction processing system developed by BioGenesis Enterprises.

Metcalf & Eddy

Solvent extraction procedures are similar to the sediment washing process of BioGenesis in the sense that a chemical solvent is used to remove the surface coatings of contaminated materials. Removal of volume contamination depends on the porosity of the material and the treatment time as well as on the details of the chemical interactions of the contaminants with the bulk material of the sediment. A block diagram of the apparatus used by Metcalf & Eddy is shown in Figure 2. The extraction process operated at a temperature of 37.7-60.0°C and employed isopropyl alcohol and isopropyl acetate as the solvents. These conditions require more elaborate apparatus than the BioGenesis process and require more attention to operating conditions because of fire/explosion hazards. Pilot-scale experiments were carried out using multiple passes through the system and in a continuous mode. Results obtained for decontamination are shown in Table 4 for a 5-cycle treatment. This particular experiment did not use a chelator and the metal levels are not substantially reduced.

Table 3. Summary of BioGenesis Sediment-Washing Process

Contaminant	As-dredged	Treated	Percent Reduction	NJ Non-Resid.[1]	NJ Resid.[2]	NY Resid.[3]
Anthracene (ppb)	771	177	77.0	10,000	10,000	50,000
Benzo(a)anthracene (ppb)	1793	234	86.9	4000	900	224
Chrysene (ppb)	1994	286	85.7	40,000	9000	400
Total PAHs (ppb)[4]	19,502	3207	83.6	—	n/a[5]	396,500
Arsenic (ppm)	22.2	12.8	42.3	20	20	7.5
Cadmium (ppm)	18.2	1.4	92.3	100	1	1
Chromium (ppm)	226	63	72.1	—	—	10
Copper (ppm)	n/a[5]	n/a[5]	—	600	600	25
Lead (ppm)	454	60	86.8	600	400	SB[6]
Mercury (ppm) total	13.1	0.3	97.7	270	14	0.1
Zinc (ppm)	—	n/a[5]	—	1500	1500	20

[1] NJ Department of Environmental Protection. Non-residential soil, direct contact. J.J.A.C. 7:26D, revised 7/11/96.
[2] NJ Department of Environmental Protection. Residential soil, direct contact. J.J.A.C. 7:26D, revised 7/11/96.
[3] NY Department of Environmental Conservation. Recommended soil cleanup objectives. HWR-94-046 (Revised). January 24, 1994.
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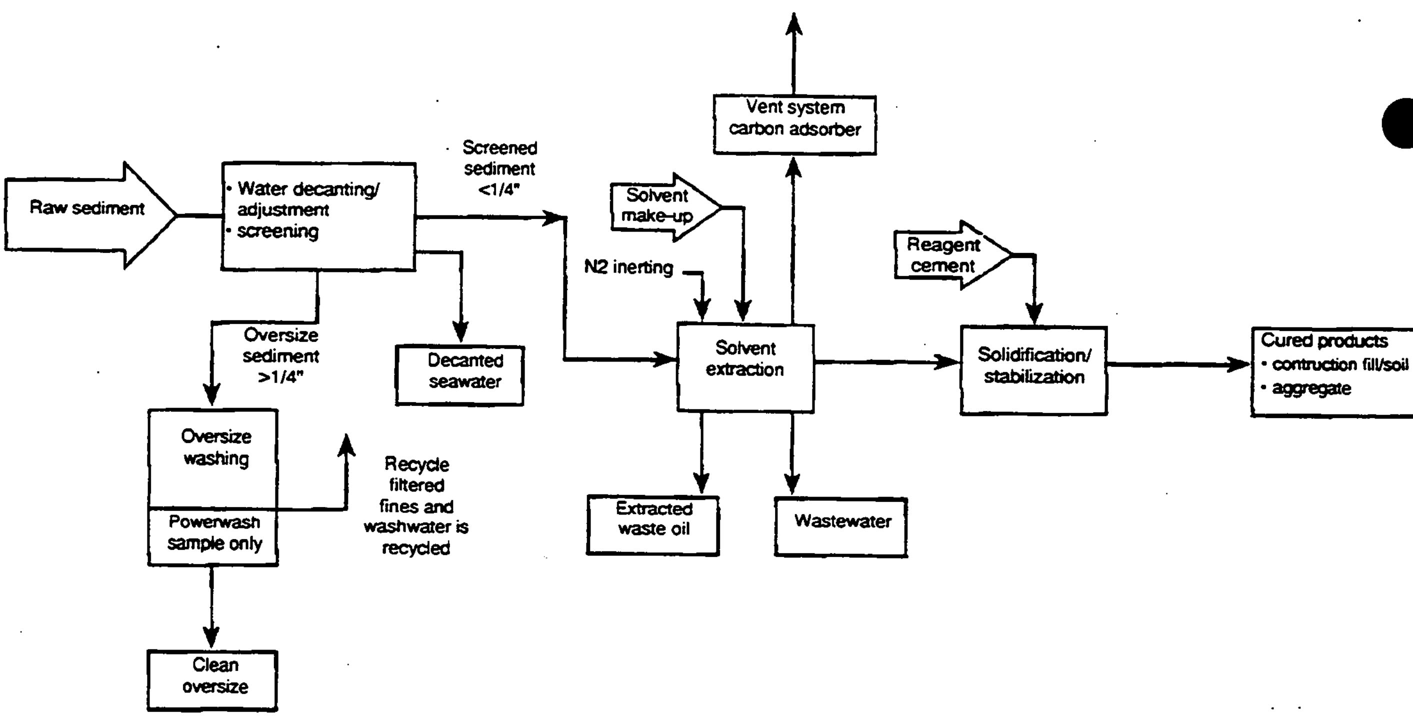

Figure 2. Schematic diagram showing the Metcalf & Eddy solvent extraction process for treatment of dredged material.

The testing included production of stabilized materials from both untreated and treated dredged material by Metcalf & Eddy, Inc. and the U.S. Army Corps of Engineers Waterways Experiment Station. The results are summarized in Table 5. It can be seen that compressive strengths of over 100 pounds per square inch can be achieved. These values are comparable to values reported by Tanal et al. (10) and Samtani et al. (11) for a project carried out on dredged material from the Port of Boston. Other relevant physical properties of the solidified and stabilized dredged material are also given in Table 5.

Institute of Gas Technology

The Institute of Gas Technology demonstrated the use of a rotary kiln for the destruction of organic compounds and immobilization of metals in the cementitious structure. A block diagram of the apparatus is shown in Figure 3. The process requires adding common mineral compounds to optimize the overall composition of the material for pozzolan production. The technology employed is that commonly in use at existing cement plants. This is encouraging since it means that existing off-line facilities could possibly be devoted to processing

Table 4. Summary of Results for the Metcalf & Eddy Solvent Extraction Process

Contaminant	As-dredged	Treated 7-stage	Percent Reduction	NJ Non-Resid.[1]	NJ Resid.[2]	NY Resid.[3]
2,3,7,8 TCDD (ppt)	35	10	71	—	—	—
O CDD (ppt)	13411	3047	77	—	—	—
TCDD/TCDF TEQ (ppt)	648	106	84	—	—	—
Total PCBs (ppm)[4]	1.54	0.029	98.1	2	0.49	1
Anthracene (ppb)	62,900	1292	97.9	10,000	10,000	50,000
Benzo(a)anthracene (ppb)	38490	894	97.7	4000	900	224
Chrysene (ppb)	33.76	1.01	97.0	40,000	9000	400
Total PAHs (ppb)[4]	858,000	17,000	98.0	—	n/a[5]	396,500
Arsenic (ppm)	68	85	—	20	20	7.5
Cadmium (ppm)	29	32	—	100	1	1
Chromium (ppm)	319	373	—	—	—	10
Copper (ppm)	1090	1310	—	600	600	25
Lead (ppm)	632	795	—	600	400	SB[6]
Mercury (ppm) total	3.5	5.3	—	270	14	0.1
Zinc (ppm)	1505	1750	—	1500	1500	20

[1] NJ Department of Environmental Protection. Non-residential soil, direct contact. J.J.A.C. 7:26D, revised 7/11/96.
[2] NJ Department of Environmental Protection. Residential soil, direct contact. J.J.A.C. 7:26D, revised 7/11/96.
[3] NY Department of Environmental Conservation. Recommended soil cleanup objectives. HWR-94-046 (Revised). January 24, 1994.
[4] See Reference 12.
[5] n/a = not available.
[6] SB = Site background.

Table 5. Results of Physical Testing of Solidification/Stabilization Products*

	Metcalf & Eddy Treated Sediment		U.S. ACE-WES Screened As-Dredged Sediment		
	15% Cement Mix	30% Cement Mix	10% Cement Mix	20% Cement Mix	40% Cement Mix
USC in psi	217	614	29	128	492
Water Content at 60°C	53.0	26.9	60.7	27.7	18.1
Water Content at 100°C	71.6	53.7	70.3	5.4	32.1
Specific Gravity	2.70	2.69	2.53	2.61	2.63
Coefficient of Permeability-cm/sec	1.16E-06	4.15E-07	1.42E-05	5.46E-06	3.12E-07
Dry Densisty in lbs/ft^3	51.6	64.1	38.1	47.5	57.5
Atterburg Limits					
Liquid	103	—	126	—	—
Plastic	59	—	67	—	—
Slope Angle Degrees	—	—	35.5	—	—

* All analytical data are based upon the average of all sample test results provided by U.S. ACE-WES.

of dredged material. The results for contaminant reduction are shown in Table 6. There is essentially complete destruction of organic compounds. The metals are reduced by dilution and by loss to the gaseous sidestream. Moreover, the metal values are in the range found for commercially available cements. Strength tests have been carried out and show that the sediment-derived product meets compressive strength standards. Cement production is therefore a method that is successful in reducing the contamination levels and provides an end product suitable for beneficial reuse.

Westinghouse

The Westinghouse Science and Technology Center demonstrated the use of a plasma torch for destruction of organic contaminants and immobilization of metals in a glassy matrix. The plasma torch is an effective method for heating sediments to temperatures higher than can be achieved in a rotary kiln. On the other hand, feeding of the material into the plasma region is more complex since dewatering is necessary, and residence times in the high temperature regions are difficult to adjust. A schematic diagram of the Westinghouse apparatus is shown in Figure 4. The results for contaminant reduction are given in Table 7. The end goal of the processing is not only to reduce contaminant concentrations, but, also to produce a useful final product. In order to do this, the overall composition of the treated material is optimized for glass production. Glass tiles and fiber glass materials were successfully produced during the pilot-scale test work. Glass production can, therefore, be considered as successful in reduction of contaminant levels and production of a valuable end product.

5. Operational-Scale Program

As mandated under WRDA 1996, the end goal of the testing program is to produce one or more production-level demonstration facilities that can used as part of the total solution for management of dredged material from the harbor. Detailed engineering designs of plants for the production of cement and glass are now in progress and will be completed in early 1998. Construction of the facilities may begin in 1998 with a prospective completion date prior to the next century. This schedule is dependent on availability of funding from the private sector. Demonstrations of the sediment-washing approach are planned for early 1998 and operation of a large-scale demonstration facility by the end of 1998.

Conclusions

A short description has been given of the highlights of a unique federal program for dredged material demonstrating decontamination. This program began with tests at the bench-scale level and will progress to a goal of production-scale volumes of up to 375,000 m^3 utilizing a "treatment train" approach. The breadth of the program has been increased through cooperation with groups who have carried on self-funded test programs. The bench- and pilot-scale results described here demonstrate that decontamination may be a viable method for

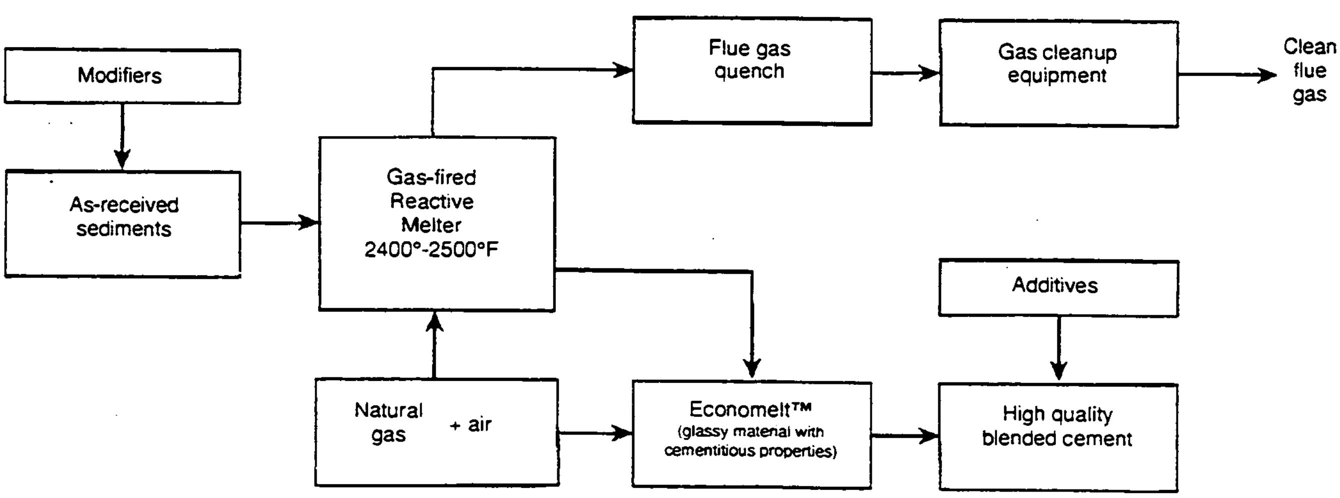

Figure 3. Schematic diagram showing the Institute of Gas Technology system for production of blended cement from dredged material.

Table 6. Summary of Results for the Institute of Gas Technology Cement Process

Contaminant	As-dredged	Treated	Percent Reduction	NJ Non-Resid.[1]	NJ Resid.[2]	NY Resid.[3]
2,3,7,8 TCDD (ppt)	23	0.35	98.47	—	—	—
O CDD (ppt)	11879	3.7	99.97	—	—	—
TCDD/TCDF TEQ (ppt)	513.2	1.406	99.72	—	—	—
Total PCBs (ppm)[4]	8.6	0.31	96.39	2	0.49	1
Anthracene (ppb)	18735	0	100	10,000	10,000	50,000
Benzo(a)anthracene (ppb)	17155	0	100	4000	900	224
Chrysene (ppb)	16878	0	100	40,000	9000	400
Total PAHs (ppb)[4]	293,854	0.16	100	—	n/a[5]	396,500
Arsenic (ppm)	39	1.52	96.10	20	20	7.5
Cadmium (ppm)	27	0.66	97.55	100	1	1
Chromium (ppm)	298	632.5	212	—	—	10
Copper (ppm)	1012	306	69.76	600	600	25
Lead (ppm)	542	29.4	94.57	600	400	SB[6]
Mercury (ppm) total	2.8	0.092	96.71	270	14	0.1
Zinc (ppm)	1535	280	81.76	1500	1500	20

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[2] NJ Department of Environmental Protection. Residential soil, direct contact. J.J.A.C. 7:26D, revised 7/11/96.
[3] NY Department of Environmental Conservation. Recommended soil cleanup objectives. HWR-94-046 (Revised). January 24, 1994.
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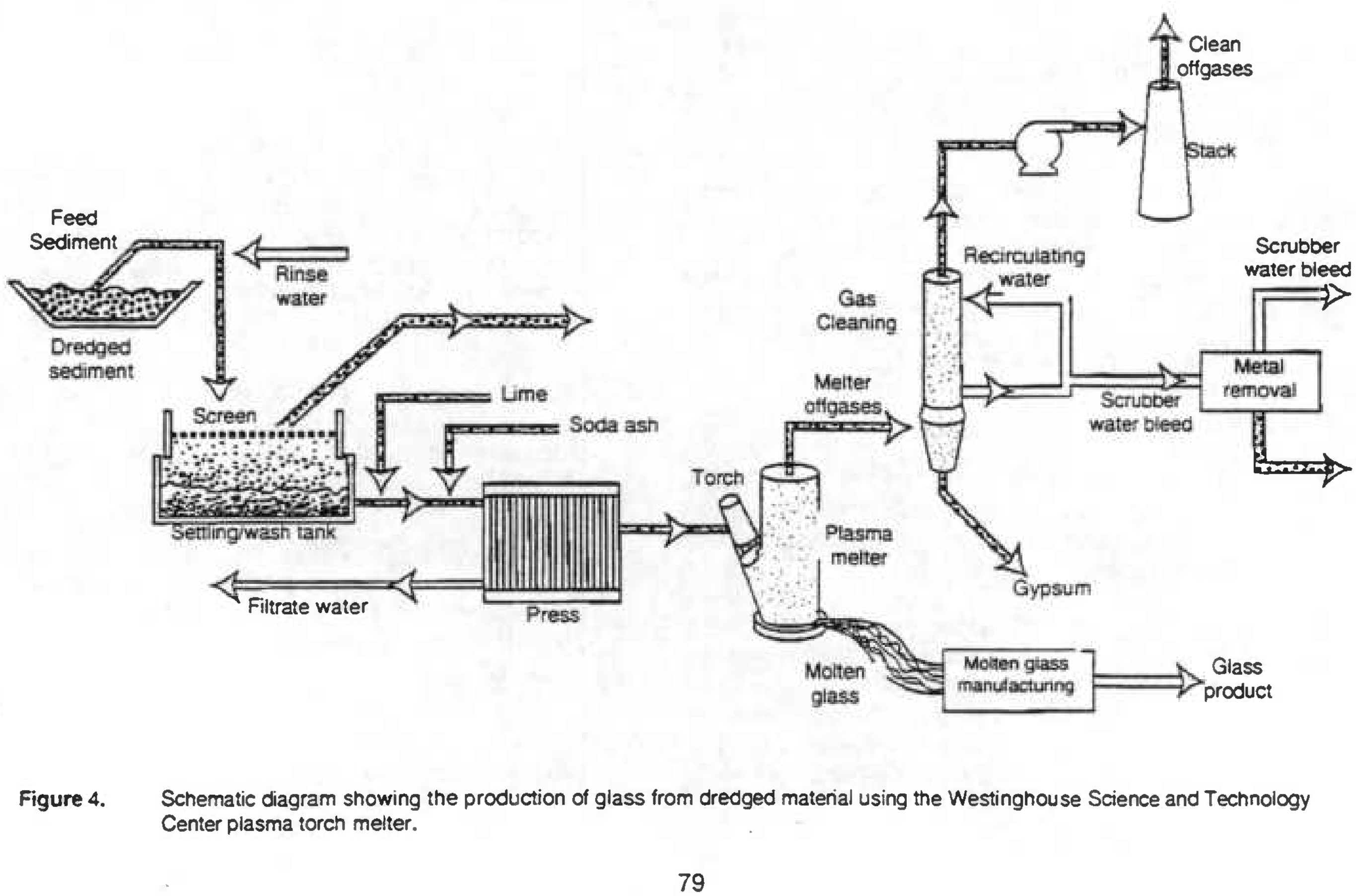

Figure 4. Schematic diagram showing the production of glass from dredged material using the Westinghouse Science and Technology Center plasma torch melter.

Table 7. Summary of Results for the Westinghouse Vitrification Process

Contaminant	As-dredged	Treated	Percent Reduction	NJ Non-Resid.[1]	NJ Resid.[2]	NY Resid.[3]
2,3,7,8 TCDD (ppt)	19.0	—	100	—	—	—
O CDD (ppt)	9655	8.0	100	—	—	—
TCDD/TCDF TEQ (ppt)	335	0.07	100	—	—	—
Total PCBs (ppm)[4]	0.900	0	100	2	0.49	1
Anthracene (ppb)	7.72	0	100	10,000	10,000	50,000
Benzo(a)anthracene (ppb)	7.19	0	100	4000	900	224
Chrysene (ppm)	8.76	0	100	40,000	9000	400
Total PAHs (ppb)[4]	109	0	100	—	n/a[5]	396,500
Arsenic (ppm)	15.8	4.94	68.7	20	20	7.5
Cadmium (ppm)	33.3	0.948	97.1	100	1	1
Chromium (ppm)	344	1001	—	—	—	10
Copper (ppm)	1145	1077	5.9	600	600	25
Lead (ppm)	594	105	82.3	600	400	SB[6]
Mercury (ppm)	2.08	0.087	95.8	270	14	0.1
Zinc (ppm)	1695	1240	26.8	1500	1500	20

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[3] NY Department of Environmental Conservation. Recommended soil cleanup objectives. HWR-94-046 (Revised). January 24, 1994.
[4] See Reference 12.
[5] n/a = not available.
[6] SB = Site background.

handling at least a portion of the contaminated dredged material from NY/NJ Harbor.

Acknowledgments

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Processing Contaminated Dredged Material From the Port of New York-New Jersey

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ABSTRACT: Shipping activities in the Port of New York-New Jersey are currently threatened by restrictions on dredging of navigational channels and private berthing areas because of concerns about the environmental effects caused by ocean disposal of the dredged material. Current proposals for solutions to the problem include ocean disposal of uncontaminated material, use of confined disposal facilities (both upland facilities and containment islands), subaqueous borrow pits, and processing and treatment for contaminated materials. A project to produce a complete "treatment train" for processing and decontaminating dredged material is described. The work is divided into several phases: treatability studies of commercial and nonproprietary technologies at volumes of 19 liters (bench scale) and up to 19 m³ (pilot scale); specification of a treatment train; and implementation of a large-scale facility that can process 76,000—382,000 m³ of dredged material per year. The goal is to achieve operational status for the facility by the end of 1999.

Introduction

Contaminated sediments in fresh and estuarine waters are a major problem worldwide. The basic reason is the realization that dredging operations required for the maintenance of navigable waterways, private berthing areas, and different types of construction operations generate large volumes of contaminated sediments, which must be disposed of in an environmentally acceptable way. Contaminated sediments can be handled by use of confined disposal facilities, subaqueous borrow pits, or through decontamination of the sediments. The cleaned sediments can be returned to the ocean, placed in a landfill, or reused in various types of beneficial applications. In practice, local and national regulations restrict the permissible disposal avenues.

Much effort has been devoted to study of the various elements of a sediment decontamination treatment train, including dredging, physical separation, treatment processes, and final disposal. Ancillary topics such as understanding contaminant distributions in sediments, sediment transport, and biotoxicity effects related to marine disposal of treated materials are also of importance. For example, in Germany, federal standards have been developed (Köthe 1995a, b) for end disposal

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TABLE 1. Summary of contaminants in select New York-New Jersey Harbor sediments (Chen 1994).

Contaminant	Newark Bay	Arthur Kill	Newtown Creek
2,3,7,8 TCDD (ppt)	130	39	9.9
OCDD (ppt)	5,494	3,016	15,369
TCDD/TCDF TEQ (ppt)	197	61	224
Total PCBs (ppm)[a]	0.92	1.16	2.86
Anthracene (ppb)	1,400	880	5,820
Benzo (a) anthracene (ppb)	3,070	1,460	6,190
Chrysene (ppb)	3,100	1,630	6,050
Total PAHs (ppb)[a]	32,550	19,120	59,380
Total Herbicides and DDT (ppb)[a]	145	1,219	420
Arsenic (ppm)	9–17	17–25	5–33
Cadmium (ppm)	1–2	1.5–3	1–20
Chromium (ppm)	175	161	305
Copper (ppm)	105–131	178–304	61–770
Lead (ppm)	109–136	111-261	68–554
Mercury (ppm) total	2–3	2–4	1–3
Nickel (ppm)	33-40	20–60	12–140
Silver (ppm)	2–4	2–5	2–3
Zinc (ppm)	188–244	230–403	104–1,260

[a] National Oceanic Atmospheric Administration.

criteria. In the Port of Hamburg (Netzband 1994; Detzner 1995), a sediment-processing plant has been constructed to help in the dewatering of sediments and reduction of contaminated material volume through physical separation. In the United States, the United States Environmental Protection Agency (USEPA) has completed a pilot-scale demonstration project, Assessment and Remediation of Contaminated Sediments (ARCS), to test different types of decontamination technologies intended for use on freshwater sediments found in the Great Lakes region (United States Environmental Protection Agency 1994).

A related United States Environmental Protection Agency and United States Army Corps of Engineers (USACE) project (Water Resources Development Acts of 1992 and 1996, WRDA) combining elements of these two examples is presently in progress in the Port of New York-New Jersey. In brief, the Port is faced with an operational crisis brought about by regulations that reduce the amount of dredged material considered suitable for ocean disposal in the coastal Atlantic Ocean. Currently there are limited alternative options and, as a result, the continued economic operation of the Port is threatened. The WRDA project is intended to demonstrate decontamination technologies for sediment treatment and to create a viable treatment train capable of processing sediment volumes on the order of 382,000 cubic meters per year by the end of 1999. It can be seen that the work entails a merging of applied and basic research and development activities with a parallel need to accomplish full-scale design and construction of operating facilities. This will require development of an effective operational public-private partnership to deal with the diverse challenges of the project. The present status of the project is summarized here.

Characteristics of Sediments From the New York-New Jersey Harbor

Measurements of the concentrations of contaminants found in the Port of New York-New Jersey have been made in three locations: Newark Bay and Arthur Kill in New Jersey, and Newtown Creek, a small tributary of the East River between Brooklyn and Queens in the City of New York. The results of the measurements of the surface concentrations are shown in Table 1. Independent sediment toxicity tests show that these sediments are Category 3, that is, they are not suitable for ocean disposal. The present decontamination project has used sediments from Newtown Creek for all tests to date. It is realized that the sediment physical and chemical characteristics will be variable and depend on location in the harbor. However, the contaminant levels at the locations chosen are representative of a major fraction of the contaminated materials that will be dredged harborwide in the near future. This information is included here since it is not generally available and is essential in any planning for choosing appropriate decontamination technologies. The results given in Table 1 were obtained in a project sponsored and evaluated by the USEPA (Battelle Ocean Sciences 1992; Chen 1994).

Selection of Decontamination Technologies

The guiding principles in selection of technologies for the demonstration testing were to select a range of approaches for flexibility in treating different sediment types and different levels of contamination and to make selections from existing commercial technologies that could be extended rapidly to full-scale operation. These principles were met by soliciting proposals through a request for proposals that was circulated to approximately 150 technology development firms. Formal proposals for 25 technologies were received and evaluated by reviewers from USEPA, USACE, United States Department of Energy-Brookhaven National Laboratory (DOE-BNL), and four participating universities: New Jersey Institute of Technology, Rensselaer Institute of Technology, Rutgers University, and Stevens Institute of Technology. Seven proposals were selected for bench-scale testing demonstrations. In addition, several tests were carried out by the USACE Waterways Experiment Station, Vicksburg, Mississippi.

The selection process envisaged a developmental process that would lead from bench-scale to full-scale operations in a series of optional steps. These further optional steps proceeded from pilot-scale tests to plants operating at 76,000 m^3 and 382,000 m^3. These values are to be compared to the yearly need to process or otherwise dispose of the 2,500,000 m^3 to 3,000,000 m^3 of dredged material deemed too contaminated for unrestricted ocean disposal. A confined disposal facility, either upland or a containment island, may be used to meet some or all of these needs. Sediment processing and decontamination can be used to respond to short-term needs and is a plausible component to other dredged material alternatives for long-term needs. The magnitude of the problem suggests there is an environmental and economic requirement for operation of several large-scale facilities with varied capabilities.

Bench-scale Tests

The bench-scale tests covered technology options for mixtures with uncontaminated materials to high-temperature thermal treatments. The specific approaches follow:

Creation of a manufactured soil by addition of compost, manure, and other materials.

Solidification and stabilization by addition of portland cement, lime or fly ash, and/or proprietary chemicals to create solid aggregates.

Soil washing using proprietary surfactants, chelating agents, and high pressure collisions to remove both organic and inorganic contaminants.

Solvent extraction, a technique similar in concept to soil washing.

Thermal desorption to remove surface contaminants. The temperatures used are not high enough to destroy the organic compounds.

High-temperature thermal destruction. High temperatures can completely destroy the organic compounds and fuse the inorganic materials into a stable matrix. Three technologies were tested that used temperatures in the range from 750°C to 3000°C. The products of the testing are suitable for beneficial reuse as aggregates, cement, and glass. These products have relatively high economic values, which would help in the creation of a self-sustaining industry.

The manufactured soil approach is attractive because our initial tests have shown that the sediments pass the USEPA Toxicity Characteristic Leaching Procedure (TCLP) test (USEPA SW 846/1311), so that the soil can be disposed of on land in several ways. Bench-scale tests showed various types of grasses grew best in a soil containing 30% native sediment together with added compost and manure. However, contamination levels are reduced only by dilution and use of the final material may be restricted.

Percent contaminant reductions obtained for the other approaches are shown in Fig. 1. The values are based on the contaminant concentrations found in the end-product, including the effect of any addition of uncontaminated materials. The collection of samples, quality assurance, and quality control were supervised by the consortium of federal agencies and four university groups. The values shown in Fig. 1 are presented in a conservative way. Minimum detection limits were used in the calculation of the reduction fraction where quantitative values were not found. This resulted in an underestimate of the actual reduction.

It can be seen that the high-temperature thermal technologies using temperatures higher than 750°C are extremely effective in destroying organic contamination. The lower temperature thermal desorption process is also effective but has the disadvantage of creating a sidestream of toxic materials, which must then be treated or disposed of in a separate step.

Solidification and stabilization and sediment washing were found to have less effect on the sediments. Analysis of the results suggest the treatments may change the chemistry of the contaminants and render them more susceptible to leaching. This could affect the contaminant analyses and suggests further experimentation with the specific chemicals used for the treatments is needed in order to improve performance and for evaluation of the testing procedures. The separations technologies used can also lead to recontamination of the material in the final stages of the process. We have tried to work with all the project participants to improve their technologies to the maximum extent possible.

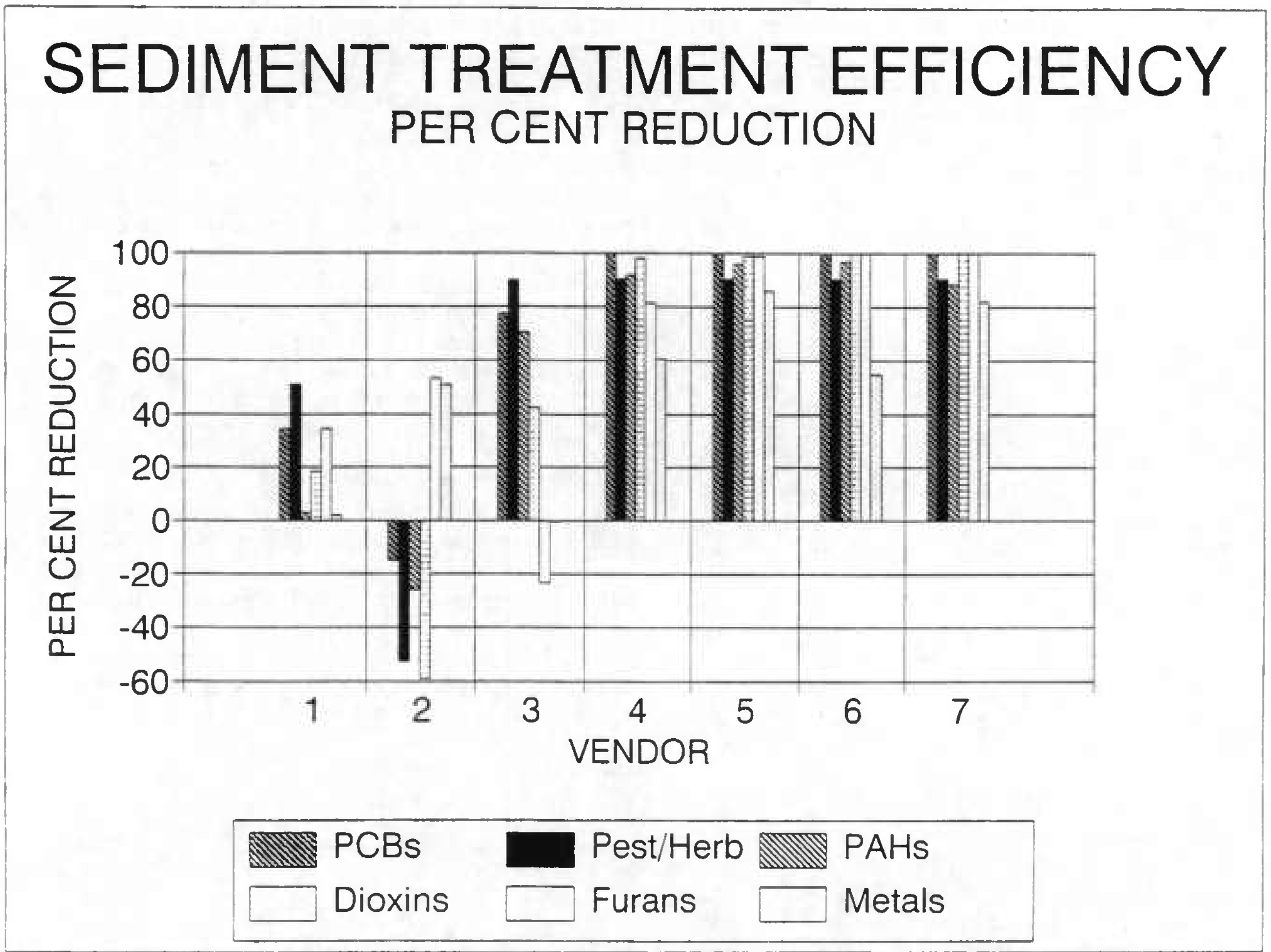

Fig. 1. The reduction of various types of sediment contaminants by seven different treatment technologies is shown. The decontamination processes are 1) solidification and stabilization using proprietary chemicals, 2) sediment washing, 3) solvent extraction, and 4) thermal desorption. 5), 6), and 7) are high-temperature thermal destruction. Several reasons for the apparent enhancement of contaminant concentrations are given in the text.

Pilot-scale Testing

Pilot-scale testing has been carried out on several of the technologies tested at the bench scale. They are manufactured soil, solidification and stabilization, solvent extraction, and high temperature treatment to produce cement and glass for beneficial reuse.

The pilot-scale tests have been completed, and analysis of the treated materials is in progress. The amount of material processed in the pilot-scale demonstrations varied from 3 m^3 to 10 m^3. The intent in this phase was to obtain more detailed information on the overall mass balance of the procedures and to obtain data to enable detailed design of large-scale facilities. It was shown that all approaches have application in the design of a complete treatment train for a commercial-scale facility. Insights were gained into the materials handling of fine-grained sediments, which will be a major part of the processing.

Related Issues

There are many issues of importance in the development of an effective sediment-processing facility, in addition to the purely technological factors. Some of the questions that are being addressed through this project are discussed in the following sections.

Risk Assessment

Risk assessment must be considered from a number of different perspectives, including: risks to the environment from disposal of the treated materials and from sidestreams produced in the processing, risks to human health including occupational exposures, and risks from failures of components of the processing equipment. Evaluations of the first two risk categories indicate that it should be possible to define an overall approach acceptable from the environmental and human health perspectives. Equipment-dependent risk will be considered during the design process for the large-scale facility to make sure problems are addressed during the design process.

Public Outreach

Processing of large amounts of sediment containing metal and organic contaminants will be of great concern to the public in the processing area in end-use locations. This will be true even though the sediment contaminant levels are not high enough for classification as a hazardous waste. For this reason, care has been taken to involve the public, including city, state, and local governmental officials, regulatory agencies, industry, and community groups, and to keep them apprised of progress. Much effort has been devoted at the community level to discussions of impacts on the local environment and in efforts to ensure that the communities in close proximity to the processing site will benefit from the operation.

Processing Costs

The usefulness of the processing facility is highly dependent on the total cost (including credits for beneficial use) of dredging, processing, and ultimate disposal of the treated sediments. Costs for the complete treatment train estimated by the project industrial contractors range from about $20 per m^3 to $120 per m^3. Sale of treated materials and resulting products, such as cement, glass products, manufactured soil, and construction aggregate, among others, will potentially sharply reduce the net treatment cost.

Disposal Criteria

Classification of the treated materials and criteria for end use are a critical part of the procedures described here. Most of the requirements are set by individual state agencies from the environmental stand point. Beneficial uses have various criteria, which are determined by the particular application.

Treatment Train

Design of a complete treatment train for sediment processing is in progress. It is based on application of the technologies described in this paper. In addition, means for dredging, dewatering, physical separation, materials transport, residuals management, and storage need to be finalized. The basis for the treatment train will rest on the employment of multiple technologies for the decontamination process.

Full-scale Project

The implementation of a full-scale project will benefit from a public-private partnership to face the complex issues of financing, siting permits, beneficial uses, continuing research and development needs, and community involvement. While this has not been done to date in the New York-New Jersey region, it is a concept that has been much discussed and used elsewhere. Preliminary discussions among USEPA, USACE, and DOE-BNL and many private sector groups are now under way in an effort to organize an effective team.

Conclusions

The results of bench-scale and pilot-scale testing of sediment decontamination technologies have shown there are several viable approaches which will be environmentally and economically acceptable. A move to demonstrations processing at the level of 76,000 m^3 to 382,000 m^3 per year is underway. Completion of this phase is projected for 1999.

Acknowledgments

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BROOKHAVEN-RENSSELAER PARTNERSHIP SUPPORTS "FAST-TRACK" NY-NJ HARBOR SEDIMENT DECONTAMINATION PROJECT

Upton, NY -- Acting under the federal Water Resources Development Act of 1992, the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (ACE) are overseeing a $6.5-million, two-year project to decontaminate sediment dredged from New York-New Jersey (NY-NJ) Harbor.

Dredged sediments must pass state and federal testing criteria prior to unrestricted ocean disposal. Recently revised regional guidelines have established more stringent biological and chemical criteria. As a result, the volume of contaminated dredged material potentially prohibited from unrestricted ocean disposal may increase.

If the harbor is not routinely dredged, large cargo ships will not be able to navigate it. The subsequent loss of business in this major port, which handles 38 million tons of cargo each year, would be financially debilitating for the NY-NJ metropolitan area.

The U.S. Department of Energy's (DOE) Brookhaven National Laboratory is working with EPA and ACE as the technical project leader for evaluating the effectiveness of technologies developed by private industry for decontaminating sediment dredged from NY-NJ Harbor. In addition, four educational institutions in the NY-NJ area -- Rensselaer Polytechnic Institute, Stevens Institute of Technology, Rutgers University and the New Jersey Institute of Technology -- are working with EPA, ACE and DOE to help provide the very broad range of technical expertise that is needed to meet the project objectives.

Brookhaven Lab's Keith Jones, the principal investigator in the harbor cleanup project, said, "We are trying to find a viable solution on a fast track, using sediment decontamination technologies that we hope will really meet the environmental and economic crises caused by contaminated sediments."

Brookhaven solicited requests from 150 vendors for clean-up technologies and received 25 proposals from 24 companies. Out of the 25 proposals, seven technologies were chosen for testing. Each of the seven finalists has been provided with approximately 17 pounds of harbor sediment, containing such pollutants as heavy metals, chlorinated pesticides, semi-volatile organics, polychlorinated bi-phenyls and dioxins, which must be decontaminated as thoroughly and economically as possible.

The seven finalists and their technologies are:

Biogenesis Enterprises Inc., Springfield, Virginia -- A soil-washing process removes organics and metals from the sediment. The resulting wastewater is then treated by chemical precipitation to remove metals and by oxidation to destroy organics. Possible beneficial uses of the treated sediment include landfill cover and topsoil replacement.

BioSafe Inc., Cambridge, Massachusetts -- Organics are destroyed by heat of 2,200 degrees F, and a metal-removal process then is employed, if necessary. Treated sediments may be used as landfill cover and construction backfill.

Institute of Gas Technology, Des Plaines, Illinois -- Organics are destroyed at high temperatures and metals are locked into a cement matrix. The resulting product is pulverized with gypsum to yield Portland cement.

International Technology Corporation, Knoxsville, Tennessee -- Heats sediment to 1,000oF to change organics to vapor for removal by desorption and uses chemicals to stabilize metals in the sediment. The company proposed that the treated sediment may be used to produce artificial reefs.

Marcor Environmental of Pennsylvania, Inc., Downington, Pennsylvania -- Chemical treatment transforms both organics and metals into a solid mineral material. Treated sediment may be used for construction backfill and secondary building material.

Metcalf and Eddy, Wakefield, Massachusetts -- Uses several technologies to separate and stabilize metals and organics. Possible uses of treated sediment include landfill cover, construction backfill and road-paving subbase.

Westinghouse Electric Corporation, Science and Technology Center, Pittsburgh, Pennsylvania -- Uses a vitrification process that heats sediments quickly up to 5,000oF, which destroys the organics and creates a glass-like material that immobilizes the metals within. The resulting product may be used to make fiberglass and glass fiber products.

In June 1996, additional tests will be undertaken at the Port Newark Marine Terminal, where two or three of the most successful bench-scale tests will be upgraded to treat 25 cubic yards of sediment from the harbor. Depending on further funding, the most successful technologies will be scaled up to industrial size -- 100,000 to 500,000 cubic yards of sediment per year.

Brookhaven National Laboratory carries out basic and applied research in physical, biomedical and environmental sciences and in selected energy technologies. Associated Universities, Inc., a nonprofit research management organization, operates the Laboratory under contract with the U.S. Department of Energy.

-30-

DAS Program

TECHNOLOGIES FOR DECONTAMINATING DREDGED ESTUARINE SEDIMENTS FROM NY/NJ HARBOR *

Keith Jones

New York/New Jersey Harbor Sediment Decontamination Project

WRDA 405 DECON
BREP MSA
EPA • COE • DOE-BNL

The bay areas surrounding New York/New Jersey Harbor (Harbor) are naturally shallow, acting as catchments for river-transported sediments and solids from surface point and non-point sources. Sediments from the Harbor must be routinely dredged to maintain navigable water depths for shipping channels and berthing areas for commerce and safe navigation. This action amounts annually to an average of 6-8 million cubic yards of sediment. Ocean disposal at the Mud Dump Site (6 nm. east of Sandy Hook, NJ) has been the primary alternative for disposal of dredged materials from the Harbor.

Dredged sediments must pass testing criteria prior to unrestricted ocean disposal. The recently revised Regional Guidance for Performing Tests of Dredged Material Proposed for Ocean Disposal (Draft December 1992), has established more stringent biological and chemical test criteria. As a result, the volume of dredged material designated as contaminated and prohibited from ocean disposal has dramatically increased. Dredged sediments from the Harbor may contain elevated levels of a wide variety of contaminants, including: heavy metals, polynuclear aromatic hydrocarbons (PAHs), and organochlorines such as dioxins, polychlorinated biphenyls (PCBs), and chlorinated pesticides.

New York Harbor scene

Under Section 405 of the Water Resources Development Act (WRDA), the U.S. Environmental Protection Agency, Region 2 and the U.S. Army Corps of Engineers - New York District are jointly managing an investigation of sediment-decontamination technologies for dredged material management. WRDA 405 authorizes a fast-track (two-year) investigation, including testing and demonstration, of decontamination technologies to treat contaminated sediments in an environmentally protective and cost effective manner. Technical support and assistance is being provided to this project by the Brookhaven Rensselaer Environmental Partnership-Multi State Alliance (BREP-MSA), which includes Brookhaven National Lab, New Jersey Institute of Technology, Rensselaer, Rutgers University, and Stevens Institute of Technology.

Treatment technologies must be capable of sufficiently reducing the contaminant levels by separation, destruction, immobilization and/or other methods that render dredged sediments suitable for ocean disposal, upland disposal, or preferably, beneficial use. Treatment will likely require several different processes due to the complex and varying nature and levels of contaminants and their widespread spatial distribution within the Harbor. A complete treatment train will be developed to encompass dredging, pretreatment, treatment, post-treatment, residuals management, end disposal and/or beneficial use, and all storage and transport involved therein. Although the exact amount ofmaterial requiring treatment in the future has yet to be determined, an estimate of approximately 500,000 c.y./year is the target figure for projecting full-scale treatment operations.

WORK IN PROGRESS

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*This work is supported by the U.S. Army Corps of Engineers and the Environmental Protection Agency.

Commercialization of Dredged-Material Decontamination Technologies

Keith W. Jones • Anthony J. Guadagni • Eric A. Stern • Kerwin R. Donato • Nicholas L. Clesceri

Keith W. Jones is a senior scientist at Brookhaven National Laboratory, Upton, New York, with research experience in nuclear and atomic physics and the development of materials characterization methods based on the use of x-ray and ion beams. He is BNL's technical project manager for the EPA and USACE programs for demonstration of sediment decontamination technologies for the Port of New York and New Jersey. Anthony J. Guadagni is a senior contracts specialist at Brookhaven National Laboratory, Upton, New York, with direct experience in research and design/development, environmental engineering, and nuclear services-type programs. He is BNL's contractual respresentative for the sediment decontamination technologies project. Eric A. Stern is a regional contaminated sediment program manager with the EPA, Region 2, New York. He works in the area of contaminated sediment assessments and dredged material management. He is the technical program manager for the WRDA NY/NJ Harbor Sediment Decontamination Demonstration Project. He has previously served with the USACE—NY District as an oceanographer working on dredged-material assessments. Kerwin R. Donato is a USACE program manager for the sediment decontamination project and is also working on the Dredged Material Management Program. He is a chemical engineer with past experience on both industrial and government projects. Nicholas L. Clesceri is a professor of environmental engineering and director of the environmental engineering program at Rensselaer Polytechnic Institute, Troy, New York. He has served as a consultant to numerous governmental agencies and private industry. His research interests have been in the area of water quality responses to man's activities. He is the deputy project manager for the WRDA Sediment Decontamination Program.

This article describes a unique federal project aimed at the commercialization of different technologies for the decontamination of dredged material. The project is organized so that commercialization is achieved in a seamless way, starting with validation at the bench- and pilot-scale levels, and ending with the actual construction of operational facilities. This is the first integrated sediment decontamination program in which a step-wise bench-scale validation process of innovative/emerging technologies will scale-up to a production-scale facility capable of processing up to 375,000 m^3 of dredged material per year. The need to develop public-private partnerships for the facility construction is emphasized as a way of obtaining adequate funding for capital and operating costs during the startup time of the commercialization process. It is expected that the end result of the project work will be the creation of economically-viable, self-sustaining decontamination technology companies.

Human industrial activities in the United States over the past 400 years have resulted in the widespread historical contamination of sediments found in the national rivers, lakes, and coastal waters. Point, non-point, and atmospheric sources have all contributed loadings to these systems. During the past 20 years, there has been an increasing awareness of the environmental consequences of this contamination in terms of its effects on both wildlife and human health. This concern has been reflected in increasingly-stringent regulations dealing with the handling and disposal of contaminated sediments in dredged material, as well as the remediation of particular highly-contaminated sites.

The Port of New York and New Jersey is an excellent example of these recent trends. The Port requires dredging several million cubic meters of sediment each year for maintenance of navigational channels and private berthing facilities. Because the Port is one of the largest on the eastern coast of the United States, it plays a key role in the economy of the region, and its continued efficient operation is important to a substantial population. However, disposal of the dredged material has become increasingly difficult because of more stringent regulations based on environmental criteria. This trend culminated on September 1, 1997, when the traditional

CCC 1051-5658/98/0802043-12

location for ocean disposal of the dredged material located off the coast of New Jersey was closed (USEPA/USDOT/USACE, 1996).

There are a number of approaches that can be used for the management and disposal of contaminated sediment from the Port. These have been outlined in a comprehensive Dredged Material Management Plan (DMMP) now under development by the U.S. Army Corps of Engineers–New York District (1996). Some of the disposal options include a containment island, subaqueous borrow pits, upland disposal in landfills, quarries, mines, etc., and decontamination followed by beneficial reuse. Decreasing the recontamination of these waterways by employing pollution prevention measures is paramount for a successful plan.

Decreasing the recontamination of these waterways by employing pollution prevention measures is paramount for a successful plan.

The status of a project to test and commercialize a treatment train for decontamination of dredged material is summarized here. Earlier summaries have been given by Stern et al. (1996, 1997) and Jones et al. (1997). The project was authorized and funded by Congress under the Water Resources Development Acts (WRDA) of 1992 and 1996, with the goal of demonstrating the feasibility of decontaminating sediment from the Port of New York and New Jersey.

The goals of the project are easily summarized: (1) the technologies must meet appropriate cleanup standards; (2) they must be environmentally acceptable; and (3) the cost of treatment must be economically feasible. Commercialization of decontamination technologies must consider these three criteria. In addition, there are sociological factors involving the many stakeholders that are equally important.

Cleanup technologies are relatively well established as a consequence of several decades of experience on cleanup of many different types of soil, sediment, sludge, and wastewater. Decontamination of sediments may pose a problem because of the solids and moisture content, its cohesiveness, salinity in estuarine and marine systems and the co-matrix of a variety of persistent contaminants, and possible pretreatment such as de-watering. Technology selection has been conservative because the time scale for development of an operational facility was short, based on the urgent need for solutions to the dredged material problem in the Port. A useful summary of the current state-of-the-art has been presented recently (Committee on Contaminated Marine Sediments, 1997).

It is useful to consider the time scale for implementation of a decontamination approach to the handling of dredged material. Grübler (1997) has examined the time frames taken for implementation of new technologies, and claims that this generally amounts to about 50 years. A current example is the development of the computer industry, from what can be taken as a starting point in 1947 with the invention of the transistor, to 1997 when the technology has effectively revolutionized most aspects of the modern world (Isaacson, 1997). The remediation industry has been in development for the past 20 to 25 years. Hence, in analogy, it can be argued that decontamination of dredged material is poised for rapid development in the next few years, and that a mature industry can develop in 10 to 20 years.

However, the rate-of-progress depends on actions by various concerned parties in the Port region. They will include the states of New York and New Jersey, the City of New York and other local municipalities, the Port Authority of New York and New Jersey, the EPA—Region 2, and the USACE—New York District, cultivating community support and acceptance for decontamination. Anyone interested in the commercialization of decontamination technologies in the Port region would benefit from a study of these entities. A number of general background works can be cited (Almond, 1997; Bone, 1997; Jackson, 1995). The operation of the New York State government during the period between World War I and World War II is described by Caro (1974). Similarities in the way the legislature operated in that era, with operations in the present day, are easily discernable. Some issues relevant to the operation of the Port Authority and the states are described by Danielson and Doig (1982). It is instructive to note the slow rate of change in operations of the entities described. Instances of contamination of industrial sites in New Jersey are given by Sheehan and Wedeen (1993) that help explain how the Port sediments came to be contaminated. The operations of the Army Corps of Engineers are illustrated by its approach to shoreline restoration (Pilkey and Dixon, 1996). The way the Corps manages large-scale engineering projects is illustrated by the authors.

The successful commercialization of decontamination technologies necessarily will require a form of public-private partnership.

It can be seen that the successful commercialization of decontamination technologies necessarily will require a form of public-private partnership, bringing together the private technology developers with the multitudinous public parties. This type of approach has been applied in the Great Lakes region through the EPA's Great Lakes National Program Office. A recent summary of regional activities has been provided by the Sediment Priority Action Committee (1997). A very general examination of the process of bringing new technologies for groundwater and soil cleanup to the commercial stage has been carried out by the National Research Council (Committee on Innovative Remediation Technologies, 1997). The content of the book has been summarized by Hirschhorn (1997). Many of the points covered can be related to the goals of the present project.

CONTAMINATED DREDGED MATERIAL IN THE PORT OF NEW YORK AND NEW JERSEY

Recently, the problem of sediment contamination and its impacts on navigational dredging in the Port has received considerable attention from involved regulatory agencies and environmental/public interest. Implementation of the revised 1991 guidance in the EPA/USACE Regional Testing Manual resulted in a considerable increase in the volume of dredged material that is prohibited from unrestricted ocean disposal. The need to maintain the viability of the Port while avoiding open ocean disposal of contaminated dredged material has led to these investigations of sediment decontamination technologies for application to navigational dredging and/or environmental problem areas. Squibb et al. (1991) concluded that concentrations of a variety of toxic contaminants in these sediments are elevated sufficiently in many locations to cause adverse effects to the biological community. Heavy metals (Hg, Cd, Pb, Ni, Cu, Zn, and As), chlorinated pesticides (including DDT + metabolites, chlordane, dieldrin, and endrin), polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and dioxins/furans are the major contaminants in the Port. Furthermore, several contaminants, detected in the Port sediments as well as in the tissue of fish and shellfish, have resulted in fishing advisories in the Port.

APPROACH TO COMMERCIALIZATION

It was necessary to structure the work in a series of tests that would begin at the laboratory scale, and would be completed with the operation of a full-scale facility.

An innovative approach to the organization of the project was developed at its outset. It was recognized that it was necessary to structure the work in a series of tests that would begin at the laboratory scale, and would be completed with the operation of a full-scale facility. It was also realized that if these steps were undertaken through a series of individual procurements, the time scale for completion would be extended by several years. Furthermore, under Federal Acquisition Regulations, it could well be difficult to make successive awards to a single contractor.

The solution was to organize the project into a step-wise sequence. Contractors successfully completing demonstrations at the bench-scale level (19 ℓ) could then be considered for participation in a series of optional steps at the pilot-scale (19 m^3), operational-scale (76,000 m^3), and full-scale (380,000 m^3) levels. Work has now progressed into the third phase and has been very successful in producing a coherent project, or "systems approach," that has progressed very rapidly from phase to phase.

The project was also organized so that it could serve as a general technical resource for the technology vendors interested in commercialization of decontamination processes. Efforts have been made to give assistance to the vendors funded through the project, and also to add vendors so as to stimulate a wider technology base, and to share knowledge gained with public agencies and the wider general public in the region.

This has been very rewarding because there have been several instances in which contributions have been made to technical aspects of the tests, and to the many questions involved in site selection and acquisition. In addition, efforts to expand the technology base have been rewarded by working with additional vendors that could provide existing infrastructure.

At all times it has been recognized that economics is a major driving force in the work. A technically elegant solution is needed, but overall operational costs must be bearable. Funding for the work must be obtained from several sources. While federal and state funds will be available, they will not be sufficient for construction and operation of major facilities. Therefore, private funding sources must be applied in a major way in the commercialization process.

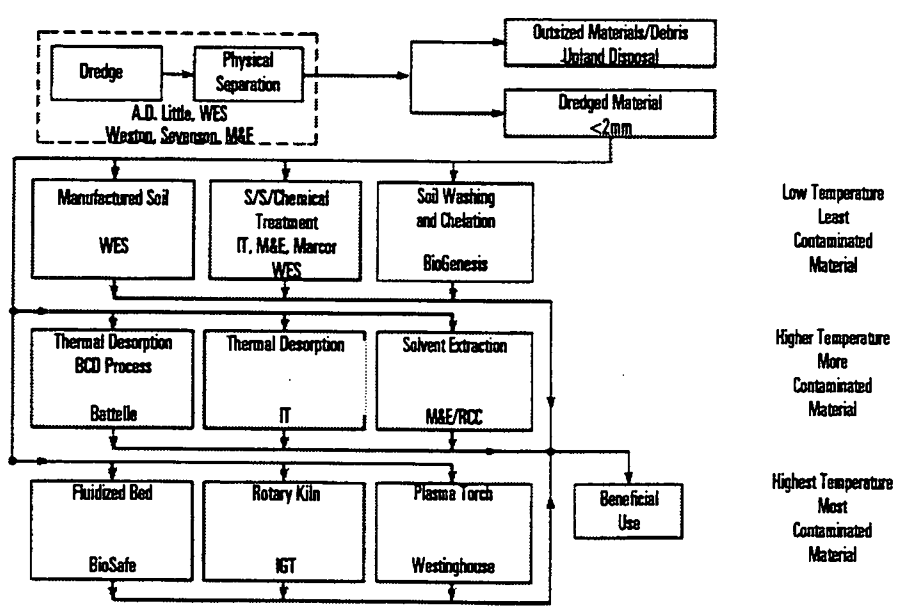
BENCH- AND PILOT-SCALE TESTING SUMMARY

A matrix of technologies was selected for the initial bench-scale testing phase. They included low-, medium-, and high-temperature methods. A block diagram showing how they can be combined into a treatment train is shown in **Exhibit 1**. Results obtained in the treatment tests have been presented previously (Stern et al. 1996 and 1997; Jones et al. 1997). The overall conclusions of the work are that it is possible to assemble a complete "treatment train" that can be used to process dredged material with a wide range of contaminant concentrations. A short discussion of technologies from the three temperature classes is given to indicate regions of application and to touch on some of the drawbacks.

Manufactured soil production has been developed by the USACE Waterways Experiment Station, and applied in test projects. Its inherent simplicity makes it an attractive approach. Initially, contaminant reductions are accomplished only through dilution coming from the addition of materials needed for soil formation. Over time, however, organic contaminants may be reduced through phytoremediation and other natural methods. Sites for disposal will be determined by criteria formulated by the states of New York and New Jersey. For example, comparison with residential and nonresidential soil cleanup standards show that the contaminants in the manufactured soil will exceed standards in several instances. There probably will be sediments that are less contaminated, and instances in which this approach could be useful in noncritical applications.

BioGenesis Enterprises has demonstrated a sediment-washing and chemical treatment process that has achieved reductions in both organic and inorganic contaminants of about one order of magnitude. Creation of

Exhibit 1. Block Diagram Showing Possible Components of a Treatment Train for Decontamination of Contaminated Dredged Material



Treatment technologies are subdivided into those that use low, medium, and high temperatures to deal with the contamination. The names of the contractors responsible for each test are indicated. (WES=Waterways Experiment Station; M&E=Metcalf & Eddy, Inc.; IT=International Technology Corporation; RCC=Resources Conservation Company; IGT=Institute of Gas Technology.)

a soil from the end of material would result in a further reduction of about 70 percent through dilution, and extend the applicability of the two methods.

Processes using intermediate temperatures were successful in reducing contamination levels (with the exception of metals) by one to two orders of magnitude. In some cases a contaminant-containing side stream is produced that would be difficult to dispose of in a full-scale plant. This fact, combined with relatively high treatment costs and low projected economic return on the treated materials, led to assignment of relatively low priorities, to the use of these technologies in the overall treatment train.

High temperature treatments were successful in producing reductions in organic contaminant levels on three or more orders of magnitude. Some reduction of metal concentrations occurred through emission into gaseous side streams, and through dilution by additives used to produce cement or glass. The main drawback of the high-temperature methods rests in the costs associated with the energy required for heating the dredged material to temperatures above 1000°C. The advantages are the destruction of organics and incorporation of the inorganics in a glassy or cementitious matrix so that they are not likely to leach from the product material. The production of end products that have the potential for high-return beneficial reuse is essential to the economics of these high-temperature processes.

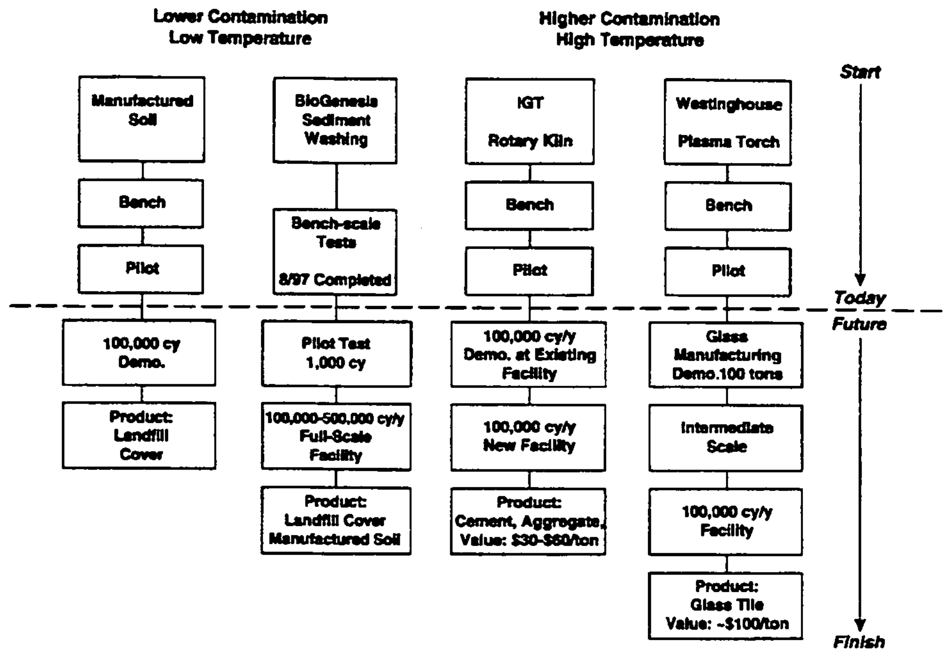
The testing program led to a treatment train that included both low- and high-temperature technologies that could satisfactorily treat dredged material with different levels of contamination.

In summary, the testing program led to a treatment train that included both low- and high-temperature technologies that could satisfactorily treat dredged material with different levels of contamination. It was realized that improved methods for extraction of inorganics would be important for future technology improvements.

OPERATIONAL-SCALE TREATMENT TRAIN FOR DREDGED MATERIAL DECONTAMINATION

Following the completion of most of the bench- and pilot-tests, program emphasis has shifted to the commercialization of the selected technologies. The steps to be taken in putting a large-scale treatment facility into operation are shown in **Exhibit 2**. A number of steps are being taken in parallel by the vendors. BioGenesis can supply a facility with relatively simple equipment. Thus, they are searching for an appropriate site for a plant. The sites for this work require an area of 10-20 acres or more, water, rail, and highway access, storage facilities for the as-dredged material and processed material, and ancillary office and work space. Other infrastructure such as adequate electric and gas supplies and access to a publicly-owned treatment works for waste water disposal are also needed. Ideally, this infrastructure could be shared with one of the other project participants, Westinghouse Science and Technology Center and The Institute of Gas Technology, to reduce overall duplication of effort related to the site development. Since the facility will be contractor owned and operated, the responsibility for site acquisition has remained largely with the contractors, with assistance from the federal agencies in evaluation of suitability.

Exhibit 2. Block Diagram Showing Use of Selected Technologies to Form a Treatment Train



The present status of each technology is shown and the steps to be taken in the future to achieve commercialization are indicated (IGT=Institute of Gas Technology).

The planning for the next steps is largely complete. Process flow diagrams have been produced for all technologies and piping and instrumentation diagrams have been completed. In some cases equipment lists have been completed and cost estimates obtained from suppliers. Designs of the complete facilities have begun. The sediment-washing process of BioGenesis is simple to implement and could be in operation in late 1998 at a treatment capacity of about 75,000 m^3. Time scales for full operation of the Westinghouse and Institute of Gas Technology processes will require from 18 to 24 months.

BENEFICIAL REUSE PRODUCTS

The development of beneficial reuse products that can be sold at a profit is a key component of the commercialization of dredged-material decontamination technologies. The beneficial reuse alleviates the problem of finding appropriate ways of non-ocean disposal for dredged material. The combination of tipping fees derived from receipt of the dredged material and the profits from beneficial reuse are a key to setting dredging costs at a level that is acceptable to the Port users, such as the Port Authority of New York and New Jersey, the Army Corps of Engineers, and private clients.

Presently, costs range from \$5-\$8/m^3 for dredging and unrestricted ocean disposal, and from $45-$55/m^3 for dredging and disposition at upland sites. The latter values need to be substantially reduced to ensure that the Port remains competitive with neighboring ports on the east coast. It is fairly clear that the manufactured soil option will have a relatively low return, perhaps less than $10/m^3. This return, combined with a comparatively low treatment cost, would be sufficient to enable a substantial cost cut in the tipping fee. The processing costs to produce blended cement (Institute of Gas Technology) and glass products will run in a broad range from $50-$100/m^3. Returns from beneficial reuse will be in the same range. Hence, the tipping fee could be thought of mainly as a profit that makes possible the creation of a self-sustaining business.

The beneficial use area is one in which close cooperation between the states and private sectors is highly desirable. Criteria for acceptability of processed dredged material for different uses need to be clearly defined by the states. The criteria need to include acceptable contamination levels and conventional criteria for the application, such as standards for compressive strength for concrete products and permeability for landfill cover.

DECONTAMINATION COSTS

Success of decontamination as a component of a dredged-material management plan for the Port requires that it is cost competitive with other solutions or components of the Dredged Material Management Plan. One option is to solidify and stabilize contaminants in the dredged material to produce a material suitable for disposal as a sub-base for a parking lot constructed on a former landfill. Another option is disposal in an already constructed subaqueous borrow pit in Newark Bay, New Jersey. The costs in recent years have been from $50-$70/m^3.

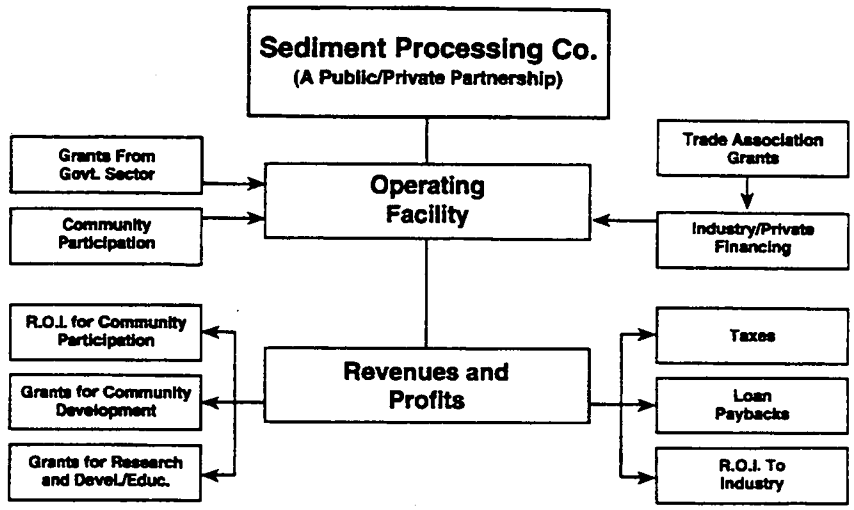
Costs for the various technologies discussed here have been refined continuously during the term of the project. The use of sediment-washing and manufactured-soil production is similar to a solidification/stabilization process, albeit with different additives. Thus, total costs of this disposal option should be at the low end of the price range mentioned above.

Thermal treatments are estimated by the vendors to be in a range from $60-$100/m^3. Beneficial use credits are about $60/ton for cement and potentially in excess of $100/ton for glass. This should be a start in bringing the overall decontamination cost to a competitive level. Production of aggregate materials is a simpler process and has been proposed by several groups. Treatment costs could be about $35-$40/m^3. Return from the sale of the aggregate would not be as high as for cement, but would still be sufficient to make the net decontamination cost equal to, or less than, current disposal costs.

It seems to be possible to do decontamination at a total cost that will be equal and possibly less than the current disposal solutions.

It is often thought that decontamination technologies will be too expensive and will not be ready for active use in the near term. Results of the project work do not confirm those conclusions. From a cost standpoint, it seems to be possible to do decontamination at a total cost that will be equal and possibly less than the current disposal solutions. Decontamination approaches do have the very positive attributes of giving a product that is environmentally benign and which has a variety of end uses.

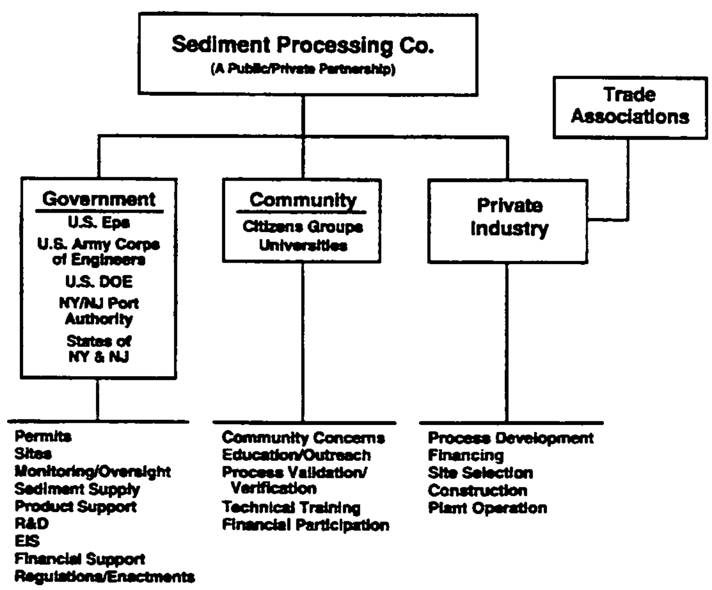
Exhibit 3. Conceptual Plan for Organization of Public-Private Consortium for Operation of Dredged-Material Decontamination Facility



PUBLIC-PRIVATE PARTNERSHIPS

Public-private partnerships have been mentioned previously as a valuable way to produce an operational entity devoted to commercialization of decontamination technologies. This concept has been practiced and

Exhibit 4. Breakdown of Groups That Might Form Part of a Public-Private Consortium for Operation of a Public-Private Dredged-Material Decontamination Facility (A Listing of Group Responsibilities and Interests Is Also Shown)



developed during the course of the decontamination project. The overall organization of a public-private Sediment Processing Company (SPC) is shown in **Exhibit 3**. This dramatizes the idea that a self-sustaining profit-making company can be created. Distribution of profits to the various stakeholders is indicated. A partial list of potential participants is given in **Exhibit 4**.

The SPC should help to unify a number of stakeholders into a coherent and focused effort aimed at making decontamination a reality. Participation from the community side is necessary and will be a great assistance in reducing frictions over use of a specific site and specific technologies. Including community groups in the actual decision-making process should be beneficial. Community development programs, education, and job training will be carried on aided, in part, by a return of a portion of the profits of the SPC to the community.

PUBLIC POLICY ISSUES

Rapid commercialization of decontamination technologies can be helped and expedited by appropriate public policy actions on all levels of government. The major need is to devise ways in which the decontamination companies are assisted in raising private capital to pay for facility infrastructure development. At the present time, major dredging contracts are let to low bidders on a project-by-project basis. This is not an adequate basis for justifying private loans for construction of facilities that must run for a long-term period in order to amortize the capital costs.

The major need is to devise ways in which the decontamination companies are assisted in raising private capital to pay for facility infrastructure development.

Consideration should be given to the development of mechanisms that could make long-term commitments for provision of sufficient volumes of dredged material that would encourage the private sector to apply their own resources to the development of new decontamination businesses through the use of private funds. Competitive bidding could be retained to ensure that the lowest possible prices are obtained. However, recognition should be given to optimal disposal practices for the dredged material so that environmental questions are properly taken into account. This supply could come, at least in part, by requiring application of decontamination technologies to a defined fraction of Federal Navigational Channel Dredging Projects.

Government can also assist in the development of markets for processed dredged material by mandating beneficial use of decontaminated material in federal and state construction projects. The use of cement, aggregate, glass, and manufactured soil proposed for beneficial use in the present project would all be candidates for participation in this type of program.

Finally, it can be seen that commercialization of decontamination technologies is a complex process. The need for development of public-private partnerships is emphasized as a general approach to construction of a facility because of the large costs. The formal authorization of a limited liability corporation to operate a public-private partnership is emphasized with the responsibility of creating and operating a dredged-material decontamination demonstration facility(ies) could be an effective approach in the Port of New York and New Jersey.

CONCLUSION

A general method for commercialization of dredged-material decontamination technologies has been developed in the context of procurements conforming to federal acquisition regulations. Technology demonstrations were observed by project members and by participating scientists from regional universities.

A new approach to proceeding from the laboratory-scale to full-scale treatment plants was developed based on the use of public-private partnerships. Limited federal funding is being used to supplement major contributions from private sources to enter into the construction phase.

It can be concluded that decontamination technologies provide a useful method for dealing with the environmental and economic problems associated with the handling of dredged material in the Port of New York and New Jersey. A flexible and innovative approach to the problem is needed on the part of both public and private interests, and is necessary for the prompt creation of this new type of business enterprise.

ACKNOWLEDGMENTS

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Creative Environmental Solutions, Inc.

INVESTIGATION AND LITERATURE SEARCH AND REVIEW OF LAND APPLICATION OF DREDGED MATERIAL

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TABLE OF CONTENTS

1. PURPOSE 1
2. BACKGROUND 1
3. REPORT ORGANIZATION 2
4. SOIL AMENDMENTS 3
4.1 Restoration of Soil Materials 3
4.2 Routine Maryland County Soil Amendment Techniques 5
5. LAND APPLICATION OPTIONS 6
5.1 Agricultural Use 7
5.1.1 Agricultural Use Literature Search and Review 7
5.1.2 Agricultural Use Case Studies 11
5.2 Aquaculture 15
5.2.1 Aquaculture Literature Search and Review 15
5.2.2 Aquaculture Case Studies 15
5.3 Forestry 15
5.3.1 Forestry Literature Search and Review 15
5.3.2 Forestry Case Studies 16
5.4 Wetlands/Habitat 16
5.4.1 Wetlands/Habitat Literature Search and Review 16
5.4.2 Wetland/Habitat Case Studies 19
5.5 Commercial and Residential Uses 20
5.5.1 Commercial and Residential Uses Literature Search and Review 20
5.5.2 Commercial and Residential Uses Case Studies 21
6. LAND APPLICATION ISSUES 24
7. ADDITIONAL CASE STUDIES OF UPLAND APPLICATIONS 25
7.1 Matapeake DMP Site 25
7.2 Edge Creek DMP Site, Talbot County 26
7.3 Peachblossom Cove DMP Site, Talbot County 26
7.4 Tred Avon 2 DMP Site 27
8. SUMMARY 28
9. LIST OF PREPARERS 29
10. REFERENCES CITED 30
APPENDIX A: Photographic Documentation of Selected Case Studies
APPENDIX B: Mini Feasibility Study: Interim Agricultural Use of a Dredged Material Placement Area

INVESTIGATION AND LITERATURE SEARCH AND REVIEW OF LAND APPLICATION OF DREDGED MATERIAL

1. PURPOSE

This report was prepared for Creative Environmental Solutions, Inc. (CES) by the Maryland Environmental Service (MES), to provide CES with information regarding the land application of dredged material, specifically agricultural applications. Information was obtained from a literature search and review, site visits and interviews with Federal, State and local agency personnel and landowners.

The context for this report is the potential for land application options for placement of estuarine sediments dredged from the Tolchester to Sassafras River section of the C&D Canal Approach Channel. Significant studies have been completed on material from this channel area because it has been placed in open-water placement sites in the Pooles Island area (MES, 1993a). The dredged material is characterized as uncontaminated fine-grained silt and clay with some sand (0 to 6% sand, 55 to 60% silt and 34 to 45% clay) (Panageotou *et al.*, 1997).

A mini feasibility study on interim agricultural use of a dredged material placement area was completed to evaluate concurrent uses of an upland DMP site over the life of the site. Summary information on this study is included as Appendix B.

2. BACKGROUND

Throughout the United States, sediments must be dredged from waterways and ports each year to maintain and improve navigation channels for commercial and recreational vessels. There are three placement categories used in the Maryland Chesapeake Bay area: open-water, upland and beneficial use (USACE and EPA, 1992). The beneficial use concept is intended to use suitable (clean) dredged marine and estuarine sediments as a natural or economic resource. Beneficial use sites utilize confined or unconfined placement (USACE, 1989). As defined by the US Army Corps of Engineers (USACE) and the Environmental Protection Agency (EPA), beneficial use, in the broadest sense, includes habitat restoration and enhancement, beach nourishment, aquaculture and mariculture, parks and recreation, agriculture, horticulture and forestry, strip mine reclamation and landfill cover, industrial and commercial development, recycling and fill material (USACE and EPA, 1992; USACE, 1989).

Dredging of the navigation channels in the Chesapeake Bay and tributaries for commercial and recreational navigation has been ongoing for many years. Today, dredging and dredged material placement is strictly regulated to minimize or avoid significant environmental effects. It has been estimated that over 85% of the sediments dredged from the Bay and tributaries are potentially suitable for use as a natural or economic resource (MPA *et al.*, 1997). The 1991 Governor's Task Force recognized this potential and established beneficial use as a preferred placement option (MDOT, 1991). Leading Bay-area environmental organizations and State regulatory and resource agencies have endorsed the beneficial use concept and have also strongly encouraged the use of upland placement alternatives (MDOT, 1996). The EPA's Chesapeake Bay Program is currently developing a beneficial use policy to encourage the use of suitable dredged sediments for habitat restoration and other beneficial uses that support Bay Program objectives (Blankenship, 1996).

Worldwide, beneficial use of dredged material has been ongoing for many years (Landin *et al.*, 1994; PIANC, 1996; Landin and Smith, 1987). In the past decade, beneficial use efforts have been directed toward natural resources and environmental projects. Predominantly, the focus has been on wetland/habitat applications due to the significant loss of wetlands throughout estuarine systems in the United States (Landin *et al.*,1994; NRC, 1994). The wetland/habitat applications involve wetland restoration or creation projects using confined and unconfined placement techniques along existing coastline that has experienced wetland loss and erosion.

For purposes of this report, upland land applications of dredged material were investigated. These included agriculture, aquaculture, forestry, wetland/habitat and residential and commercial development. The information provided on wetland/habitat and residential and commercial development provides examples of ongoing or completed projects, with a focus on the techniques used and their applicability to agriculture and forestry.

3. REPORT ORGANIZATION

This report is organized into nine sections. The first and second sections present the purpose and background, respectively. The fourth section presents a discussion of soil amendments that facilitate vegetative growth on dredged material. The fifth section presents the various land application options, including information from the literature search and review and the case studies. The sixth section addresses land application issues. The seventh section presents summary discussions of sites that were identified and investigated for this report. This includes land applications of dredged material that were not agricultural, forestry, wetland/habitat, commercial or residential in nature. The eighth section summarizes the report. The ninth section presents a list of preparers and the tenth section contains the references cited. Appendix A contains photographic documentation of some of the case studies discussed in the report and Appendix B contains summary information from a mini feasibility study of interim agricultural use of a dredged material placement area.

4. SOIL AMENDMENTS

There are several materials that have been researched as soil amendments to allow for reuse of soils such as dredged material. Nutrient imbalance and unfavorable pH are seen as two of the major constraints to vegetative growth on dredged material (Bramley and Rimmer, 1988). It has been well established that liming of estuarine dredged material is necessary, when it is placed in upland locations, given the acidity that results from oxidation of the dredged material. Generally, it has also been found that fine-grained dredged materials, which contain higher levels of nitrogen and phosphorus, tend to promote more vigorous plant growth than coarse-textured materials (Gupta *et al.*, 1980; Combs *et al.*, 1983; Francingues *et al.*, 1985; Landin *et al.*, 1989).

Soil amendments applied to dredged material placement sites for agricultural and wetland/habitat use include liming combined with the reuse of on-site topsoil or the addition of fertilizer, compost, manure or sludge (USACE, 1984; USACE, 1985; EPA, 1986; Landin, 1987; Landin *et al.*, 1989; De Silva *et al.*, 1991; Rechcigl, 1995; Gus Gardner, Queen Anne's County, personal communication, April 1997).

4.1 Restoration of Soil Materials

The USACE prepared an instructional report for the restoration of problem soil materials for USACE construction sites (USACE, 1985). The USACE defines problem soil types as soils that are acidic, saline-alkaline (or saline-sodic), excessively drained, poorly drained, dispersive clays or wind erodible. For the land application of Chesapeake Bay dredged material, issues such as salinity, acidity, drainage and erodibility are the primary concerns. The techniques that are used to reclaim problem soil types for construction can also be applied to reclamation of dredged material.

The USACE begins the discussion on restoration of soils by addressing the need for the incorporation of plans for probable land uses that are appropriate for the material and the site. The next step after addressing the land use type is to address the physical manipulation that will be necessary to reclaim the soil.

For management of dewatered and graded dredged material, each treatment must be customized to the proposed land use. If the site is designated for aquaculture, residential or commercial development or for use as fill material, amendments that enable vegetative growth are not necessary, except in areas of potential seeding or landscaping. For sites that are designated for agriculture, forestry or wildlife habitat areas, amendments that enable vegetative growth are required.

For acidic soils, the USACE incorporates techniques that increase the pH level to allow for plant growth. In estuarine dredged material, acidic soil results from naturally occurring sulfide compounds in the material. These materials, upon exposure to air, oxidize and result in low pH and acidic soil conditions (Fanning and Fanning, 1989). The USACE recommends preventing exposure to air, potentially by capping, however with dredged material placement sites, exposure to air must occur to allow dewatering. Therefore, simply capping the material is an unsuitable management practice. Liming to increase the pH to approximately 5.5 is also necessary. This process involves incorporation of lime into the topsoil; thus, stockpiling the topsoil from the placement area on-site allows for its use after dewatering and grading. This also alleviates the need to acquire topsoil from off-site sources.

The USACE stresses that the "total capacity of the lime to correct acidity, or the neutralizing value, is measured by the calcium carbonate equivalent." Based on this requirement, a lime material that is closer to a calcitic or dolomitic limestone is preferred. In addition, the smaller the limestone particle size, the faster the neutralizing ability. The USACE recommends 3 to 6 months prior to seeding as the ideal time for lime application. In an agricultural application, this may not be possible, so the finest particle size limestone should be utilized for neutralization. The lime should be worked into the topsoil to at least 6 inches, if not more for agricultural use. The rate of lime application is based on treating 6 inches of topsoil; therefore, rates should be doubled for 12 inches and tripled for 18 inches. To determine the appropriate lime application rate, the soil should be tested and the appropriate calculation techniques utilized. The USACE recommends the Barnhisel (1976) and/or Shoemaker, McLean and Pratt (1961) techniques.

Because saline conditions can negatively effect plant growth, the salinity of the placed dredged material should be tested and appropriate vegetation selected. The techniques that the USACE recommends for treatment of saline soil materials are: using water from drainage ditches or irrigators to rinse the salt out; or, using exchange reactions with gypsum, iron sulfate, calcium chloride, magnesium chloride and aluminum sulfate. The USACE notes that problems with saline soils would be encountered mostly in the Western United States, but similar conditions exist in recovered marine and estuarine sediments.

Drainage issues are predominantly a concern for sandy and clayey soils. Dredged material from the Chesapeake Bay could be sandy which would require engineering design to allow for retention of water on-site to assist with vegetative growth, if desired. Clayey soils could require engineering design to allow runoff of water on-site to prevent impoundment of water and potential flooding of an area. Most maintenance dredged material from the main shipping channels in the Maryland portion of the Bay is fine-grained in nature. The amount of drainage or impoundment necessary to achieve the selected land use will dictate the necessary engineering design factors.

4.2 Routine Maryland County Soil Amendment Techniques

Discussions with Maryland county personnel have shown several standard soil amendment techniques applied to dredged material placement sites, specifically to agricultural sites, in Maryland Eastern Shore counties. These techniques are also applicable to habitat areas and selected landscape or seeding areas of residential or commercial sites. The counties add lime to bring up the pH and then add fertilizer, compost or manure in addition to or in place of reusing topsoil, to increase the organic content of the soil. Typically, the dredged material for these county projects has a sandy, coarse-grained composition. Therefore, these coarse-grained dredged materials would require more fertilizer, compost, or manure amendments than the fine-textured dredged materials investigated for this report. This would be in addition to, or in place of, topsoil to increase the organic matter content.

In Queen Anne's County, soil amendment techniques for placement sites that will be reverted to agricultural use after dewatering involve the following general steps:

1. Strip the topsoil from the site;
2. Stockpile and seed the topsoil on-site;
3. Construct the dikes with on-site clay and other on-site soil materials or with a liner and other on-site soil materials;
4. Place the dredged material;
5. Place the topsoil on the exterior of the dikes and seed;
6. Dewater the site;
7. Strip the topsoil from the exterior of the dikes;
8. Stockpile and seed the topsoil on-site;
9. Grade the placement area to the owner's specifications;
10. Spread the topsoil over the graded area;
11. Test the soil for acidity and salinity; and
12. Add lime and fertilizer and mix with the soil.

At that point, the site reverts back to the owner for subsequent planting and use (Gus Gardner, Queen Anne's County, personal communication, April 1997).

The practice of stripping the topsoil and reusing it as a soil amendment is essentially the same technique that was verified by Dyvejonck (Landin, 1987) in a study done on dredged material from the Mississippi River. Dyvejonck found that sandy dredged material that had topsoil placed before seeding was the most effective growth medium for grass species. Areas without topsoil had significantly lower to no growth of seeded grass species.

Use of topsoil as a soil amendment is very effective for sandy dredged material. Therefore, use of topsoil, in combination with lime, for fine-grained dredged material from the Bay would further enhance growth and may reduce the need for additional soil amendments such as fertilizer, compost, manure or sludge.

As with the use of any soil amendment, the dredged material should be tested prior to application of lime and fertilizer to determine the appropriate application rates and the area should be monitored to prevent over-fertilization in the future.

5. LAND APPLICATION OPTIONS

Land application of dredged material involves: determining the placement needs; conducting a site review; determining an environmentally and economically feasible option(s); presenting the option(s) to the pertinent agencies; public involvement; preparation of environmental documentation; obtaining approval; and then performing construction and monitoring of the site.

In the United States, the majority of documentation and published information on land application projects that have occurred over the past two decades involves wetland and island creation projects by the USACE along coastlines. Land application of dredged material in the Chesapeake Bay has included such projects as agriculture, habitat areas, beach nourishment, construction of commercial facilities such as Seagirt and Dundalk, fill material, and residential development. In addition to past and ongoing projects, extensive research has been conducted in preparation for restoration and development of Chesapeake Bay islands such as Bodkin Island and Poplar Island (Maynord *et al.*, 1992; USACE and MPA, 1996). Internationally, the Port of Rotterdam has an ongoing research project to develop beneficial use technology. The general results of this research effort are said to be encouraging, but the results have not yet been publicly released.

The following sections outline agriculture, aquaculture, forestry, wetland/habitat, and commercial and residential applications of dredged material. Literature on land application of dredged material, specifically wetlands/habitat, includes sources from throughout the United States.

5.1 Agricultural Use

5.1.1 Agricultural Use Literature Search and Review

Although Maryland counties, specifically Eastern Shore counties, have conducted dredged material placement on agricultural land with subsequent use of the sites for several decades, no published reports or other written information on the techniques used or results of the projects (agricultural productivity and yield) were identified for this report. Agricultural reuse projects conducted by the USACE in Maryland also appear undocumented. The USACE agricultural reuse project discussed in the case studies (page 15) is the only known site in Maryland and information on the project was obtained from a county representative. All of the information on case studies (presented in the next section) comes from interviews with agency personnel and landowners who participated in the projects.

The following subsections outline research conducted on agricultural production in relation to dredged material.

5.1.1.1 Glasgow Garden Festival

The Port of Glasgow utilized dredged material for the Glasgow Garden Festival (Paipai, 1994). The studies found that salinity and acidity were the major inhibiting factors to using the dredged material as a subsoil and topsoil material. It was also determined that nutrient enhancement was essential. Salinity, acidity and nutrient enhancement were carefully managed and the project was successful. It was awarded the 1987 Better Environment Award for Industry.

5.1.1.2 Thin-layer Placement, Conversion of Agricultural Land

The USACE' working definition of thin layer disposal is: "the disposal of dredged material involving the purposeful, planned placement of material at thicknesses that are generally believed to either greatly reduce the immediate impacts to biota or greatly hasten the recruitment of native biota to the material without transforming the habitat's ecological function" (Wilber, 1992).

A project conducted by the USACE in Mississippi placed three feet of material (considered thin in this case, relative to the ten feet of material sometimes placed in the area) on a soybean field (Wilber, 1992). This enabled the landowner to change the crop production to cotton, a more economically valuable crop. The elevation change made the area more suitable to cotton; there was no discussion of soil amendments.

5.1.1.3 Agricultural Use of Fine-Grained Dredged Material

The Permanent International Association of Navigation Congresses (PIANC) (1992) in their document, *Beneficial Uses of Dredged Materials: A Practical Guide*, discusses how fine-grained dredged material can be beneficially used for topsoil in agriculture. Dewatering, desalination and consolidation must be accomplished before the material can be used. Clean, uncontaminated dredged material can be used for food production. PIANC also discusses how land improvement is a beneficial use when the quality of existing land can be improved by the placement of dredged material. The elevation may be increased to make the land more suitable for a particular use or dredged material may be used to improve the soil structure for agricultural use. Dewatering of the dredged material is often facilitated by internal division of the placement area into cells to allow filling to a limited depth on a rotational basis and reworking the dredged material with low ground-pressure agricultural or earth-moving equipment. Dewatering techniques are routinely practical to consolidate dredged material (Herbich, 1992). Crust management techniques suitable for use at upland locations have been routinely practiced and refined at the Hart-Miller Island Dredged Material Containment Facility (MES, 1993b).

There exists the potential to use dredged material placement areas (DMPAs) for wetland and dune plant nurseries (Wilber, 1991). The outfall pipe for the DMPA is adjusted to prevent complete dewatering of the dredged material and thereby maintain sufficient water to grow the target plant species. The site can also be dewatered and then rehydrated. The dewatering and rehydrating option allows consolidation of the material that preventing dewatering does not. Studies have shown that the use of fertilizers to establish wetland vegetation on fine-grained dredged material is not necessary (Gupta, 1980; Combs 1983; Francingues *et al.*, 1985). Therefore, unlike upland agricultural use, turning an upland DMPA into a wetland/dune plant species nursery could avoid the need to fertilize the material.

5.1.1.4 Soil Amendment & Agricultural Crop Studies, Masonville, Maryland

A comprehensive study of agricultural use of dredged material was performed by the University of Maryland for the Maryland Port Administration at the Masonville Dredged Material Placement Site in the Baltimore Harbor area (Snow *et al.*, 1983). Masonville is located between the Key Bridge and the Howard Street Bridge on the south shore of the Patapsco River in the Curtis

Creek area of Baltimore. The dredged material that was placed at this site varied from fine-textured to coarse-grained. Test plots were established in two ages of dredged material, and the soil amendments used were: no amendments; partially limed; limed; limed plus Washington D.C. (Blue Plains) compost; and limed plus sludge from Baltimore. The study was conducted to determine the productivity of various agricultural plant species (radishes, cucumbers, sweet potatoes, Canada bluegrass, Kentucky bluegrass, tall fescue, red fescue, soybeans and field corn) in the different unamended and amended test plots and in different ages of placed dredged material.

One of the primary concerns related to dredged material is sulfuricization (Fanning & Fanning, 1989). This is the process whereby the naturally occurring sulfide compounds in dredged material transform to create acid sulfate soils (low pH soil conditions) as they oxidize (dewater and become exposed to air). The Masonville study also found that *Phragmites* (common reed) appeared to promote the 'ripening' (changes in the physical and chemical properties with time) of the dredged material; though it did present a serious weed problem in the test plots and has little habitat value. The *Phragmites* was controlled by manual methods (without herbicides) during the study. The study also found that fine-textured dredged material was more susceptible to compaction and puddling problems when compared to coarse-grained material such as sand. Though the fine-textured material is more susceptible to compaction (Snow *et al.*, 1983), it has higher nutrient concentrations and has been shown to facilitate greater vegetative growth than coarse-grained material (Gupta, 1980; Combs 1983; Francingues *et al.*, 1985).

The Masonville study determined that significant liming of the dredged material was necessary to facilitate growth due to the natural sulfuricization process. The study estimated 18 tons per acre of lime was required to bring the pH to 6.5 (the accepted level for agronomic and vegetable crops in Maryland). The study found that Blue Plains compost had more of a liming effect than Baltimore sludge. This was attributed to the fact that the Blue Plains compost was already lime-stabilized, whereas the Baltimore sludge was not, and that the Baltimore sludge had been treated with ferrous sulfate, which further lowered the pH and raised the sulfur content.

Test plots without lime, including ones with the compost or sludge soil amendments, were completely unsuccessful. Vegetables grew on the limed plots, but there was greater yield and healthier crops from the limed plots in the older dredged material area. The lime+compost was the best amendment for enhanced growth. The depth of liming and amending was also found to be important. The greater the depth, the greater the yield and health of the plants. Generally, the shallow-rooted crops, such as radishes, did better than the deep-rooted crops, such as corn. This was attributed to the depth of oxidation and the depth of the amendments.

5.1.1.5 Use of Dredged Material as a Soil Amendment for Marginally Productive Agricultural Soil

Gupta *et al.* (1980) conducted studies to determine the physical properties of dredged material, marginal soils and mixtures of both. Greenhouse studies were also performed to determine the dry matter production of barley (*Hordeum vulgare*) and annual ryegrass (*Lolium multiflorum*) grown in these three soil mixtures. The dredged material was from uncontaminated sites and the marginal soils were obtained from sites within 20 kilometers of the dredged material site. Soil samples were collected from Alabama, Connecticut, Illinois, Michigan, Minnesota, Mississippi, New Jersey, New York, Ohio and South Carolina and were shipped to Minnesota for the study. The dredged materials were characterized as clay, silt loam, sandy loam, sand, silty clay loam and silty clay.

The Gupta *et al.* (1980) study found that the majority of the marginal soils were sandy in composition. The control used was medium-textured productive soils from Minnesota. Plant yields were greater for the fine-textured dredged material than for the coarse-textured marginal soils. When coarse-textured dredged material was mixed with fine-textured soils, the soils had greater yield than without the dredged material. The treatment of a mixture of dredged material and marginal soils had plant growth intermediate to the dredged material only treatment and the marginal soil only treatment. The dredged material only treatment had the greatest yield. Yield increased when fine-textured material was added to coarse-textured material, whether it was dredged material or marginal soil.

The Gupta *et al.* (1980) study concluded that marginal agricultural soils could benefit from the addition of fine-textured dredged material by increasing the depth of the aeration zone in the soil, improving the soil texture, increasing soil organic matter, increasing plant nutrient levels and reducing wind and water erosion by increasing vegetative growth.

Subsequent studies by Combs *et al.* (1983) of the elemental composition of barley and ryegrass grown on dredged material and marginal soil amended with dredged material found that the addition of fine-textured dredged material to coarse-textured, marginally productive soils produced species-specific increases in elemental accumulation in the plants and increased the dry matter production. The addition of coarse-textured dredged material to fine-textured soils did not affect the plant composition and reduced the yield.

The dredged material used for Combs *et al.* (1980) study was from the Gupta *et al.* (1980) study. The treatments were: dredged material only; 2/3 dredged material and 1/3 marginal soil; 1/3 dredged material and 2/3 marginal soil; and marginal soil only. Elemental composition of the plant referred to the phosphorus, potassium, calcium, magnesium, nitrogen, sodium, aluminum, iron, manganese, zinc, copper, barium, nickel and cadmium concentrations in the plants grown on the soil treatment. The study found that the initial 1/3 dredged material treatment significantly increased the mean treatment concentrations of barium, cadmium, copper, sodium and zinc. This was more significant for barley than for ryegrass, though ryegrass also had a more significant increase in nickel and manganese. When further additions of dredged material were used, there was generally a limited increase in the elemental content of the plants.

In conclusion, the Combs et al. (1983) study found that the maximum productivity and thus the maximum benefit was from the 1/3 dredged material and 2/3 marginal soil treatment. The study also concluded that salinity, acidity and metals levels should be monitored to prevent detrimental effects from dredged material addition.

Clean dredged material, such as the material investigated for this study, would not be considered clean if it contained metals concentrations that were greater than acceptable limits which could be detrimental to plants or animals. Therefore, no dredged material would be placed on an upland site that had the potential to introduce unsafe metals concentrations to the environment. Each placement option has unique site conditions that would be evaluated prior to placement and material proposed for placement would be tested after dewatering and prior to use to verify that all elemental and nutrient levels were within expected ranges.

5.1.2 Agricultural Use Case Studies

Following are summary discussions of sites that were identified and investigated for this report. The summary discussions present information obtained from interviews with Federal, State or local agency personnel and/or landowners.

Many of the county sites are predominantly sandy material which is more coarse-textured than the dredged material investigated for this report, as was stated in Section 4.2. The counties typically stockpile and utilize the topsoil to facilitate vegetative growth. The amendments are added to the topsoil, which is typically 6 or more inches deep, and tilled in prior to planting. Stockpiling and reusing the topsoil enhances the naturally higher nutrient levels in the fine-textured dredged material, when compared to coarse-grained material (Francingues *et al.*, 1985). Therefore, the fine-textured material may not require as much soil amending. As discussed previously, liming will almost certainly be necessary due to the natural sulfuricization process that dredged material undergoes when exposed to air. The soils should be tested prior to adding amendments to determine the quantities of lime and fertilizer necessary.

5.1.2.1 Maryland Counties

Several Maryland counties utilize agricultural and other open, unforested land to create DMP sites. The owner leases a portion of their land to the county for approximately five years (the lease period varies, depending on site conditions and the county). For several of the projects, the landowner is paid an average of $1.00 per cubic yard (cy) for placement (Gus Gardner, Queen Anne's County, personal communication, April, 1997).

There are additional county placement sites that are on previously used agricultural land. These sites were not reverted to agricultural production after their use or are being used for other purposes not discussed in detail in the following sections and their projected use is unknown. These are included in Section 7 as additional case studies of interest.

5.1.2.1.1 Queen Anne's County

There are several sites in Queen Anne's county that were agricultural land prior to being used for placement. Currently, no sites were found in Queen Anne's County that have been dewatered and graded and were in use as agricultural production.

5.1.2.1.1.1 Grove Creek DMP Site

Constructed:	Initially constructed 1988. Reclaimed within one year and utilized for agricultural use until 1996. In 1996, it was reused as a placement site.
Size:	1.4 acres of placement in 1988 and 1996.
Dredged Material:	From Grove Creek. Sandy composition.
Vegetation:	Currently upland grasses on the exterior and top of the dike from seeding. Vegetation in interior unknown. After placement in 1988, the owner was able to grow alfalfa within three weeks of placement and use the land for agricultural use until 1996.
Notes:	The same techniques utilized for the Price Creek DMP Site for construction and topsoil were used at Grove Creek. When the site was reclaimed, topsoil was spread over the graded area and the soil amended with lime and fertilizer.

Discussions with the landowner revealed that one week after placement in 1988, the material had dewatered sufficiently and the area was reclaimed. Within three weeks of dewatering, the area was amended and planted. The area was planted with alfalfa for the first three of the seven years and yielded successful crops all three years. The last four years the area was left fallow but maintained by mowing. The second placement in 1996 was also sandy material and as of April 1997, the material was dewatered but not reclaimed.

5.1.2.1.1.2 Price Creek DMP Site

Constructed:	1994. Dikes approximately 10+ feet. Material has dewatered to approximately 4 feet below top of dike.
Size:	Approximately 10 acres
Dredged Material:	From Price Creek. Silty sand composition.
Vegetation:	Developed herbaceous growth. Predominantly *Phragmites*. Upland grasses on exterior and top of dike from seeding.
Notes:	Site graded to the north. Spillway still draining facility. Spillway drains to riprapped and vegetated channel that goes to Craney Creek and then to the Chesapeake Bay. Evidence of wildlife. No evidence of agricultural or recreational use of site.

The county stripped and stockpiled the topsoil on-site, constructed the dikes with on-site clay and other soil material (or with a liner and on-site soil material, if clay is unavailable), placed the dredged material, and used the topsoil to spread on the dikes and seed. The county maintains the weir, spillway, dikes and fencing during the dewatering. Once the material dewaters, the county will strip the topsoil, stockpile it on-site and grade the site to the owner's specifications. Once graded, the topsoil will be spread over the area and the soil amended with lime and fertilizer. Photographic documentation is presented in Appendix A.

5.1.2.2 US Army Corps of Engineers

5.1.2.2.1 Kent Narrows Dredged Material Placement (DMP) Site

Constructed:	Constructed in 1996/1997. Three placement cells. Two are connected on the south side of the main house and one is on the north side of the house. Dikes are 8 to 10 feet above existing ground elevation.
Size:	Approximately 10 acres.
Dredged Material:	From Kent Narrows. Silty sand composition.
Vegetation:	No vegetative growth on interior of cells; water is still evident and crusting has begun.
Notes:	Cells are graded to the east. The spillway for the northern cell is piped directly into the Bay. The northern cell has two "fingers", which are inward extensions of the dike. These fingers are designed to facilitate the dewatering process. The two connected cells on the south side are connected by a weir and spillway from the western cell into the eastern cell. The spillway of the northern cell is also piped directly into the Bay.

This site has a five year lease. At the end of the lease period, the site would be reclaimed for agricultural use. Photographic documentation is presented in Appendix A.

5.2 Aquaculture

5.2.1 Aquaculture Literature Search and Review

Aquaculture and DMPA's have many common design characteristics (Coleman *et al.*, 1991). These include perimeter dikes that retain water, construction on relatively impervious soils, and water control structures that regulate discharge and drainage. There are also similar regulatory and permitting requirements and they are typically located near a waterway on large tracts of open land near transportation routes and/or market areas.

The USACE conducted three projects at two DMPA's in Texas to grow and harvest penaeid (marine) shrimp (Coleman *et al.*, 1991). The studies found that shrimp could be grown and harvested at expected production levels for the demonstration project. At the end of the demonstration project, the site was successfully leased to a private shrimp farming enterprise.

There are many different species that are produced by aquaculture as opposed to harvesting from naturally-occurring stock. Therefore, several aquaculture opportunities are currently available for different species.

5.2.2 Aquaculture Case Studies

There are no known dredged material placement sites that were reverted to aquaculture use in Maryland. Therefore, other than the information obtained in the literature search and review, there are no case studies to present.

5.3 Forestry

5.3.1 Forestry Literature Search and Review

The USACE's Engineering Manual on beneficial uses of dredged material (USACE, 1986) refers to several beneficial use options for upland placement sites. The USACE specifies that dredged material could be used as a soil amendment for marginal growing areas, similar to the use on agricultural land (refer to Section 4.1.1.2). The USACE also specifies that the same physical and chemical soil properties discussed for agricultural use (liming, soil amending, etc.) would apply to forestry, except that there would be fewer constraints due to the fact that the products are not meant for human consumption. The USACE does specify that use of dredged material placement sites for forestry does have one major drawback, that the area would be unavailable for subsequent placement actions due to the long growing period for tree species. There are also limitations on the tree species that would be successful on dredged material placement sites, dependent on the composition of the dredged material and depth of placement.

MES was unable to locate documentation of upland placement sites in Maryland that were subsequently used for forestry production. There may be sites that were planted with trees as part of a reclamation project, such as habitat area sites. No sites are known to be used for commercial forestry or forestry production purposes.

5.3.2 Forestry Case Studies

A site in Queen Anne's County was used by the County as a placement site approximately 20 years ago. The owner planted pine trees after dewatering, grading and soil amending (Mary Landin, USACE-WES, personal communication, April, 1997). MES was unable to located additional information on this site. As per personal communication with Mary Landin (April, 1997), the pine trees were doing well several years later when members of WES were asked to conduct soil sampling of the area.

The soil amendments and techniques utilized for the agricultural and wetlands/habitat sites would be applicable to a forestry site. The soils would need to be tested and appropriate amendments selected for the species of trees to be planted in the area. The trees species would also need to be selected based on the site elevation, water availability, soil conditions, soil composition and the particular growth habits and requirements of the selected tree species.

5.4 Wetlands/Habitat

5.4.1 Wetlands/Habitat Literature Search and Review

The USACE's instruction manual for restoration of problem soils at USACE construction sites (USACE, 1985) recommends that vegetation be selected that will "initially accomplish the first two of the following four goals:

- Stabilize the soil against erosion by water, wind and gravity.
- Minimize sediment and surface runoff and downstream impacts from contaminants.
- Improve fish and wildlife habitat and create self-sustaining ecosystems of low maintenance.

- Enhance the natural beauty (aesthetics) of the site and develop basic recreational and related resources at the site."

The USACE also recommends that the selected vegetation be tolerant to the stresses of the site (related to soil composition, elevation, available water, etc.), available in sufficient quantities and at the right season, and native to the area, versus introduced species. Vegetation should be established using the appropriate planting techniques and a maintenance program implemented to provide sufficient weed control. Plantings for wildlife should allow for a combination of forage and cover, and can be directed towards a specific type of waterfowl and/or wildlife, if desired.

The following sections present examples from the literature on proposed projects and existing dredged material placement sites that were reverted to wetland/habitat use.

5.4.1.1 Bodkin Island, Chesapeake Bay, Eastern Shore, Maryland

Bodkin Island was identified as a possible beneficial use opportunity. The USACE design document for Bodkin Island outlines the historical, existing and proposed conditions for Bodkin Island (Maynord *et al.*, 1992). The report states that Bodkin Island is an historical black duck nesting habitat located off the eastern shore of the Chesapeake Bay that went from 106 nests in 1954 to 34 nests in 1991. The island has experienced severe erosion over that time which has reduced the island from 4.8 acres in 1954 to 0.94 acres in 1991. The current size of the island does not allow for brooding habitat; hens and newly-hatched ducklings must swim significant distances, which results in high mortality. The proposed restoration would use fine sand material to increase the island to 3.57 acres of nesting and feeding habitat, plus 1.02 acres of riprapped slopes.

Studies completed for the proposed Bodkin Island restoration project found that the most suitable vegetation for upland nesting areas (up to approximate elevation +4.0 feet) included Japanese honeysuckle (*Lonicera japonica*), poison ivy (*Rhus toxicodendrons*), saltmeadow cordgrass (*Spartina patens*) and black cherry (*Prunus serotina*). Although these species are not desirable from a human perspective, and in many ways would serve as a deterrent for humans, these plant species are desirable for black duck nesting and foraging needs, as well as for other migratory species. It is noted that human deterrents are sometimes desirable to protect created habitat from damage due to overuse by humans.

Although planning and design have been completed, insufficient federal funds have been available. Therefore, project implementation is uncertain.

5.4.1.2 *Poplar Island, Maryland*

Poplar Island was identified as a possible beneficial use island construction project. The proposed Poplar Island project underwent an extensive Environmental Impact Statement and Feasibility Study that researched the potential environmental impacts and proposed rehabilitation of Poplar Island to a size similar to the 1847 landmass (USACE and MPA, 1996). The recommended altemative would create a 1,110 acres site within a 35,000-foot perimeter of dikes. The site would be 50 percent upland (up to +20 feet mean lower low water [MLLW]) and 50 percent low and high marsh.

The upland portion of the site would include depressional areas (nontidal, freshwater wetlands), forest and scrub-shrub areas. The interior dikes that would separate the upland from the wetland areas would be constructed of sand while the placed material would be predominantly silt and fine-grained material from the main channels of the Bay. The plant species designated for the upland habitat area include species such as loblolly pine, red maple, sweet and black gum, oak species, black cherry and vine and shrub species such as poison ivy, Virginia creeper, blackberry, etc. All of the recommended species are common to Maryland woodlands in the Bay area. The Poplar Island project would also rely on natural succession to convert the island to the most suitable vegetative composition for the site. The monitoring plan includes invasive plant control measures and soil amendment adjustments for pH, salinity and organic matter content, as needed.

5.4.1.3 *Nott Island, Connecticut*

The USACE has been constructing island and marsh habitats from dredged material for years. An evaluation of a site in Connecticut from 1977 to 1986 documents the success of establishing upland habitat on a dredged material island using sandy silt dredged material from a saline environment (Landin *et al.*, 1989).

In 1977, a sandy disposal mound on Nott Island, Connecticut, was cleared and graded and used to create a diked area. The diked area was then filled with sandy silt material from the Connecticut River. Once dewatered, the two materials were mixed and the soils amended. All-purpose fertilizer and lime were added and experimental plots planted with a seed mixture of tall fescue, orchard grass, timothy, perennial ryegrass, native red clover and white Dutch clover. The rest of the site was seeded with tall fescue and white Dutch clover.

The monitoring study found that the grasses did well but the legume species were not successful at becoming established. This was attributed to low pH, low potassium and failure to use nitrogen-fixing inoculates with the clover seeds prior to planting. By the following year, 1978, the dominant plant species was tall fescue, with orchard grass and timothy present as associated species, and white Dutch clover in isolated inclusions.

By 1986, the eighth year of monitoring, Nott Island resembled a stable old-field habitat typical to New England. The Nott Island study found that adjusting the pH was a crucial part of developing a dredged material placement area and that inoculation of legume species could assist with their establishment on a site. In addition, the Nott Island study found that the densest vegetative growth was in areas with the greatest percentage of silt material mixed in with the sandy material.

5.4.2 Wetland/Habitat Case Studies

Following are summary discussions of sites that were identified and investigated for this report. The summary discussions present information obtained from interviews with Federal, State or local agency personnel.

5.4.2.1 US Army Corps of Engineers

5.4.2.1.1 Goose Point Dredged Material Placement (DMP) Site

The USACE created a placement site at Goose Point, Cecil County, Maryland, along the north side of the C&D Canal in 1965 (Steve Allen, USACE, Philadelphia District, personal communication, April, 1997). The area was seeded and became naturally vegetated with grass species. In the 1990's the USACE closed off the drainage and created a freshwater, emergent wetland and ponded area. In 1993/94 they amended the soils again with lime and fertilizer and planted trees. As of April, 1997 there was considerable mortality of tree species, and the USACE is monitoring the pH and liming the soil periodically, as needed. The USACE is currently unclear as to the direct reason for the mortality of tree species. It is thought that it may be attributable to low pH or high salinity levels of the dredged material.

5.4.2.1.2 Grove Neck DMP Site

Constructed:	Placement in 1965. No construction occurred. Area reverted naturally to habitat area.
Size:	Approximately 50 acres
Dredged Material:	Silty material from the C&D Canal Approach

	Channel
Vegetation:	Natural vegetation including trees, shrub, herbaceous, emergent and SAV.
Notes:	Area utilized as a placement site in 1965. Remained abandoned until the 1980's when the Corps attempted to reuse the site. Area had become a natural habitat area with a freshwater impoundment.

This is a site that naturally reverted to a habitat area from 1965 to 1995, without soil amendments. When work was undertaken in 1995 to create more edge wetland habitat, portions of the dredged material were excavated to expand the impounded area. This material was placed on adjacent uplands where it was treated with lime, seeded and planted with trees. As of a site visit in May, 1997 the area was experiencing early successional growth and there were only small patches of open ground that would require additional liming and planting. This, most likely, occurred because movement of the material in 1995 exposed dredged material that had been previously buried. The newly exposed material then went through the natural sulfuricization process resulting in open areas where vegetation will not establish until the low pH conditions are modified through liming or through natural cycling.

Soil sampling conducted in 1995 by Environmental Resources, Inc. (1995) on the material that had been recently excavated and placed on uplands at Grove Neck found that the upland soils were loam to silt or heavy silt loam and the wetland soils were silty clay loam. The soil pH levels were low (acidic) but the organic matter content and micro-nutrients were generally medium to very high. Laboratory studies verified that soluble salts and low pH could account for the lack of native vegetative growth on the newly placed material. Environmental Resources recommended to the USACE that the areas be limed and planted. Treatment with lime alleviated the vegetative growth problem over the majority of the site and subsequent lime spot-treatment will be conducted to treat the remaining open areas. Even though the sulfuricization process occurred on the newly exposed dredged material, there was no evidence of acidic pH levels in the areas of impounded water, beyond a brief and localized effect during the operations, that did not remain (Steve Allen, USACE, Philadelphia District, personal communication, May, 1997). Photographic documentation is presented in Appendix A.

5.5 Commercial and Residential Uses

5.5.1 Commercial and Residential Uses Literature Search and Review

The USACE's Waterways Experiment Station (WES) is investigating the commercial use of dredged material as a remanufactured soil (Ruff and Lee, 1997). Remanufactured soil requires the use of fine-textured material, whereas many beneficial use projects such as beach nourishment, landfill, and berm and dike construction require coarse-textured material. The remanufactured soil uses dredged material as the silt or soil base of the mixture and cellulose (yard waste, sawdust, vegetable waste, etc.) to supply the necessary organic matter. Organic-rich waste materials add the slow-release organic nutrients necessary for fertile soil. WES, with other private developers, is currently testing this technology using seed germination tests and extended growth tests. They are also setting up several field projects to demonstrate the techniques. One such project was conducted in Toledo, Ohio in 1996. The demonstration site in Toledo enabled researchers to obtain the most productive mixture for plant growth.

Nu-Soil™ is a product, marketed by S&L Fertilizer Co., that was created from dredged material that was dewatered and recycled and mixed with other materials to create topsoil (S&L Fertilizer Co., 1995). Nu-Soil™ has a number of applications based on two products, topsoil and topsoil base. Nu-Soil™ can be used as a planting medium as a topsoil base or as a growth medium, because it does not need additional fertilizing for approximately eight years.

Beneficial use technology for remanufactured soil, such as the Toledo and Nu-Soil™ projects, is moving towards the use of dredged material as the primary component to create the remanufactured soil. There are currently no known sites in Maryland that convert dredged material to topsoil or other remanufactured soil products. Fine-textured material, such as the material dredged from the main Bay channels, would be a good base component due to the initially high amounts of nutrients available. Development of a remanufactured soil center in Maryland would also provide a site for recycling of organic household debris and yard waste such as vegetable scraps, grass clippings, etc. which could be used as components to provide a slow-release fertilizer characteristic for the remanufactured soil.

As with forestry and agriculture, MES was unable to obtain published documentation on commercial and residential projects that reuse dredged material and dredged material placement sites in Maryland. Information on commercial and residential projects in Maryland comes from interviews with agency personnel and landowners.

5.5.2 Commercial and Residential Uses Case Studies

Following are summary discussions of sites that were identified and investigated for this report. The summary discussions present information obtained from interviews with Federal, State or local agency personnel and/or landowners.

Many United States cities are constructed on dredged material (Mary Landin, USACE-WES, personal communication, April, 1997). Examples include portions of Baltimore, Washington D.C., New York and Portland. In Maryland, the Dundalk and Seagirt marine terminals in the Baltimore harbor are examples of commercial facilities constructed on dredged material. Dredged material is a viable material for commercial construction activities as evidenced by the aforementioned projects. USACE dredging activities in the Portland area utilize much of the material (which is predominantly sandy material) for beneficial use projects, predominantly construction (Jeff Dorsey, USACE, North Pacific Division, personal communication, April, 1997). These uses include levee construction, fill material, construction aggregate, construction of stockyards for cattle (to raise the ground elevation and prevent flooding) and use of placement sites for residential development.

Some Maryland counties, specifically eastern shore counties, have utilized dredged material placement sites for residential development and as fill material sources for other projects.

5.5.2.1 Dorchester County

Dredged material from placement sites in Dorchester county has been used for fill material for construction of other sites. The material is dewatered on-site, then hauled to the destination location. An example of such an application is the creation of Rooster Island in Dorchester County, Maryland (Chuck Weber, Dorchester County, personal communication, April 1997). Material was placed and dewatered in a diked area on the upland. Once dewatered, the material was hauled to the Rooster Island site and graded appropriately to create a breakwater and fast land. The soil was amended with fertilizer and lime, and the area seeded.

5.5.2.2 Somerset County

Several projects in Somerset County involved placement of material from the Crisfield Harbor on upland sites in the Crisfield area (Melvin Cusick, Somerset County, personal communication, April, 1997; D&T Realty & Ross Co. and Somerset County, 1988). One site is still being used as a dredged material placement site. The second site is no longer being used by the County as a DMP site, but as of 1989 it is still being used to place backfill from a pipeline job in the area. This placement site is designated for residential development upon completion of placement. The third site, owned by private developers, was used for dredged material placement until 1987 and is currently being developed as a residential housing area. The houses are constructed on piling foundations. The houses have public water and sewer, so there are no septic field or drinking water quality concerns. There are at least 4 houses that have been constructed and one that is currently under construction.

The houses have lawns; and the dredged material was amended to allow for turf and landscape planting growth (Scott Tawes, personal communication, April, 1997). Discussions with one of the developers revealed that two of the four constructed houses used sod and two were seeded. The lots were limed and fertilized and the materials mixed with topsoil. One of the lots that used sod is growing well, but the other lot was not successful, possibly due to inadequate watering. Both of the lots that were seeded are doing well. In all four lots, the landscape trees do not appear to be doing well. They appear stunted in growth and the addition of fertilizer boosters has been unsuccessful at stimulating significant growth. The willow and pear plantings have not shown significant growth since they were planted in approximately 1990 and the pine plantings (exact species unknown) died.

5.5.2.3 Talbot County

5.5.2.3.1 Knapps Narrows DMP Site

Constructed:	Constructed in 1979.
Size:	Approximately 20 acres.
Dredged Material:	From Knapps Narrows. Silty sand composition.
Vegetation:	Dominated by *Phragmites*. Dikes did not appear seeded.
Notes:	In the past, dewatered material was sold for fill/construction material. The site has a twenty year lease that continues until 1999. It is located on a previously used agricultural field. There are four cells within the main exterior dike.

5.5.2.3.2 Tred Avon 1 DMP Site

Constructed:	Initially constructed in late 1970's. Used once and leveled.
Size:	Approximately 15 acres.
Dredged Material:	From Tred Avon River. Silt composition.
Vegetation:	A large portion of the site is fallow, a mowed field.
Notes:	Located on a previously used agricultural field. A nursing home is constructed on a portion of the placement site.

6. LAND APPLICATION ISSUES

There are several issues when considering land application of dredged material. These include distance from the proposed site, site accessibility, dredging and placement techniques, material rehandling requirements, size of the project, timing of the project and socioeconomic benefits and costs (USACE and EPA, 1992).

The USACE provides several recommendations for success of a habitat development project that are applicable to the land application of dredged material. These include:

- Examine nearby sites in the project vicinity to determine needs and the likelihood of success.
- Be sure to include all site variables and allow a margin of error.
- Develop a set of criteria and objectives where development and natural resource goals are included during the early planning stages of the project.
- Remain flexible in the criteria and objectives.
- Develop a contingency plan in case alternate habitats develop over time on the dredged material placement site.
- Provide careful instructions to dredging inspectors regarding construction and placement, and follow up to be sure these were conducted correctly.
- Provide appropriate funding.
- Monitor development on the project to determine success or failure and to allow for any necessary adjustments.
- Develop long-range management plans [if developing a wetlands/habitat area and retaining ownership] (Landin *et al.*, 1989).

These recommendations are useful because they address some of the logistical issues that must be addressed when considering the land application of dredged material. Additional issues that must be considered include finding a site where the landowner is willing to participate in the beneficial use project, logistical considerations given the site conditions, distance from the dredging activity and available materials.

7. ADDITIONAL CASE STUDIES OF UPLAND APPLICATIONS

Following are summary discussions of sites that were identified and investigated for this report that included land applications of dredged material that were not agricultural, forestry, wetland/habitat, commercial or residential in nature. The summary discussions present information obtained from interviews with Federal, State or local agency personnel and/or landowners.

7.1 Matapeake DMP Site

Constructed:	Approximately 1992. Dikes 10+ feet above existing ground level. Material has dewatered to approximately 8 feet below top of dike.
Size:	Approximately 10 acres
Dredged Material:	From Matapeake area of Chesapeake Bay. Silty sand composition.
Vegetation:	Well-developed herbaceous growth; beginnings of shrub and sapling growth. Maple, locust and loblolly pine saplings and upland grasses on exterior and top of dike. Substantial willow and *Phragmites* growth on interior of dike.
Notes:	Site graded to east. Spillway still draining facility; hand-dug trench to weir. Spillway drains to riprapped and vegetated channel that drains into Chesapeake Bay. Evidence of wildlife (deer tracks and mammalian burrows). No evidence of recreational use of the site.

This site was constructed by the MDNR and the land leased for approximately five years. At the end of the five years, ownership reverts to the Episcopal Diocese.

During construction, the topsoil was stripped from the area and stockpiled on-site. Once the dikes had been constructed and material placed, the topsoil was spread over the exterior of the dike and the area seeded. Photographic documentation is presented in Appendix A.

7.2 Edge Creek DMP Site, Talbot County

Constructed:	Initially constructed in 1987. Reclaimed in 1988.
Size:	Approximately 2 acres.
Dredged Material:	From Edge Creek. Sandy composition.
Vegetation:	Old field. Seeded with upland grasses.
Notes:	Dewatering took only six months. Reclaimed in 1988. Was a low-land wooded lot prior to placement. Site never utilized for agricultural production. Site is currently maintained by mowing.

At the time of the proposed construction, the adjacent landowner took the county to court in an attempt to stop placement; they were unsuccessful. Photographic documentation is presented in Appendix A.

7.3 Peachblossom Cove DMP Site, Talbot County

Constructed:	Initially constructed in 1982. Reclaimed Spring 1983.
Size:	Approximately 3 to 5 acres.
Dredged Material:	From Peachblossom Creek. Sand composition.
Vegetation:	Site needed to be limed with significant quantities to be planted with upland grasses. Maintained by mowing.
Notes:	Reclaimed in 1983 but not reverted to agricultural use.

Information from Maryland Department of Natural Resources plan sheets:

- Dredged material treated with lime, fertilizer, seeded and mulched
- Utilized stockpiled topsoil on-site to prepare seedbed.

From Seeding Specifications:

- Seeding from Feb 1 to April 30 or Aug 15 to Oct 31
- Seedbed preparation: 25lbs of 10-10-10 fertilizer per 1000 sq.ft. Harrow or disc into soil to a depth of 3 to 4 inches. Apply pulverized ground limestone, 50lbs per 1000 sq.ft.
- Seeding: apply 1.4-2.3lbs per 1000 sq.ft. of Kentucky 31 Tall Fescue on a moist seedbed with suitable equipment, min. coverage is ¼ inch.
- Mulching: immediately after seeding, uniformly mulch entire area with unweathered small grain straw at a rate of 1 1/2 to 2 tons per

acre. Mulch to be anchored with mulch anchoring tool on the contour or asphalt tie down methods (on ditches only).

Photographic documentation is presented in Appendix A.

7.4 Tred Avon 2 DMP Site

Constructed:	Approximately 1986. Not reclaimed. Intend to continue use as placement area when funding available.
Size:	Approximately 100 acre site, 30 to 50 acres in use as placement facility.
Dredged Material:	From Tred Avon River. Silty composition.
Vegetation:	Predominantly *Phragmites* inside dike. Loblolly pine, sweet gum and cedars along exterior and tops of dike.
Notes:	Outflows to Miles River through culvert under Glebe Road. Small county mechanically dredged projects sometimes deposit material into site. Dredging projects have to be within a 10-mile radius of site due to hauling distances and costs. This site also had two fingers, similar to Kent Narrows DMP Site.

There have been a significant number of complaints from residents of Easton because they feel that Tred Avon 2 is the potential source of a mosquito infestation problem. The site has naturally reverted to a habitat area. The contribution of the Tred Avon 2 DMP Site to the mosquito population relative to the contribution of other sources has not been determined.

Dessication cracks that form in the drying crust do provide breeding habitat for the salt marsh mosquito. Techniques have been developed and utilized at dredged material placement sites that control mosquito generation. Therefore, if a DMP site is found to be contributing to a mosquito problem, there are measures available to alleviate the problem.

8. SUMMARY

There are several land application options for upland placement of dredged material from the C&D Canal Approach Channels between Tolchester and the Sassafras River. The fine-grained material from this area is well suited to vegetative growth due to the naturally high levels of nutrients, when compared to coarse-grained material. Though there are few well-documented projects and little information available on USACE and state dredged material land application projects located in Maryland, the Maryland Eastern Shore Counties have been using dredged material, predominantly coarse-grained, for agricultural, commercial and residential use for decades.

The information in this report gives a brief overview of the information available on the subject of land application options for dredged material. More in-depth information is available on the different soil amendment and reuse options presented in brief in sections four, five and seven of this report. The references provided in section nine of this report represent a portion of the available literature on this subject.

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APPENDIX A

PHOTOGRAPHIC DOCUMENTATION OF SELECTED CASE STUDIES

APPENDIX A: PHOTOGRAPHIC DOCUMENTATION OF SELECTED CASE STUDIES

This appendix presents photos of selected case studies. These photos are presented in an order that is similar to a DMP site's natural progression. These photos exemplify different stages of a DMP site development from initial placement through eventual reclamation.

Figure 1 presents the Kent Narrows DMP Site which was constructed in late 1996. This site is a representation of the early stages of dewatering of a site, prior to drying of the upper crust and natural colonization. The property owner's residence is visible in the right edged of the panorama.

Figure 2 presents examples of a typical weir and spillway for a county DMP site. These photos are of the Matapeake DMP Site.

Figure 3 presents the Price Creek DMP Site that has been dewatering for three years. This site exemplifies the later stages of dewatering where the crust has formed and the site has begun to be naturally colonized by grass species.

Figure 4 presents the Price Creek DMP Site spillway that flows to Craney Creek then to the Bay.

Figure 5 presents the Grove Neck DMP Site that was a placement site from 1965 that went through natural regeneration. As shown in the photos, this site represents the later stages of natural colonization, if a DMP site was left unattended and permitted to naturally develop. This site took over 20 years to reach this stage of early successional growth.

Figure 6 presents the Peachblossom DMP Site that was a dredged material placement site on agricultural land. As can be seen in the panorama, the dikes were leveled and the area seeded. The site was not reverted to agricultural use, but has been maintained by mowing.

Figure 7 presents the Edge Creek DMP Site that was a dredged material placement site on agricultural land. As can be seen in the panorama, the dikes were leveled and the area seeded. The site was not reverted to agricultural use, but has been maintained by mowing.

APPENDIX B

MINI FEASIBILITY STUDY: INTERIM AGRICULTURAL USE OF A DREDGED MATERIAL PLACEMENT AREA

SUMMARY REPORT

PILOT PROJECT FOR DREDGING CITY OF PERTH AMBOY MUNICIPAL MARINA CITY OF PERTH AMBOY, MIDDLESEX COUNTY, NJ AND BENEFICIAL USE OF DREDGED SEDIMENT FOR MINE RECLAMATION AT BARK CAMP MINE FACILITY HUSTON TOWNSHIP CLEARFIELD COUNTY, PA

September 30, 1998

Prepared For

Pennsylvania Department of Environmental Protection
Bureau of Abandoned Mine Reclamation
Bureau of Land Recycling and Waste Management
and
New Jersey Department of Commerce and Economic Development
Office of Maritime Resources
and
City of Perth Amboy
Office of Economic and Community Development
and
New York/New Jersey
Clean Ocean and Shore Trust

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PADEP | CITY OF PERTH AMBOY | THE PORT AUTHORITY | NJ MARITIME RESOURCES | NJDEP

TABLE OF CONTENTS

INTRODUCTION 1
Supporting Communities and Government Agencies 1

PROJECT BACKGROUND 3
New York/New Jersey Harbor Dredging Background 3
Pennsylvania Abandoned Mine Reclamation Problem 4
Consolidated Technologies, Inc. Company Profile 5
Bark Camp Mine Facility Profile 6

PROJECT SUMMARY 7

TECHNOLOGY REVIEW 9

PERMITTING 10
City of Perth Amboy Municipal Marina 10
CTI Portside Facility in Elizabeth, New Jersey 11
CTI Bark Camp Facility in Houston Township, Pennsylvania 11

TESTING OF DREDGE MATERIALS AND ADDITIVES 12
Quality Control 12
Quality Assurance 14

DESCRIPTION OF PROJECT OPERATIONS 15

CONCLUSIONS 19

APPENDICES

REGULATORY CORRESPONDENCE .... Appendix A

ANALYTICAL & GEOTECHNICAL RESULTS .... Appendix B

PROJECT SUMMARY REPORT

PILOT PROJECT FOR DREDGING
CITY OF PERTH AMBOY MUNICIPAL MARINA
AND
BENEFICIAL USE OF DREDGE MATERIAL
FOR MINE RECLAMATION AT THE BARK CAMP MINE FACILITY

September 1998

CTI Project No. 97-301-19

INTRODUCTION

Consolidated Technologies, Inc.'s (CTI) is pleased to present this Project Summary Report for a pilot dredging project and the beneficial use of dredged materials for abandoned surface mine reclamation and remediation ("pilot project"). This report describes services provided for the dredging of the City of Perth Amboy Municipal Marina, and the beneficial use of the dredged materials for the remediation and reclamation of an abandoned Coal Mine known as Bark Camp in Huston Township, Clearfield County, Pennsylvania. CTI was contracted by the New Jersey Department of Commerce and Economic Development, Office of Maritime Resources, (Division of Purchase and Property, Purchase Bureau) to perform this work.

This pilot project has been conducted with the assistance and full support and cooperation of the members of the communities and agencies listed below, each of which has been issued a copy of this report.

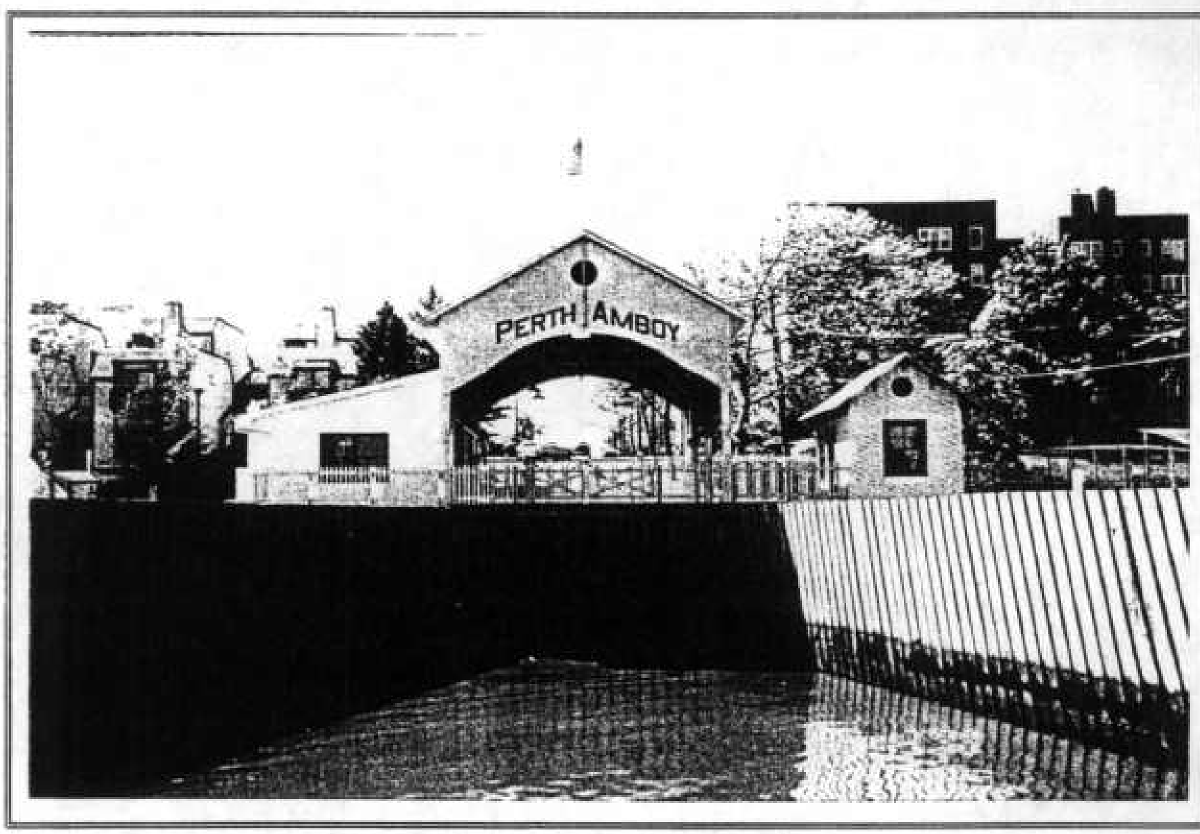
Perth Amboy Pilot Project - Supporting Communities and Government Agencies

- Clean Ocean and Shore Trust **(COAST)**,
- New Jersey Department of Commerce and Economic Development **(NJDOCED)**, Office of Maritime Resources **(Maritime Resources)**
- New Jersey Department of Environmental Protection **(NJDEP)**,
- City of Perth Amboy, Bureau of Commerce and Economic Development **(Perth Amboy)**
- Pennsylvania Department of Environmental Protection **(PADEP)**, Bureau of Abandoned Mine Reclamation **(BAMR)**
- Pennsylvania Department of Environmental Protection **(PADEP)**, Bureau of Land Recycling and Waste Management **(BLRWM)**

- Huston Township, Clearfield County, Pennsylvania,
  Board of Supervisors and Environmental Committee **(Huston Township)**
- Port Authority of New York and New Jersey **(PANYNJ)**
- U.S. Department of the Army, Corps of Engineers, New York District **(USACOE)**

The Perth Amboy Marina pilot project is the first abandoned coal mine reclamation/remediation project conducted in the Commonwealth of Pennsylvania utilizing dredged sediments. This project has been conducted pursuant to a PADEP Beneficial Use Order (BUO) issued to CTI and its affiliates for a demonstration project involving the reclamation of the Bark Camp Mine facility. Under this BUO, CTI may utilize up to 500,000 cubic yards of dredged material from the Hudson-Raritan Estuary and the Delaware River Basin.

Based upon the demonstrated success of this technology and the continued commitment of each participant associated with this pilot project, the beneficial use of dredged materials for the reclamation and remediation of abandoned mine lands provides a potential long-term solution to the future dredging needs of our ports and channels. CTI is committed to the furtherance of this technology and looks forward to identifying other beneficial uses of natural resources and industrial by-products.



City of Perth Amboy Municipal Marina

PROJECT BACKGROUND

New York/New Jersey Harbor Dredging Background

The continued operation of port facilities and private terminals along the New York Harbor and Upper Newark Bay is vital to the economies of the States of New Jersey and New York. On a regional basis, shipping into and out of the New York/New Jersey Harbor supports an estimated several hundred thousand jobs and generates in excess of $20 billion in annual revenues.

Ports of New Jersey / New York

Reportedly, if not dredged, New York Harbor channels may loose a foot of depth annually. To maintain the required depth for shipping into the region, approximately 5 to 7 million cubic yards of sediment material must be dredged annually. Until 1992, most of the dredged material from this region was acceptable for ocean disposal. Changes in federal and state regulations now restrict ocean disposal of certain dredged sediments containing low to moderate levels of chemical constituents that may pose a threat to the environment and human health in an aquatic environment. These changes have caused the volume of sediments removed from the region to decrease dramatically in recent years. Additionally, these restrictions on ocean disposal have created a critical need for *long-term* upland management options for large quantities of dredged sediments

One of the most significant objectives of this pilot project is to evaluate the ability of the manufactured fill created from the dredged sediments and additives to prevent the leaching of any potentially hazardous chemical constituents that could be in the sediment or additives into the environment. Prior to this pilot project, laboratory bench tests performed on manufactured structural fill created from impacted dredged sediments have demonstrated that the pozzolanic bonding which occurs when the manufactured fill is created mitigates the ability of chemical constituents to leach from the manufactured fill material.

Pennsylvania Abandoned Mine Reclamation Problem

Pennsylvania is confronted with a severe environmental situation related to abandon mine lands throughout the Commonwealth. The two major problems associated with abandoned coalmines are acid mine drainage (AMD) and fall hazards created from strip mine "highwalls" left unreclaimed and exposed. The PADEP has estimated that the cost to remediate water problems caused by these mine sites is in excess of $15 billion. In addition to the abandoned sites that the Commonwealth is responsible for, private industry and bonding companies have the responsibility to reclaim and remediate many additional mine sites. PADEP estimates that nearly 250,000 acres in the Commonwealth have been left unreclaimed. Many of the abandoned mines have severely degraded the quality of surrounding surface waters and groundwater. In fact, AMD is the largest non-point source of water pollution in the Commonwealth, tainting more than 2,500 of Pennsylvania's 54,000 miles of waterways. In addition, abandoned mines destroy the aesthetic and functional values of land and frequently endanger public safety.

A large source of suitable fill material at a very low cost is needed to begin to reclaim the highwall areas and provide capping and grouting material needed to permanently eliminate AMD.

Damage Caused by Acid Mine Drainage

Consolidated Technologies, Inc. Company Profile

Consolidated Technologies, Inc. (CTI), with offices located in New Jersey, Pennsylvania and Delaware was founded in 1995 with the mission of conducting research and development of environmentally safe beneficial uses of dredged sediments. These efforts have provided a potential long-term solution to the New York/New Jersey dredging and Pennsylvania abandoned mine reclamation situations.

CTI and its business affiliates, have worked closely with the Pennsylvania State University and independent geotechnical laboratories to develop various technologies for the manufacturing of engineered fill materials through solidification and stabilization of dredged materials. From this research, CTI has identified proprietary techniques for creating manufactured structural fill for the remediation and reclamation of abandoned strip mines.

Bark Camp Mine Facility Profile

The Bark Camp Facility consists of approximately 1,200 acres of land. The surface mine was operated from approximately 1960 to 1988, when it was abandoned. Two underground deep mines were also operated during the 1950s. The Bark Camp Facility is located within the Moshannon State Forest, a Pennsylvania Department of Conservation and Natural Resources (DCNR) property. Since the Commonwealth owns the lands, the economic burden for the reclamation and remediation of Bark Camp has become the responsibility of the citizens of Pennsylvania.

Bark Camp Run, a stream passing through the site, is affected by AMD emanating from the abandoned mines. The AMD has rendered Bark Camp Run acidic and sterile downstream of the mine. Groundwater aquifers in the area, which are used as sources of potable water, are naturally high in iron pyrite due to coal deposits. These aquifers also demonstrate acidic properties.

Bark Camp Abandoned Mine Facility

The highwall at Bark Camp consists of approximately 11,000 linear feet of exposure extending 40 feet to a "bench" and then an additional 60 feet above the bench to a hillside. PADEP estimates that 10 to 12 million tons of material will be required to complete the reclamation of Bark Camp. For economic reasons, these large volumes prohibit the use of ordinary materials (clean fill) to reclaim Bark Camp.

Bark Camp Abandoned Mine Highwall

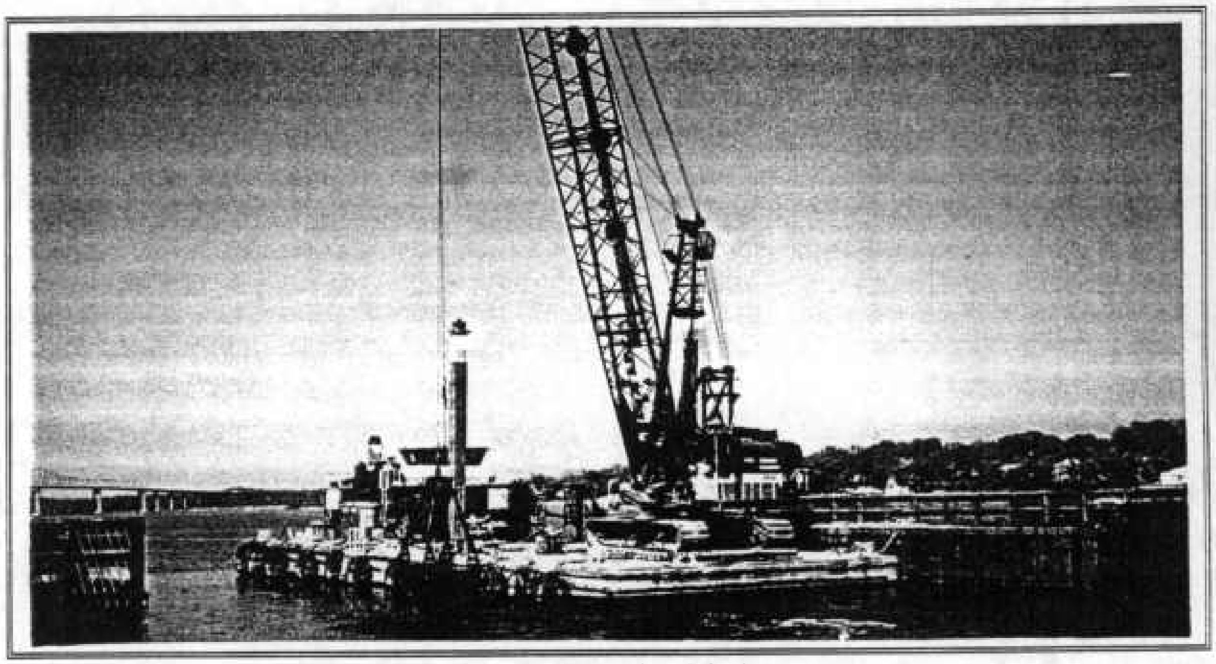
The beneficial use of the processed dredged sediment from the Perth Amboy Marina was demonstrated by CTI for the Commonwealth of Pennsylvania in a demonstration project for the remediation and reclamation of the Bark Camp Surface Strip Mine (Bark Camp) located in Huston Township, Clearfield County, PA. A part time site inspector representing Huston Township and a full time PADEP inspector oversee the processing and placement activities at Bark Camp.

PROJECT SUMMARY

The New Jersey Office of Maritime Resources was established in part to pursue the development, funding, implementation and operation of programs and projects which will ensure the continued economic viability of New Jersey's commercial and recreational navigation, berthing, and mooring facilities and other maritime assets. Of particular importance to New Jersey is dredging and dredged materials management techniques which preserve and/or restore the environmental integrity of its navigable waterways.

In response to Maritime Resources solicitation during early 1998, CTI submitted a Work Plan and Cost proposal to perform the dredging, transportation, processing, and beneficial use of approximately 35,000 cubic yards of sediment from the Perth Amboy marina.

The project consisted of maintenance dredging of the marina and nearby ferry slip and transporting the dredged materials to CTI's portside facility located in Elizabeth, New Jersey, on the Arthur Kill waterway. There, the dredged materials were dewatered, off-loaded, screened to remove oversized debris, pre-amended, and loaded into railcars for shipment to Bark Camp. The pre-amended materials were off-loaded from the railcars at the Bark Camp rail siding and hauled in off-road trucks to the processing pad at the mine facility. The pre-amended materials were processed with additional admixtures to create the final manufactured fill product. This fill was spread and compacted in lifts along designated segments of the highwall. Details of the operation are presented in subsequent sections of this report.



Dredging the Perth Amboy Marina

Dredging at the Perth Amboy Marina commenced on May 15, 1998. Processing at CTI's portside facility in Elizabeth began several days later. The first delivery of pre-amended material arrived at Bark Camp on May 28, 1998, and was processed and placed that same day. The final manufactured fill from Perth Amboy was placed at the mine on September 9, 1998.

The following is a brief synopsis of some of the pertinent statistics related to this project:

- Volume of sediment dredged = 19,029 cubic yards.
- Volume of oversized debris disposed = 1,600 cubic yards
- Percent of total volume of dredged material classified as oversized debris = 9%

- Processing time (exclusive of downtime) at Elizabeth facility = 40 days
- Number of railcars containing sediment shipped to Bark Camp = 359
- Final amendment processing time at Bark Camp facility = 37 days

TECHNOLOGY REVIEW

CTI has extensive experience in creating engineered fill products and cementitious grouts from waste materials for beneficial re-use applications. These grouts are formed by combing specific percentages of industrial by-products including coal ash with various activators including other by-products of industry such as cement kiln dust and lime kiln dust. CTI has applied similar technology to the production of the manufactured fill created from a mixture of dredged material originating from the Perth Amboy Marina, coal ash materials, and various activators.

The manufacture of cementitious grouts from ashes for large applications relies upon alkali activation to initiate hydration reactions. Structures dating from ancient Roman and Greek cultures, many still standing today, were constructed from this type of cementitious material. A pozzolan can be defined as a siliceous or siliceous and alumnus material, which possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

The beneficial use of coal ash in this manner is predicated on the production of approximately 90 million tons of coal ash produced annually in the United States. Only a small percentage of this material is currently beneficially re-used in land management applications. Approximately 20% of the total ash produced is used as a partial replacement of cement in concrete, as construction fill, or as roadbase. Almost one-half of the coal ash produced annually is landfilled. The manufactured fill utilized at Bark Camp contains coal ash from several ash generators.

In proven mine reclamation applications, pozzolanic materials (coal ash) are activated by the addition of water and alkaline activators to create a cementitious fill material. The formulation of the manufactured fill utilized at Bark Camp using similar pozzolanic materials and activators along with the dredged sediments, are over time, capable of achieving the desired physical and chemical properties including strength and permeability. The high moisture content of the dredged sediments eliminates most, if not all, of the need to add water to the mix. Additionally, the small particle size of the dredged sediments (70% to 90% passing #200 sieve) enhances the creation of an excellent low-permeability roller-compacted fill.

The net result of this type of processing and beneficial use of dredged materials provides major benefits versus traditional land disposal including the following:

- **Solidification** of the dredged sediments creates a material capable of being transported and handled effectively to allow for placement in upland areas, including strip mines, without the potential for loss of water or contaminants during transit.

- The **Stabilization** aspect of the process minimizes the potential for leaching of contaminants from the materials, and creates a fill product with geotechnical properties which actually facilitate remediation of AMD from former mine sites.

- The manufactured fill created from the dredged sediments is capable of being placed as structural fill in areas of former strip mines in need of reclamation and capping. Because of the large number of mine sites in Pennsylvania requiring reclamation, there is virtually **no limit** to the amount of sediments which can be dredged from the Estuary and accepted for the beneficial use of mine reclamation and remediation. This provides the Ports of New York and New Jersey with a **long term** effective solution to its dredging dilemma, as well as providing a solution to Pennsylvania's mine reclamation dilemma

PERMITTING

This pilot project was conducted pursuant to all local, state, and federal regulations applicable to the dredging, processing, transport, and beneficial use of the dredged sediments and additives. Certain permits were required for each location and/or operation of the project. A summary of the permits issued for each facility and/or operation is presented below.

City Of Perth Amboy Municipal Marina

- USACE Dredging permit initially issued October 1995, re-issued March 1998.
- NJDEP Waterfront Development/Water Quality Discharge permit initially issued April 1993, re-issued April 1998.

- Sampling and Analysis Plan (SAP) for the in-situ sediment from the Perth Amboy Marina submitted by CTI to the PADEP and the NJDEP for review and approval. Supplemental SAP submitted to PADEP on March 9, 1998. SAP approved March 13, 1998.

CTI Portside Facility in Elizabeth, New Jersey

- NJDEP Waterfront Development Permit issued January 1998.
  As part of the permitting process for this facility, CTI prepared and submitted various site specific environmental protection plans. The plans included a Health and Safety Plan and a Spill-Prevention and Contingency Plan.
- NJDEP Air Quality Regulation Program issued a permit to Construct, Install or Alter Control Apparatus or Equipment and Certificate to Operate to CTI for the erection and operation of an additives storage silo at the Elizabeth facility issued April 1998.
- NJDEP Acceptable Use Determination (AUD) for the dredged material from the Perth Amboy Marina issued May 1, 1998.
- NJDEP Beneficial Use Determination (BUD) to utilize coal ash in the manufactured fill issued May 6, 1998

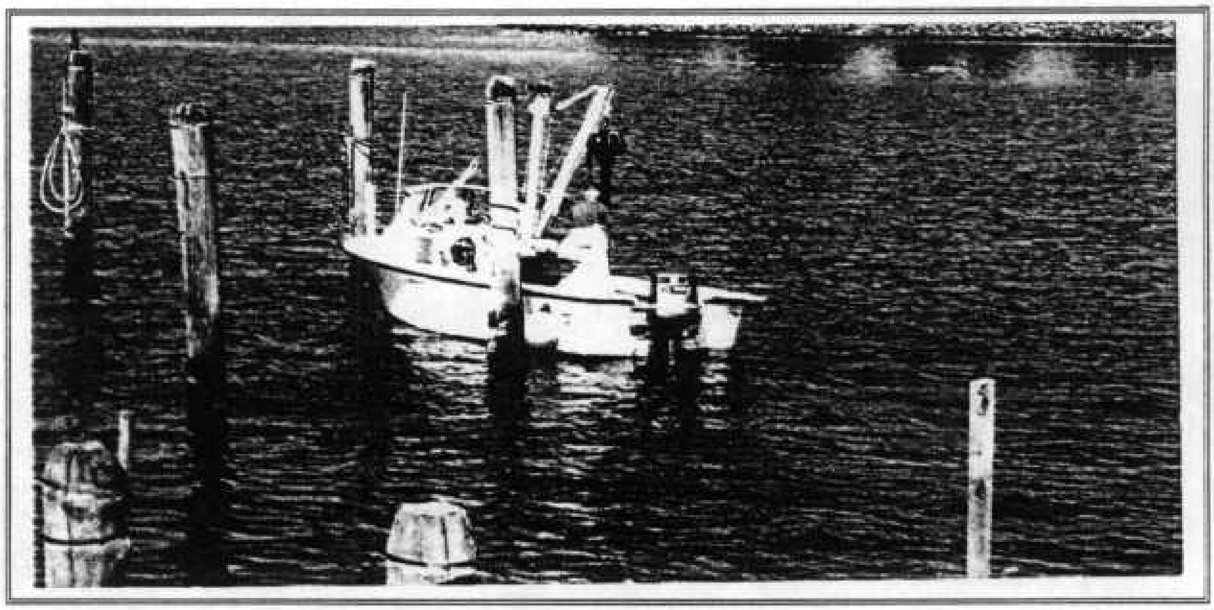
CTI Bark Camp Facility in Huston Township, Pennsylvania

- PADEP Amended Beneficial Use Order No. 40030 to CTI and its affiliates for the beneficial re-use of stabilized dredged materials at Bark Camp mine facility, Clearfield County, PA. Order issued June 1997.
  Note: As part of the permitting process for Bark Camp, CTI prepared and submitted various site specific environmental protection plans for PADEP review and approval. These plans included a Health and Safety Plan, a Ground and Surface Water Monitoring Plan, a Spill- Prevention and Contingency Plan, a Soil Erosion and Sedimentation Pollution Control Plan, and a Facility Operating Plan. Each plan was approved by the PADEP and has been fully implemented. A National Pollution Discharge Elimination System (NPDES) permit was also issued to CTI for the Bark Camp facility.

- PADEP General Construction NPDES permit issued January 1998.
- PADEP issued a final approval for the use of the Perth Amboy Marina dredge material at the Bark Camp Mine Facility. The approval was issued April 13, 1998 in accordance with PADEP Amended Beneficial Use Order No. 40030.

TESTING OF DREDGED MATERIALS AND ADDITIVES

The Waterfront Development Permit, BUO, and Operating Plan for the Perth Amboy project contain specific Quality Assurance & Quality Control (QA/QC) measures, which were implemented throughout the project to provide assurances to protect the public health, welfare, and the environment. In addition to the many day-to-day operational QA/QC measures implemented by CTI, an extensive testing protocol was undertaken to physically and chemically characterize and monitor the dredge materials and industrial by-products used to create the manufactured fill product. A brief description of the testing protocol is presented below.



In-Situ Dredge Material Sampling

Quality Control

Quality Control measures for this project included characterizing the chemical and/or physical properties of the raw dredged sediment and any additives utilized in the treatment process prior to commencing dredging. The physical and chemical properties of the additives were determined from testing and analytical results provided by the generators of these materials. Vendors supplying coal ash products were required to demonstrate to CTI that the ash materials meet the PADEP Module 25 chemical criteria for ash placement in mine reclamation. Additionally, Material Safety Data Sheets (MSDS) that are available for these materials were provided to CTI and were kept on file in the administrative office at the Bark Camp facility.

The chemical analyses protocol for the dredged sediment intended for Bark Camp consists of three stages. Theses include the core sampling and analyses of in situ dredged material samples (Stage I); the sampling and analysis of the dredge material at the portside offloading facility, which is intended to confirm that the material being shipped is similar to the in situ materials (Stage II); and the sampling and analysis of the treated materials at the Bark Camp facility to assure that the manufactured materials comply with the criteria established in the BUO (Stage III).

The sampling and analysis for the Perth Amboy Pilot Project was conducted in accordance with the requirements of the BUO and the New Jersey Department of Environmental Protection (NJDEP) guidance manual entitled The Management and Regulation of Dredging Activities and Dredged Material in New Jersey's Tidal Waters; October, 1997. The New Jersey manual (hereinafter referred to as the "Guidance Document") specifies sampling and analytical requirements for upland disposal and beneficial re-use of dredged materials in the State of New Jersey. The manual specifies sampling procedures and frequency requirements, target analyte lists, analytical test methods to be used, and acceptable method detection limits for in-situ sediment samples.

A Sampling and Analysis Plan (SAP) for the in situ sediment was prepared for this project and was submitted for the NJDEP and PADEP's review and approval. Nineteen (19) individual core samples of the in situ sediment were taken to the proposed project depth plus allowable over-dredge. Five (5) composite samples were prepared from the individual core samples. The individual core and composite samples were subjected to the analysis specified in the Guidance Document and the approved SAP.

Bench tests utilizing the sediment from the in-situ testing and various percentages of CTI's proprietary additives were performed to simulate the creation of the manufactured fill. The bench test product samples were analyzed in order to chemically and physically characterize the manufactured fill and to determine the ability of the fill from each mix design tested to stabilize chemical constituents found in the in-situ Perth Amboy sediment.

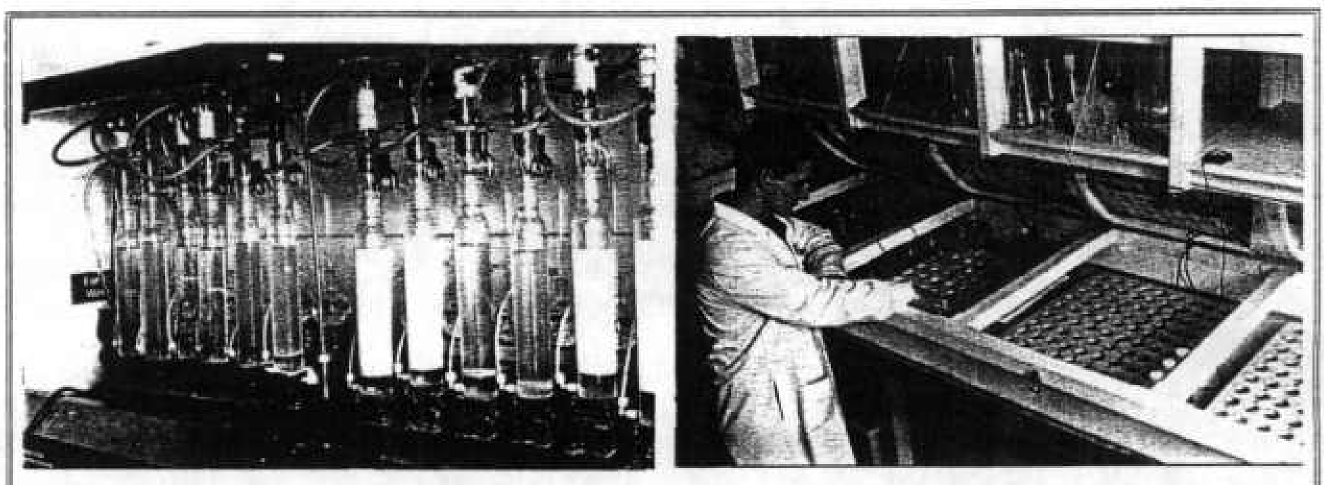
The analytical and test results for the Stage I in-situ sediment samples were submitted to the NJDEP and PADEP for their respective review and approval. Subsequently, on April 17, 1998 the NJDEP issued a Waterfront Development Permit permitting the City of Perth Amboy to dredge the marina, and on May 21, 1998, the PADEP issued a written approval for use of the dredged materials from the Perth Amboy marina at Bark Camp. Copies of the Waterfront Development Permit and the PADEP approval letters are presented in **Appendix A**.

Quality Assurance

Quality Assurance measures (Stages II and III) for this project were implemented to confirm that the chemical and/or physical properties of the pre-amended dredged material transported to Bark Camp and the manufactured fill were similar to that of the in situ sediment sample properties.

Stage II testing occurred at the CTI portside facility in Elizabeth, and was performed to confirm that the pre-amended dredged material was physically and chemically characteristic of the material sampled in Stage I. This confirmatory sampling was performed pursuant to the BUO, at a frequency of one composite per 25,000 cubic yards of dredged material. Accordingly, one (1) composite sample was chemically analyzed and geotechnically tested pursuant to the requirements specified in the BUO. The analytical and test results were reported to the PADEP for its review and information.

The final stage (Stage III) of the QA process was performed after the final amendment of the dredged sediment at the Bark Camp facility. One (1) composite sample of the manufactured fill was obtained pursuant to the BUO requirement of one composite sample per every 25,000 cubic yards of material. The composite sample was chemically analyzed and geotechnically tested pursuant to the specific requirements specified in the BUO for the manufactured fill. The analytical and test results were reported to the PADEP for its review and information.



Laboratory Analysis & Testing of Dredge Materials

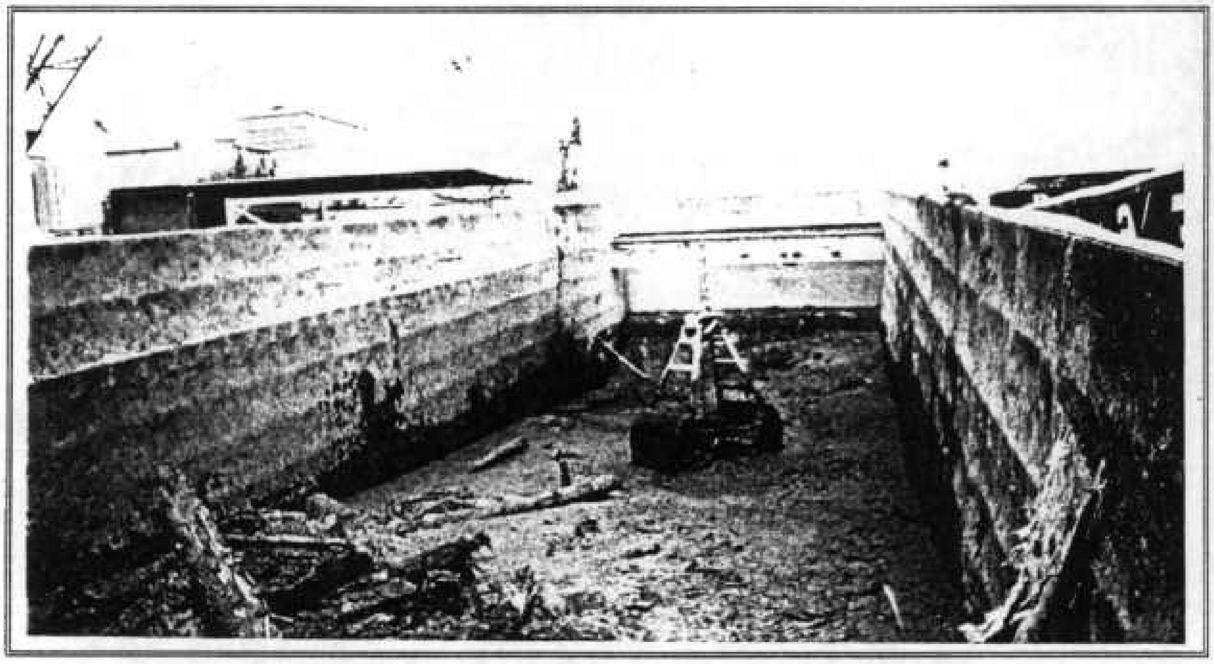
A tabular summary (**Tables 1 through 8**) of the analytical results for the in situ sediment samples, the pre-amended (portside) dredge material, and the manufactured fill placed at the Bark Camp facility are presented in **Appendix B**. A copy of the geotechnical test results of the manufactured fill sample is also presented in **Appendix B** as Table 9. These data demonstrate that the technology producing the manufactured fill derived from the Perth Amboy marina dredged material has effectively stabilized the chemical constituents present in the in-situ dredge material, and that the manufactured fill is physically competent as an engineered fill material suitable for use in mine reclamation.

DESCRIPTION OF PROJECT OPERATIONS

On March 24, 1998, Ocean and Coastal Consultants (O&CC) performed a pre-dredge survey of the Perth Amboy Marina and issued a volumetric estimate, based on the design grades and elevations for the marina, indicating a total volume of 20,932 cubic yards of sediment to be dredged from the Perth Amboy Marina.

CTI's subcontractor, Jay Cashman, Inc. (JCI) commenced dredging at the Perth Amboy Marina on May 15, 1998. The dredging was performed utilizing a dredge-plant mounted on a spud-barge and equipped with various types of clamshell buckets, and two hopper barges. JCI utilized a local tug service to transport the hopper barges to and from CTI's Elizabeth transfer facility.

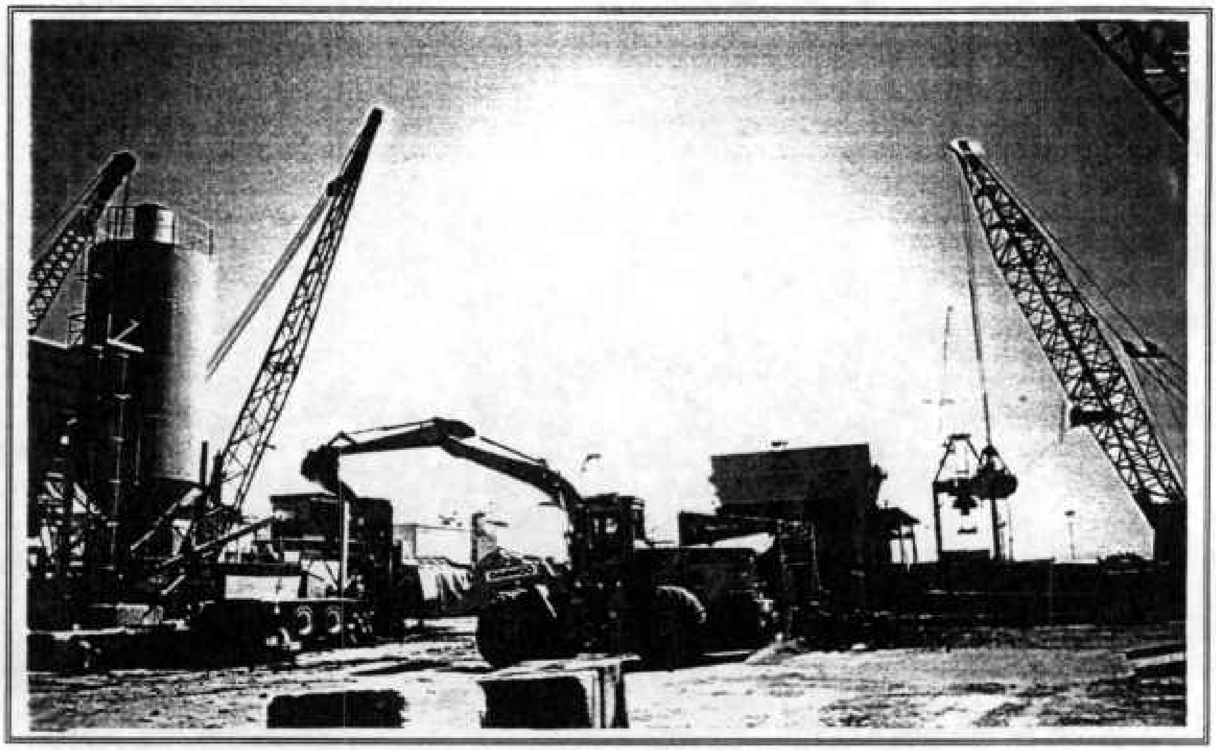
Off-loading of the dredged material at the Elizabeth facility was accomplished utilizing a 50-ton crane equipped with a clamshell bucket. As necessary, the loaded barges were moored at the Elizabeth facility to allow the sediment to settle for dewatering of the barges prior to off-loading. Water decanted from the loaded barges was pumped through a particulate filter to portable frac-tanks. After an adequate period of settling, the water in the tanks was tested for compliance with discharge criteria contained in the Water Quality Certificate. Upon confirmation, the decanted water was discharged from the tanks to the Arthur Kill waterway.



Off-loading Hopper Barges at CTI Portside Facility, Elizabeth, NJ

The raw dredged material was off-loaded into a large receiving hopper and through a series of screens to separate debris from the sediment. The debris was staged for transport and disposal at an alternate approved disposal facility. The dredged material was placed into a pugmill where it was mixed with coal fly ash to pre-amend (physically stabilize) the material for transport to Bark Camp. The raw material was solidified to ensure that no free liquids were present in the material. From the pugmill, the pre-amended material was discharged via a radial-stacking conveyor to a temporary storage area. The material was loaded from the stockpile into gondola rail cars for transport to the Bark Camp Facility. Off-loading and processing of the dredged sediment at CTI's Elizabeth facility was completed on July 31, 1998

Due to its lack of suitability as a component of the manufactured fill material, the oversized debris recovered from the dredged materials at the Elizabeth facility was transported to and disposed of at an appropriate permitted disposal facility. This debris included pilings, timbers, large metal objects, concrete, and similar unsuitable materials.



Pre-Amendment Processing at CTI's Portside Facility, Elizabeth, NJ

The pre-amended dredge material was transported to the Bark Camp facility by Conrail and a short line rail road, the Pittsburgh & Shawmut R.R.. All rail cars were covered with tarps during transport. The railcars were unloaded at Bark Camp utilizing an excavator located on an elevated off-loading structure. The material was placed directly into off-road trucks and transferred to the final processing area. There the material was blended with additives in a pugmill system according to a pre-determined mix design, and discharged onto a radial stacking conveyor. The final manufactured fill was transported utilizing off-road trucks to the reclamation area of the highwall. The fill was spread in two-foot thick lifts with a low-ground-pressure bulldozer and compacted using a vibratory roller. Final processing and placement of the Perth Amboy material at the Bark Camp facility was completed on September 9, 1998.

Railcar Off-loading Facilities at Bark Camp Mine

On August 3, 1998, O&CC performed a post-dredge survey of the marina and issued a final volume determination for the project. A total of 19,029 cubic yards of material was dredged from the Perth Amboy Marina during this pilot project. O&CC's estimate was based upon the volumetric difference of pre- and post-dredge surveys of the marina.

As discussed earlier, CTI and PADEP performed geotechnical and chemical testing of the manufactured fill material created from dredged sediment. Laboratory bench tests and tests of the actual manufactured fill produced from the Perth Amboy pilot project have yielded extremely positive results, demonstrating the effectiveness of the manufactured fill for the remediation and reclamation of abandoned coal mines.

CONCLUSIONS

The following conclusions can be made with the completion of the City of Perth Amboy Marina pilot dredging and beneficial use project:

Approximately 19,000 cubic yards of material was dredged and removed from the marina. With this volume of material removed, all required areas have been successfully dredged to the design criteria. The volume of material dredged and removed is approximately 45% less than the initial estimated volume of material required to be dredged (35,000 cubic yards[1]) due to changes in the marina design.

Approximately 9% or 1,600 cubic yards of the material dredged and removed from the marina was oversized debris not suitable as a component of the recyclable fill used for reclamation of the Bark Camp mine. The oversized debris was transported to and disposed of at a permitted landfill. The oversize debris created delays in the portside off-loading and pre-amendment processing of the dredged material. The debris was determined to be a result of past demolition and dumping practices and is not considered typical of a maintenance dredging project.

By adding and mixing the dredged material with specific quantities and sources of coal ash, the dredge material was successfully pre-amended at the portside facility, rendering a material that could be handled and transported by common earth handling techniques and equipment. The material was solidified to remove free liquid. The processing techniques implemented and equipment utilized at the portside facility were modified throughout the duration of the project to provide the most cost-effective and efficient process.

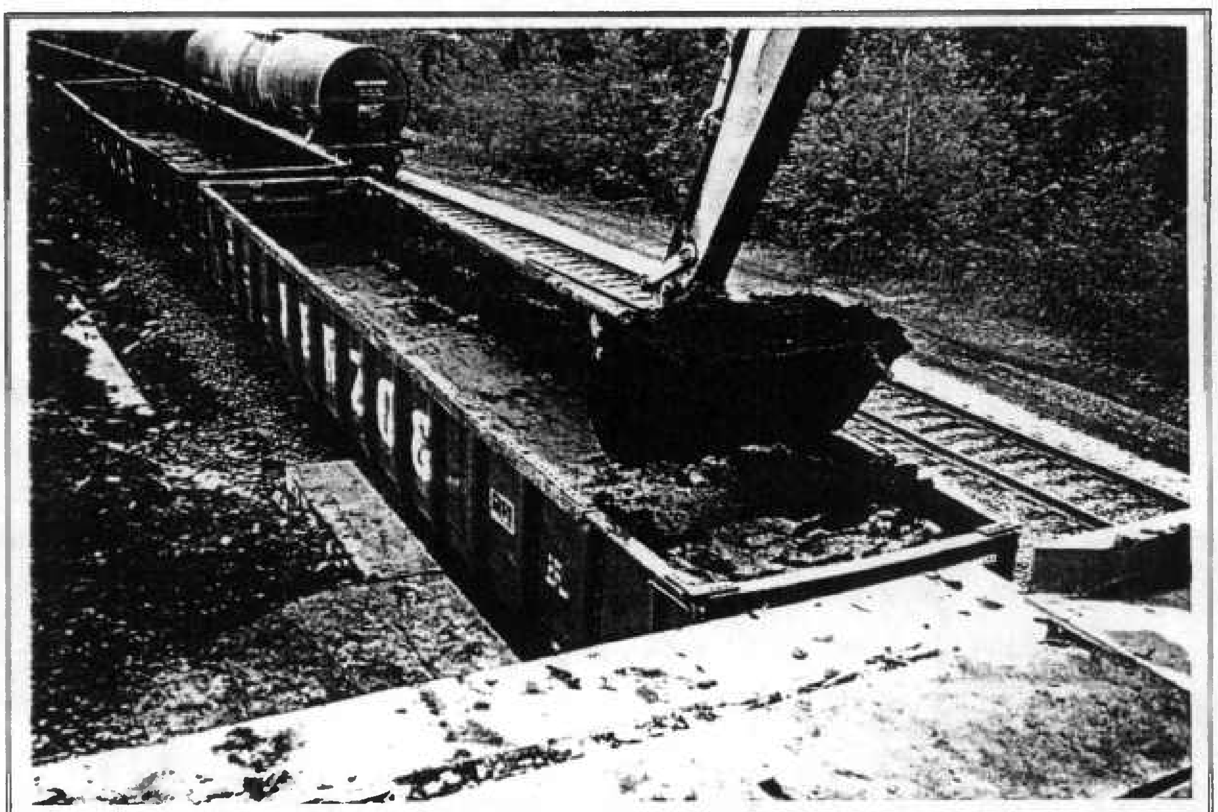
Approximately 25,000 cubic yards of pre-amended dredge material was transported by rail in tarped gondola railcars. Three hundred and fifty-nine loaded railcars were shipped to Bark Camp. All arriving railcars were successfully off-loaded at the Bark Camp rail siding with little need to modify the equipment or techniques planned for this aspect of the project. As with the portside pre-amendment operations, the processing techniques implemented and equipment utilized at the Bark Camp Facility were modified throughout the duration of the project to provide the most cost-effective and efficient process.

Laboratory chemical analyses and geotechnical test results indicate that the processes creating the recyclable fill manufactured at Bark Camp have successfully solidified and chemically stabilized the dredge material removed from the Perth Amboy marina. The long-term ability of the manufactured fill to sustain these properties will be monitored via visual observations and groundwater & surface water quality monitoring at the Bark Camp facility by CTI and PADEP.

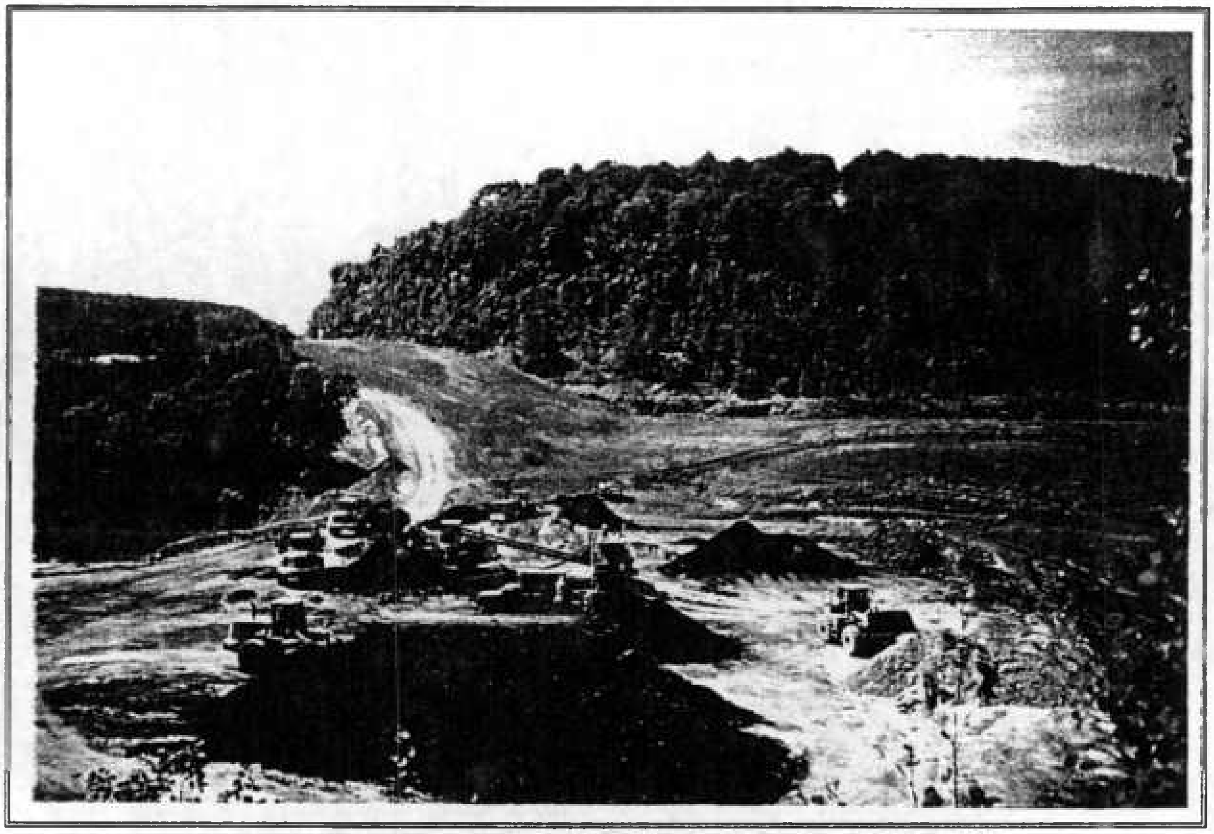
As demonstrated by the impacts to the operational budget throughout this project due to the unexpected reduction of volume of material dredged from the Perth Amboy marina, scales of economy can be realized when this technology is applied to a large-scale project.

The Perth Amboy Marina pilot project has demonstrated that dredge materials can successfully be beneficially used for upland placement in coal mine reclamation and remediation projects.

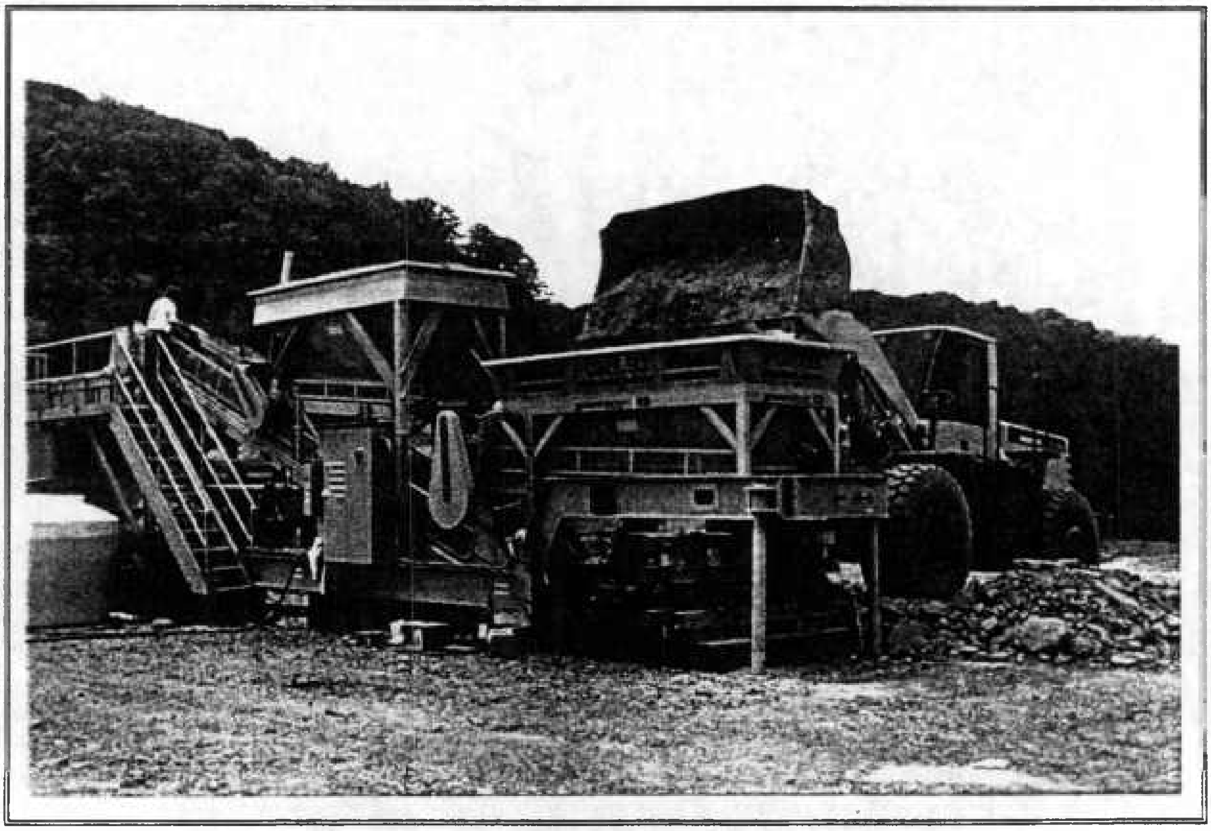
[1] 35,000 cubic yard estimate based upon NJDEP and USACE permit application documents prepared for and submitted by the City of Perth Amboy.



Off-loading Railcars at Bark Camp Mine



CTI Final Processing Facility at Bark Camp Mine

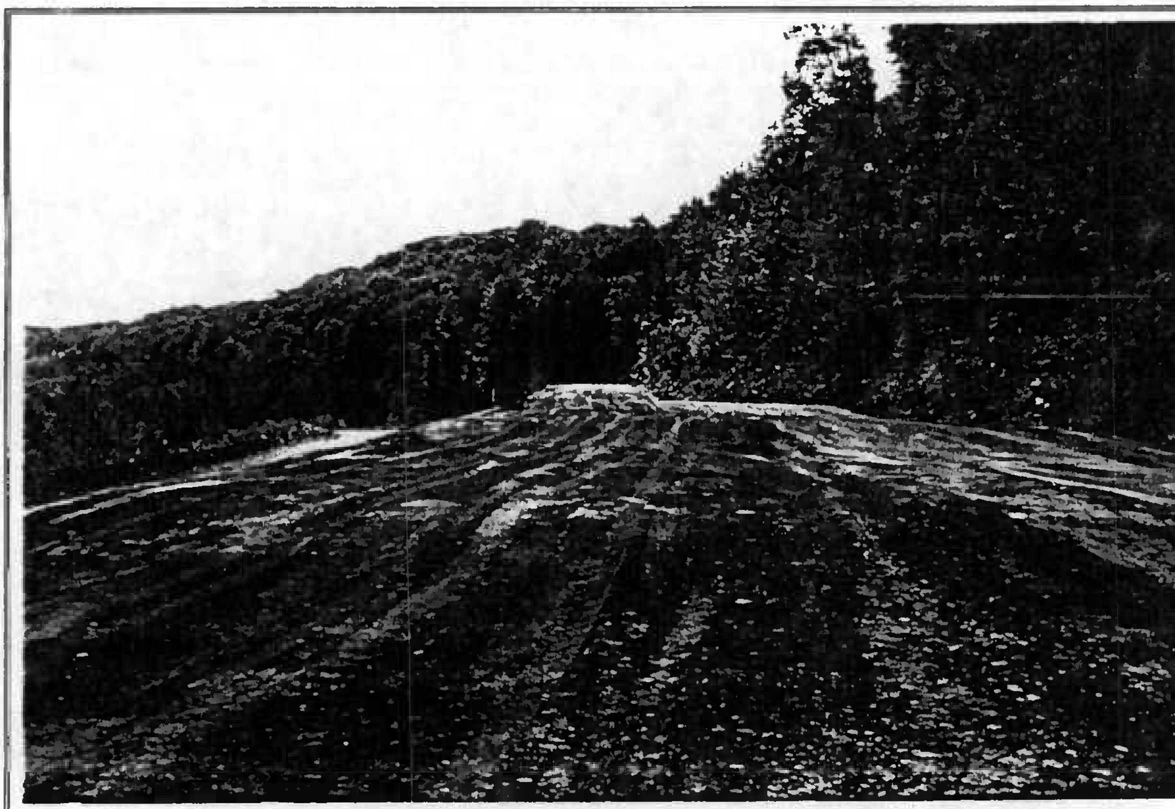


Processing Manufactured Fill from Dredge Material at Bark Camp


Processing Manufactured Fill from Dredge Material at Bark Camp

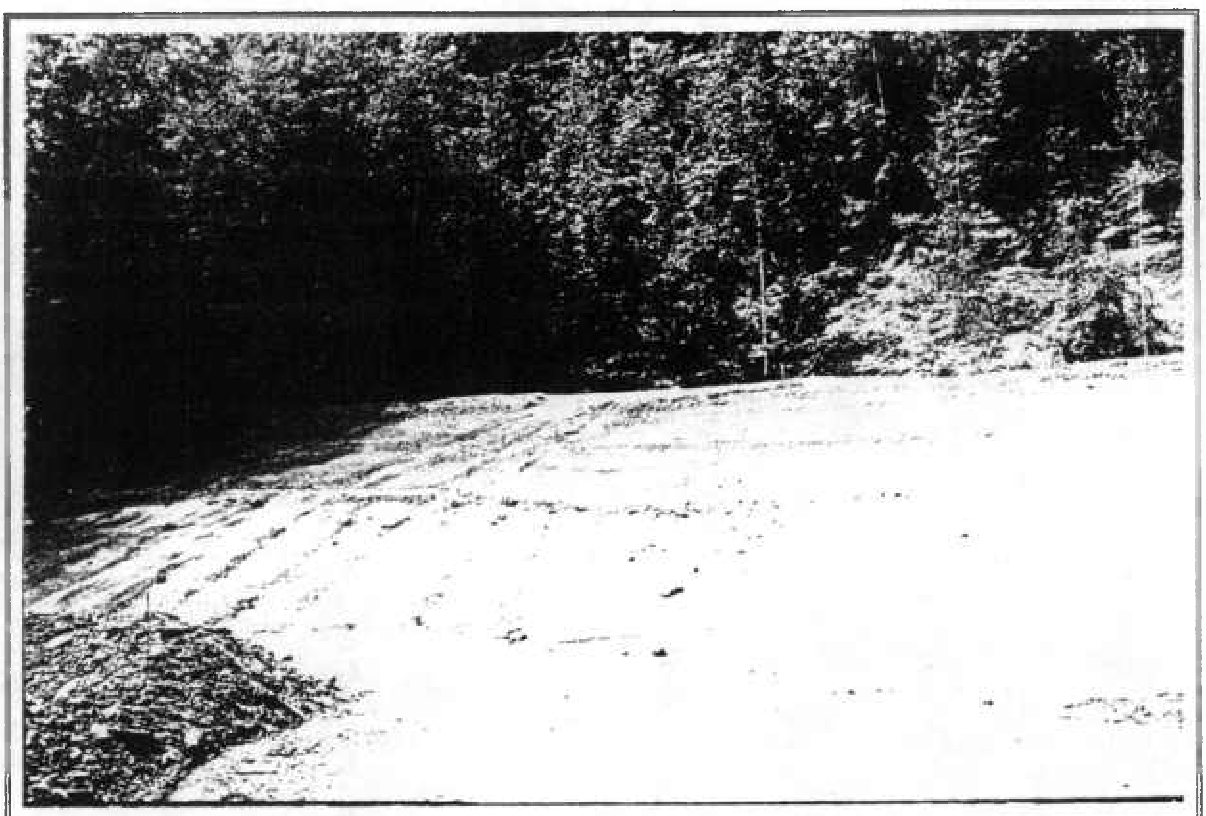

Manufactured Fill Being Placed at Bark Camp

Manufactured Fill Being Placed at Bark Camp



Manufactured Fill Being Placed at Bark Camp

Manufactured Fill Being Placed at Bark Camp



Manufactured Fill Being Placed at Bark Camp

\1997main\Projects\7301\Reports\Perth Amboy\COAST-Perth Amboy Summary Report (10-06-98).doc

APPENDIX A

REGULATORY CORRESPONDENCE

STATE OF NEW JERSEY
DEPARTMENT OF ENVIRONMENTAL PROTECTION
(See Issuing Division below)

CNS Copy

PERMIT*

The New Jersey Department of Environmental Protection grants this permit in accordance with your application, attachments accompanying same application, and applicable laws and regulations. This permit is also subject to the further conditions and stipulations enumerated in the supporting documents which are agreed to by the permittee upon acceptance of the permit.

Permit No. 1216-92-0003.6	Application No. 1216-92-0003.6	
Issuance Date APR 17 1998	Effective Date APR 17 1998	Expiration Date APR 17 2003
Name and Address of Applicant City of Perth Amboy 260 High Street Perth Amboy, NJ 08861	Name and Address of Owner Same as applicant	Name and Address of Operator Same as applicant
Location of Activity/Facility (Street Address) Perth Amboy Marina Eastern End-Smith St. Perth Amboy, NJ Lot See Below Block See Below	Issuing Division Land Use Regulation Program	Statute(s) NJSA 12:5-3 NJSA 58:10A-1
Type of Permit Waterfront Development Water Quality Certificate	Maximum Approved Capacity, if applicable N/A	

This permit grants permission to:

Perform maintenance dredging of approximately 35,000 cubic yards of accumulated material to restore the marina to a depth of 10ft + 2ft overdredge. The dredging will be performed using a closed clamshell bucket with placement of the dredged material in one of three work scows for dewatering and transport to the processing facility. The material will be off-loaded and pre-amended at the Construction & Marine Equipment Co. (CMEC), Inc. facility, located in Elizabeth, New Jersey, prior to transport for reuse at the Bark Camp Mine Site in Penfield, Huston Township, Pennsylvania.

The applicant proposes to replace approximately 315 linear feet of existing bulkhead and construct approximately 235 linear feet of stone rip-rap embankment for shore stabilization. Boat ramps and floating docks will be constructed to provide for 83 permanent boat slips and eight transient slips. The marina is to be constructed according to the plans consisting of six sheets titled "Waterfront-Marina Development for the City of Perth Amboy, New Jersey" prepared by James R. Guerra, P.A. dated June 1995. The sheets titled "Marina Plan-Fishing Pier" and "Overall Marina Plan" were last revised August 8, 1995 and September 6, 1995, respectively.

The project is located at: Block 125, Lot 1 and 1.01
Block 52, Lots 2.01 through 7.01
Block 51, Lot 5.01

Prepared by: Suzanne U. Dietrick
Suzanne U. Dietrick

Revised Date	Approved by the Department of Environmental Protection
	Name (Print or Type) ____________ Title ____________
	Signature ____________ Date ____________

*The word permit means "approval, certification, registration, etc."

This permit is approved subject to, and in accordance with, all applicable Tidelands Grants issued for the Perth Amboy Marina site. The site is located on tidelands maps 609-2112, 602-2106 and 602-2112. Issuance of this permit does not in any way relinquish the State's ownership interest in the property, if any exists.

This permit is authorized under and in compliance with the Rules of Coastal Zone Management governing Maintenance Dredging (7:7E-4.2(f)); Dredge Material Disposal (N.J.A.C. 7:7E-4.2(h)); Marina Development (N.J.A.C. 7;7E-7.3A); Water Quality (N.J.A.C. 7:7E-8.4).

This permit is issued subject to and provided that the following conditions can be met to the satisfaction of the Land Use Regulation Program. All conditions must be met prior to construction unless otherwise specified. Compliance with Administrative conditions shall be determined once copies of all specified permits, certifications, plans, agreements, etc. have been received, not less than 30 days prior to construction, and approved by the Land Use Regulation Program. All Physical Conditions are subject to on-site compliance inspection by the Bureau of Coastal and Land Use Enforcement. As per N.J.A.C.. 7:7-1.4, you must notify the Bureau of Coastal and Land Use Enforcement, (P O Box 422, Trenton, New Jersey 08625), in writing at least 3 days prior to commencement of construction or site preparation.

This permit shall be RECORDED in the office of the County Clerk (the REGISTRAR OF DEEDS AND MORTGAGES in the applicable counties) in the county wherein the lands included in the permit are located within ten (10) days after the receipt of the permit by the applicant and verified notice shall be forwarded to the Land Use Regulation Program immediately thereafter.

This permit is NOT VALID until the permit acceptance form has been signed by the applicant, accepting and agreeing to adhere to all permit conditions, and returned to the Land Use Regulation Program at CN 401, Trenton, New Jersey 08625.

Administrative Conditions:

1. The permittee shall allow an authorized representative of the Department the right to inspect construction pursuant to N.J.A.C. 7:7E-1.5.

2. The permittee shall obtain all appropriate local, state, and federal approvals.

Perth Amboy Marina
File No. 1216-92-0003.6

Physical Conditions

1. Bulkhead repair and/or replacement shall be no further than 18 inches outshore of existing structures.

2. The permittee shall utilize silt curtains to minimize the release of sediments to the Arthur Kill. If this management practice is infeasible, dredging shall be prohibited from April 1 to June 30 in order to protect the migratory fishery resource.

3. Efforts shall be made to maximize the size of the "bite" of the closed clamshell bucket.

4. A minimum of 18 inches of freeboard shall be maintained in all scows in order to maintain a "No Barge Overflow".

5. The discharge of return water from the dewatering/settling barge at the Construction & Marine Equipment Company, Inc (CMEC) processing facility, shall meet a total suspended solids (TSS) action level of 30 mg/l. TSS shall be determined through gravimetric analysis. No discharge from the dewatering/settling barge shall be permitted until the results of the gravimetric analysis confirm that the TSS action level will be met. Additional decant shall not be added to the dewatering/settling barge between the time of sampling for TSS and the termination of the discharge for which the analysis has been performed. The permittee shall utilize a hydrometer, nephelometer or other instrument accepted by the Department to measure the TSS levels during the actual discharge to the Arthur Kill to determine possible exceedances of the 30 mg/l TSS action level. If at any time during the discharge, an exceedance of the TSS levels is indicated, the permittee shall immediately cease the discharge of return water until such time as the return water can meet the TSS action level. All return water shall be discharged in a manner so as to minimize the resuspension of bottom sediments in the Arthur Kill.

6. One portable sewage pump out station and two fixed sewage pump out stations shall be available for use by vessel owners throughout the boating season (i.e., April through October) each year.

Approved by:

4/16/98
Date

Robert B. Piel, Jr., Manager

CONE⟨?⟩.

Pennsylvania Department of Environmental Protection

P.O. Box 669
Knox, PA 16232-0669

May 21, 1998

Bureau of Abandoned Mine Reclamation

814-797-1191

Mr. Craig R. Schantz
Consolidated Technologies, Inc.
2230 DeKalb Street
Suite 200
Norristown, PA 19401

Re: Bark Camp Demonstration Project
Huston Township, Clearfield County

Dear Mr. Schantz:

I am writing to advise you that the last revisions to your Operating Plan, submitted on May 13, have been received and are in accordance with our discussions which occurred May 11 in Williamsport. The Operating Plan for the Bark Camp project is acceptable to the Department and may be considered to be approved. With this approval, CTI has fulfilled the requirements of the amended Beneficial Use Order relating to the quality and handling of the dredge material and admixtures.

Further, CTI has fulfilled the requirements of the Department in terms of preparing and upgrading the Bark Camp site including the rail siding, staging area, haul roads, and areas to be backfilled. Likewise, CTI has received a permit for expanded erosion and sedimentation facilities, and has properly implemented same.

Given that these requirements have been met, the Department hereby gives approval to CTI to transport dredge material from the marina at Perth Amboy, New Jersey, into the Commonwealth of Pennsylvania for use at the Bark Camp Demonstration project in accordance with the amended Beneficial Use Order, dated June 6, 1997, the contract between the Department and CTI, dated November 25, 1997, and the approved Operating Plan.

If you have any questions, please contact me immediately.

Sincerely,

J. Paul Linnan

J. Paul Linnan
Chief
Division of Field Operations

cc: Huston Township Environmental Committee
Ernie Giovannitti
Richard Bittle
John Hamilton

Pennsylvania Department of Environmental Protection
Rachel Carson State Office Building
P.O. Box 2063
Harrisburg, PA 17105-2063
July 15, 1998

Office of Mineral Resources Management

717-783-5338

Ms. Beverly Fedorko
Special Assistant to the Commissioner
New Jersey Department of Environmental Protection
P.O. Box 401
Trenton, NJ 08625

Dear Beverly:

This is a follow-up to our July 3 telephone call regarding the Pennsylvania Department of Environmental Protection's Bark Camp Mine Reclamation Laboratory located near Penfield in Clearfield County. We are encouraged by the progress of Consolidated Technologies, Inc. at the site of the mine reclamation project utilizing the river silt and fly ash mixture as a manufactured structural fill

The Department's Mining and Reclamation Advisory Board (MRAB) held its summer quarterly meeting on July 9 and 10 in DuBois, Clearfield County The MRAB is a legislatively mandated council purposely created with a broad and diverse membership including citizens, environmental advocates, members of the Legislature and the private sector. The Board is charged with advising DEP on mining and reclamation matters.

DuBois was selected by the Board as their meeting location, with the intent of visiting the river silt and fly ash project at Bark Camp The reaction from the MRAB was overwhelmingly supportive. The members were impressed with the improvements at the site since their visit last year We could not have been more pleased with the Board's endorsement. They were also very encouraged with the local support for the reclamation project including the degree of local involvement via the Huston Township Supervisors and their environmental committee.

The Department remains committed to this beneficial use of river silt and fly ash mine reclamation demonstration effort at Bark Camp. We also appreciate the New Jersey Department of Environmental Protection's continued cooperation and support for the project. Allow me to reiterate my previous invitation for you and Commissioner Shinn to visit the Bark Camp site. Please give me a call to arrange a visit or if you have anything you would like to discuss further.

Sincerely,

Robert C. Dolence
Deputy Secretary for
Mineral Resources Management

cc: Secretary James M. Seif
Fred Wolf, Chairperson MRAB

APPENDIX B

ANALYTICAL & GEOTECHNICAL RESULTS

TABLE 1
Analytical Results
Inorganic Compounds
Summary Report
Perth Amboy Municipal Marina

Parameter	In Situ Bulk Sediment			In Situ Bulk Sediment			Stabilized Sediment**			Leachate Regulatory Level*
	Reach A (Total)	Reach B (Total)	Reach C (Total)	Reach A (TCLP)	Reach B (TCLP)	Reach C (TCLP)	Port (total)	Port (TCLP)	Mine (SPLP)	
Imorganics Compounds	(mg/kg)	(mg/kg)	(mg/kg)	(mg/L)	(mg/L)	(mg/L)	(mg/kg)	(mg/L)	(mg/L)	(mg/L)
Antimony	11.8	11.2	24	NA	NA	NA	NA	NA	NA	None
Arsenic	41	13.5	56	ND	ND	ND	72	ND	NA	5.0
Barium	100	49	130	ND	ND	ND	180	ND	NA	100.0
Beryllium	1.53	1.28	1.63	NA	NA	NA	1.1	NA	NA	None
Cadmium	ND	ND	ND	ND	ND	ND	2	ND	NA	1.0
Chromium	84	29	92	ND	ND	ND	99	ND	NA	5.0
Copper	310	59	240	NA	NA	NA	280	NA	0.2	None
Lead	350	120	240	ND	ND	ND	220	ND	NA	5.0
Manganese	330	490	420	NA	NA	NA	300	NA	NA	None
Mercury	2.7	0.59	2.81	ND	ND	ND	4.1	ND	NA	0.2
Nickel	35	22	34	NA	NA	NA	31	NA	0.089	None
Selenium	1.2	ND	1.6	ND	ND	ND	3.3	ND	NA	1.0
Silver	ND	ND	ND	ND	ND	ND	4.2	ND	NA	5.0
Thallium	ND	ND	ND	NA	NA	NA	NA	NA	NA	None
Vanadium	61	45	66	NA	NA	NA	76	NA	NA	None
Zinc	370	110	260	NA	NA	NA	330	NA	0.029	None
Total Cyanide	0.46	0.32	1.1	NA	NA	NA	NA	NA	NA	None

NA = Not Analyzed

ND = Not Detected

* 25 Pa. Code, Section 261.24, Maximum Concentration of Contaminants For The Toxicity Characteristic

** Stabilized sediment sampled from railcars at Elizabeth NJ port facility (pre-amended) and from final manufactured fill at Bark Camp facility (mine)

TABLE 2
Analytical Results
Volatile Organic Componds
Summary Report
Perth Amboy Municipal Marina

Parameter	In Situ Bulk Sediment			Stabilized Sediment**		Leachate Regulatory Level*
	Reach A (TCLP)	Reach B (TCLP)	Reach C (TCLP)	Port (TCLP)	Mine (SPLP)	
Volatile Organic Compounds	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Benzene	ND	ND	ND	ND	ND	0.5
2-Butanone	13	19	23	ND	ND	200.0
Carbon Tetrachloride	ND	ND	ND	ND	ND	0.5
Chlorobenzene	ND	ND	ND	ND	ND	100.0
Chloroform	ND	ND	ND	ND	ND	6.0
1,2-Dichloroethane	ND	ND	ND	ND	ND	0.5
1,1-Dichloroethene	ND	ND	ND	ND	ND	0.7
Tetrachloroethene	ND	ND	ND	ND	ND	0.7
Trichloroethene	ND	ND	ND	ND	ND	0.5
Vinyl Chloride	ND	ND	ND	ND	ND	0.2

NA=Not Analyzed

ND=Not Detected

* 25 Pa. Code, Section 261.24, Maximum Concentration of Contaminants For The Toxicity Cheracteristic

** Stabilized sediment sempled from railcars at Elizabeth NJ port facility (pre-amended) end from final manufactured fill at Bark Camp facility (mine)

TABLE 3
Analytical Results
Polychlorinated Biphenyls
Summary Report
Perth Amboy Municipal Marina

Parameter	In Situ Bulk Sediment			Stabilized Sediment**		Leachate Regulatory Level*
	Reach A (Total)	Reach B (Total)	Reach C (Total)	Port (Total)	Mine (SPLP)	
PCB's	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(ug/L)	(ug/L)
Aroclor 1016	ND	ND	ND	ND	ND	2 ≤ 50
Aroclor 1221	ND	ND	ND	ND	ND	2 ≤ 50
Aroclor 1232	ND	ND	ND	ND	ND	2 ≤ 50
Aroclor 1242	ND	ND	ND	ND	ND	2 ≤ 50
Aroclor 1248	ND	ND	ND	ND	ND	2 ≤ 50
Aroclor 1254	ND	ND	ND	ND	ND	2 ≤ 50
Aroclor 1260	ND	ND	ND	ND	ND	2 ≤ 50

ND=Not Detected

* 25 Pa. Code, Section 287.1, PCB containing waste definition

** Stabilized sediment sampled from railcars at Elizabeth NJ port facility (pre-amended) and from final manufactured fill at Bark Camp facility (mine)

TABLE 4
Analytical Results
Pesticides and Herbicides
Summary Report
Perth Amboy Municipal Marina

Parameter	In Situ Bulk Sediment			Stabilized Sediment**			Leachate Regulatory Level*
	Reach A (Total)	Reach B (Total)	Reach C (Total)	Port (Total)	Port (TCLP)	Mine (SPLP)	
Pesticides/Herbicides	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(ug/L)	(ug/L)	(ug/L)
Aldrin	ND	ND	ND	ND	NA	NA	None
alpha-BHC	ND	ND	ND	ND	NA	NA	None
beta-BHC	ND	ND	ND	ND	NA	NA	None
delta-BHC	ND	ND	ND	ND	NA	NA	None
gamma-BHC (Lindane)	ND	ND	ND	ND	ND	NA	0.4
gamma-Chlordane	ND	ND	ND	NA	ND	NA	0.03
alpha-Chlordane	ND	ND	ND	NA	ND	NA	0.03
4,4-DDD	ND	ND	ND	ND	NA	NA	None
4,4-DDE	14	ND	11	ND	NA	NA	None
4,4-DDT	16	ND	ND	ND	NA	NA	None
Dieldrin	ND	ND	ND	ND	NA	NA	None
Endosulfan I	ND	ND	ND	ND	NA	NA	None
Endosulfan II	ND	ND	ND	ND	NA	NA	None
Ensulfan sulfate	ND	ND	ND	ND	NA	NA	None
Endrin	ND	ND	ND	ND	ND	NA	0.02
Endrin aldehyde	ND	ND	ND	ND	NA	NA	None
Endrin ketone	ND	ND	ND	NA	NA	NA	None
Heptachlor	ND	ND	ND	ND	ND	NA	0.008
Heptachlor epoxide	ND	ND	ND	ND	ND	NA	0.008
Methoxychlor	ND	ND	ND	ND	ND	NA	10.0
Toxaphene	ND	ND	ND	ND	ND	NA	0.5
2,4-D	ND	ND	ND	ND	ND	NA	10.0
2,4,5-TP (Silvex)	ND	ND	ND	ND	ND	NA	1.0

NA=Not Analyzed

ND=Not Detected

* 25 Pa Code, Section 261 24, Maximum Concentration of Contaminants For The Toxicity Characteristic

** Stabilized sediment sampled from railcars at Elizabeth NJ port facility (pre-amended) and from final manufactured fill at Bark Camp facility (mine)

TABLE 5
Analytical Results
Semi-Volatile Organic Compounds
Summary Report
Perth Amboy Municipal Marina

Parameter	In Situ Bulk Sediment			Stabilized Sediment**			Leachate Regulatory Level*
	Reach A (Total)	Reach B (Total)	Reach C (Total)	Port (Total)	Port (TCLP)	Mine (SPLP)	
Semi-Volatile Organic Compounds	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(mg/L)	(mg/L)	(mg/L)
Acenaphthene	ND	ND	ND	ND	NA	ND	None
Acenaphthylene	ND	ND	ND	ND	NA	ND	None
Aniline	ND	ND	ND	ND	NA	NA	None
Anthracene	ND	ND	ND	ND	NA	ND	None
Benzidine	ND	ND	ND	ND	NA	NA	None
Benzo (a) anthracene	ND	ND	ND	1000	NA	ND	None
Benzo (a) pyrene	ND	ND	ND	ND	NA	ND	None
Benzo (b) fluoranthene	ND	ND	ND	ND	NA	ND	None
Benzo (g,h,i) perylene	ND	ND	ND	ND	NA	ND	None
Benzo (k) fluoranthene	ND	ND	ND	ND	NA	ND	None
Benzoic acid	ND	ND	ND	ND	NA	NA	None
Benzyl alcohol	ND	ND	ND	ND	NA	NA	None
Bis (2-ethylhexyl)phthalate	370J	ND	ND	4500	NA	NA	None
4-Bromophenyl-Phenylether	ND	ND	ND	ND	NA	NA	None
Butylbenzylphthalate	ND	ND	ND	ND	NA	NA	None
4-Chlora-3-methlyphenol	ND	ND	ND	ND	NA	NA	None
4-Chloroaniline	ND	ND	ND	ND	NA	NA	None
Bis (2-chloroethozy)methane	ND	ND	ND	ND	NA	NA	None
Bis (2-chloroethyl)ether	ND	ND	ND	ND	NA	NA	None
Bis (2-chloroisopropyl)ether	ND	ND	ND	ND	NA	NA	None
2-Chloronaphthalene	ND	ND	ND	ND	NA	NA	None
2-Chlorophenol	ND	ND	ND	ND	NA	NA	None
4-Chlorophenyl-phenylether	ND	ND	ND	ND	NA	NA	None
Chrysene	ND	ND	ND	1200	NA	ND	None

NA=Not Analyzed

ND=Not Detected

* 25 Pa Code, Section 261 24, Maximum Concentration of Contaminants For The Toxicity Characteristic

** Stabilized sediment sampled from railcars at Elizabeth NJ port facility (pre-amended) and from final manufactured fill at Bark Camp facility (mine)

TABLE 5 (cont.)
Analytical Results
Semi-Volatile Organic Compounds
Summary Report
Perth Amboy Municipal Marina

Parameter	In Situ Bulk Sediment			Stabilized Sediment**			Leachate Regulatory Level*
	Reach A (Total)	Reach B (Total)	Reach C (Total)	Port (total)	Port (TCLP)	Mine (SPLP)	
Semi-Volatile Organic Compounds (cont.)	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(mg/L)	(mg/L)	(mg/L)
Di-n-butylphthalate	ND	ND	ND	ND	NA	NA	None
Di-n-octylphthalate	ND	ND	ND	ND	NA	NA	None
Dibenz (a,h) anthracene	ND	ND	ND	ND	NA	ND	None
Dibenzofuran	ND	ND	ND	ND	NA	NA	None
1,2-Dichlorobenzene	ND	ND	ND	ND	NA	NA	None
1,3-Dichlorobenzene	ND	ND	ND	ND	NA	NA	None
1,4-Dichlorobenzene	ND	ND	ND	ND	ND	NA	7.5
3,3-Dichlorobenzidine	ND	ND	ND	ND	NA	NA	None
2,4-Dichlorophenol	ND	ND	ND	ND	NA	NA	None
Diethylphthalate	ND	ND	ND	ND	NA	NA	None
2,4-Dimethylphenol	ND	ND	ND	ND	NA	NA	None
Dimenthylphthalate	ND	ND	ND	ND	NA	NA	None
4,6-Dinitro-2-methylphenol	ND	ND	ND	ND	NA	NA	None
2,4-Dinitrophenol	ND	ND	ND	ND	NA	NA	None
2,6-Dinitrotoluene	ND	ND	ND	ND	NA	NA	None
2,4-Dinitrotoluene	ND	ND	ND	ND	ND	NA	0.13
1,2-Diphenylhydrazine	ND	ND	ND	ND	NA	NA	None
Fluoranthene	160J	ND	ND	1800	NA	ND	None
Fluorene	ND	ND	ND	ND	NA	ND	None
Hexachlorobenzene	ND	ND	ND	ND	ND	NA	0.13
Hexachlorobutadiene	ND	ND	ND	ND	ND	NA	0.5
Hexachlorocycopentadiene	ND	ND	ND	ND	NA	NA	None
Hexachloroethane	ND	ND	ND	ND	ND	NA	3.0

NA=Not Analyzed

NO=Not Oetected

* 25 Pa Code, Section 261 24, Maximum Concentration of Contaminants For The Toxicity Characteristic

** Stabilized sediment sampled from railcars at Elizabeth NJ port facility (pre-amended) and from final manufactured fill at Bark Camp facility (mine)

TABLE 5 (cont.)
Analytical Results
Semi-Volatile Organic Compounds
Summary Report
Perth Amboy Municipal Marina

Parameter	In Situ Bulk Sediment			Stabilized Sediment**			Leachate Regulatory Level*
	Reach A (Total)	Reach B (Total)	Reach C (Total)	Port (total)	Port (TCLP)	Mine (SPLP)	
Semi-Volatiles Cont'd	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(mg/L)	(mg/L)	(mg/L)
Ideno (1,2,3-cd) pyrene	ND	ND	ND	ND	NA	ND	None
Isophorone	ND	ND	ND	ND	NA	NA	None
2-Methylnaphthalene	ND	ND	ND	ND	NA	NA	None
2-Methylphenol	ND	ND	ND	ND	NA	NA	None
3 &4 Methyphenol	ND	ND	ND	ND	NA	NA	None
Pyridine	ND	ND	ND	ND	ND	NA	5.0
N-Nitrosos-di-n-propylamine	ND	ND	ND	ND	NA	NA	None
N-Nitrosodiphenylamine	ND	ND	ND	ND	NA	NA	None
N-Nitrosodimethylamine	ND	ND	ND	ND	NA	NA	None
Naphthalene	ND	ND	ND	ND	NA	ND	None
3-Nitroaniline	ND	ND	ND	ND	NA	NA	None
2-Nitroaniline	ND	ND	ND	ND	NA	NA	None
4-Nitroaniline	ND	ND	ND	ND	NA	NA	None
Nitrobenzene	ND	ND	ND	ND	ND	NA	2.0
2-Nitrophenol	ND	ND	ND	ND	NA	NA	None
4-Nitrophenol	ND	ND	ND	ND	NA	NA	None
Pentachlorophenol	ND	ND	ND	ND	ND	NA	100.0
Phenanthrene	120 J	ND	ND	1600	NA	ND	None
Phenol	ND	ND	ND	ND	NA	NA	None
Pyrene	220 J	ND	ND	2700	NA	ND	None
1,2,4-Trichlorobenzene	ND	ND	ND	ND	NA	NA	None
2,4,6-Trichlorophenol	ND	ND	ND	ND	ND	NA	2.0
2,4,5-Trichlorophenol	ND	ND	ND	ND	ND	NA	400.0

NA-=Not Analyzed

ND=Not Detected

* 25 Pa Code, Section 261 24, Maximum Concentration of Contaminants For The Toxicity Characteristic

** Stabilized sediment sampled from railcars at Elizabeth NJ port facility (pre-amended) and from final manufactured fill at Bark Camp Mine facility (mine)

TABLE 6
Analytical Results
Dioxins and Furans
Summary Report
Perth Amboy Municipal Marina

Parameter	In Situ Bulk Sediment						Stabilized Sediment****				TEF*
	Reach A (Total)	Reach A (Total)	Reach B (Total)	Reach B (Total)	Reach C (Total)	Reach C (Total)	Port (Total)	Port (Total)	Mine (SPLP)	Mine (SPLP)	
	Reported**	TTE***	Reported**	TTE***	Reported**	TTE***	Reported*	TTE***	Reported**	TTE***	
Furans (pg/g)											
2,3,7,8 - TCDF	16	1.6	3.2	0.32	13	1.3	4.79	0.479	0.0017	0.00017	0.100
1,2,3,7,8 - PeCDF	7.5	0.375	ND	ND	ND	ND	4.28	0.214	ND	ND	0.050
2,3,4,7,8 - PeCDF	10	5	ND	ND	ND	ND	3.59	1.795	ND	ND	0.500
1,2,3,4,7,8 - HxCDF	24	2.4	ND	ND	21	2.1	8.26	0.826	ND	ND	0.100
1,2,3,6,7,8 - HxCDF	8.4	0.84	ND	ND	7.2	0.72	3.05	0.305	ND	ND	0.100
2,3,4,6,7,8 - HxCDF	8.5	0.85	ND	ND	6.7	0.67	3.11	0.311	ND	ND	0.100
1,2,3,7,8,9 - HxCDF	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.100
1,2,3,4,6,7,8 - HpCDF	83	0.83	6.7	0.067	63	0.63	1.66	0.0166	ND	ND	0.010
1,2,3,4,7,8,9 - HpCDF	8.8	0.088	ND	ND	7.8	0.078	26.1	0.261	ND	ND	0.010
OCDF	140	0.14	ND	ND	110	0.11	19.8	0.0198	ND	ND	0.001
TOTAL Furans		12.123		0.387		5.608		4.227		0.0002	
Dioxins (pg/g)											
2,3,7,8 - TCDD	5.7	5.7	ND	ND	ND	ND	3.18	3.18	ND	ND	1.000
1,2,3,7,8 - PeCDD	ND	ND	ND	ND	ND	ND	1.19	0.595	ND	ND	0.500
1,2,3,4,7,8 - HxCDD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.100
1,2,3,6,7,8 - HxCDD	20	2	ND	ND	21	2.1	11.3	1.13	ND	ND	0.100
1,2,3,7,8,9 - HxCDD	13	1.3	ND	ND	13	1.3	7.88	0.788	0.0005	0.00005	0.100
1,2,3,4,6,7,8 - HpCDD*	180	1.8	28.00	0.28	120	1.2	129	1.29	0.0006	0.000006	0.010
OCDD	3000	3	800	0.8	2200	2.2	1207	1.207	ND	ND	0.001
TOTALDioxins		13.8		1.08		6.8		8.19		0.0001	

Regulatory Limit (PADEP Beneficial Use Order No. 40030) = 530 pg/g total Dioxins or Furans (Total) and 0.03 pg/g Dioxins or Furans (SPLP)

ND=Not Detected

* Toxicity Equivalent Factor, International 1988 Method

**Reported individual (laboratory) cogener concentration

*** 2 3 7 8 - tetrachlorodibenzo(p)dioxin toxic equivalent

**** Stabilized sediment sampled from railcars at Elizabeth NJ port facility (pre-amended) and from final manufactured fill at Bark Camp facility (mine)

TABLE 7
Analytical Results
Reactive Cyanide and Reactive Sulfide
Summary Report
Perth Amboy Municipal Marina

Parameter	Stabilized Sediment**
	Bark Camp
	(mg/kg)
Reactive Cyanide*	ND
Reactive Sulfide*	170

* 25 Pa. Code, Section 261.23, Characteristic of reactivity

** Sampled from manufactured fill at Bark Camp facility (mine)

TABLE 8
Analytical Results
Geotechnical Testing
Summary Report
Perth Amboy Municipal Marina

Parameter	In Situ Bulk Sediment													Stabilized Sediment
	PAM 1	PAM 2	PAM 3	PAM 4	PAM 5	PAM 6	PAM 7	PAM 8	PAM 9	PAM 10	Reach A	Reach B	Reach C	Port****
Carbon TOC (mg/kg)	15000	16000	18000	31000	15000	27000	21000	18000	15000	16000	23000	15000	16000	27,100
Density Bulk (lb/cu ft)	92	84	85	79	93	94	92	83	82	86	86	82	87	48.9
Water by Evaporation	45.8	53.4	59.9	47.6	57.4	42.6	51	63.6	47	42.9	51	44.5	49.8	N/A
Particle Size % Sand*	15	4	6	19	7	48	25	11	7	10	32	10	5	22
Particle Size % Silt**	47	53	63	41	56	27	40	54	48	47	33	47	58	76 (silt & clay)
Particle Size % Clay***	38	43	31	40	37	25	35	35	45	43	35	43	42	

* equal to or greater than 0.0625 mm diameter

** less than 0.0625 mm diameter and equal to or greater than 0.0039 mm diameter

*** less than 0.0039 mm diameter

**** Stabilized sediment sampled from railcars at Elizabeth NJ port facility (pre-amended) and from final manufactured fill at Bark Camp facility (mine)

PAM = Perth Amboy Marina

Reach A = Composite of PAM 6, 7 & 8

Reach B = Composite of PAM 1, 4, 9 & 10

Reach C = Composite of PAM 2, 3 & 5

TABLE 9
Analytical Results
Confirmatory Geotechnical Test Results
Summary Report
Perth Amboy Municipal Marina

Parameter	Stabilized Sediment*	Permit Requirement
	Bark Camp	
Permeability**	1.2 X 10^{-6} cm/sec.	< 10^{-5} cm/sec.
Unconfined Compressive Strength***	115 psi	35 psi minimum
Freeze-Thaw Durability***	pass	<30% weight loss

* Sampled from final amended manufactured fill at Bark Camp facility

** EPA Method 9100

*** ASTM Method D1633

**** ASTM Method D4842

Costs of Remediation at Mine Sites

April 1998

U.S. Environmental Protection Agency
Office of Solid Waste
401 M Street, SW
Washington, DC 20460

This technical background document, *Costs of Remediation at Mine Sites*, was submitted for public review to EPA's RCRA Docket # F-97-2P4P-FFFFF. It provides supplementary information and support for the May 12, 1997 Supplemental Proposed Rule, *Land Disposal Restrictions Phase IV; Second Supplemental Proposal on Treatment Standards for Metal Wastes and Mineral Processing Wastes, Mineral Processing and Bevill Exclusion Issues, and the Use of Hazardous Waste as Fill* (62 FR 26041). The Agency has received comments from the public on this document and has listed these comments and Agency responses in the final section of the document. The Agency finalizes this document as of April 1998 and submits it to RCRA Docket # F-98-2P4F-FFFFF to provide supplementary information and support for the April 1998 Final Rule, *Land Disposal Restrictions Phase IV: Final Rule Promulgating Treatment Standards for Metal Wastes and Mineral Processing Wastes; Mineral Processing Secondary Materials and Bevill Exclusion Issues; Treatment Standards for Hazardous Soils, and Exclusion of Recycled Wood Preserving Wastewaters.*

TABLE OF CONTENTS

1.0 INTRODUCTION 1
- 1.1 Cost Factors 1
- 1.2 Organization of Report 3

2.0 ACID ROCK DRAINAGE 4
- 2.1 Waste Rock Pile 5
- 2.2 Underground Mine Drainage 10

3.0 SEEPAGE AND OVERFLOW FROM LEACH SYSTEMS AND TAILINGS IMPOUNDMENTS 13
- 3.1 Overflow or Breach of an Impoundment Structure 13
- 3.2 Leakage from the Face or Toe of a Dam 14

4.0 MINE SITE CASE STUDIES 16
- 4.1 Overview 16
- 4.2 Case Studies 20

5.0 REFERENCES 58

DISCLAIMER

The mention of company or product names is not to be considered an endorsement by the U.S. Government or by the Environmental Protection Agency.

1.0 INTRODUCTION

Costs associated with the remediation of modern mine sites are not well documented in the public record of published literature for several reasons, including the following:

- Remedial measures may be designed and implemented in response to compliance and enforcement actions, chemical spill events, state permit requirements, etc. However, while specific remedial actions taken must be reported regulatory agencies, costs typically are not.
- Some actions may involve limited, short-term actions (i.e., cleaning up minor spills); however, others may require more complex, long-term solutions that are often completed in multiple phases. Cumulative cost data are unlikely to be readily available for such long-term actions.
- Costs are often considered proprietary to the mine operator.

The objective of this project is to develop data on the costs of addressing typical environmental problems that arise at modern mines. EPA collected information for this report throughout 1995. The costs presented may be used by permit writers, regulatory agencies, enforcement personnel, and mine operators for mine planning (including financial assurance), as well as estimating the costs of future enforcement and/or remedial actions. These costs do not reflect permitting and legal expenses. Total remedial costs associated are dependent on location, nature and extent of the problem, type and duration of required remedial actions, and regulatory agencies involved.

1.1 Cost Factors

The costs associated with mine site remediation are highly variable (MEND, 1995) because of the site-specific nature of many environmental problems encountered at mine sites. Table 1-1 presents some of the factors that can influence costs associated with mine-site remediation. This list is not intended to be all-inclusive.

Table 1-1. Factors That Influence the Cost of Remediation at Mine Sites.

Category	Factors
Remediation Goals	Level of clean-up required/desired
Waste Characterization Sampling	Type and volume of material/waste Number and frequency of sampling events Methods selected/required
Water Quality	Degree of contamination (water and sediments) Quantity of metals loadings Lateral extent of plume/contamination Acid Rock Drainage (ARD) issues
Site Characteristics	Size of operation Site access (remote, etc.) Climate (temperature, precipitation, etc.) Geologic materials Elevation Topography (steep slopes, etc.)
Liners	Soil Clay Amended soil Synthetic Soil and subsurface properties
Site Hydrology	Precipitation Flow rate (groundwater and surface water) Water control (routing, diversions, etc.)
Water Treatment	Type of treatment (passive vs. active, chemical usage, etc.) Volume to be treated Management of treatment residuals Length of time required
Site Operations	Effect on production Time to achieve remediation goals Total ore and waste rock tonnage Extent of site impacts Earthwork requirements Labor Imported materials, if any
Regulatory Considerations	National Pollutant Discharge Elimination System (NPDES) and state surface water and groundwater quality requirements Resource Conservation and Recovery Act (RCRA) and state waste management rules State/Federal mine design, operating, and reclamation requirements Dam safety requirements Local regulations, including zoning

Table 1-1. Factors That Influence the Cost of Remediation at Mine Sites (cont.).

Category	Factors
Water Quality Monitoring	Number of analytes and analyses Laboratory analysis Size of area to be monitored Number of sampling stations Groundwater monitoring Surface water monitoring
Reclamation Requirements	Area to be revegetated Type and amount of cover materials Feasibility and duration Post-reclamation land use

Any one of these factors can significantly impact the final cost of remediation at a mine site. Actual incurred costs will vary considerably, and careful consideration of site-specific factors is necessary to achieve an accurate cost estimate.

1.2 Organization of Report

The remainder of this report presents available information on costs of remedial measures. Sections 2.0 and 3.0 provide general information from published materials on the ranges of costs associated with common environmental problems at mine sites. Section 2.0 addresses acid drainage, while Section 3.0 describes control of discharges from waste impoundments and piles. Ranges of cost data are provided because costs are highly variable and dependent on site-specific factors (see Table 1-1). Section 4.0 provides case studies of remedial measures undertaken at modern mining operations.

2.0 ACID ROCK DRAINAGE

In this report, the term *acid rock drainage* (ARD) refers to drainage from the natural oxidation of sulfide minerals contained in rock that is exposed to air and water, resulting in the production of sulfuric acid (Steffen, Robertson, and Kirsten, 1989). This phenomenon is often referred to as *acid mine drainage* (AMD). However, it is not necessarily confined to mining activities but can occur wherever sulfide-bearing rock is exposed to air and water. Some natural springs are acidic, usually in the vicinity of outcrops of sulfide-bearing rock. The principle components of the ARD process are reactive sulfide minerals, oxygen, and water (Steffen, Robertson, and Kirsten, 1989). The oxidation reactions, which are often accelerated by biological activity, yield low-pH water having the potential to dissolve and mobilize heavy metals that may be contained in the water, rock, or elsewhere. If water is available as a transport medium, the resultant drainage can contain products of the acid generation process, typically elevated levels of metals and sulfate. This drainage can have detrimental impacts on water quality.

Mining sometimes results in the exposure of mine wastes, tailings, or mine workings that contain sulfides in sufficient quantities to result in acid generation. However, not all operations that expose sulfide-bearing rock will result in ARD. Acid drainage will not occur if the sulfide minerals are sulfur deficient or if the rock contains sufficient alkaline material to buffer and neutralize the acid. In the latter case, the pH may be raised as a result of neutralizing reactions as the drainage passes through the waste. The quality and rate of release of ARD is governed by various chemical and biological reactions at the source of acid generation and along the drainage path.

More acidic waters can carry greater amounts of metals in ionic form than can more neutral waters. The oxidization of sulfide minerals (and other materials) begins when slightly acidic rain water comes into contact with sulfide-containing rock. The acidic rain water begins to react with the sulfide minerals, and the majority of the remaining sulfide minerals are oxidized and carried away by the sulfuric acid or ferric sulfate solutions that have been generated.

The degree to which sulfide minerals are dissolved is dependent on the amount of sulfur ion and total metals present. In many sulfide minerals, the amount of sulfur is insufficient for complete oxidation. In others, the sulfur ion is completely consumed during oxidation of the mineral. Minerals such as pyrite, chalcopyrite, and pyrrhotite contain excess sulfur and, therefore, generate excess sulfuric acid (H_2SO_4). High concentrations of sulfuric acid continue to oxidize other minerals until the acid is neutralized locally or until the low-pH waters generated travel away from the source. The sulfuric acid and ferric sulfate are usually derived locally but may, in some cases, come from an external source such as circulating groundwater. Pyrite is generally considered to produce the majority of free sulfuric acid.

The initial oxidation of pyrite is generally expressed by the following equation (Drever, 1988):

$$4FeS_2 + 14O_2 + 4H_2O = 4FeSO_4 + 4H_2SO_4 \qquad (2\text{-}1)$$

As shown in Equation 2-1, each mole of pyrite (FeS_2) generates one mole of free sulfuric acid (H_2SO_4). This reaction becomes self-generating in the presence of water and oxygen.

If ARD is not controlled, it can pose a threat to the environment due to the toxicity of heavy metals and other pollutants. Figure 2-1

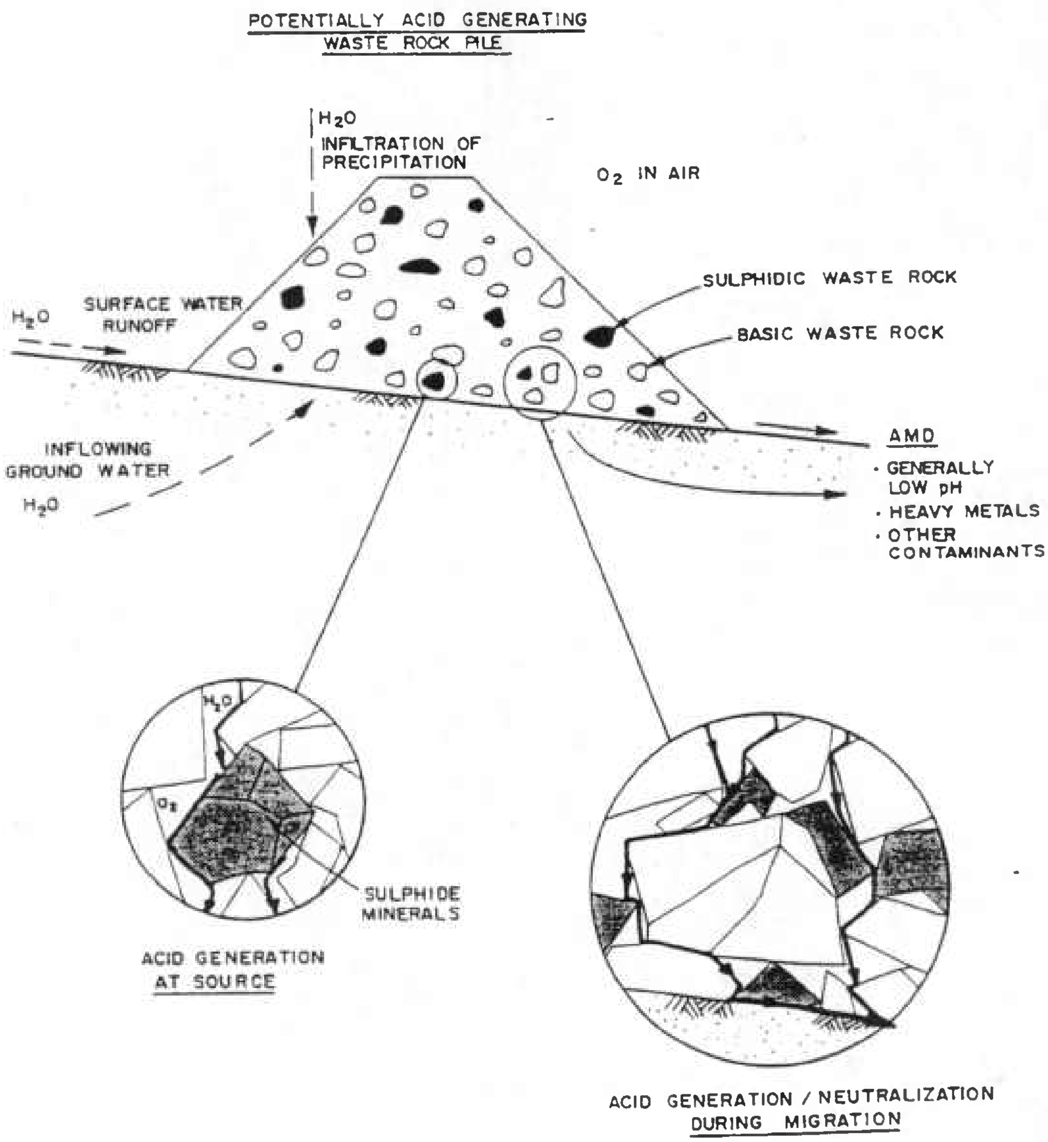


Figure 2-1. Schematic Showing Concept of Acid Generation and ARD Migration.

(Steffen, Robertson, and Kirsten, 1989) presents a conceptual schematic of acid generation and migration through a waste rock pile. The process involves the sulfide-containing and basic rock present in the pile, the potential sources of oxygen and water, and the acid generation/neutralization occurring where these elements are in contact. This figure illustrates water percolating through the dump, coming into contact with both acid-generating and -neutralizing materials, and emerging from the ore as ARD.

ARD may occur from natural sources, as well as in locations where sulfide-containing rock has been exposed during excavation and construction, mining, or other activities. Steffen, Robertson, and Kirsten (1989) list the following as sources of ARD from mining operations:

- Waste rock dumps from metal mines and spoil piles from coal mining,
- Drainage from underground workings,
- Surface runoff from open pit mine faces and pit workings, and
- Ore stockpiles and spent ore piles from heap leach operations.

For the purposes of this report, costs have been developed for remediating environmental problems resulting from waste rock piles and drainage from underground workings. These two scenarios are considered indicative of estimated remedial costs associated with ARD-caused environmental problems.

2.1 Waste Rock Piles

2.1.1 Typical Environmental Problems

Waste rock is generated by excavation and construction operations performed to access an ore body at a mine, especially at open pit mining operations. As sulfide-containing waste rock is exposed to precipitation and runoff, ARD may develop. Because most modern open pit mines generate significant quantities of waste rock, the potential for developing ARD is relatively high if the requisite geochemical regime is present. The chemical and physical properties of the waste rock pile will significantly affect the chemical concentration of ARD and the rate of change of that concentration (Steffen, Robertson, and Kirsten, 1989). Different ARD concentrations and characteristics will result in variable costs of remedial actions for waste rock piles.

The potentially severe environmental problems resulting from waste rock piles and underground mines that generate ARD usually produce negative impacts on the quality of both surface water and groundwater in proximity to the mine. A change in the pH of downgradient surface waters may have detrimental effects on beneficial uses of those waters, such as domestic supply, agricultural supply, aquatic habitat, etc., primarily because of the dissolution of material and other impacts to the water chemistry discussed above.

2.1.2 Engineering Solutions

The goal of remediation at an ARD-producing site is reducing the migration of ARD to the environment. Water is the transport mechanism for contaminants, and, therefore, the solutions to ARD-caused problems usually focus on preventing the contact of water with the ARD source (Steffen, Robertson, and Kirsten, 1989), thus inhibiting the generation of acid and water outflows.

Suppression of acid generation is usually accomplished through one of four methods, including (1) exclusion of oxygen from the waste; (2) exclusion of water from the waste; (3) addition of chemicals that react with sulfuric acid generated and neutralize the water; and (4) promotion of the chemical reaction by adding oxygen and water to consume all available pyrite, leaving only the more insoluble sulfates behind and, thus, mitigating ARD generation.

Management of water contact with an ARD source is accomplished through four methods: (1) diversion of all surface water away from the source, (2) prevention of groundwater infiltration into the source; (3) prevention of precipitation infiltration into the source, and (4) controlled placement of acid-generating waste (Steffen, Robertson, and Kirsten, 1989).

Diversion of Surface Water: Diversion of surface water can be accomplished by constructing diversion ditches and berms or by selecting a site that will avoid high-flow runoff areas. Construction of diversion ditches and berms may be a short-term solution. However, long-term structures can be designed to minimize debris accumulation and control erosion. Diversion structures do require periodic inspection and maintenance even if they are designed for long-term use. In addition, flow volumes used for the design of diversion structures can be reduced by locating waste rock piles away from the bottoms of drainages and minimizing their surface areas. Costs incurred in constructing diversion structures to reduce potential surface water flow through the pile, as presented in Table 2-1, should be compared to the construction and operation costs incurred in selecting an alternative site. The costs presented in Table 2-1 include only direct costs incurred during remedial action.

Table 2-1. Summary of Estimated Costs of Engineered Solutions for Acid Rock Drainage for Waste Rock Piles (U.S. Dollars/Ton of Waste) (MEND, 1995)[a].

Remedial Technology	Lowest Observed Value	Highest Observed Value
Diversion Ditches and Berms	$1.00/yd^3$ material moved[b]	$50.00/yd^3$ material moved[b]
Collect and Treat	$0.02[c] $0.20[b]	$0.12[c] $0.49[b]
Collect and Treat with Soil Cover	$0.12[c] $0.26[b]	$0.42[c] $0.66[b]
Composite Soil Cover	$0.69[c] $0.83[b]	$0.87[c] $1.01[b]
Synthetic Liner (200-year life)	$8.00/yd^2$ [b]	$40.00/yd^2$ [b]

[a] The values shown include only direct costs and not legal or permitting expenses.
[b] Final unit costs in 1994 dollars.
[c] Capital unit costs in 1994 dollars.

Note: Actual costs may be more or less than those shown in the table based on site-specific circumstances.

Similarly to waste rock piles, tailings piles may also be significant ARD sources. Costs associated with tailing ARD mitigation are presented in Table 2-2.

Table 2-2. Summary of Estimated Costs of Engineered Solutions
cid Rock Drainage for Tailings (U.S. Dollars/Acre of Tailings Footprint).

medial Technology	upper estimates = capital costs lower estimates = final costs	
	Lowest Observed Value	Highest Observed Value
ct and Treat	$131,000[a] $452,000[b]	$205,000[a] $503,000[b]
llect and Treat with Soil ver	$192,000[a] $423,000[b]	$385,000[a] $558,000[b]
mposite Soil Cover	$40,000 $48,000	$649,000[a] $877,000[b]

Synthetic Liner (200 year life)	\$45,000 \$51,000	\$628,000[a] \$854,000[b]

[a] Capital unit costs in 1994 dollars (MEND, 1995).
[b] Final unit costs in 1994 dollars (MEND, 1995).

Note: Actual costs may be more or less than those shown in the table based on site-specific circumstances.

Prevention of Groundwater Infiltration: Contact of groundwater with an ARD source may be prevented by intercepting or isolating groundwater before it enters the waste material, or by selecting a site to avoid areas where groundwater infiltration is limited. Because collection and interception methods are prone to failure in the long term, site selection is the best method of management. As an example, a gravity-controlled water system is much more trouble-free than a pumping system. The performance and cost of different groundwater interception and isolation methods vary over a wide range, depending on hydrogeologic and other site-specific parameters. The estimated costs of these engineering solutions are presented in Table 2-1.

Prevention of Precipitation Infiltration: The most practical method of controlling precipitation infiltration is by installing a low-permeability cover or liner, which is commonly constructed from soil and/or synthetic materials. These covers can be applied to near horizontal rock faces in open pits, underground mines, and waste rock piles. An important consideration in selecting the most appropriate cover material or combination of materials is the length of time during which control is required. The estimated costs of these engineering solutions are presented in Table 2-1.

Controlled Placement of Waste: Controlling ARD migration in waste rock piles can be aided by engineered placement methods such as cellular pile construction, compacting, mixing with low permeability material, etc. (Steffen, Robertson, and Kirsten, 1989). These methods of placing waste rock to minimize infiltration should be considered in conjunction with other control methods, such as impermeable covers to further reduce infiltration.

2.2 Underground Mine Drainage

The environmental problems resulting from acid drainage from underground mines are similar to those from waste rock piles. However, the costs associated with remediation are different. The ARD from underground workings generally occurs as a point surface discharge, typically containing low-pH water. This point will usually be the lowest elevation entry into the mine.

Environmental problems from underground mines producing ARD cause negative impacts to the quality of both surface water and groundwater in proximity to the mine. The engineered solutions to these environmental problems are intended to manage contaminated waters and keep those waters from affecting rivers, streams, and groundwater uses.

Surface water may flow into underground mines through portals and ventiiation shafts, as well as through fractures and fissures. Groundwater contamination is common at underground mines, and its interception, treatment, and control can be achieved by various methods that depend on the site's geology and hydrologic characteristics.

The cost for designing, installing, and maintaining water treatment systems is approximately proportional to the volume of water requiring treatment times the amount of material per unit volume of water. Moreover, the location of the site, the annual average precipitation amount, and the retention characteristics of the mine or ore pile can cause variations in flow rates. The design of the water treatment system must account for high- and low-flow fluctuations based on seasonal variations in precipitation. The operating cost of most water facilities is dependent on power consumption, reagent consumption, and personnel requirements. These costs must be calculated for each site. Daily direct costs can range from $100 to $1,500, depending on the complexity of the process and the flow volume treated. Once a water treatment facility is built, the volume of water treated does not significantly affect the cost.

2.2.1 Treatment Methods

Several methods of water treatment are currently being used or tested at mine sites, including lime precipitation, evaporation, biologic treatment using aerobic and anaerobic bacteria, wetland treatment systems, electrolyticwinning, and ion encapsulation in zeolites. The costs of these treatment methods are presented in Table 2-3.

Table 2-3. Cost To Treat Acid Rock Drainage (Dollars/Gallon/Minute Flow).

Remedial Technology	Range of Average Capital Cost	Range of Average Annual Operating Costs
Lime Precipitation	$2,900 to $6,400/gal/min[a]	$700 to $3,600/gal/min[a]
Evaporation	$2,000 to $6,000/gal/min	$200 to $2,200/gal/min
Passive Wetland	$2,900 to $18,500/gal/min[a]	$120 to $420/gal/min[a]

[a] From Gusek (1995).

Note: Actual costs may be more or less than those shown in the table based on site-specific circumstances.

The volume of water discharged from mines and waste piles located in dry climates is generally low, whereas discharge volumes tend to be higher in wetter climates. Low flows can typically be processed by evaporation methods or the use of wetlands. The costs associated with these processes are small, including the cost of an impoundment, miscellaneous plumbing, and importing peat for the beds and monitoring. A treatment system for a mine site demonstrating an average flow of less than 5 gallons per minute could be constructed for less than $10,000. Annual operating costs may average 10 percent of the initial construction cost. Large-scale process plants can have capital costs exceeding $20 million with annual operating costs exceeding $500,000 (Gusek, 1995).

For higher flow rates, the preferable system is lime precipitation. The standard lime process plant includes a receiving pond, lime storage bins, and mixing tanks where the lime is added and mixed with the influent. The influent then passes through a thickening tank where the precipitate is settled and dewatered. The pH of the overflow water is adjusted, if necessary, and the overflow water is discharged. Engineering for this type of plant includes the grading of a site, construction of ponds, purchase of tanks and process machinery, and fabrication. Fabrication of a weather-tight building to house the apparatus in colder climates is also necessary. The cost of this type of a facility may range from $50,000 to tens of millions of dollars (Gusek, 1995). Maintenance and operation of the facility may cost from several hundred to several thousand dollars per day, depending on the water flow volume and the amount of metals dissolved. Each plant must be specifically designed for the volume and characteristics of the waste water and the level of treatment required.

2.2.2 Collection of Acid Water

Acidic waters generated from mines can usually be diverted and collected at a single point where they are either gravity fed or pumped to a treatment plant. Waters generated from waste piles can be more difficult to direct to a single point. Associated costs include rehabilitation of the mine openings, surface grading and plumbing. Pump installation and operating costs are an additional cost, if they prove necessary. Operational costs must account for variable water flow rates and the pumping distance and elevation from the source(s) to the treatment plant.

Drainage from waste piles can be more difficult to collect. The factors affecting water collection depend on the location and size of the waste piles, the topography underlying the piles, and the permeability of the underlying strata. If the waters can be diverted to a single collection location by gravity, then the costs are similar to those for mine openings. If the installation of a collection system involves excavations, dikes and impoundments the cost is greatly increased. The cost of moving rock and dirt generally ranges between $5 to $50 per cubic yard. When the location, types, and quantities of borrow materials are known, a cost estimate can be developed.

If the waste is not overlying an impermeable membrane or if it does not have the proper characteristics to seal itself from the underlying strata, it is possible that acid water (or other waste water) will infiltrate through porous underlying strata. In this scenario, it may be necessary to drill a series of dewatering and collection wells into the strata to remove acid drainage. The configuration of the dewatering wells may be designed to encircle the area, to create a capture zone (cone of depression in the water table) associated with a single well, or in a line to form a curtain. Drilling costs, including materials, generally range from $10 to $50 per linear foot of borehole. These costs are dependent on the location of the site, the depth of the borehole and the amount of rig downtime beyond the control of the contractor.

Upon completion of drilling and testing of the dewatering wells, a pump collection system can be designed and installed along with the required plumbing. The cost of this system is dependent on the number of dewatering wells, the depth of the boreholes, the amount of water, and the elevation and distance the water has to be pumped. Pumps operating in acidic waters are usually designed to resist the affects of corrosion. If no electric power lines exist at the site, additional expenses are incurred to bring in power lines, install generators to maintain engine powered pumps.

3.0 SEEPAGE AND OVERFLOW FROM LEACH SYSTEMS AND TAILINGS IMPOUNDMENTS

Typical environmental problems occurring at the site of a tailings or leach system impoundment are a result of pollutant-laden process water overflowing or escaping through the dam; percolating downward into the groundwater; or moving through a breach in the retaining dam.

3.1 Overflow or Breach of an Impoundment Structure

The effects of a downstream release normally are a result of a higher than anticipated precipitation event or failure of an impoundment structure. The structural failure of an impoundment may be instantaneous. In this case, nothing can be done to stop the damage as it occurs. The solution to this situation normally requires rebuilding the dam and initiating a cleanup of the materials deposited downstream (or downgradient) from the site. If the breach or outflow is certain, but not immediate, measures can be taken to prevent the event. Such measures include increasing dam and liner height, directing flows to secondary structures, or implementing procedures to provide for a controlled release.

3.1.1 Dam Breach

The cost of the repair of an impoundment dam normally includes engineering design, location and procurement of materials, haulage of materials and installation. The haulage costs for the fill material are highly dependent on the distance that the material must be transported. The costs of material placement typically range from $5 to $50 per cubic yard with the engineering costs averaging 10 percent of the total cost of the project.

The cost of clean up of the tailings and miscellaneous debris that flow out of the impoundment, is based on the type and amount of tailings spilled, the standards set for clean up and the water flow volume in the stream (if a stream exists). For example, if a small spill occurred next to a large river, the river may disseminate all or most of the tailings, making tailings removal impossible. Another scenario might involve a small spill occurring in a drainage which contains no active stream. In this case, it may be possible to return the solids from this spill back to their original location, using earthmoving equipment. The cost of moving the material back in place can be as little as a few dollars per cubic yard. If the spill consists of only natural materials without any toxic constituents, it might be feasible to leave the material in place and reclaim it.

Another scenario might involve a large toxic spill occurring along a small active stream. This type of spill could generate the highest cleanup cost. It may be necessary to use earthmoving equipment, dredges and hand laborers to remove material from the stream and adjacent riparian areas.

The cost of this type of cleanup is so site specific that it can only be estimated following determinations made by the site engineers and regulatory agencies involved.

3.1.2 Overflow of an Impoundment

Releases of water from an impoundment can be anticipated if the overflow is expected to occur as a normal result of the mining operation. In the case of a sudden high flow precipitation event, the overflow could occur unexpectedly as in the dam breach described above. The remedial actions described above in Section 3.1.1 can be similarly applied to an overflow.

In a scenario where there is a gradual rise in the water level of the impoundment caused by greater than annual average precipitation or increase in discharge from the processing plant, a solution can be designed and implemented prior to the overflow. Some solutions might include increasing the height of the impoundment, building an additional impoundment, and installing/increasing the size of water treatment plant/controlled discharge (see Section 2.2.1).

3.2 Leakage from the Face or Toe of a Dam

Leakage from a dam can be stopped either by modifying the dam or by collecting, treating, and discharging the leakage. Modern tailings ponds generally contain enough fine grained material that they tend to plug themselves with the "slimes" generated from the milling process. If water leakage occurs, the most common solution in a wet climate is to construct a water treatment plant and then collect, treat, and discharge the water. In a dry climate, where a mine typically has water shortages, collected solution is often reclaimed and returned to the mill for re-use.

The waters contained in impoundments commonly found at modern cyanide and acid leach plants contain a lower percentage of suspended solids and as a result can be more susceptible to leakage than conventional process mills. In this case, it is very important to stop all leaks both for environmental and economic reasons. Repair of a leak may be as simple as replacing or repairing an impermeable liner. This could involve engineering of the repair, procurement of materials and installation by laborers. The cost of repairing a small leak may be as little as a few hundreds of dollars.

The costs of repairing a leak that occurs below a large leach pad/pond can be much higher. As an example, if a leak develops near the center of a hypothetical pad having horizontal dimensions of 200 by 200 feet and a height of 50 feet, the leak must first be isolated. The expense and time spent locating the leak are dependent upon the experience of the mine operator and the amount of monitoring and detection instrumentation already located near the pad. It may be necessary to drill a series of angle boreholes to ascertain the location of the leak. After locating the leak, the overlying material must be excavated to expose the leak. The excavation must be engineered to insure stable slopes for safety reasons. In this hypothetical scenario, approximately 15,000 cubic yards of material would have to be removed to reach and expose the leak. The calculated cost for removing the material from the pad would be $75,000, if the cost for hauling material is $5 per cubic yard. The cost of repairing the leak would additionally involve engineering time, materials and labor. The total cost to repair this type of leak is estimated to be approximately $100,000.

4.0 MINE SITE CASE STUDIES

4.1 Overview

The initial objective of this project was to develop comprehensive data on remedial measures undertaken at selected modern mining operations throughout the United States, specifically focussing on cost data. Such detailed cost data, if available, would allow for site-by-site comparisons of the unit costs associated with addressing specific problems, and the factors that influence those costs. Unfortunately, there is generally no centralized source of information on modern mine site remedial costs, at the national level or in most States.

To collect site-specific cost information, EPA had it's contractor (SAIC) contact State offices responsible for regulating mining activities as well as reviewing published literature. State office visits were then conducted to obtain publicly available file materials documenting remedial activities. Such visits were undertaken in South Dakota, South Carolina, Nevada, Colorado, and Montana. Information on remedial activities in Arizona was obtained from the EPA Region IX Office in San Francisco. Overall, information was reviewed for many non-coal mining sites (more than 100 modern/post-1980 operations) where remedial actions have been taken to address actual or perceived threats to the environment. Cost data were not readily available, except for Arizona and South Dakota. This is largely because most States do not require submittal of these data. Where cost information was found in other States, it was primarily submitted on a voluntary basis. Similarly, while the literature provides extensive information on many significant environmental incidents, it also does not typically include cost information (presumably, at least in part, because such data are considered proprietary). As a result, the only comprehensive approach to cost data collection would be to contact the mining companies themselves. Such an effort was beyond the scope of this report.

Despite the above limitations, cost data were obtained for 24 modern (post-1980) mining operations throughout the western United States. These data are summarized in Table 4-1 and the accompanying case studies. The problems encountered at case study sites are representative both of environmental effects common to many mines (ARD issues, water management difficulties, etc.) as well as unique site-specific issues. One site, Noranda's Montanore Project represents a *proposed* mining operation where cost data were available for water collection and treatment options. This information was included because it is also applicable to water treatment costs associated with remedial activities at other sites. The varying level of detail in the case studies reflects the inconsistency of available data and ranges from a single dollar value for total remedial costs at a site, to breakdowns of each individual cost element (including site characterization, and design, construction, and maintenance of remedial alternatives). In most of the case studies, the level of detail regarding the site is not sufficient to estimate unit costs (per acre, gallon etc.). For example, many of the case studies do not present water flow data, the acreage affected or remediated, or the dimensions of tailings dams, heaps, waste rock piles, etc.

Table 4-1. Examples of Costs for Remedial Measures at Specific Sites.

Name and Location of Mine	Type of Problem	Remedial Action Taken	Cost Data (Dollars)
Microgold II Mine Florance, Idaho.	Releases of mercury from plant contaminated soils and tailings pond. Did not significantly impact groundwater, although source of elevated levels in two wells is unknown (might have been background).	Excavation and encapsulation of soil using synthetic liner and cover.	$120,000 was put into escrow for clean-up.
Lucky Friday Mine Mullan, Idaho	100 gallons of copper sulfate solution overflowed a tank, drained into a sump and eventually into the Coeur d'Alene River.	Installed concrete curbing around tanks, installed paving in tank area and planted willows and other vegetation along river.	$47,700
Copper Cities Magma Copper Arizona	Unauthorized discharges/seepages from waste management and process solution units; NPDES non-compliance.	Construction of 100-year, 24-hour collection facilities and pumpbacks.	NPDES compliance costs/remedial measures: 1991 - $180,000 to $300,000 early 1993 - $544,173 O&M costs (an unspecified portion allocated to repairs/remedial activities): 1991 - $696,620 1992 - $155,188
Pinto Valley Magma Copper Arizona	Unauthorized discharges/seepage from tailings and leach dumps, ponds, and solution ditches, including storm overflows and tailings and solution dam breeches.	Repair of tailings and solution dams; new and increased seepage collection activities.	Costs to respond to non-compliance 1992/93 order for problems: $636,537
Miami Operations Cyprus Miami · Miami, Arizona	NPDES non-compliance, unauthorized discharge of wastewater to surface and groundwater.	Broad improvements in site-wide water management practices over a 10 year period. Discontinuation of unauthorized discharges including elimination of an unlined acid sump, groundwater pumping; construction of runon and runoff controls and additional enhanced containment systems, and waste rock excavation and capping.	Total capital costs for improved water management and NPDES compliance were slightly greater than $1 million.
Cyprus Sierrita Mine Sierrita, Arizona	Unauthorized discharge to surface water from process pond (ARD issues) and tailing water reclaim line.	To address pond seepage, constructed hydraulic barriers; replace PVC pipe with steel-encased pipe.	$101,030 for pond, $70,000 for pipe

Table 4-1. Examples of Costs for Remedial Measures at Specific Sites (cont.).

Name and Location of Mine	Type of Problem	Remedial Action Taken	Cost Data (Dollars)
Ray Complex ASARCO Arizona	Subsurface leakage of solutions from leach dumps, ponds, and processing facility - low pH and elevated copper; also water quality impacts from contaminated runoff.	Repair leaks in facilities and impoundments, dig drainage trenches to intercept leaks, drive a 13,000-foot long water diversion tunnel, build diversion dams and construct wetlands, provide long-term water treatment.	Net capital cost for NPDES compliances have exceeded $40 million with annual O&M cost for the treatment plant, ongoing surface water monitoring, and maintenance of containment structures exceeding $1.5 million in 1993.
Magma Copper Company Superior Division Arizona	Unauthorized discharges. Seepage of tailings and acidic mine water to surface water. Elevated metals levels - copper, cadmium, lead, and zinc.	Construction of seepage collection and pumpback systems, improved water reclaim in the mill (especially acidic water), and remediation of contaminated soils.	Capital costs of NPDES compliance activities to manage/control discharges reported in 1991 as about $280,000.
Thompson Creek Tonopah Mineral Resources Challis, Idaho	Acid generation from tailings and waste rock; unanticipated discharge from tailings pond.	No decision on approach to long-term remediation of tailings made to date. Short-term installation of tailings seepage pumpback. Options for long-term include pyrite removal in mill; buffering; water treatment, etc.	$7.5 million bond for water quality protection added for ARD remediation. Other total remediation cost estimates: $6 to $25 million.
Grey Eagle Mine Noranda Happy Camp, California	Tailings impoundment was source of water quality impacts (active 1982-86).	Water treatment plant used during active operations; tailings pond closed with geotextile cover and revegetated surface.	Treatment costs not available; but liner cost $131,000 per acre (unknown how many acres).
Franklin Consolidated Mine Idaho Springs, Colorado	Pyritic upper tailings pile eroding into Gilson Gulch, fine grained tailings in lower pile moved 100 feet by wind erosion.	For upper tailings pile, graded and compacted tailings; earthen berm and runon controls installed. For lower pile, cover source of blowing tailings with burlap and clean-up of windblown tailings; also berms installed in mill to contain spills.	State bond was increased by $16,000 to cover clean-up costs.
Gilt Edge Mine Lead, South Dakota	Acid water drainage and releases of cyanide into surface and groundwater; long-term from spent ore/pits and short-term from pad leaks.	For spent ore and pit seepage, installed collection and treatment ponds in drainages; treatment using reverse osmosis; spent ore eventually to be capped. For short-term pad leak, installed plug, repaired pad, and installed treatment for excess water.	Estimated at $3.7 million for long-term impacts; $350,000 for pad leak.
Paradise Peak Mine FMC Gold Nevada	Oil spill in the vicinity of the maintenance shop. Spill caused by failure of oil skimmer in shop clean-up water sump. Little potential for hydrocarbons to impact ground or surface water.	Sealing the point of discharge, installing berms around the contaminated area, performing soils removal, and ceasing water washdowns (use of dry reagent).	$103,801
Buckskin Operation Douglas Co., Nevada	Seepage containing cyanide in groundwater downstream from tailings impoundment.	Pump impoundment and install new lined pond; install tailings water reclaim system.	Approximately $200,000

Table 4-1. Examples of Costs for Remedial Measures at Specific Sites (cont.).

Name and Location of Mine	Type of Problem	Remedial Action Taken	Cost Data (Dollars)
Dee Gold Mining Newmont Gold Elko, Nevada	Water containing cyanide seepage from tailings dam; detected in nearby alluvial aquifer.	Installed groundwater recovery wells and vertical interceptor ditch; pumped recovered water to tailings impoundment.	Approximately $2 million
Jerritt Canyon Independence Mining Elko, Nevada	Seepage from tailings impoundment	Delineate seepage, install ground water recovery system and modify mill process to allow for recovered groundwater and tailings water re-use.	Approximately $2.1 million
Goldstrike Mines American Barrick Elko, Nevada	Break in waterline caused pond overflow resulting in release of 25,000 to 30,000 gallons seepage/runoff.	Decommissioned waterline and pump out of ponds.	$160,000 (Includes study of impacts)
Buckhorn Operation Cominco Resources Carlin, Nevada	Leaks from fuel lines and pipes; and diesel spill. Elevated total petroleum hydrocarbons in groundwater.	Collection of surface water runoff with oil-water separation, groundwater treatment by bioremedial solution and recovery/oil-water separation; soils excavation.	Over $290,000
Richmond Hill LAC Minerals Lead, South Dakota	Unanticipated acid drainage from spent ore (2.7 million tons).	<u>Short-term</u>: installation of runon/controls; construction of seepage collection and treatment system; and liming of rock. Long-term: return spent ore to pit and install impervious cap.	$8.5 million (additional bonding requirement)
Wharf Resources Lead, South Dakota	Nitrate in ground water downgradient of spent ore pile; may also be contribution from blasting residues.	Installation ion exchange system to treat spent ore removal for nitrate.	Approximately $2 million
Golden Sunlight Mine Whitehall, Montana	Cyanide leakage from tailings impoundment; environmental threats associated with ground movement in mill caused by massive weight of a waste rock pile.	Redesigned tailings impoundment, installed pumpback wells, provided alternative water wells and treatment of local domestic wells. **For ground movement impacts**, pumpback wells installed, waste rock moved to more stable area, and improved process solution containment systems installed.	$12 million has been spent as of March 1995 to address ground movement effects; an additional $1.8 million in costs expected in 1995. (No cost data for tailings seepage.)
Zortman-Landusky Mine Pegasus Mining Montana	Extensive ARD/AMD drainage to surface and groundwater from pits, cut ore, and waste rock; also cyanide releases from heaps and spent ore.	Installed pumpback systems and built a treatment plant; considering other, long-term/improved containment and treatment options.	$720,000 for current treatment plant; in 1993-94, $2.8 million spent on reclamation (unclear how much for environmental impacts); drafts of proposed compliance plans suggest significant additional costs to be incurred.
Montanaore Mine Noranda Kootenai National Forest, Montana	Proposed mine will have tailings pond with anticipated seepage of 450 gallons per minute	Proposing a seepage collection system with wetlands, evaporation or electrocoagulation treatment.	Projected cost of water management/treatment ranges from $2.5 million to $20.4 million.

The cases studies describe a wide range of different levels of environmental concern as well as mine sizes. Overall, they generally support the previous chapters by showing that remedial costs are highly site-specific. Of additional note, the cost data for some sites only provides the expenditures to date. Future costs may be significant, especially where the long-term performance of a remedial alternative cannot be accurately predicted and/or perpetual care is likely to be required.

4.2 Case Studies

4.2.1 Case Study No. 1 - Elevated Nitrate in Groundwater at Leached Ore Piles

Site Name: Wharf Resources, Lead, South Dakota

Type of Mining: Cyanide Heap Leaching, on/off pad with spent ore neutralization

Nature of Environmental Effects: During the late 1980s, elevated levels of nitrate were observed in groundwater monitoring wells downgradient of Wharf's spent ore pile. Some nitrate loadings may also been the result of residuals from blasting operations.

Remedial Actions: Installation of the countercurrent ion exchange technology (CCIX) to reduce nitrate and nitrite levels in the spent ore/process solution. Ion exchange is a commonly used methodology for reduction, because the nitrate shows affinity for several types of resins. The CCIX system uses countercurrent flow through a packed bed resin with nitrogen removal and regeneration occurring simultaneously.

Costs of Remedial Activities: According to the South Dakota Department of the Environment and Natural Resources, the company's cost for installing the CCIX at the Wharf site was approximately $2 million. This does not include long-term operating costs, such as the costs associated with managing rinse solution.

References: SD DENR, 1995. SD DENR, 1991c.

4.2.2 Case Study No. 2 - ARD from Spent Ore Disposal/Waste Rock Pile

Site Name: Richmond Hill, LAC Minerals, Lead South Dakota

Type of Mining: The Richmond Hill mine is located in the Black Hills regions of South Dakota. Cyanide heap leaching operation with an on/off pad and spent ore neutralization. The facility is located at between 5,500 and 6,000 feet with approximately 28 inches of precipitation annually.

Nature of Environmental Effects: In 1992, the State of South Dakota observed acid mine drainage associated with spent ore disposal at the Richmond Hill mine in the Black Hills. An initial sample taken from the toe of the waste rock dump had a pH of 3.1 and subsequent additional sampling showed pH levels of 2.6 and 3.6 with elevated levels of sulfate, TDS, aluminum, copper, iron, and manganese acidic conditions and high concentrations of metals and sulfates. The original mine plan included processing a small quantity of sulfide rock and the State incorporated limited measures to address acid drainage in the mining permit. However, the actual generation of acid drainage was significantly greater than originally anticipated; necessitating more extensive short- and long-term mitigation measures. After additional testing, LAC Minerals determined that all of the waste rock generated during operations, 2.7 million tons, was acidic.

Remedial Actions: Remedial activities for acid drainage involved both short- and long-term actions. In the short term, the facility constructed treatment ponds at the toe of the dump and added caustic (some water is also diluted with uncontaminated storm water). Treated water can either be land applied or discharged via an NPDES permit. Other short-term measures included: removal of sulfide ore and placement on the pad, construction of runon controls, and addition of some neutralizing materials to the pile.

The long-term remedy for the site involves removal of acid generating waste rock and placement in the pit (presumed to also be acid generating). An impervious cap will then be installed.

Costs of Remedial Activities: According to the State, the cost of remedial measures at the site (primarily for long-term actions) is shown by the increase in the reclamation bonding requirements for Richmond Hill. After acid drainage was discovered, the surety bond for the site was increased by approximately $8.5 million. This includes the following subcosts.

Moving Waste Rock to the Pit	$2,521,000
Reclaiming Remaining Waste Dump	$150,000
Cover for Waste Rock in Pit	$653,000
Haul Sulfide ore from Pad	$65,000
Regrade and Revegetate Pad 3	$780,000
Regrade and Revegetate Pads 1	$126,000
3:1 Pad Base Addition	$4,221,000
APPROXIMATE TOTAL	$8,500,000

These amounts do not include the initial costs of delineating the extent of the problem and designing alternatives.

References: SD DENR, Undateda. Durkin, 1994.

4.2.3 Case Study No. 3 - Impoundment Overflow

Site Name: American Barrick Goldstrike Mines, Elko, Nevada

Type of Mining: American Barrick operates a cyanide heap leaching operation near Elko, Nevada. Waste rock/spent ore is managed in an on-site dump.

Nature of Environmental Effects: During summer 1993, American Barrick began to observe a sustained flow in the sedimentation pond that was not caused by surface runoff (instead it was likely seepage from the dump). The sedimentation pond is used to manage runoff from the waste rock pile. Runoff from the dump collects in the sedimentation pond. The gully in which the pond is located drains to Rodeo Creek, an ephemeral drainage. In late July 1994, between 25,000 and 30,000 gallons of water overflowed the pond (i.e., were discharged without a permit). The water flowed approximately 1,900 feet down Rodeo Creek from the point of intersection of the gully and the creek.

Regulatory Action: The State issued a Finding of Alleged Violation and Order (FOAV) for the release. (All of the information in this summary was included in the facility's written presentation for a Show Cause hearing related to the Order). In the Order, the State required that the operator delineate the extent of any impacts on soils and shallow groundwater. According to American Barrick's contractor, sulfate was the only parameter observed at elevated concentrations in ground water and soils (high sulfate levels were also found in the seepage).

Remedial Actions: American Barrick determined that a water line located above the pile was likely source of the discharge. This pipe was subsequently decommissioned. Further, Barrick pumped millions of gallons of water from the sedimentation pond to the tailings pond, to ensure no other discharges.

Costs of Remedial Activities: The total costs of remedial measures reported by American Barrick in 1994 were $160,000. This included $110,612 for pumping water from the sedimentation pond and $49,108 for preparing the delineation sampling plan. It should be noted that seepage from the waste rock pile was also observed in 1993. However, there was no discharge from the pond (and no violation). In 1993, American Barrick also had to pump nearly 2 million gallons of water from the pond, relocate an equipment washdown area, and modify stormwater management at the waste rock pile (the State files do not include any cost data from this incident).

Reference: Barrick, 1995.

4.2.4 Case Study No. 4 - Tailings Impoundment Seepage

Site Name: Jerritt Canyon Joint Venture, Independence Mining Company, Elko, Nevada

Type of Mining: Independence Mining Company operates the Jerritt Canyon Joint Venture in Elko, Nevada. Detoxified tailings from the vat leaching operation at the site are disposed in a tailings impoundment. Chlorination is used in the neutralization process. As of October 1991, more than

15,000,000 tons of ore had been processed in the vat leach operations. The tailings impoundment was initially constructed to provide for full containment (i.e., zero discharge).

Nature of Environmental Effects: The operator, Freeport McMoRan Gold (FMG) at the time, first suspected seepage from the impoundment in 1983. Nevada Division of Environmental Protection staff observed seepage from the tailings impoundment during an inspection in 1990. The seepage appears to flow from the eastern and southern sides of the tailings impoundment. The seepage caused elevated major ion concentrations, including chloride and TDS levels in the surficial aquifer. Cyanide has not been detected above the State's action level.

Remedial Actions: Since 1984, the operators of the mine have been investigating/delineating the seepage and undertaking remedial measures. Remedial measures have included installing a ground water recovery system. In addition, modifications were made to the milling process and associated piping to allow for direct reuse of tailings water from the impoundment, as well as re-use of recovered groundwater.

Costs of Remedial Activities: The most recent cost data available was presented in an October 18, 1991 letter from Independence to the State Bureau of Mining and Reclamation. Independence and the previous owners had spent nearly $2.1 million on delineating the seepage/contamination, installing a ground water recovery system, and making modifications to the milling process. Between 1984 and 1990, FMG spent $570,000 and Independence spent $1,500,000 during 1990-1991. Although the seepage remediation system was operational in October 1991, some additional future investments were expected by Independence to optimize system performance and maintain the collection system.

References: NDEP, 1990. Independence, 1991.

4.2.5 Case Study No. 5 - Cyanide Leakage from Tailings Impoundment

Site Name: Dee Gold Mining Company, Elko County, Nevada

Type of Mining: Newmont Gold Company now operates a cyanide heap leach operation near Elko that was formerly operated by Dee Gold. Some of the tailings from the leaching process are disposed of in tailings disposal facility No. 2. This unit is located in an ephemeral tributary of Boulder Creek. Boulder Creek, a perennial stream, flows approximately 1,000 feet downstream of the dam. The tailings dam was initially constructed to provide for full containment (i.e., zero discharge), with the clay core keyed into the underlying bedrock.

Nature of Environmental Effects: Monitoring data collected during the 1980s showed cyanide-laden seepage flowing from the tailings impoundment into the Boulder Creek alluvium. The highest measured cyanide concentration in the cyanide plume was 6 ppm. According to the operator's contractor, in November 1990, seepage was detected in the Boulder Creek alluvial aquifer. Seepage may have been enhanced originally by the initial location of a reclaim pond near the north abutment. The pond was moved shortly after seepage was detected.

Remedial Actions: To provide short-term seepage control, the facility installed three downgradient groundwater recovery wells. Collected water was pumped back to the impoundment. In 1991, the operators decided to design and install a vertical interceptor trench drain (VITD) to contain the seepage from the tailings impoundment. The VITD was planned to be operational in early 1992. The flows collected in the VITD system would presumably be returned to the impoundment.

Costs of Remedial Activities: As of late 1990 (the most recent cost data), the cost of designing and installing the VITD system as estimated to be approximately $1.25 million. This does not include the costs of delineating the seepage, installation and operation of the recovery wells, or ongoing VITD system operation and maintenance.

References: Dames & Moore, 1990. Rayrock, 1990. Hydro-Engineering, 1991.

4.2.6 Case Study No. 6 - Cyanide Leakage to Groundwater from Tailings Impoundment

Site Name: Buckskin Operation, Douglas County Nevada

Type of Mining: The Buckskin Operation is located 10 miles west of Yerington in Douglas County, Nevada. The facility was originally operated as a mine and mill by Pacific Silver Corporation. In 1987, Sonora Mining Corporation purchased the operation and began using the mill to vat leach ore from Sonora's Jamestown Mine in California (the mine became inactive). Carbon-in-pulp processing is used for gold recovery. Wet tailings from both Pacific Silver and Sonora's leaching operations were managed in an impoundment located on the edge of a large alluvial plain. Sonora modified Pacific Silver tailings disposal methods by greatly reducing the area of ponding/active disposal. Although the impoundment was generally constructed by Pacific Silver in accordance with State-approved designs, the operator apparently did not install a liner.

Nature of Environmental Effects: Groundwater contamination was initially observed at the site during 1987 when cyanide was detected in a water supply well downstream of the tailings impoundment. These findings influenced Sonora's proposed tailings management proposal. A zero discharge permit was issued for Sonora's operations in August 1990. Under the permit, the facility was required to install three groundwater monitoring wells downgradient from the tailings impoundment. Subsequent monitoring data collected during the 1980s showed cyanide-laden seepage flowing from the impoundment into the underlying ground water. The elevated cyanide concentrations appeared to have been localized; a Geraghty & Miller report from 1991 showed no contamination in off-site wells.

Remedial Actions: During 1987, in response to the initial detection of cyanide contamination, Sonora conducted a site investigation to delineate the contamination caused by Pacific Silver, altering Sonora's plans for tailings management. In late 1990, after cyanide was detected in the permit compliance monitoring wells, the State issued an order to Sonora requiring them to stop the leaks from the Buckskin tailings impoundment. As a result, Sonora indicated that the company would "pump the existing impoundment dry" and install a new lined unit. The order specifically required that Sonora design and install a tailings water reclaim line. Remedial actions were undertaken in 1990-1991.

Costs of Remedial Activities: The 1987 investigation of groundwater contamination by Sonora's contractor cost approximately $52,000 with modifications to the tailings impoundment design expected to cost $50,000 - $100,000 (no final cost data available from 1987). No specific cost data were found on the remedial measures undertaken in 1990-1991. However, in a late 1991 newspaper article, a company official indicated that the costs of the remedial measures would be approximately $200,000.

References: Botts, 1990. Bateman, 1990. Wahler, 1987. Bergsohn, 1991.

4.2.7 Case Study No. 7 - Fuel Spill from Ancillary Facilities

Site Name: Buckhorn Operations, Cominco American Resources, Carlin, Nevada

Type of Mining: Cominco American Resources' Buckhorn Operation is a cyanide heap leach facility near Carlin, Nevada.

Nature of Environmental Effects: In late 1991 and 1992, Cominco observed several releases of hydrocarbons from ancillary operations. These included: (1) a gasoline release from underground piping, (2) a diesel fuel leak from underground piping, and (3) a surface spill of diesel oil. The contamination area associated with the gasoline leak was approximately 1 acre with groundwater concentrations of Total Petroleum Hydrocarbons of up to 37.9 ppm. The diesel leak from the pipe contaminated approximately .33 acre with ground water TPH concentrations of up to 1.32 ppm. The spill contaminated about .8 acre with trace amounts of TPH detected in groundwater. Finally, there are other localized areas of oil and diesel contamination at the plant site. Surface water contamination was limited to a confined marsh area with TPH concentrations of up to 1,360 mg/l. In November, 1992 the State issued a Finding of Alleged Violation and Order (FOVA) for sitewide hydrocarbon contamination. All of the information in this description is included in the facility's written response to the FOVA.

Remedial Actions: The selected remedial measures included collection and oil/water separation of surface flows, installation of groundwater recovery wells with oil/water separation and fuel recovery, injection of bioremediation solution through a new injection well and constructed trenches, and bioremediation of previously excavated soils.

Costs of Remedial Activities: A December 8, 1992 presentation by Cominco American Resources to the State of Nevada indicated that the cost of delineating the contamination and implementing selected remedial measures would exceed $290,000. This included site investigation and remediation activities, however, a complete breakdown of individual cost elements was not available.

References: Cominco, 1992.

4.2.8 Case Study No. 8 - Cyanide Leakage from a Heap/ARD Discharge from Spent Ore

Site Name: Brohm Mining Corporation, Gilt Edge Mine, Lead, South Dakota

Type of Mining: Brohm mining corporation operates a cyanide heap leach facility near Lead, South Dakota. Over 3,000,000 tons of neutralized spent ore has been disposed of Ruby Creek, which flows during wet periods. Ruby Creek flows into a perennial stream, Bear Creek.

Nature of Environmental Effects: Beginning in 1993, ARD has been observed in both Ruby Creek and Strawberry Creek with observed pH levels as low as 1.5-2.0. Historic tailings are the only wastes found in Strawberry Creek, however, studies completed by the operator have shown a hydraulic connection between Brohm's pit and Strawberry Creek.

In addition, from June 17 through 19, leakage occurred from one of Brohm's leach pads causing cyanide releases to ground and surface water. This violated Brohm's zero discharge permit.

Remedial Actions: U.S. EPA issued NPDES permits requiring Brohm to control the discharges in Ruby and Strawberry Creeks. As a result, Brohm installed a series of treatment ponds and a temporary holding pond in Ruby Creek. Water treatment is currently done by reverse osmosis. A lined collection pond for surface water and pumped ground water was also installed in Strawberry Creek. Further, over 165,000 tons of historic tailings in Strawberry Creek were cleaned-up. As of June 1995, Brohm was planning to install a second treatment system for all of the water in Ruby and Strawberry Creeks plus pit water (to be operated until the waste rock is reclaimed and capped). According to the operator, water quality has now been restored.

To address the 1991 pad leakage, Brohm was required by the State to submit reports documenting the extent of the contamination, and develop a remediation plan. The settlement between the State and Brohm included lowering solution levels in the surge pond, installing a bentonite plug in the area of the leakage, permanently repairing the pad, and constructing a treatment system for excess water.

Costs of Remedial Activities: The short-term costs of acid drainage remedial measures are provided by the facility and long-term reclamation costs are provided by the State's bonding calculations. The facility's estimates for short-term measures (spent between 1993 and 1995) include:

Interim mitigation and treatment	$1,960,000
Historic tailings remediation	$451,000
Water treatment system	$741,000
ARD plan	$208,000
TOTAL	$3,360,000

This does not include the January 1994 reported cost ($400,000) for a reverse osmosis unit for water treatment (presumably their second, the first was purchased in 1993 for $350,000).

As described in the State's bond calculations, approximate long-term costs of remediation for ARD can be observed in several line items, including:

Ruby waste dump cap	$2,162,000
Limestone on Pit Benches	$78,000
Pit Cap	$650,000
Crusher area cap	$48,000
Leach pad cap	$472,000
QA of Cap Construction	$110,000
Pit water treatment	$195,000
Ruby dump capital items	$661,000*
TOTAL	$4,376,000

* Capital items include construction of ponds and water diversion ditches, sludge disposal, and water treatment during a planned four-year reclamation period.

The total reclamation bond for the site is now $8,517,000.

The costs of the remedial measures associated with leakage from the heap are available through the State's requirement of a performance bond for remediation. The total bond amount was $350,000.

References: SD DENR, 1991a. SD DENR, 1992b. SD DENR, 1993. Brohm, 1995. SD DENR, Undatedb.

4.2.9 - Case Study No. 9 - Tailings Erosion (Small Operation)

Site Name: Franklin Consolidated Mining Company, Inc., Clear Creek County, CO

Type of Mining: A small underground mine and cyanide vat leaching operation for gold production. The operator recently changed the gold recovery process from a Merrill-Crowe circuit to Carbon-in-Leach. Spent ore/tailings have been disposed of in two units, the upper and lower tailings impoundments. The upper tailings impoundment contained approximately 7,000 tons of tailings as of

October 1993; the amount in the lower tailings unit was not specified. An additional 2,500 tons of pyrite concentrate were found in the mill area.

Nature of Environmental Effects: During a mine site inspection by the Colorado Division of Minerals and Geology on October 15, 1993, State inspectors found that pyritic tailings in the upper impoundment were continuing to erode into Gilson Gulch. The inspection report notes that Franklin was required to have submitted a corrective action plan for the eroding tailings by September 30, 1993; however, no plan had been received as of the date of the inspection. In addition, a drainage pipe was found at the base of the tailings to direct runoff/seepage into a lined pond. However, the pipe was apparently not functioning and ponding was observed. At the lower tailings impoundment, pyritic tailings had been dispersed by wind 100 feet outside of the unit. As a result of the observed impacts, the State of Colorado Mine Land Reclamation Board issued a Notice of Violation on March 1, 1994.

Remedial Actions: The corrective action plan for the impacts involved grading and erosion control for the upper pile. The upper pile tailings were to be compacted in a single pile and an earthen berm constructed to confine these materials. The diversion ditch above the pile was to be "improved" and deepened. For the lower pile, the plan including wind erosion control by covering with burlap netting and clean-up of the windblown tailings. In addition to tailings related-activities, the facility was required to install curbing in the mill building to contain cyanide spills.

Cost of Remedial Activities: The costs of remediation are reflected in post-inspection revisions to the operator's bond. No specific line item costs for remedial measures are available. However, as noted in Franklin consultant's February 23, 1994 letter describing the proposed actions, a bond increase of $16,000 was generally necessary to cover the remedial actions.

References: York-Feirn, 1993. Poulter, 1994.

4.2.10 Case Study No.10 - ARD and Cyanide Discharges; Metals Loading; Liner Failure

Site Name: Summitville Mine, Summitville, CO

Type of Mining: This Superfund site was a gold mine in the San Juan Mountains of southern Colorado. Ore was mined from an open pit and beneficiated on a single cyanide heap leach pile. The facility operated during the mid-1980s. Waste rock from the pit was disposed of in on-site piles. The site is located in an area of historic underground mining operations.

Nature of Environmental Effects: From the beginning of operations in the mid-1980s, it became clear that the initial plan of operations included an inadequate determination of water management requirements. Subsequent treatment technologies for unanticipated discharges proved inadequate. Further, acid drainage and associated metals loadings from waste rock piles as well as historic drainage tunnels were discovered. Finally, the potential for acid generation was underestimated during mine planning. When operator declared bankruptcy in December 1992, the fluid levels in the heap were within 5 feet of the emergency spillway (and would have overflowed without treatment). In addition, avalanches damaged the liner during initial construction necessitating the construction of a seepage collection and pumpback system.

Remedial Measures: Long-term remedial/site reclamation measures remain to be determined for the site. EPA/State of Colorado have been operating the wastewater treatment system since the operator went bankrupt. The current focus is on opportunities for bioremediation to address both cyanide detoxification and acid generation.

Costs of Remedial Activities: This site presents extraordinary clean-up requirements in a highly sensitive environment. Because no final remedy has been selected or schedule for site clean-up completion established, it is impossible to provide detailed cost estimates. However, the long-term costs of clean-up measures are now projected to approach $100 million.

References: Pendleton, 1995. Plumlee, 1995. Jones, 1993.

4.2.10 Case Study No. 10 - Pre-mine Planning, Proposed Water Treatment Options

Site Name: Noranda, Montanore Mine, Kootenai National Forest, Montana

Type of Mining: Proposed copper and gold underground mining operations with a conventional flotation mill. Tailings will be managed in an impoundment.

Nature of Environmental Effects: The tailings impoundment is anticipated to have seepage of up to 1,798 liters per minute; requiring discharge to the Kootenai River Basin. In addition, excess mine water will be land applied and managed in percolation ponds. Seepage from the percolation ponds can also impact surface water. To meet applicable State water quality standards, Noranda must provide for water collection and discharge treatment.

Mitigation Measures: The plan of operations includes plans for a drainage system and options for water treatment. Constructed wetlands are the least costly suggested treatment technology, however, their effectiveness are not certain. Active treatment technologies proposed include evaporation and electrocoagulation.

Costs of Remedial Activities: The estimated cost of constructing the drainage collection system is $1.5 million. Wetlands treatment would cost between $1 and 2 million, while evaporation and electrocoagulation would cost $18.9 and $6.9 million, respectively.

Reference: Marshall, 1990.

4.2.11 Case Study No. 11 - Water Quality Impacts from Tailings Impoundment

Site Name: Noranda, Grey Eagle Mine, Happy Camp, California

Type of Mining: 500-ton-per-day open pit gold mine with vat leach operation. Spent ore disposed in tailings impoundment. Operations began in 1982 with closure in 1986.

Nature of Environmental Effects: The tailings impoundment was a source of water quality impacts necessitating construction and operation of a water treatment plant.

Remedial Measures: The water treatment plant was used during active operations. For closure, an impermeable cover consisting of a geotextile cover with a clay liner and surface revegetation was required. To date, the cover has proven effective in preventing infiltration through the tailings.

Costs of Remedial Activities: The construction costs of the cover averaged $131,000 per acre of tailings (the specific area to be covered was unavailable).

4.2.12 Case Study No. 12 - ARD and Cyanide Discharges from Large Heap Leach Operation

Site Name: Zortman-Landusky Mine, Pegasus Mining, Montana

Type of Mining: Extensive surface mining operations with heap leaches and processing circuits. Active operations began in the late 1970s - early 1980s. Pegasus is currently planning an expansion of leaching operations. The facility is located in an historic mining district with several drainages impacted by old adit discharges and/or historic mining.

Nature of Environmental Effects: Acid drainage as well as cyanide releases have impacted surface and ground water in two separate watersheds. While some impacts have been increased by releases from historic adit and wastes, Zortman's impacts are evidence by extensive water quality data.

Remedial Measures: Zortman initially installed containment and pumpback systems in each drainage and have developed a wastewater treatment facility. However, the existing facilities have proven inadequate to capture all surface and subsurface drainage; they specifically cannot contain maximum flows. Through an ongoing enforcement action, a broad water quality compliance plan is being developed.

Costs of Remedial Activities: No specific cost data are available from the files and the long-term cost will ultimately depend on the selected remedy. However, a 1994 newspaper article in the Helena Independence Record cited the mine manager as indicating that the company spent $720,000 constructing the current water treatment facility. Further, he indicated that over $2.8 million was spent on "reclamation" in 1993-1994 (uncertain how much of this was directed to remediation). Finally, the size of the site, complexity of the impacts, and types of remedies under consideration suggest that millions of additional dollars will likely be required for continued monitoring, design, construction, and maintenance of remedial measures/treatment systems.

References: Independence Record, 1994. Hydrometrics, 1994. Hydrometrics, 1995.

4.2.13 Case Study No. 13 - Cyanide Seepage from Milling Operations

Site Name: Golden Sunlight Mine, Placer Dome, Inc., Whitehall, Montana

Type of Mining: An open pit gold mine with cyanide heap leaching that has been active since 1983. The facility is currently in the process of permitting an expansion. Operations at the site began in December 1992. However, the facility was shut down between June 1994 and February 1995 due ground movement and resulting mill damage.

Nature of Environmental Effects: Environmental impacts, from "minor" spills to long-term effects on the surrounding environment, have been prevalent at Golden Sunlight since the beginning of operations. The most significant impacts have been associated with ongoing cyanide-contaminated seepage from the tailings impoundment, sloughing/cracking of waste rock dumps, and the threats of acid drainage. The most recent environmental/safety incident involved "ground movement" in the plant area (and related ground water impacts) caused by the massive weight of waste rock in piles at the site (this is the only incident with available cost data).

Remedial Measures: To address cyanide-contaminated seepage, Golden Sunlight redesigned the presumably lined tailings impoundment, installed pump-back wells, and provided alternative water supply wells and water treatment for downgradient domestic water supplies. Pumpback/dewatering wells have been installed in the plant area to address the ground movement-related impacts (as well as changing waste rock management practices). Further, the operator moved 15 million tons of waste rock to a more stable on-site location. Finally, Placer Dome installed a containment system for 12 tanks that hold weak cyanide solution, a concrete corridor to protect water lines, and a stronger tank for tailings water reclaim storage.

Costs of Remedial Measures: As noted above, there are no remedial cost data for any of the environmental impacts other than those related to ground movement. To address ground movement, the operator had spent about $12 million as of March 1995 with an additional $1.8 million expected to be spent by end of the summer.

References: Pay Dirt, 1995a. Pay Dirt, 1995b.

4.2.14 - Case Study 14 ARD from Tailings Impoundment

Site Name: Thompson Creek Mine, Tonopah Mineral Resources, Inc., Challis, Idaho

Type of Mining: The Thompson Creek mine is located in Custer County, approximately 35 miles southwest of Challis. The site consists of an open pit molybdenum mine. Mine ore is beneficiated by crushing, grinding, and conventional flotation. Tailings are managed in an impoundment, while waste rock is disposed in two angle of repose piles. Mining began in the mid-1980s. The mine is located near the Salmon River and its tributaries.

Nature of Environmental Effects: Beginning in the late 1980s, the operator began to observe acid generation from a tailings impoundment. The impoundment was initially intended to be a zero discharge unit. However, seepage was encountered from the beginning of operations necessitating the construction and operation of a pumpback system. In addition, some types of waste rock were found to have acid generation potential, although no impacts were observed in downstream drainages.

Remedial Measures: Cyprus initially estimated that water quality standards could be met by diluting impoundment seepage with natural runoff. No water treatment beyond sediment control was expected to be required. To address the acid drainage, the operator has investigated a wide range of different potential remedial measures for the tailings impoundment. Such measures have included conventional treatment systems, application of buffering solution to the tailings, and installation of pyrite recovery/flotation system in the mill. To address waste rock, the facility uses selective placement of potentially acid generating materials (including capping/buffering with other non-reactive rock types). No final selection of a long-term alternative has been made to date.

Costs of Remedial Measures: The long-term costs of remedial measures are difficult to determine because the final remedy has not been selected. Some evidence of the magnitude of such costs is provided by the bond required by the State Department of Water Resources for the tailings impoundment (to address potential water quality impacts that were not expected during mine planning). As of 1991, the value of this bond was over $7.5 million (no more recent data are available).

Reference: Steffen Robertson & Kirsten, 1982. Steffen Robertson & Kirsten, 1991a.

4.2.15 Case Study No. 15 - ARD and Metals Contaminated Seepage of Process Solutions

Site Name: Magma Copper Company, Pinto Valley Division, Copper Cities Unit, Arizona

Type of Mining: Reprocessing of Miami tailings for copper recovery.

Nature of Environmental Effects: NPDES permit no. AZ0020419 (1986) authorized discharge of seepage and runoff from the inactive dumps and shop area to Pinal Creek from discharge point 002, from inactive dumps to Pinal Creek via discharge point 003, and from inactive dumps and undisturbed landscape to Pinal Creek from discharge point 004, in accordance with effluent limitations, monitoring requirements, and other conditions. In April 1991, an EPA inspector observed unauthorized discharges of effluent below the No. 5A seepage control dam, and at the base of the No. 004 collection dam. Magma's sampling data from the 5A area indicated that the water was low pH, with elevated concentrations of copper, zinc, and manganese. A water sample collected above the No. 004 collection dam contained arsenic, barium, copper, manganese, nickel, lead, and zinc.

Magma noted in response to a June 21, 1991 Findings of Violation and Order (FOV) that the "outfall location" near the No. 004 collection dam was actually the downstream end of the open channel spillway of the dam, and attributed it to a nearby spring. Magma also reported in the 1991 response that the stain below the 5A dam was about 2,000 feet long and six to eight inches wide, with a lower limit approximately two-thirds of a mile above the confluence of the unnamed wash where it was located with Pinal Creek. Magma felt that there was insufficient information that could be used to estimate the amount of solution that had entered the drainage. Magma found no evidence of environmental damage as a result of the staining.

In September 1991, a pipe separated at a pump by the No. 002 containment area and acid (pH=3.5) effluent containing copper, lead, and zinc was discharged to Pinal Creek for about 30 minutes. (FOV)

Further seepage from the No. 5A seepage control dam was reported in January 1992, and EPA issued a FOV on January 24, 1992.

Remedial Measures: In order to receive its NPDES permit, Cities Service Company (owner until 1986) constructed 100-year, 24-hour storm collection facilities in 1981-1982, to capture leaching solutions from old mine dumps and contaminated stormwater, and prevent them from being discharged. In 1991, Magma proposed to cease discharges of copper solution from the No. 5A seepage control dam, by one of three measures: attempting to redrill and pressure grout the 5A dam; installing caisson and pumps above the 5A dam; or constructing a new dam. Magma also proposed to move the 004 discharge point to a location upstream of the entrance of the rerouted spring, remove No. 11 tailings starter dam, and upgrade upstream collection facilities.

Remedial measures taken were reported in a 1/22/93 letter to EPA:

Tinhorn Wash/Outfall 002: Corrective actions taken at Tinhorn Wash included rerouting the discharge pipeline from the pumping system to prevent a discharge in the event of a future failure of the pipeline, and relocating the pumping system.

No. 1 Basin/Outfall 004: To best address EPA's concerns, Magma elected to relocate the discharge point outfall location approximately 10 feet downgradient of its existing position, and submitted an NPDES permit renewal application accordingly, in June 1992.

No. 5/5A Basin/Outfall 003: Based on hydrogeologic information, Magma chose to construct a large containment facility (Zook Dam) to collect the seepage identified by EPA from this area. Other potentially less costly alternatives, including treating and releasing, may have been acceptable. However, time constraints precluded Magma from completely investigating, or permitting and constructing, a treatment system.

Costs of Remedial Activities: In 1991, Magma stated that its expected NPDES compliance costs were as follows:

No. 5A Seepage Collection Dam: $30,000, $100,000, or $150,000
Move 004 discharge point, remove No. 11 dam, and upgrade facilities: $150,000

In early 1993, Magma reported the following costs of NPDES compliance (Table 4, 2/5/93 letter):

Item	Cost	Date
Tinhorn Wash/Outfall 002	$ 3,579	1/92
No. 1 Basin/Outfall 004	$ 1,500	estimated 2/5/93
No. 5/5A Basin/Outfall 003	$539,093	1-12/92 (final cost slightly higher)
TOTAL	$544,173	

O&M costs were described in 2/5/93 letter and provided for November 1986 to 1991, then updated in a 2/23/93 letter. Costs are estimated because Miami Unit maintenance personnel repair Copper Cities water control facilities during inspections and in conjunction with work done on non-NPDES facilities located at the Copper Cities. Magma's estimates for O&M, capital, and other costs of NPDES related facilities were as follows:

1986	1987	1988	1989	1990	1991	1992
$15,505*	$103,618	$80,661	$52,714	$65,874	$155,188	$696,620

* November 5-December 31, 1986

References: Magma, 1991a. USEPA, 1992.

4.2.16 Case Study No. 16 - Tailing Impoundment and Leach Operation

Site Name: Magma Copper Company, Pinto Valley Division, Pinto Valley Operations, Arizona

Type of Mining: Open pit, concentrator, and dumpleaching/SX-EW.

Nature of Environmental Effects: NPDES permit no. AZ0020401 (1984) authorized discharge of stormwater overflow from discharge points 002, 003, and 004, and tailings seepage from discharge point 005 to Pinto Creek. On January 16, 1991, an EPA inspector observed an unauthorized discharge of effluent surfacing about 50 yards below Gold Gulch 2 reservoir, which contained water and copper dump leach solution that overflowed from Gold Gulch 1 dam.

On June 22, 1990, and January 16, 1991, an EPA inspector observed effluent surfacing below the toe of tailings dam no. 3 and flowing toward Pinto Creek. On January 16, the seepage was flowing at about one gallon per minute. A sample of the seepage contained 0.42 mg/L of total copper.

On August 18, 1989 and January 4, 1991, the face of tailings dam no. 3 failed, and tailings entered Pinto Creek. An estimated 96,000 gallons of a mixture of tailings and water was discharged in 1989, and an estimated 150 to 250 tons of tailings were discharged to Pinto Creek and its tributaries in January 1991.

On January 16, 1991, an EPA inspector observed an unauthorized discharge of a mixture of storm runoff water and industrial water, which consisted of shop runoff water, pump gland water, and other industrial wastewater, surfacing below the Miller Springs catchments dam and flowing at about six gallons per minute towards Pinto Creek. A sample collected during the inspection contained 0.0023 mg/L of total copper.

On August 11, 1991, September 5, 1991, and September 23, 1991, the Miller Springs ditch became plugged, causing the ditch to overflow to a tributary of Pinto Creek and Pinto Creek. An estimated 3000 gallons of effluent containing suspended solids and copper were discharged on August 11, an estimated 24,000 gallons were discharged on September 5, and an estimated 39,000 gallons were discharged on September 23.

EPA issued a Finding of Violation on November 27, 1991 (IX-FY92-02), and Magma submitted a response and preliminary engineering plan on January 29, 1992. Magma notified EPA on July 15, 1992 that all upgrade projects outlined in the plan and the follow-up quarterly reports had been completed.

Exceptionally heavy rainfall in January 1993, added to unusually high precipitation in December 1992, caused area wide flooding and subsequent damage to water control facilities at Pinto Valley Operation (PVO). Massive rainfall exceeded design capabilities of water management facilities and resulted in extensive damage. Gila County was declared a state and federal flood disaster area in January 1993. Pinto Valley Operation facilities were upgraded in 1992 to handle stormwater runoff from a 100-year, 24-hour storm event, but continuing heavy storm event conditions caused an upset condition starting on January 8, 1993. The PVO area received 86% of its average annual rainfall in seven weeks in December 1992 and January 1993. The PVO mill was shut down for eight days in

January in order to commit all pumping resources to overflow prevention. Millions of gallons of water were deliberately pumped into the PVO open pit.

In August 1992 and early January 1993, overflow process leachate solution containing sulfuric acid, beryllium, cadmium, copper, nickel, and zinc was diverted from Gold Gulch I to prevent a breach in the dam, with overflow contained in Gold Gulch II. In January, approximately 30% of the 20.9 million gallons released was being recovered, compared to 98% in August. On January 19-20, 1993, Gold Gulch II overflowed into Pinto Creek, releasing approximately 27.7 million gallons of stormwater and PLS. In February, heavy precipitation again required a bypass of Gold Gulch I to prevent a breach in the dam, with overflow contained in Gold Gulch II and approximately 658,000 gallons released and 30% recovered.

In January and February 1993, heavy precipitation contributed to an overtopping of the No. 1 Tailings Dam berm, resulting in an erosional event on the face of the dam. Approximately 54.1 million gallons of storm water and process water, and 90,000 cubic yards of tailings were released.

In July 1994, EPA and Arizona Department of Environmental Quality (ADEQ) announced that Magma Copper Company would pay $625,000 for Clean Water Act violations at Pinto Valley, Superior, and Copper Cities. Under the agreement, Magma also undertook a supplemental environmental project that required the cleanup of pollution in the Pinal Creek drainage area from the abandoned Old Dominion Mine near Globe, Arizona, and paid $50,000 to initially fund three additional projects to benefit affected watersheds.

Remedial Actions: Magma planned to upgrade the seepage collection facilities in place prior to the March 1991 sloughing of the face of tailings dam no. 3, and reconstruct or construct new ancillary facilities, including access roads, powerlines, and transformers and pipelines.

In early 1993, Magma reported the following NPDES compliance activities:

Upper Catchment/Miller Springs: A hydrologic assessment was performed to establish site specific conditions. A toe drain collection system was then designed and installed at Upper Catchment to eliminate seepage to the Miller Springs area. An internal berm was raised and sediment that had accumulated in the catchment was removed.

No. 1 Seepage Collection System/Outfall 002: To address the moist area below the outfall culvert, Magma installed an elbow riser on the intake side of the outfall culvert, so as to ensure that an acceptable amount of stormwater storage capacity was in place to comply with the existing NPDES permit. A permanent pump and cassion collection structure were also installed to recycle stormwater to process operation.

Gold Gulch: A review of hydrogeologic data collected from the area led Magma to decide that the establishment of a new outfall location would address the issues raised by EPA, and submitted a revised NPDES permit application. Costs incurred related to Gold Gulch were described as miscellaneous upgrades to facilities.

Cottonwood Canyon: Magma could not identify the source of the intermittent seeps identified by EPA. Magma therefore decided to relocate the existing permitted outfall downgradient of the seeps, and submitted a revised NPDES permit application.

Miscellaneous: Magma incurred costs to lease equipment and for miscellaneous parts and labor.

No. 3 Tailings Dam Expenditures: Magma hired contractors to perform repairs on the face of the No. 3 Tailings Dam at the time of the slough. These costs were considered costs of NPDES compliance. Costs were incurred for earthwork, surveying, miscellaneous equipment rental, a pump study, and pump purchase.

Prior to and after the March 1991 sloughing, Magma incurred additional costs to constantly maintain and, where necessary, repair the tailings dam face, which Magma considered a cost to operate and maintain the tailings dam itself, rather than a cost for NPDES compliance. Contractors retained to perform other tailings dam work are charged to O&M of the tailings dam. Filling in erosional areas on the benches and assuring proper drainage were also considered O&M activities.

Costs to repair the seepage collection facilities that were in place prior to the sloughing were considered compliance costs. Following the sloughing, Magma designed and constructed new facilities engineered to a more rigorous design standard than required for compliance with the existing NPDES permit. Estimated costs for upgrades from the facilities in place prior to the sloughing, to these more rigorous design standards, were subtracted from the actual costs for the new facilities.

Extensive remedial activities were performed by Magma following the heavy rainfall period in December 1992 and early 1993.

<u>Costs of Remedial Activities</u>: Magma submitted a Summary of Expenditures to Comply with Administrative Orders IX-FY91-27 (Superior), IX-FY92-02 (Pinto Valley), and IX-FY92-08 (Copper Cities) on January 22, 1993 (not located), and supplemental information on February 5, 1993. Magma's stated costs for the Pinto Valley Operations were as follows:

Item	Cost	Date
Upper Catchment/Miller Springs:	$ 57,868	10-11/91, 3/92, 6/92
No. 1 Seepage Collection System:	$ 5,451	2-3/92
Gold Gulch:	$ 4,733	5/92
Cottonwood Canyon:	$ 1,000	estimated

Misc. equipment, materials, parts, labor:		$ 61,1511-6/91
Subtotal	$130,204	(2/5/93 response)
No 3 Tailings Dam Expenditures:	$406,333	(2-7/91)
	$100,000	estimated prior in-place seepage collection facilities to meet NPDES compliance.
Subtotal	$506,333	
TOTAL	$636,537	

Magma reported that O&M costs at PVO are generally charged against an operating unit such as the concentrator, and that NPDES costs are not captured separately. O&M costs for the tailings dam and industrial water supply facilities are not included. In 1993, Magma's estimates for O&M, capital, and other costs were as follows (2/23/93 response):

1987	1988	1989	1990	1991	1992
$298,548	$352,366	$359,557	$310,685	$2,076,505	$741,663

A Magma representative stated on October 1, 1993 that the cost of the cleanup of "the spill" at Pinto Creek was about $250,000 at that point, but that the total cost would not be known for about one month. Total cost information was not located in EPA's files.

References: USEPA, 1991c. Magma, 1992b. Magma, 1993b. Magma, 1993d. USEPA, 1993. USEPA, 1994b.

4.2.17 Case Study No. 17 - Discharge from Tailings Dam and Process Pond

Site Name: Magma Copper Company, Superior Division, Arizona

Type of Mining: Underground copper mine and milling facilities.

Nature of Environmental Effects: On March 8, 1989, an EPA inspector observed a discharge from the toe of Tailings Dam No. 6 into an unnamed dry wash tributary to Queen Creek. Magma ceased this discharge after April 10, 1989. A sample of the discharge contained copper and zinc.

On August 15, 1990, during a storm event, the berms on the east and west sides of Smelter Pond No. 1 were breached, resulting in an unauthorized discharge of over one million gallons of mine drainage water to an unnamed tributary of Queen Creek. The discharge contained cadmium, lead, copper, and zinc, and had a low pH (3.4).

From April 18 through April 26, 1991, Magma discharged mine drainage or tailings water containing copper and zinc from an unauthorized discharge point known as Clear Water Ditch.

In a letter dated May 28, 1991, EPA required that Magma, Superior Division, provide information related to the recent discharges described above, including planned remedial activities and costs of actions to cease these discharges. EPA issued a Finding of Violation and Order requiring compliance with NPDES permit requirements on August 28, 1991 (IX-FY91-27).

<u>Remedial Actions</u>: Early in 1993, Magma listed the following activities performed by contractors:

Install secondary sump below seep pump.
Construction for seepage control.
Install two 450 ft. siphon lines.
Equipment rental.
Install 3 culverts.
Install lime lines sp #1.
Install culvert NW corner.
Culverts, build-up berm, dig out ends.
Install culverts at depot.
Install alternate power sources for seep pumps.

In June 1991, Magma described the following proposed activities:

- Construct diversion dike at northeast side of Smelter Pond No. 1, to divert runoff from Clear Water Ditch into Smelter Pond No. 1 for subsequent treatment.
- Increase storage capacity of Smelter Pond No. 1 by installing a pumpback system, raising Smelter Pond No. 1 crest, dredging contained solid materials, and/or dredging contained solid materials.
- Sample, analyze, and possibly excavate contaminated soils from Clear Water Ditch and open drainage channel.
- Enlarge and improve the secondary sump collecting initial seepage from the Smelter Pond area.
- Investigate alternate methods of handling pyrite operations drainage (cyclone overflow water), such as installation of a pump and associated piping to pump cyclone overflow water directly to the Mill #2 Settling Pond or Tailings Dam #5 for water reuse within the mill operations.
- Investigate alternate methods of handling sandfill cyclone overflow water, such as installation of a pump and associated piping to pump the cyclone overflow water to the Mill Pond for reuse as process water within the mill.

Costs of Remedial Activities: In June 1991, Magma estimated that its NPDES compliance costs would be as follows:

- Dike design, soils drilling/investigation, runoff investigatory work: $61,900 (dike construction costs currently unknown).
- Pumpback system: $120,000; design and runoff characterization work for dam raise: $12,100; actual dam raise construction costs unknown.
- Contaminated soils, preliminary estimate: $58,300
- Construction of second sump: $3,000; enlargement of this sump: $5,000.
- Anticipated pump/piping costs for pyrite operations drainage: $15,000.
- Anticipated pump/piping costs for sandfill cyclone overflow: $5,000.

TOTAL estimated costs: $280,300.

Early in 1993, Magma reported the following NPDES compliance costs:

Contractors:	$ 10,615
Magma equipment:	$ 55,127
Pumps:	$ 2,954
Pipes:	$ 10,739
Misc. equipment:	$ 3,375
TOTAL:	$ 87,811

O&M/capital/other costs (2/23/93):

1989	1990	1991	1992
$63,226	$113,995	$120,041	$154,476

References: USEPA, 1988. Cyprus, 1989. Cyprus, 1991a. Cyprus, 1991b. Cyprus, 1992.

4.2.18 Case Study No. 18 - Contaminated Groundwater Uncontrolled Process/Mine Water Discharges

Site Name: Cyprus Miami Mining Corporation, Cyprus Miami Operations, Arizona

Type of Mining: Open pit copper mining with flotation mill and SX/EW.

Regulatory Actions: EPA first issued Finding of Violation and Order No. IX-FY86-78 to Inspiration Consolidated Copper Company (ICCCo.) on July 28, 1986. EPA then issued modified orders in October 1986 and February 1987. In July 1988, Cyprus Miami Mining Corp. (Cyprus) purchased the assets of the Inspiration operations from ICCCo. EPA drafted a revised FOV dated

December 1, 1988 based on a meeting in October 1988 with Cyprus. In August 1989, EPA and Cyprus again met, and Cyprus redrafted FOV IX-FY86-78. Cyprus submitted the revised FOV to EPA on December 18, 1989, including language that Cyprus was not responsible for the CWA violations of ICCCo., despite remedial actions taken. Cyprus stated that it did not concede the accuracy of any statement or finding of fact in the FOV. The following violations come from the December 1989 version submitted by Cyprus.

Nature of Environmental Effects: Based on a 1980-1983 groundwater study for the Globe/Miami area and EPA's inspections, EPA found that subsurface flows of mine wastewater from Webster Lake, Ellison Pond, and the acid sump (unlined) "created a severe contamination plume in the alluvial system formed by the former Webster Gulch channel," and subsurface flows from these sources had advanced and continued to advance downgradient through the Holocene alluvium underlying Bloody Tanks Wash and Miami Wash. A "significant portion" of the mine wastewater present in this aquifer, which is "hydrologically linked" with overlying tributaries of Pinal Creek including Miami Wash and Bloody Tanks Wash, used to surface along portions of Miami Wash and in the Bixbe Road Seepage Cut just west of Miami Wash, which discharges into Miami Wash. Aerial photographs of Inspiration Consolidated Copper Company's operations in September 1980, and an EPA inspection in June 1985, showed that mine wastewater was discharged from the Bixbe Road Seepage Cut into Miami Wash, and surfaced at various points along portions of Miami Wash, where it continued downstream to Pinal Creek. In inspections in 1986, EPA observed that mine wastewater continued to discharge into Miami Wash, which was flowing at flood stage into Pinal Creek, from two sources: the Bixbe Road Seepage Cut and a culvert in New Webster Gulch near the No. 5 Decant Structure.

In February 1991, EPA issued a new FOV to Cyprus (IX-FY91-06), and then issued an amended FOV on July 10, 1991. On July 18, 1991, Cyprus submitted costs of past steps taken to achieve NPDES compliance, and a report by a contractor describing additional NPDES compliance activities pursuant to the 1991 order and estimating costs for these activities. Cyprus estimated that it might be able to reduce these estimated contractor costs by performing some of the planned work itself.

Remedial Actions:

1986 FOV issued.

ICCCo. complied with a number of EPA's requirements in the original and first two modified orders. Among other measures taken, ICCCo. permanently drained and ceased discharging mine wastewater to Webster Lake and Ellison Pond, and eliminated the unlined acid sump.

Between July 1988 and December 1989, Cyprus attempted to remediate the contamination plume by removing and disposing of mine wastewater in the aquifer that could contribute to a discharge at the Bixbe Cut, maintaining tailing interceptor wells, installing two new monitor wells below Hicks

Crossing, increasing the pumping capacity at Kiser Basin to 1200 gpm, increasing burch pumping to 1000 gpm, and performing aquifer modeling work to develop remedial plan.

1991 FOV

Past steps taken by Cyprus as of July 1991:

- NPDES 001: Sediment was removed from the NPDES 001 containment structure to reestablish stormwater runoff storage capacity.
- NPDES 003: Improvement included raising the containment structure berm for increased storage capacity and new culvert installation.
- NPDES 004: Completed construction of earthen containments and dikes for control of stormwater runoff, with a July 1991 storage capacity of 3.5 million gallons.
- NPDES 005: Improvements included construction of a large (2.3 million gallons) stormwater containment structure, leach dump terracing, ditching, and berming along the 005 drainage area. Pre-existing water tanks and mine water truck quick fill were installed so that mine dewatering water could be used for dust control.
- NPDES 007: Three earthen containment structures (12 million gallon stormwater storage capacity) were reconstructed along the 007 drainage area using existing sand, silt, and fill material.
- NPDES 005/006 Compliance Plan (July 1991):

The compliance plan intended to eliminate flow at the NPDES 006 compliance point and contain a 10-year return period storm at the 005 compliance point. The 006 compliance point was located on a shallow channel incised into the bedrock about 500 feet downstream from a haul road constructed with wasterock placed in the drainage. Exceedences of the copper standard tend to be associated with higher discharges (greater than 30 gpm), which were happening approximately 30% of the time. Discharge at 006 was thought to be sustained by a shallow reservoir of subterranean water that was recharged during storm events and gradually drained through the fractured granite bedrock underlying the basin between storm events. Surface drainage above 006 suggested that stormwater runoff from a considerable portion of the drainage basin discharges from "Feehan's Flume" into a closed basin created by waste rock placement. The stormwater impounded in the basin below Feehan's Flume (runoff from 92 acres) was thought to rapidly seep into and through the fractured bedrock that is present below a relatively thin layer of sediment, leaching copper from the fractured bedrock when the groundwater table rises after a storm event.

The existing detention basin at the 005 compliance point contained a 1.4-year storm event. The compliance plan for this drainage proposed enlarging the existing detention basin, constructing another detention basin downstream, and pumping the captured stormwater to the North Barney Pit. The near-term expansion of the Bluebird Pit was expected to reduce the drainage area to the 005 compliance point, but this was not factored into the modeling effort.

NPDES 005 would receive spillway flow from the proposed detention basin north of the haul road during storm evens greater than a 11.6 year frequency. The proposed basin would receive storm runoff pumped from the detention basin in the 005 watershed. The compliance plan was designed to eliminate discharge at NPDES 005 in 50 out of 58 years, based on SCS rainfall-runoff relationships and historical precipitation records. The average amount of water delivered to North Barney Pit would be about 16.9 million gallons per year.

Phase one would prepare the system upstream to accept the pumped storm runoff, with the water ultimately going to the North Barney Pit. Approximately 6400 linear feet of eight-inch diameter plastic pipe would be installed to connect the proposed Live Oak Containment structure #2 to North Barney Pit. The Live Oak Containment structure #2 would be constructed with a clay core, filter material, and riprap or mine waste. An estimated 21,700 cubic yards of clay and filter material would be required. A pump station would be installed at Live Oak Containment Structure#2 capable of pumping at least 1000 gpm into the North Barney pipeline. A 300-foot, 670 cubic yard trench would then be constructed to divert the Upper Feehan's Flume drainage to Live Oak Containment structure #2.

Phase two would complete three containments (Basins #1, #2, and #3) in the northern section of the Feehan's Flume watershed. The earthen dike material would come from waste rock. Clay cores would not be installed because these basins would be pumping stations not intended to store water over the long term, and because leakage should be captured in basins #4 and #6, downstream. Based on rainfall-runoff modeling, the proposed earthen dikes were designed to be high enough to contain flows from 100-year storm events regardless of pumping rate to North Barney Pit. A pipeline from the proposed basin #4, north of the haul road, would be constructed (pump and pipeline - 700 gpm) (to where?). A 5550-foot pipeline from #4 to #1 and a 2500-foot pipeline from #1 to North Barney Pipeline near Live Oak Containment Structure #2 would be constructed, with pump and pipeline in basin #1 capable of transporting 900 gpm. Phase two earthwork would eradicate the diversion ditch built in Phase 1.

Phase three activities would include excavation of 40,000 cubic yards from the north half of the haul road, and 30,000 cubic yards from the eastern toe of the waste dump in order to place 4000 cubic yards of clay and 10,000 cubic yards of filter material against the south half of the haul road (six feet of clay between 14 feet of filler). The haul road would serve as a gravity containment structure with an impermeable upstream face. The containment structure (basin #4) would serve as a pumping station and stormwater runoff retention basin. The proposed 29 acre feet (AF) detention basin would have a pumping system of 700 gpm and would receive water from Feehan's Flume, a small concrete containment structure at the NPDES 006 compliance point (pumped across haul road), and NPDES 005 facilities. In case of overflow, a cut of approximately 70 cubic yards into the native hill east of the containment structure would serve as a spillway to the haul road and the two detention basins discussed in phase six.

Phase four entailed construction of a 350-foot earthen ditch to divert flow in Feehan's Flume to basin #4.

Phase five entailed construction of a 100-cubic-yard concrete containment structure (basin #7) to collect excess flow from basin #4, with 350 gpm pumped through 650 feet of eight-inch pipe over the haul road, and prevent discharge at the NPDES 006 compliance point.

Phase six included enlarging detention basin #5 by a factor of 2.5, to contain 17.7 AF, by excavating 17,200 cubic yards of earth, and installation of pump and 2000 feet of pipeline to transport 200 gpm to basin #4 (phase three). A smaller detention basin #6 (6.7 AF) would be constructed with a clay core at the road crossing downstream and would serve as the last containment before flow discharges to Bloody Tanks Wash, pumping at 200 gpm to detention basin #5 via 1800 feet of eight inch pipeline. Basins #5 and #6 would have double barrel 36-inch corrugated metal pipe emergency outlets.

Cost estimates were included in the compliance plan for the following items:

Phase 1
- Pipeline from Live Oak Containment #2 to North Barney Pit
- Pump and Control Panel
- Live Oak Containment #2: place clay and filter
- Excavate diversion trench to divert upper Feehan's flume drainage area to Live Oak #2

Phase 2
- Basin #1, #2, #3 earthwork/waste haulage
- Pump and control panel
- Pipeline from basin #4 to basin #1
- Pipeline from basin #1 to connect to North Barney Pipeline

Phase 3 (basin #4)
- Haul road excavation
- Waste dump excavation
- Excavate key
- Excavate spillway
- Place clay and filter
- Pump and control panel

Phase 4 Excavate trench to divert Feehan's Flume to basin #4

Phase 5 (basin #7)
- Clearing and grubbing
- Excavate key
- Reinforced concrete, rock fill, 6" stainless steel pipe
- Pump and control panel

Phase 6 (basins #5 and #6)
- Enlarge existing basin #5
- Improve outlet - #5
- Pipeline from basin #5 to basin #4
- Excavate - #6
- Clay fill - #6
- Outlet - #6
- Pipeline from #6 to #5
- Pump and control panel

Costs of Remedial Activities: Past steps taken by Cyprus as of July 1991:

NPDES point no.	Cost
001	$ 365
003	$ 781
004	$10,755
005	$26,267 (internal earthwork)
	$32,067 (quick fill installation-contractor)
007	$10,221
TOTAL	$80,456

NPDES 005/006 compliance plan (July 1991):

Phase 1	$ 122,770
Phase 2	$ 150,159
Phase 3	$ 229,800
Phase 4	$ 2,400
Phase 5	$ 104,468
Phase 6	$ 144,470
Subtotal	$ 755,000
Mobilization (2.5%)	$ 19,000
Subtotal	$ 774,000
Engineering/Administration (15%)	$ 116,000

Contingencies (15%)	$ 116,000
TOTAL	$1,006,000

Detailed containment structure and facility designs, electrical power, pump and piping design specifications, and equipment selection were not included in the above cost estimate for points 005 and 006.

References: ASARCO, 1994a. USEPA, 1994a. ASARCO, 1994b. Fennemore, 1994. ASARCO, 1994c.

4.2.19 Case Study No. 19 - ARD from Tailings Dam and Leaching Operations

Site Name: ASARCO, Inc., Ray Complex, Arizona

Type of Mining: Copper mine - open pit, leach dumps, milling and SX-EW

Nature of Environmental Effects: On July 1, 1991, EPA issues an administrative order against ASARCO. The case was referred to DOJ in September 1991, and DOJ issued a demand letter in October 1992. Settlement negotiations were initiated in November 1992. As of September 1991, ASARCO was charged with 16 unauthorized discharges of process water, improper operation and maintenance, water quality standards exceedences, failure to monitor, and failure to report. Between September 1991 and June 1994, ASARCO had 18 unauthorized discharges and 154 days of water quality standards violations stemming from subsurface flows from ASARCO's leach dumps to Mineral Creek, in addition to NPDES permit violations. ASARCO was asked to address effects including discharges containing pollutants to Mineral Creek, seepage from pregnant leach solution collection dams and the electrowinning facility, and runoff from a proposed leach dump and waste rock dump.

In its June 1994 compliance plan, ASARCO described areas at the Ray Mine that ASARCO had identified as having the potential for adversely impacting water quality; steps that ASARCO had taken or was planning to take to investigate or address these potential impacts; where possible, an estimation of the time frame for completion; and where possible, an estimate of costs. ASARCO updated this information in a sixty-day progress letter dated August 29, 1994.

Subsurface concerns.

Subarea A - North of pit and tunnel inlet. Subsurface conduit of acidic (pH=4) solution to a point downgradient of the 4D RDA (sulfide leach dump).

Subarea C - South of pit and tunnel outlet. Leaks in the liner of the Big Dome Pond were detected by an electromagnetic induction survey. Pumpback wells located between the Big Dome Pond and Mineral Creek encountered "relatively low pH" water, possibly the result of liner leaks.

ASARCO's electromagnetic induction survey also showed an anomaly in the area downgradient of the Stacker Dam, indicating that the dam might not have been keyed into the bedrock. Seepage was detected at one gallon per minute beneath the Lower Slimes Dam, and "low pH" water has been detected in monitoring wells downgradient of the dam. Electrolyte was seeping from the electrowinning building as a result of leaks in the electrowinning cells and the floor of the tank house. Monitor wells encountered "low" pH, high copper water.

ASARCO also reported possible seepage under the dam at the electrowinning impoundment, which might be captured by the pumpback wells west of the building; possible seepage into Mineral Creek through an unconformity in the Mineral Creek channel, possibly resulting in a ring of turquoise stained rock observed in the creek; and approximately 4000 feet of recently exposed cemented mineralized gravels in the bed of Mineral Creek, which might leach metals back into the creek.

Stormwater runoff.

ASARCO reported that in Subarea A, above the tunnel inlet between Big Box Canyon Dam and the area where runoff flows into the pit, runoff from overburden dumps enters Mineral Creek. EPA commented that ASARCO should also address runoff from the new planned 4G dump leach area, which was exceeding water quality standards.

In Subarea B, the major portion of the mine area, all runoff is or can be directed to the pit.

In Subarea C, the area below the tunnel outlet and below the pit, which drains toward Mineral Creek, ASARCO also describes stormwater runoff measures, and measures to prevent water from Dalton's Pond from reaching Mineral Creek or groundwater.

<u>Remedial Actions</u>:

Subarea A.

Subsurface. ASARCO installed an exploratory trench to further delineate the subsurface conduit, planned to install a drain and sump in this trench with pumpback capacity, and planned to conduct groundwater monitoring to confirm that the installed control is operating correctly. In the process of installing the trench, two turn of the century, man-made adits were uncovered, with low pH (3.9) water containing 65.3 mg/L dissolved copper flowing out of one adit at a rate of 0.73 gpm.A suspected third adit had not been located. ASARCO filled the trench below the adit with coarse rock surrounding 25 feet of 32" slotted HDPE vertical collection pipe, and planned to install a pump by November 1, 1994. ASARCO planned to use the collection pipe to monitor groundwater quality, and had not yet determined how many additional pumpback wells, if any, would be required, nor what the associated costs would be.

Stormwater. ASARCO planned to construct two diversion ditches, one on the east side and one on the west side of the rock deposition areas (RDAs), to divert an estimated 50% of stormwater from reaching the 4 and 5 series RDAs. These ditches would be lengthy and would pass through rough terrain.

ASARCO found that construction of maximum saturation event (exceeding 100-year flood) containment was not feasible in this area due to topographic and space constraints. Portions of existing RDAs would have to be removed. ASARCO therefore argued that the only means of insulating Mineral Creek from runoff from overburden dumps that was technically feasible, and potentially economically feasible, would be to extend the existing tunnel to a point above the overburden dumps. Runoff would either be pumped back for reuse or treatment, or drain to the pit area. The tunnel would have to extend through 13,000 feet of bedrock, underneath the far eastern end of Subarea A, and a small diversion dam would be constructed to divert Mineral Creek into the tunnel extension. To help offset the cost of the tunnel, ASARCO proposed to cover more than 60 acres of manmade wetlands below the tunnel with expanded RDAs. The wetlands were created in the construction of the Little Box Dam and the Big Box Dam. These measures were required under EPA's recently established stormwater control program for industrial stormwater discharges, and ASARCO argued that they exceeded the conditions of its existing permit.

In response to a request from EPA that ASARCO consider interim stormwater containment measures during construction of the tunnel, ASARCO provided cost information for construction of containment ponds in Subarea A, but argued that the high cost ($4.4 million) of these ponds made it overly burdensome for EPA to require interim containment measures in this case.

Subarea B.

Stormwater. As a short term solution, ASARCO constructed dikes and rollovers in all disturbed areas where runoff can be directed into the pit, to ensure that runoff would reach the pit. However, due to the increased volume of water in the pit, and the need to reduce water levels to prevent interference with present operations, ASARCO planned to build a water treatment plant, and was considering a location above the Elder Gulch tailing pond. Effluent from a new treatment plant would be discharged in accordance with a revised NPDES permit, or pumped to Elder Gulch Tailings Pond, where it would mix with other water and be recycled back into operations, depending on the current water balance. ASARCO constructed a pilot water treatment plant to assess the feasibility of this project. ASARCO emphasized the need to identify an alternative to pit storage of stormwater, so that the Pearl Handle Pit could be deepened and new benches opened, in order for mining to continue beyond 1996.

Subarea C.

Subsurface. ASARCO repaired leaks in the liner of Big Dome Pond. A pumpback well downgradient from the pond was pumping back low pH water until mid-July, when the pump probes had to be lowered because the water level in the well had fallen; as of August 1994, the well was pumping 3.6 hours per day.

Downgradient of Stacker Dam, ASARCO installed monitoring wells, which would serve as pumpback wells, one screened in bedrock and one screened in alluvium. If the pumpback system proved to be insufficient to control flow, ASARCO planned to install a 150-foot cutoff wall in the drainage. ASARCO also installed monitoring wells, which would serve as pumpback wells, downgradient of the Lower Slimes Dam, and planned to install a cutoff wall in that drainage, if necessary.

At the electrowinning building, ASARCO installed two surface collection sumps with pumpback capacity, at the north and south ends of the building. These sumps were initially concrete, but were subsequently lined with HDPE due to degradation in the concrete. ASARCO also installed six pumpback wells, three shallow and three deep, around the tank house, to pump any recovered fluids to Big Dome Pond; and three shallow wells in the basement of the electrowinning building to dewater the subgrade. In June 1994, ASARCO was in the process of replacing the electrowinning cells, originally concrete with PVC liners, with new cells constructed of polymer concrete (vinyl ester resin). Cells were being lined with HDPE liner until they were replaced. ASARCO initiated a maintenance program to eliminate piping drips and leaks below the cells; grouted and caulked cracks in the floor; and rebuilt parts of the floor, including installation of fully welded HDPE liners in select areas of the floor. Depending on the success of the HDPE floor liner, ASARCO was considering rebuilding the floor and coating it with polymer concrete. However, the HDPE liner proved effective in preventing solution from migrating through the floor, and by August 1994 ASARCO planned to install liner wherever necessary.

Stormwater. To control runoff in this area, ASARCO was constructing a combination of dikes, dams, ditches, holding ponds, and pumpback systems. ASARCO planned to install new controls in areas providing less than 10-year, 24-hour containment: the area immediately south of the diversion tunnel outlet (north of Susie D Dam), the western slope of the Sag Dump, the an area north of the electrowinning building. ASARCO planned to increase monitoring to include discharges and accept discharge limitations for four outfalls receiving stormwater that has contacted disturbed ares.

In addition, water collecting in Dalton's Pond (runoff from the mill and mine offices area) was pumped to Big Dome Pond, where it was treated, put in a process water circuit, or returned to the pit. ASARCO installed a 2000 gpm pump in the pond to increase dedicated pumping capacity, and modifications were made to reduce the drainage area to the pond. ASARCO planned to fully line the pond to prevent subsurface discharge to groundwater. The pollution control dam below the pond was being raised seven feet.

Costs of Remedial Activities: As of August 1994, ASARCO's contractor costs for work required for the Aquifer Protection Permit (APP) for the State of Arizona totaled $2.8 million. Additional APP studies were expected to cost $577,000.

NPDES compliance costs reported by ASARCO in June and August 1994 were as follows:

Subarea A.	
Install trench	$ 6,000
Pump, sump, pipeline and electrical equipment	$10,000
Additional pumpback wells, if needed	not estimated
Diversion ditches	$2 million
Stormwater ponds	$4,368,000
Extend tunnel	$20 to $25 million
Subarea B.	
Dikes/rollovers	not estimated
Build new water treatment plant	$10 million
Develop alternative to pit storage of sw	not estimated
Subarea C.	
Repair liner leaks, Big Dome Pond	$16,500
Four pumpback wells	$28,840
Pumpback system equipment, Stacker Dam	$ 8,000
150-foot cutoff wall, Stacker Dam	$87,000
Pumpback system equipment, Lower Slimes Dam	$ 8,000
130-foot cutoff wall, Lower Slimes Dam	$76,000
Pumpback well installation, Lower Slimes Dam	$ 5,472
Electrowinning building	
Sumps	$ 50,000
Six pumpback wells	$ 90,000
Three shallow wells	$ 20,000
Install sumps, pumpback pumps, wells	$165,460
Replacement of all cells	$1.1 million
Drip/leak elimination program	$ 40,000
Grout/caulk floor	$ 2,000
HDPE liner experimental project	$ 65,000
HDPE liner in all appropriate areas	$300,000 to $400,000
Complete floor rebuild/polymer concrete	$1.8 million

Dalton's Pond work to date (August 1994)	$ 38,194
Line Dalton's Pond	$225,000
2,000 gpm pump	$ 14,138 (incremental cost of increasing pump capacity was $9,000)
Water treatment plan	$3 million to $10 million

Improvements related to past violations in Subarea C (August 1994): $1,289,441.

O&M costs related to the operation of the water treatment plant, personnel costs to monitor Mineral Creek and maintain dams and diversion ditches were $527,725 in 1992 and $1,594,418 in 1993. O&M costs for the Big Dome Pond pumpback wells are estimated to be $14,144.

References: ASARCO, 1994a. USEPA, 1994a. ASARCO, 1994b. Fennemore, 1994. ASARCO, 1994c.

4.2.20 Case Study No. 20 - Fuel Spill at Maintenance Facility

Site Name: Paradise Peak Mine, FMC Gold Corporation, Nevada

Type of Mining: Open pit gold mine with cyanide heap leaching and milling operations

Environmental Effects: In August 1992, an inspection was performed by the Nevada Department of Environmental Protection. The inspection team found an area of oil spill discharge in the vicinity of the mine maintenance shop. The facility subsequently found that the source of the spill was a leak from an underground shop clean-up vault. The vault included a oil skimmer that provided for separation and recovery of oil from shop drain water. Water was then released to a drainage ditch. The leak was caused when a mechanical control failure allowed the oil in the vault to flow into the drainage ditch. FMG admitted being aware of the problem since Summer 1992 and intended to develop a remedial action plan, however, due to apparent inadvertent oversight little work had been done to address the problem prior to the inspection. The facility indicated that site investigations showed that there was little potential for hydrocarbons to reach underlying ground water (prior to undertaking the remedial actions described below). The operator was issued a Notice of Violation for the release. All of the information described below was obtained from the facility's written presentation at a State Show Cause Hearing.

Remedial Measures: Immediately after the inspection, in cooperation with the State, the facility developed a plan to address the spill. This included: (1) sealing the discharge point from the vault, (2) restricting access to contaminated area, (3) sampling to determine the nature of the release, (4) installing berms around the contaminated area to prevent oil migration, and (5) ceasing water washdowns and using a dry reagent for spill clean-up. Subsequently, after soil sampling, the operator conducted a soils removal actions. Approximately 831 tons of contaminated soil was sent off-site for disposal. Further, the facility proposed to dispose of washwater in the tailings impoundment (it is unknown if this was approved by the State).

Costs of Remedial Activities: The facility's Show Cause submittal provides cost data for remedial measures they include (in 1991-1992 dollars):

Site investigation contractor	9,053
Internal FMG labor and equipment	12,894
Analyses	15,926
Waste disposal contractor	41,563
Trucking contractor	14,971
Other	9,441
TOTAL	103,801

In addition, FMC Gold budgeted approximately $10,500 for modifications to allow discharge of washwater to the tailings impoundment (unclear if this was spent).

References: FMC Gold Company, 1992.

4.2.21 Case Study No. 21 - Copper Sulfate Spill

Site Name: Lucky Friday Mine, Hecla Mining Company, Mullan, Idaho

Type of Mining: The Lucky Friday Mine began operation in 1987 producing gold, silver, lead, and zinc. The facility consists of an underground mine and 1,000 ton per day flotation mill. Flotation tailings are managed in an on-site impoundment. The mine is located along the South Fork of the Coeur d'Alene River, one mile east of Mullan, Idaho.

Nature of Environmental Effects: On September 6, 1988, 100 gallons of copper sulfate were accidentally dumped into the Coeur d'Alene River. An employee was mixing copper sulfate solution in a vat, which overflowed into a sump. The sump drained to the tailings impoundment where the solution was eventually discharged to the river. The incident was not reported to the State until September 12, 1988, when State inspectors observed dozens of dead fish and variety of dead aquatic insects. According to the available references, the impacts of the release (i.e., harm to aquatic organisms) extended 1.3 miles downstream from the facility. The State determined that it would be at least seven years before the fishery was restored.

Remedial Measures: Hecla undertook several remedial measures in response to the copper sulfate spill. Concrete curbing was placed around the copper sulfate mixing tanks. The curbing was designed to retain the volume of the largest vat. In addition, the east side of the mixing area was paved to minimize potential pollutant migration. Further, Hecla planted numerous willow trees and other vegetation along the river bank where aquatic life was impacted. Finally, the operator initiated a semi-annual environment auditing program.

Costs of Remedial Activities: No detailed cost information is available related to remediating the copper sulfate spill. However, in responding to draft Consent Order, the facility noted that over $47,700 had been spent on remedial measures

References: IDER, 1988. IDER, 1990. Hecla, 1990.

4.2.22 Case Study No. 22 - Mercury Soil Contamination Remediation

Site Name: Microgold II Mine, Powell and Micro Gold II Partnership, Florance, Idaho.

Type of Mining: In 1983, the Microgold II partnership began operation of an open pit mine with ore being crushed and passed over shake tables where mercury was added. The site only operated during summer 1983 with 120 tons of ore being beneficiated. The resulting amalgam was then heated, allowing the mercury to vaporize and gold to be collected. Mercury was captured for reuse. Tailings from the shaker tables were managed in an unlined tailings pond. The facility was located approximately 1,400 feet from the west fork of Meadow Creek, which flows into the Wind River, a tributary of the Salmon River.

Nature of Environmental Effects: Releases of mercury contaminated the soils around the shaker table mixing area and the sediments in tailings pond. When the State issued a Notice of Violation and Order in November 1983, mercury levels in the soils were as high as 1,163 ppm. Subsequent sampling in 1985 found mercury levels of 100-250 ppm in the tailings sediments and 50-380 ppm in the mixing area soils. Tailings water had mercury only slightly above background. The State required the operator to sample groundwater. Groundwater data generally showed levels consistent with background, although the source of elevated levels in two wells could not be distinguished between mining and a naturally contaminated spring.

Remedial Measures: Under an Administrative Order issued by the Idaho Department of Health and Welfare (IDHW) in February 1985, the operator was required to conduct a site investigation and develop a clean-up plan. Three options clean-up options were identified. The option selected by IDHW involved excavation of contaminated soil and on-site encapsulation (using a synthetic liner and cover). The clean-up began in Spring 1986 and was completed in October 1986.

Costs of Remedial Activities: No line-item remedial cost information was found in the State files. However, on August 29, 1986, the State and the facility agreed to a Consent Decree that required Microgold to place $120,000 in escrow to pay for the clean-up.

References: IDHW, 1983. IDHW, 1984. CH2M Hill, 1985. U.S. District Court, 1986.

4.2.23 Case Study No. 23 - Unauthorized Discharge of Leach Solution to Surface Water

Site Name: Cyprus Sierrita Mine, Sierrita, Arizona

Type of Mining: Large open pit copper mine with flotation mill and dump leaching/SX-EW operations.

Nature of Environmental Effects: In 1992-1993, Cyprus Sierrita had unauthorized discharges of process solution to Demetrie Wash - an ephemeral stream that flows through the site. Long-term discharges were caused by subsurface migration/seepage from an unlined process pond to the wash. The bond contains barren solution, other process waters, and storm water runoff. The pond water has generally low pH and elevated concentrations of copper and zinc. Additional short-term impacts on Demetrie Wash occurred when a 2.7 million gallons was released after a tailings pipeline broke. The water was approximately 67% dilute tailings water reclaim and 33% ground water recovered from wells located downgradient of the tailings impoundment. The water had less than .01 ppm copper.

Remedial Measures: To address the long-term seepage issues, the operator performed a conductivity study to delineate the source of the seepage. The operator subsequently constructed hydraulic barriers. For the tailings line break, the operator replace the existing PVC pipe with steel-encased piping.

Costs of Remedial Measures: As reported to EPA Region IX, the total cost of addressing subsurface seepage (as of 1994) was $101,030. The cost of replacing the pipeline (also as of 1994) was $70,000. Of specific note, similar to the other Arizona sites discussed above, Sierrita has also undertaken facility-wide remedial measures to address unauthorized discharges of process water to surface and ground water (no cost data were readily available for facility-wide actions but known to be in the millions). This case study was included as an example of costs associated with a single, unit-specific remedial action.

Reference: EPA 1994.

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EPA Responses to Public Comment on *Costs of Remediation at Mine Sites (Costs Report)*

Comment: A number of commentors submitted comments on the applicability of the information presented in *Costs of Remediation at Mine Sites* to re-evaluation of the Bevill exclusion.

Response: In the May 12, 1997 Second Supplemental Proposal (62 FR 26041) the Agency posed the question of whether certain wastes currently excluded from Subtitle C regulation under the Bevill exclusion warrant further study or regulatory controls. Public comments on this question will be summarized and presented to the public by the Agency at a future date. Because the purpose of this question was to solicit information only, the Agency has taken no regulatory action on the issue in today's final rule.

Comment: One commenter commented upon an incident reported on in the Costs Report. According to the commenter's summary, on July 30, 1994, between 25,000 and 30,000 gallons of water overflowed a dirt containment berm at the base of a waste rock disposal area and flowed approximately 1,900 feet down Rodeo Creek (which was dry).

The commenter claimed that the discharged water was not a hazardous waste (sulfate was the only parameter observed at elevated concentrations) and that the release was subject to existing state/federal regulation. According to the commenter, the source of water discharged was removed and investigation demonstrated that the release resulted in no adverse environmental or health effects.

The commenter argued that these incidents show the effectiveness of the Nevada regulatory program in requiring operators to identify and adequately respond to spills and releases (Comm 1099).

Response: The purpose of the Costs Report is to illustrate the typical costs associated with various types of clean-up activities at modern mining and mineral processing sites and not to evaluate the effectiveness of state regulatory programs.

Comment: One commenter had comments on the Cyprus Miami Mine site described in the Costs Report which contains information, according to the commenter, on alleged releases from the Cyprus Miami mine to surface water and ground water.

The commenter argued that this site does not provide support for EPA's proposal prohibiting land storage of mineral processing secondary materials. The commenter contended that neither the facts nor EPA's record demonstrate that any adverse environmental impacts resulted from the "releases" at the Cyprus Miami mine, nor do they demonstrate that these "releases" were in any way related to recyclable mineral processing secondary materials stored on the land.

The commenter also argued that the incidents at this site do not provide support for EPA's proposal that the addition of a non-Bevill feedstock to a production unit should disqualify the resulting wastes from the Bevill exemption. The commenter claimed that neither the facts nor EPA's record demonstrate that any of the "damages cases" cited at the Miami facility were in any way related to the use of alternative feedstocks in smelters or any other production units. (Comm 1041).

Response: The purpose of the Costs Report is to illustrate the typical costs associated with various types of clean-up activities at modern mining and mineral processing sites. The threats mineral processing secondary materials pose through land storage are illustrated in the Agency's *Charaterization of Mineral Processing Wastes and Materials*, *Damage Cases and Environmental Releases from Mines and Mineral Processing Sites*, *Human Health and Environmental Damages from Mining and Mineral Processing Wastes* documents included in today's rulemaking docket.

In today's final rule, the Agency has decided not to promulgate the option which would deny the Bevill exclusion to wastes emanating from processes using other than virgin feedstocks.

Comment: One commenter stated that EPA also suggests that its restrictive approach to reuse of mineral processing secondary materials will reduce the levels of the hazardous substances in Bevill wastes and implies that such a reduction will translate into lower remedial costs at mining and mineral processing sites. The commenter stated that the Agency cites the Costs Report as evidence of the significant costs of cleaning up these sites. The commenter believed that any additional loading of hazardous substances in a Bevill exempt waste due to use of an alternative feedstock is not likely to materially increase any site clean-up costs, and the referenced EPA document provides no data whatsoever to support EPA's contention. Moreover, the commenter argued, the proposal would eliminate the Bevill exclusion even when a non-hazardous alternate feedstock is used. In such a case, the commenter contended, the use of the non-Bevill feedstock may well reduce the overall concentration of a hazardous constituent as it could dilute an otherwise hazardous concentration of a substance (Comm 1043).

Response: The Agency has decided in today's final rule not to promulgate the option which would deny the Bevill exclusion to wastes emanating from processes using other thatn virgin feedstocks.

Akinori Sakamoto

Cement and Soft Mud Mixing Technique Using Compressed Air-Mixture Pipeline: Efficient Solidification at a Disposal Site

Abstract

Dredging, conveyance, and disposal of the soft bottom mud have been greatly improved by various methods to achieve efficiency and environmental preservation. A compressed air-mixture conveyance system using a pipeline is one of the suitable methods for soft mud transfer from the dredging site to the disposal site. The method requires no excess water to assist the mud flow in the pipeline, eliminating turbid-water treatment installation at the disposal and reclamation sites. However, a long period is required for the wet and soft mud to become dry. To shorten the time required for drying, various compacting and drying methods have also been used. Mixing a solidifier like cement in the dredged mud is a solution but an expensive mixing plant is necessary.

The cement-mixing method using the compressed air-mixture pipeline for soft mud conveyance has been developed for effective and economical disposal work. This method uses plug flow generated in the pipeline with compressed-air assistance to mix cement-based solidifier with mud in the pipeline. Uniform cement mixing is achieved by injecting solidifier into an expander pipe with a larger diameter than the pipeline. This method will eliminate conventional mixing plants and will be more economical than other methods.

In July 1997, field tests of the new method were carried out by injecting 50 kg/m^3 and 70 kg/m^3 of solidifier in the expander pipe fitted to a 200 m^3/h capacity pipeline. Good test results showed that the method is applicable to actual operations. The outline of the new method and the field tests at the Ishinomaki reclamation site (Miyagi Prefecture) are described.

This paper was first presented in July 1998 at the WODCON VX, Las Vegas, Nevada, USA and was published in the conference proceedings. This revised version is reprinted here with permission.

Introduction

In modern Japan where development has been proceeding steadily, both large urban centers and smaller cities have had the serious problem of dealing with reclaimed soft mud at disposal sites. The method of soft mud reutilisation through addition of a solidifier has come into wide use. In general, the solidification disposal method involves the use of a barge mounting a special mixer. However, the barge is equipped with high-grade systems to undertake a variety of tasks, so cost is a major stumbling block for use only at reclamation sites. Therefore, a new method was required to yield a large amount of reclamation-strength end product in a short time through utilisation of facilities with highly efficient mixing characteristics.

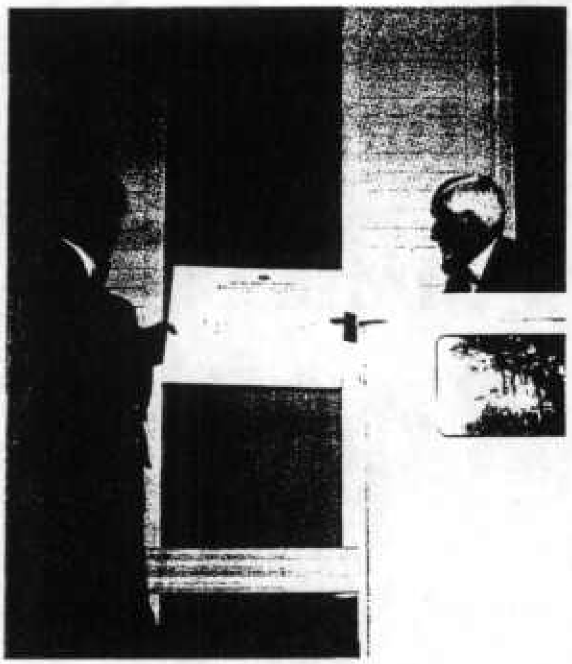
The technique described here is the solidifier (cement) and soft mud mixture technique that uses the compressed air-mixture pipeline to take advantage of the characteristics of plug flow during compressed air transfer, allowing direct introduction of the solidifier into the soft mud during transport, for full utilisation of the transfer action.

This paper describes the solidification disposal method, the theory behind the cement and soft mud mixture technique using the compressed air-mixture pipeline, and the results of limited and full trials using this technique.

Background to Technological Development

Environmental problem

From the latter half of the 1950s, the high rate of economic growth caused a persistent shortage of land sites in waterfront areas that formed the basis of economic activities. As Japan lacks both land and



Akinori Sakamoto (left), receiving the IADC Award from Mr Peter Hamburger, IADC Secretary General, at the closing ceremonies of WODCON XV.

IADC Award 1998

Presented during the WODCON XV, Las Vegas, Nevada, USA June 28-July 2, 1998

At the 15th WODCON held in Las Vegas, Nevada, USA, from June 28-July 2, 1998, Mr Akinori Sakamoto was presented with the annual IADC Award for young authors. Mr Sakamoto graduated from the Applied Chemical Department of Muroran Institute of Technology in March 1994 where he studied Chemical Plant Engineering. He then joined the Machinery and Electric Department of Toa Corporation, Tokyo, Japan, as a mechanical engineer, where he now specialises in reclaimed land solidification engineering.

Each year at a selected conference, the International Association of Dredging Companies grants an award to a paper written by a young author. The Paper Committee of the conference is asked to recommend an author who is younger than 35 years of age and whose paper makes a significant contribution to the literature on dredging and related fields.The purpose of the award is "to stimulate the promotion of new ideas and encourage younger men and women in the dredging industry". The IADC Award consists of US$1,000, a certificate of recognition and publication in *Terra et Aqua*.

resources in general, dredging and land reclamation were undertaken as national projects to meet the need for more space.
The conventional reclamation method at the time involved surrounding the area to be reclaimed with steel or concrete, then using suction dredgers to transfer the soil. More than a sixth of Tokyo Bay was thus reclaimed, drastically altering the coastline. This reclamation method made possible the creation of modern industrial Japan through the provision of waterfront industrial sites.

In the 1970s, the environmental problems involving inland sea areas such as the Seto Inland Sea and the "Big Three" bays (Tokyo, Osaka and Ise Bays) became serious enough to require urgent action for preservation of the environment. In addition to improvement of the drainage system and waste water disposal methods, the dredging of soft mud from the bay areas became essential. However, soft mud is not suitable for use as reclamation material, so it had to be dumped offshore.

Subsequent global environmental concerns led to a close examination of the effect of offshore dumping on marine organisms and the conclusion that there should be limitations placed on such dumping, so soft mud became very difficult to dump.

As offshore dumping became impossible, the only available method of disposing soft mud was to find suitable disposal sites, a very difficult task in Japan where such sites are quite difficult to locate, and so these are resources which need to be utilised most effectively. Therefore, the use of grab bucket dredgers that enable the collection of mud maintained in its near-original condition, rather than suction dredgers, became the preferred barge for dredging operations.
These social requirements led to the development of grab bucket dredgers to transfer mud in near-original conditions through use of the compressed air-mixture pipeline.

Compressed air-mixture transfer method
When pipeline transfer of grab-bucket dredged mud in near-original conditions is attempted through use of conventional suction pump equipment, the large amount of friction produced within the pipeline prevents transfer of the material over a long distance. Long-distance transfer of such material generally requires dilution with water or other fluid to deal with the friction problem. However, dilution increases the dredged mud volume, making it difficult to find enough space at the disposal site.

In contrast, mixing of grab bucket dredged mud with compressed air of very low or negligible friction reduces the entire friction to enable long-distance pipeline transfer.

in combination with the currently-used compressed-air transfer systems. The new method can achieve disposal at low cost.

Outline of New Solidifier Mixing System Using Compressed-air Transfer Pipeline

Outline of development

Development of the new solidification disposal method required easy bulk disposal at low cost. The turbulence effect of the plug flow during compressed air-mixture transfer in the pipeline was investigated and the basic concept of mixing the solidifier and soft mud was developed.

The main items for consideration were:

- use of the turbulence effect of the plug flow; and
- establishment of a mechanism and system for directly adding the solidifier during conveyance in the pipeline.

Experiments showed that the addition of the solidifier via the compressed air inlet was adequate for the mixing effect. However, with this method, there is a limitation to the transfer distance as with the mixing plant barge method, thus making long-distance transfer difficult. A mechanism was required for adding the solidifier into the plug flow within the pipeline to achieve long-distance transfer.

Theory of the method

Mixing theory

When compressed air is injected into the pipeline during the transfer of soft mud, the two-phase flow of air and liquid is formed as shown in Figure 3. The liquid phase part (or plug flow) moves in the turbulent flow in the pipe, and a mixing effect is expected. The new mixing system uses the effect of plug flow to mix the solidifier in the pressurised pipeline.

Solidifier mixing mechanism

When the solidifier is directly injected into the compressed-air transfer pipeline to mix with soft mud, the solidifier concentrates at the air-phase parts, and no uniform mixing of materials can be expected as in Figure 4. This was confirmed by tests in the past. Based on various experiments, a new mixing system was developed as shown in Figure 5, in which the expansion pipe (the expander) with a larger diameter than the transfer pipeline diameter was inserted midway through the pipeline.

The plug flow in the pipeline is disturbed in the expander, and becomes a wave-like flow. This allows addition of the solidifier to the soft mud. Soft mud and solidifier flow in the smaller diameter pipeline at end of the

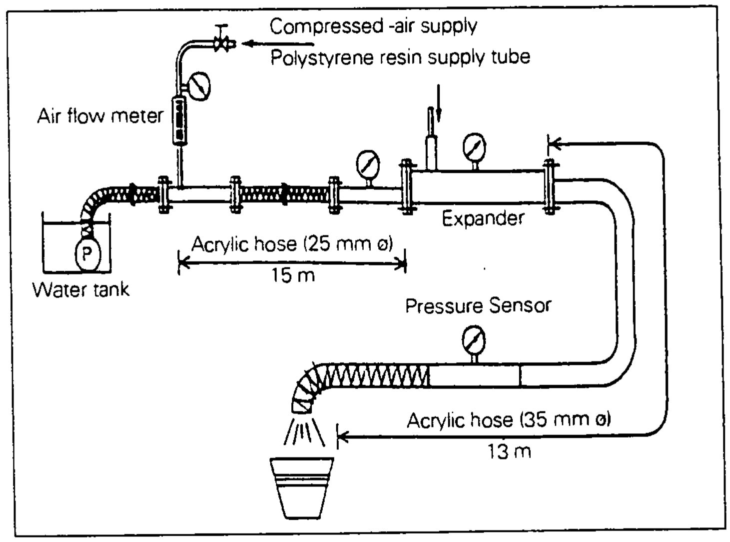
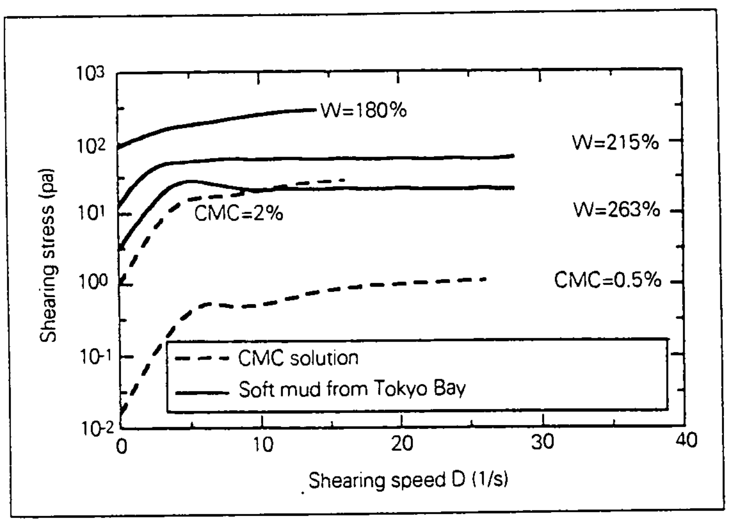


Figure 6. Scale model test configuration.

Figure 7. Fluidity characteristics of CMC solution.



expander tail, and plug flow is formed again to mix the solidifier with the soft mud. The new mixing system is applicable to distances of up to 3,000 m, which is the maximum transfer length of the compressed-air transfer system. The special-purpose mixing plant barge cannot be applied to this transfer distance.

The essential engineering points are appropriate diameter and length of the expander. To establish the engineering technique, scale model tests were conducted to clarify the behaviour of the plug flow for development of the expander.

Scale Model Tests

Test method

Tests were carried out using a one-tenth scale model of the actual system. The scale model configuration is shown in Figure 6. The compressed-air transfer pipeline the cross sectional direction as shown in Figure 8;

2. Contraction turbulence: Turbulence induced by rapid contraction as shown in Figure 9.
3. Turbulence owing to recycled plug: Turbulence generated when a plug is recycled as shown in Figure 10.

Blockage prevention effect

The solidifier powder must be injected by compressed air into the expander, and the supply port may be blocked by adhesion of solidifier when the port becomes wet. Therefore, the supply port was located at the upstream side of the expander, where the plug flow separates from the upper wall of the expansion pipe owing to rapid expansion. This provides an air pocket around the solidifier supply port, preventing blockage of the supply port Figure 11.

Expansion pipe size and mixing ratio

The mixing ratio was assessed in three stages when resin particles were input, and the diameter ratio (d1/d2) of the expander of the compressed-air transfer pipe length and the diameter ratio (L/d2) of the expander of the expander length were also studied.

The results are shown in Figures 12 and 13.

Figure 12 shows an adequate mixing effect is attained when the expansion diameter is two to three times larger than that of the compressed-air transfer pipe. Figure 13 shows an adequate mixing effect is achieved when the expander length is six to fourteen times larger than the expander diameter.

Adoption of test results for design

Based on these results, the expander design and application to the compressed-air transfer pipeline were conducted.

The diameter of the expander was fixed as two to three times larger than that of the compressed-air transfer pipeline, and the length of the expander was six to fourteen times larger than the diameter of the expander.

Based on these design criteria, a prototype expander was designed and fabricated for field verification tests (Figure 14).

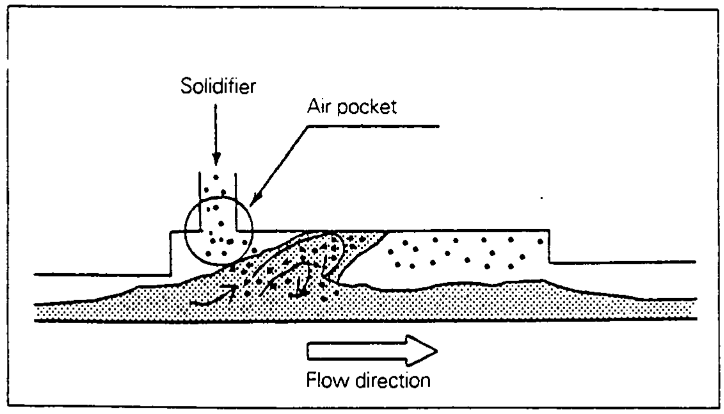


Figure 11. Supply port location.

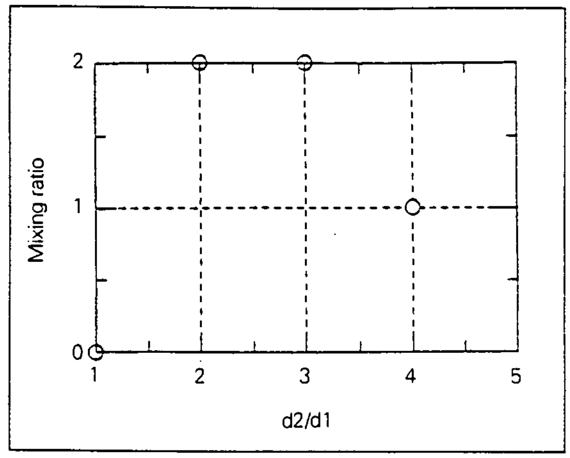


Figure 12. Expander diameter and mixing ratio.

Figure 13. Expander length and mixing ratio.

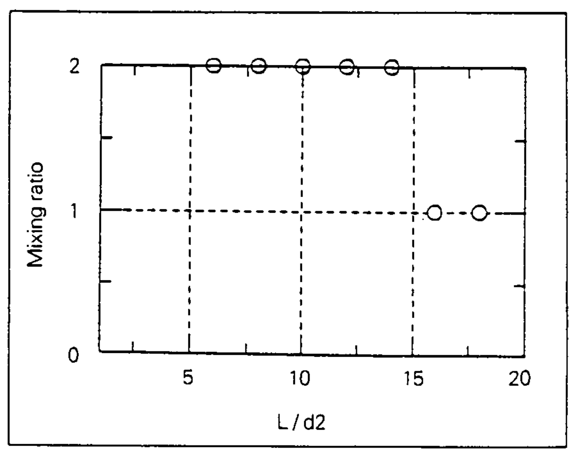


Table II. Test specifications with expansion pipes based on scale model tests.

	Treatment (m3/h)	Pipeline capacity (mm)	Expansion pipe (mm)		Volume of solidifier (kg/m3)	
		dl	diameter	pipe length		
1996	60	250	500	5,500	50	75
1997	180	400	800	4,800	50	75
	230				50	

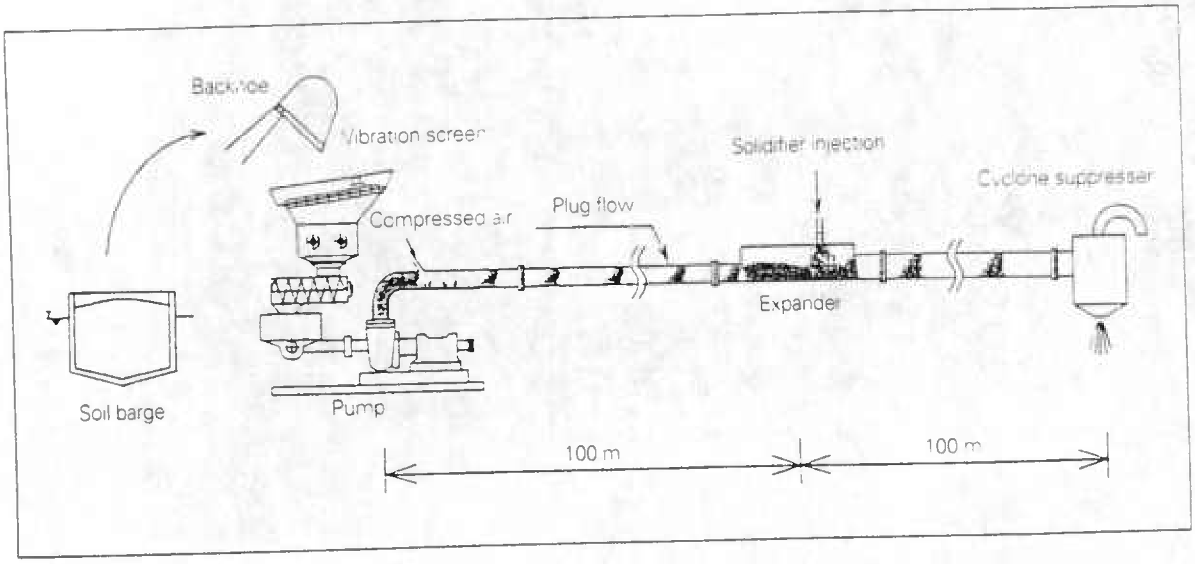


Figure 17. Test installations

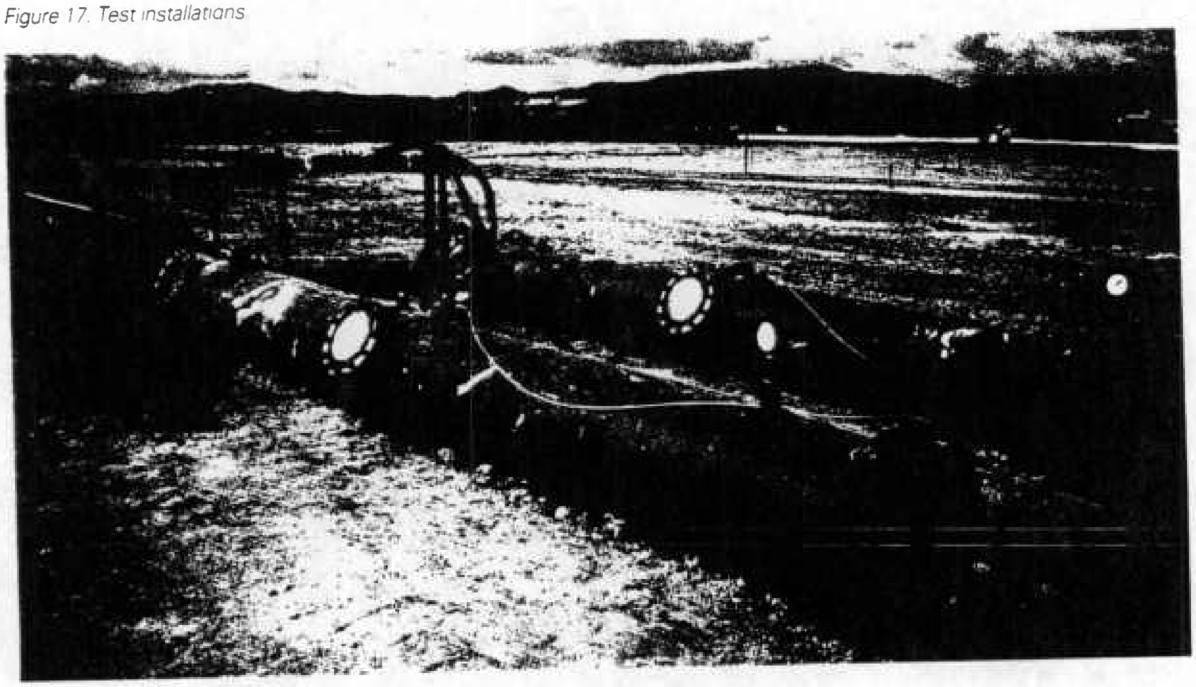


Figure 18. Expander (60 m³/h).

Figure 19. Expander (200 m³/h).

2. Dredged mud
   Dredged mud to be modified was provided by a grab bucket dredger. The mud was transported by a soil barge. Table III gives average values obtained from physical tests on the dredged mud that was used for field tests.

3. Evaluation method of solidified mud
   Various evaluation methods have been used to assess the soil nature. In Japan, modified mud is generally assessed by the unconfined compression strength test. In our tests, the unconfined compression strength and cone penetration tests were used for evaluation of modified mud characteristics. The cone penetration tests can be applied to modi-

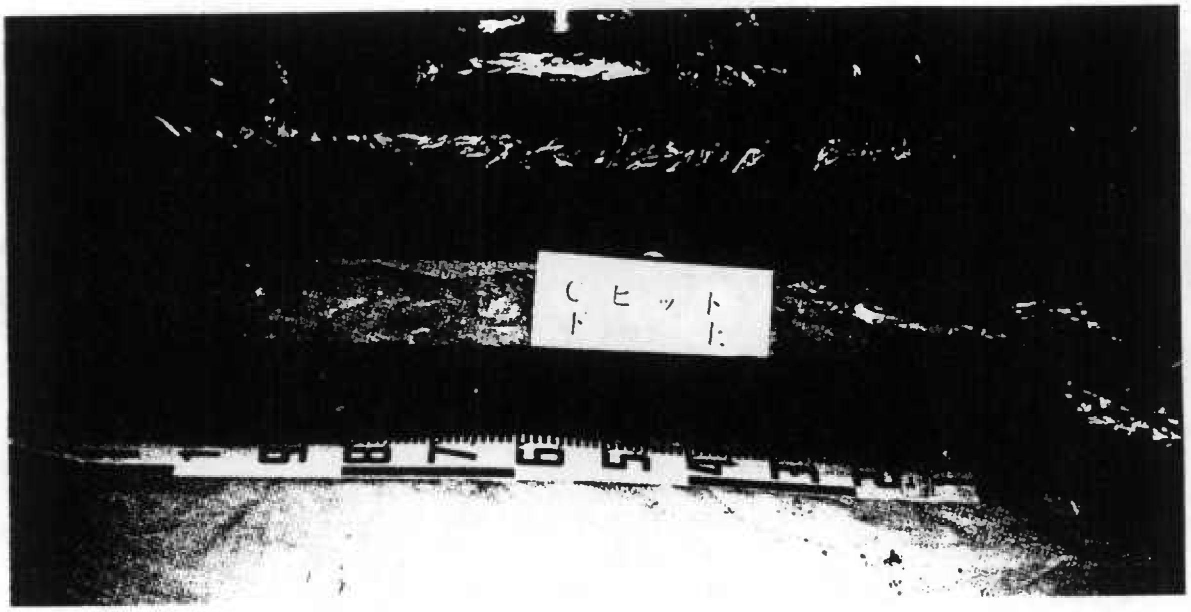
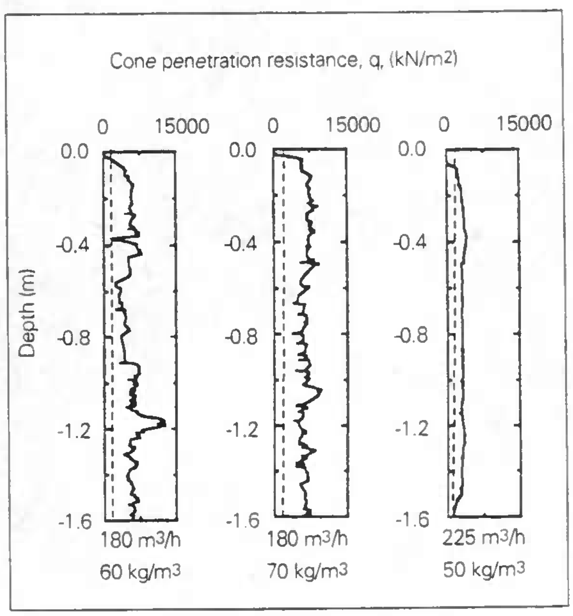


Figure 22. Collected test specimens.

Figure 23. Cone penetration resistance and distribution by depth.



(b) Cone penetration test

The cone penetration test is achieved by measuring penetration resistance values when the cone rod is inserted into the soil ground. In the field test of 60 m^3/h capacity, portable cone penetration tests were carried out but penetration was impossible at part of the test field area. Based on this experience, electrically-driven cone penetration tests were carried out for the 200 m^3/h capacity, using the improved type of the conventional tester with a cone tip angle is 60° with a cross-sectional area of 10 cm^2. The latter situation is described here.

Test results

1. Unconfined compression strength test results

Figure 21 shows the relationship between the solidifier volume used and unconfined compression strength of modified mud, which were obtained from the field tests. The test specimen was collected by boring into modified soil ground, which was cured for one month after placement. Figure 22 shows the collected test specimens. All test specimens satisfied the target value of 200 kN/m^2.

2. Cone penetration test results

The relationship between unconfined compression strength and cone penetration resistance is expressed as follows:

$$qt = 20 \times (qu/2) \quad (1)$$

where,

qt: Cone penetration resistance (kN/m^3, after pore water pressure compensation)

qu: Unconfined compression strength (kN/m^3)

Figure 23 shows the distribution of cone penetration resistance values by depths. The dotted line in the figure indicates the targeted strength for soil modification, which was obtained by converting into qt values using equation (1). The soil strength over all the modified soil ground area met the target value for modification. Moreover, the modified soil quality in the depth direction was comparatively uniform. Figure 24 shows the cone penetration tests being performed.

3. Conclusions based on verification tests

Use of the expander based on basic R&D enabled mixing of the solidifier during transfer of soft mud by plug flow in the pipeline. The mixing effect in the expander by plug flow was confirmed together with

Dredged Sediment Disposal

Sediment washing provides one solution

Brad Carpenter, Renee Haltmeier, and Charles Wilde

The Hudson River Estuary has a natural, undredged depth of 5.8 m (19 ft), but ships using the New York-New Jersey Harbor need a 12 to 14 m (40 to 45 ft) depth for safe navigation. The difference between natural and required depths means that 3 million to 5 million m^3 (4 million to 7 million yd^3) of sediment must be dredged and disposed every year in order for the harbor to remain open. According to New York and New Jersey port authorities, the port generates more than $20 billion in revenue and is responsible for more than 180 000 jobs. Thus, any prolonged interruption in dredging would adversely affect the regional economy.

Until 1992, dredged sediment was disposed in the ocean at a site called Mud Dump. Thereafter, dredging contaminated material was severely limited. As of Sept. 1, ocean disposal was phased out because some dredged sediment contains chemical contaminants, including polychlorinated biphenyls (PCBs) and dioxins, that could affect fish and shellfish. The Dredged Materials Management Plan for New York-New Jersey Harbor states that about 75% of the total annual dredging volume requires some form of processing or decontamination prior to disposal.

A Hotly Contested Issue

Since 1992, the dredged-material disposal issue has been a political and technical battlefield. Environmental groups say scientific advances in testing show potential adverse impacts of disposing contaminated dredged material in the ocean. Business groups oppose limits on ocean disposal, basing their claims on traditional testing methods and the need to maintain a viable port.

In 1995, New Jersey's governor developed a task force, the Dredged Materials Management Team, to bring interested groups together, review efforts from other regions, identify testing criteria and technology, and evaluate sediment dispos-

Sediment dredging is critical to safe navigation in harbors.

The Advantages

BioGenesis Sediment Washing has the following advantages:

- The only byproducts are wastes removed from the sediment, treatable water, and biologically active sediment suitable for beneficial use.
- The chemicals used in the process are 100% biodegradable and have low toxicity.
- Costs range from \$50 to \$260/m^3 (\$40 to \$200/yd^3), depending on site variables and economies of scale. Variables affecting cost include contaminant type, sediment type and volume, contamination levels, and cleanup target.

al options, including decontamination technologies. The team included officials from the New Jersey Department of Environmental Protection, U.S. Environmental Protection Agency (EPA) Region 2, the U.S. Army Corps of Engineers New York District, the Port Authority of New York and New Jersey, environmental groups, academia, unions, marine terminal groups, nonprofit foundations, and shipping companies.

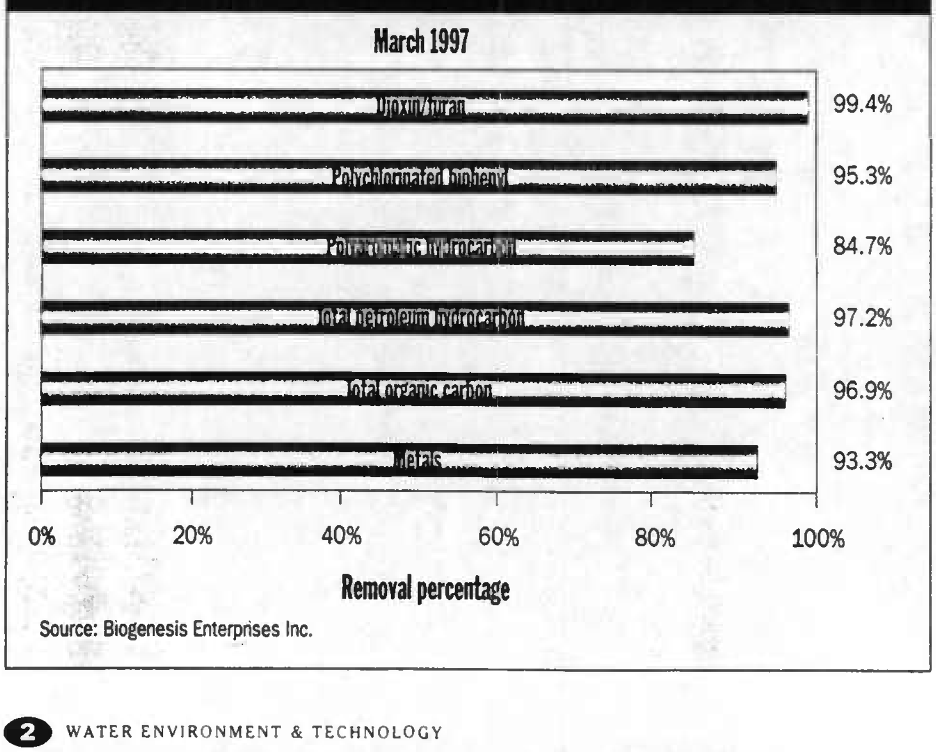
After 6 months of evaluation, the team suggested locating an underwater confined-disposal pit in the Newark Bay area. It also suggested more thoroughly investigating decontamination technologies, such as soil washing; and consider using a succession of treatment technologies to decontaminate dredged material and creating beneficial uses for this material.

On the federal side, EPA Region 2 and the Corps of Engineers New York District are responsible for managing environmental issues associated with dredging and disposing material in the Hudson River Estuary. Under the Water Resources Development Act of 1992 (WRDA), these agencies jointly sponsored work to demonstrate technologies that treat or remove organic and inorganic contaminants from dredged sediment. They also are addressing issues of materials handling and beneficial use of treated sediment.

Seven projects resulted from initial WRDA contracting in 1995. These were administered by Brookhaven National Laboratory with the goal of establishing a production-scale facility able to treat 382 400 m^3 (500 000 yd^3) of dredged material annually by the end of 1999. BioGenesis Enterprises Inc. of Oak Creek, Wis., is one of three firms designated to reach full-scale capacity between 1998 and 2000.

The BioGenesis Sediment Washing Technology (patent-pending) uses proprietary, nonhazardous cleaning solutions; a truck-mounted gondola for large particles (2 mm and greater) and organic material; and a sediment washer for small particles (less than 2 mm). The technology cleans a broad spectrum of organic and inorganic pollutants, including polycyclic aromatic hydrocarbons (PAHs), PCBs, dioxins, pesticides, and metals. Fine-grained soils and harbor sediments typically are poor candidates for treatment using conventional soil washing processes. BioGenesis overcomes the inability of these processes to handle heavy pollutants, wash fine particles, and treat sediments efficiently at low cost.

Figure 1. New York-New Jersey Harbor Sediment Decontamination

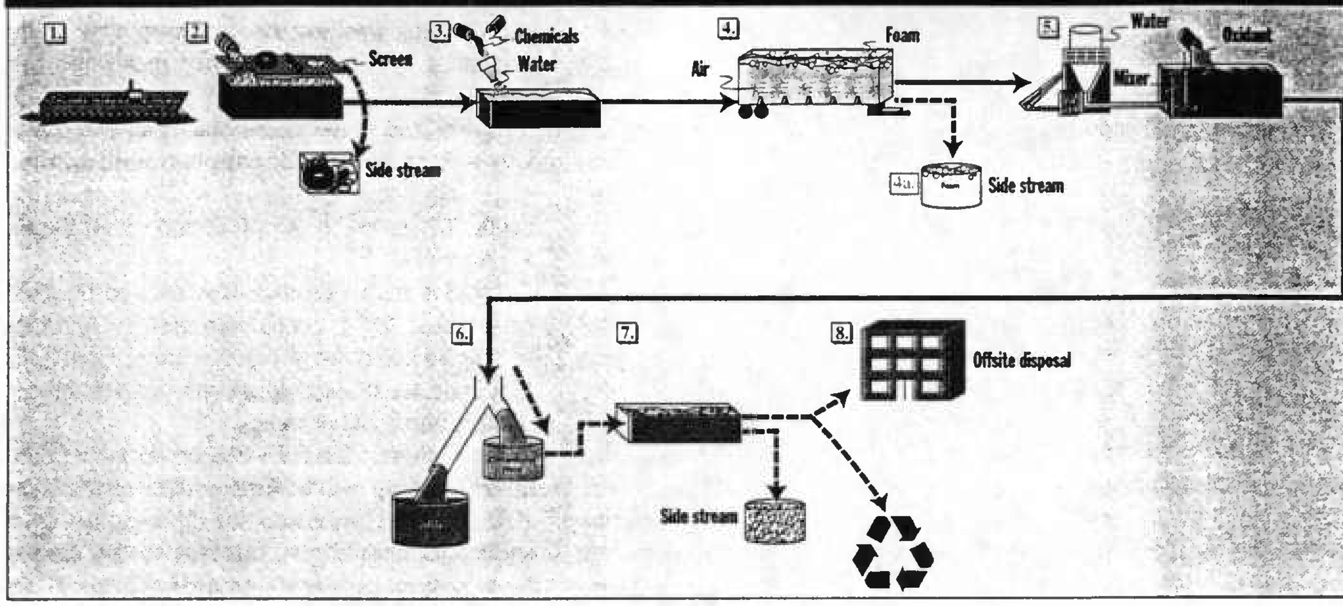


Source: Biogenesis Enterprises Inc.

Technological Benefits

BioGenesis demonstrated its soil washing process in EPA's Superfund Innovative Technology Evaluation program in 1992 and in Environment Canada's Great Lakes Cleanup Fund and Wastewater Technology Centre's Contaminated Sediment Treatment Technology program in 1993 and 1994. The soil washing system was successfully demonstrated at a refinery where about 3447 Mg (3800 tons) of soil were contaminated with up to 3% heavy crude oils. The contaminant of concern was total recoverable petroleum hydrocarbons with levels averaging 30 800 mg/L. The soil was cleaned in a single pass through the system. Cleaning efficiency averaged between 85% and 90%, and subsequent biodegradation raised total contaminant treat-

Figure 2. Full-scale Biogenesis Sediment Washing Technology



ment effectiveness to between 95% and 98%. Results were tabulated for soil fractions greater and less than 300 μm. As expected after the initial washing, greater extraction (91%) was achieved for the larger fractions than for smaller particles. Removal efficiency was 85% on the silt–clay fraction.

For the Wastewater Technology Centre's program, the company tested its washing process on sediment from a former wood-preserving site at Thunder Bay, Ontario, Canada. The site, one of 43 "areas of concern" identified by the International Joint Commission, is contaminated with PAHs, low levels of PCBs, phenols, and several metals. Sediments contained a high fraction of fines with 81% of the material having grain size less than 38 μm and a total organic content exceeding 11.5%.

The sediment for the test was selected from the most heavily contaminated areas of Thunder Bay, as determined by 1984, 1988, and 1992 surveys. The testing, initially designed as bench-scale, subsequently was upgraded to use pilot-scale equipment to accommodate high water pressures and effectively model process parameters. PAH removal percentages averaged between 90% and 94% following a three-cycle wash.

Harbor Sediment Testing

In 1997, the company performed bench-scale testing on sediment dredged from the New York-New Jersey Harbor under the direction of EPA Region 2 and the Corps of Engineers New York District.

Test results were verified by Brookhaven National Laboratory in late February. Contaminated sediment contained PAHs, PCBs, total petroleum hydrocarbons, dioxins, furans, and heavy metals. Following decontamination of the material, Brookhaven directed the company to send "before and after" samples to Triangle Laboratories in Durham, N.C., where testing showed high removal efficiencies for all contaminants (see Figure 1, p. 48).

Due to the favorable WRDA testing results, Brookhaven decided to fund a pilot project in which BioGenesis will treat 765 m^3 (1000 yd^3) of contam-

The Process (see Figure 2)

Dredged sediment slurry is delivered to the pilot plant by barge (1). Oversized debris is removed by a vibrating screen (2). The sediment slurry is pretreated with a proprietary, nonhazardous cleaning solution and high-pressure water (3). This action homogenizes the slurry and prepares it for washing and scrubbing (4). Low-pressure air bubbles up through the slurry to form a foam layer containing floatable organic and oily waste, which is skimmed off (4a). Next, the slurry passes to sediment washing and organic treatment (5). In the sediment washer, the slurry is agitated violently by high-pressure water to separate residual contaminants from sediment particles. Then the slurry is sent to a reaction vessel, where the remaining organic contaminants are oxidized. Contaminated water is separated from treated sediment (6). The sediment is now ready for beneficial use, and the contaminated water is treated further using chemical precipitation to remove heavy metals (7). Finally, treated water is recycled to the front of the process to conserve resources (8).

inated sediment dredged from the New York-New Jersey Harbor. The project will model a full-scale treatment process (see Figure 2, p. 49) and demonstrate front-end material handling, post-treatment liquid–solid separation, and treatment of wash water to meet recycle and discharge criteria. Joining the company in this effort will be Roy F. Weston Inc. of West Chester, Pa., an international consulting and engineering firm.

Phase I of the project will model the front-end material handling and sediment washing technology and generate sufficient washed sediment to design the liquid–solids separation and water treatment equipment. This equipment then will be added to Phase I, and the entire treatment process will be modeled in Phase II. The project, including the final report, is expected to be completed by May. The ultimate goal is to turn contaminated dredged material into environmentally safe products.

Treated Sediment a Resource?

More than 75% of the raw sediment dredged from the harbor is classified as having some degree of contamination that prevents it from being used beneficially.

Following washing, the sediment retains its original, very fine matrix, which resembles wet cornstarch. When dried, the treated sediment is powdery and dense. This matrix is extremely well suited for landfill capping applications, especially when combined with a stabilizing agent. When wet, it is well suited for wetlands applications.

Landfills and wetlands are two of many possible applications. The potential also exists to use treated sediment as nonstructural construction fill and road base, for shoreline protection, and in various manufactured soil products.

Decontamination technologies, including sediment washing, will be further demonstrated in 1998. Effective solutions for cleaning dredged sediments should give impetus to the search for beneficial uses of the treated material.

***Brad Carpenter** is senior project manager at Roy F. Weston Inc. in West Chester, Pa. **Renee Haltmeier** is president at Enviro-Tech Marketing Inc. in Morristown, N.J. **Charles Wilde** is vice president at BioGenesis Enterprises Inc. in Oak Creek, Wis.*

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ADVANCED SEDIMENT WASHING FOR DECONTAMINATION OF NEW YORK/NEW JERSEY HARBOR DREDGED MATERIALS

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John D. Pauling,[4] John G. Sontag, Jr.[4]

ABSTRACT

BioGenesis Enterprises, Inc™, and Roy F. Weston, Inc., (WESTON®) a leading infrastructure redevelopment firm have teamed together to demonstrate the commercial viability of an advanced sediment washing technology to the treatment train framework provided under the Water Resources Development Act of 1992 and 1996. This project is the result of several bench and pilot-scale tests performed on dredged materials from various locations in the NY/NJ Harbor Region.

This Public/Private partnership consists of the BioGenesis/Weston Team working in collaboration with the U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, and the U.S. Department of Energy-Brookhaven National Laboratory. The contaminated sediments issues in NY/NJ Harbor has been approached by many groups and in this project, science and technology will be used to provide a real solution to a problem which is not only environmental, but economic as well.

The first phase of this 10,000 cubic yard (yd^3) project is a 500 yd^3 pilot demonstration, is a scheduled to commence in November 1998 and run through January 1999. Commercial system scale-up is anticipated to be operational by September 1999. The pilot demonstration will establish the scale-up system design parameters and full/commercial scale system economics. The demonstration will consist of the following: material handling, and pre-processing from a barge to the pilot demonstration site, sediment washing, liquid-solid separation, and manufacturing of a beneficial reuse topsoil from the decontaminated sediment. The system is also effective on soils, which is expected to enable this process to play a role in overall economic and brownfield redevelopment in the region.

The decontaminated sediment from this process will be incorporated into a "manufactured topsoil" product. This product for beneficial reuse will be produced and tested during the initial pilot phase of the project and tested extensively for use in various horticultural applications. This will involve blending and mixing the cleaned sediment with other components to make a product, which is anticipated to be saleable. This cleaned sediment, which is a resource, has a variety of applications such as construction fill, and landscaping material.

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THE CONTAMINATED SEDIMENT ISSUE

One of the greatest drivers for maintaining access to America's intermodal ports and related infrastructure redevelopment efforts over the next several years will be the control and treatment of contaminated sediments dredged from our nations waterways. More than 400 million cubic yards (CY) of sediments are dredged annually from U.S. waterways, and each year, close to 60 million CY of this material is disposed of in the ocean. The need to protect our environment against undesirable effects from contaminated sediment dredging and disposal practices is gaining increased attention from the public and government.

REGIONAL FOCUS: NEW YORK/NEW JERSEY HARBOR REGION

In the New York/New Jersey Harbor Region, the effect of contaminated sediments on dredging operations can be costly. The Port is responsible for over 180,000 jobs in the region, and $26 billion in revenue. This area is considered to be the richest consumer market in the United States, and 85% of the freight that moves through this Port remains in the region. The ships that call at this Port require a minimum depth of 12 to 14 meters (40 to 45 feet) for navigation. The natural, undredged depth of the NY/NJ Harbor is 5.8 meters (19 feet), which requires that 3 to 5 million m^3 (4 to 7 million cy) of sediment be removed for safe navigation. Estimates from the U.S. Army Corps of Engineers indicate that 75% of this material is contaminated. To impede dredging is to add undesirable costs to freight movements. Therefore, disposal options for this material have been developed in response to the termination of the dredged material ocean disposal site, the former Mud Dump Site. The options include utilizing less contaminated materials for landfill capping, providing redevelopment of Brownfield properties, and the construction of confined disposal facilities within the Harbor. The more contaminated material, which was ineligible for other remedial alternatives, is the focus of this project.

PUBLIC/PRIVATE PARTNERSHIP

Congress mandated the development of procedures suitable for the decontamination of sediments in the Port under the Water Resources Development Act (WRDA) of 1992 (Section 405C) and 1996 (Section 226). The WRDA Program is the responsibility of the U.S. Environmental Protection Agency (EPA) – Region 2 and the U.S. Army Corps of Engineers (USACE) – New York District, with the U.S. Department of Energy (DOE) – Brookhaven National Laboratory (BNL) acting as the Technical Project Manager. BioGenesis℠ Sediment Washing technology is one of the technologies being demonstrated under the review of the members of this team.

The mission of this WRDA project is to prove one or more decontamination technologies commercially viable at full scale. For the purposes of the NY/NJ Harbor, full scale is defined as 500,000 cubic yard capacity per year. This is a segment of the overall material, and suggests that the technologies be a part of an overall solution, and can be integrated into the planning of dredging activities within the region.

The demonstration of the BioGenesis℠ Advanced Sediment Washing technology is an integrated treatment train approach to sediment decontamination for NY/NJ Harbor dredged materials.

BioGenesis Enterprises, Inc. has teamed with Roy F. Weston, Inc., to implement the technology for this project. Federal funding from the WRDA legislation provides assistance to this Pilot Operation, and to the commercialization process, while the private sector will provide the capital needed for actual facility construction and operation. Further operations of the large scale facility will be funded by the State of New Jersey, Maritime Resources Decontamination Project, which will provide and fund the demonstration of the technology from 30,000 to 150,000 cubic yards of material.

TECHNOLOGY DEVELOPMENT TO APPLICATION: CORPORATE TEAM IDENTITIES

BioGenesis Enterprises, Inc.

This technology development company, started in 1989, has been developing environmentally safe specialty chemicals and successfully bringing them to commercial markets in various use categories. These products include fire suppressants, odor neutralizers, cleaning compounds, and a chemical breakthrough in production enhancement for the oil refining industry. Thus BioGenesis entered the soil washing arena with a significant advantage: experience with chemical development, production, and implementation. The chemicals that would aid in the physical removal of contaminants from soils effectively, efficiently, and economically were a progression from the chemicals manufactured by the company from the late 1980's. BioGenesis continues to develop private label chemicals, as well as supply its own brands to its distributors nationally. The Company is headquartered in Oak Creek, WI, and has operations in Springfield, VA.

Roy F. Weston, Inc.

BioGenesis has joined with Roy F. Weston, Inc. (Weston) for the technology demonstration and commercial implementation. Weston is a leading infrastructure redevelopment services firm with more than 40 years of experience. The company's services include consulting, engineering, construction and operations, and extensive ports services, including property redevelopment. Headquartered in West Chester, Pennsylvania, the company has 60 offices throughout the United States and international operations in Europe, Latin America and Asia. Weston provides to the project the engineering, construction, and operational skills needed to move the technology into the commercial marketplace.

BIOGENESIS^{SM} SOIL AND SEDIMENT WASHING: EARLY TECHNOLOGY DEVELOPMENT

Developed originally for contaminated soils treatment, the technological advances made by BioGenesis to clean sediment from NY/NJ Harbor have been extraordinary. A successful project using the soil washing equipment and chemicals produced by BioGenesis at a refinery site in Minnesota also served as a demonstration for the USEPA SITE Program, which determined the removal rates of contaminants to be between 80-90%. To improve upon typical soil washing for fine-grained materials, the Company developed a new piece of equipment, to provide the contact of chemical to contaminant and the physical collision necessary to achieve removal results from materials under 38 microns. In combination with the BioGenesis chemicals, this equipment and the principals behind it have proved to USEPA, US Army Corps and the Dept of Energy, Brookhaven National Laboratory that this is an effective way of decontaminating sediment. The material from NY/NJ Harbor can be over 90% comprised of materials under 38 microns, and several federally-funded bench scale studies have proved the system effective on materials taken from various Harbor sites.

THE DEMONSTRATION PROJECT

The demonstration project consists of three phases: Pilot Operations, Full Scale Plant Design & Construction, and Full Scale Operations. During Phase 1, Pilot Operations, scale-up engineering data has been obtained, treated material has been produced for beneficial reuse testing, and process effectiveness is revalidated. In Phase 2, Full Scale Plant Construction, full-scale equipment will be procured and the full-scale plant will be constructed based on the results of Phase 1. In Phase 3, Full Scale Operations, the full-scale plant will be used to treat 30,000 to 150,000 cy of sediment. This paper documents the Pilot Operations, which, at the time of this writing, had just been completed.

The operations of this phase of the project were specifically designed to secure the following information and data; technical validation, sediment volume throughput, upscale design, production of clean material, and system economics. With the information obtained in this phase, the technology is currently being designed for its next phase of operations, at full scale.

Planning

The Pilot Operations Phase included the following planning steps:

- Site Agreements
- Site Plan (equipment arrangements)
- Work Plan/Sampling and Analysis Plan/HASP
- PFD/Mass Balance
- Process and Instrumentation Diagram
- Electrical Single Line Drawing
- Mechanical Plans
- State Permits
- Local Permits

Pilot Operations

Material Handling Preparation. Seven hundred (700) cy of contaminated sediment was supplied by the US Army Corps of Engineers, dredged from a site in Newark Bay. SK Services (East) L.C. screened the sediment to less than ¼ inch, and removed the oversize material. The sediment was transported in tank trucks to the operations site, where it was stored in closed mixing tanks.

Pre-processing and Core Processing. At the operations site, runs of the core BioGenesis process were performed with contaminated sediment in order to determine the correct chemical addition rates and equipment settings. Sampling was performed throughout the process to evaluate the chemical mixtures and equipment layout being used. The major objectives of the Core Processing Task were to determine optimum chemical feed rates, process effectiveness under varying conditions, obtain process design information for scale-up, determine and quantify residual management, and produce treated sediment for further testing.

The core equipment used included the pre-processor, to which BioGenesis^tm cleaning chemicals were added. This provided removal of the outer layer of contamination adhered to the sediment particles. The next step involved aeration where lighter organics were removed from the slurry through skimming. Next, the sediment collision chamber removed the innermost component of the contamination through a powerful impact technology within the unit. At this point, the contaminants were removed from the solids to the water phase.

Cavitation/Oxidation. This step provided destruction of the organic contaminants through addition of an oxidant in combination with a cavitation process.

Liquid-Solid Separation. Liquid-solid separation was successfully performed using pilot scale hydrocyclone and centrifuge equipment. The system yielded cleaned sediment at approximately 65% solids, which is considered to be the appropriate moisture for blending to make manufactured soil. Samples of sediment that were treated by the core BioGenesis process have been shipped to selected vendors to obtain additional performance information that may be integrated into the scale-up design.

Water Treatment. Metals contained in the water phase will precipitate out at this point in the system. For the Pilot Operations wastewater was disposed of at a POTW.

During Pilot Operations, wastewater was bench tested to determine the most cost-effective treatment considering the level of organic and inorganic contaminants and suspended solids for implementation at full scale. At full scale, the wastewater will be treated and, to the maximum extent, recycled into the core processing system or alternatively used in the manufacture of various beneficial reuse products. Based on those results, which will vary because the input feed sediment, its contamination type and level, and process variables, the water will either be recycled to the system, used in the manufacture of soil product, or disposed offsite. These results are being incorporated into the full-scale design.

Manufactured Topsoil. Dewatered and decontaminated solids were used to create various types of material for further beneficial reuse evaluation. This was done by mixing the sediment with amending materials (peat moss, cellulose waste, vermiculite, pearlite, and BioGenesis SeaSoil organic material) to produce test quantities of various soil products, such as

- Manufactured soil - High-end growth use (i.e. potting soil)
- Manufactured soil - Low-end growth use (i.e. top soil)
- Nonstructural fill material (daily/intermediate landfill cover)

The BioGenesis WRDA project prepared the material at the pilot processing site from which, under the separate EPA Region 2 Beneficial Reuse Project, the products will be trucked to the manufactured soil test site or shipped for laboratory testing.

THE BENEFICIAL USE PRODUCTS

This component of the project is important to the overall economics of the process, because it can provide a benefit back to the bottom line, enabling a potential reduction in cost for treatment of contaminated sediment. This is a distinction not shared by most other sediment disposal options.

As part of the approach to cleaned sediment as a resource, it is necessary to provide an understanding of the markets available for decontaminated sediment blended with amendments, or "manufactured topsoil" and an estimate of the value of this product.

Material Production

Following the Sediment Decontamination Demonstration Program, a field demonstration was performed to evaluate blending characteristics of cleaned sediment with various amendments. The field demonstration program is being conducted on sediment that was decontaminated during the final week of operations of the Sediment Decontamination Demonstration Project (approximately 50 cyds of treated, dewatered sediment from 100 cyds of raw untreated sediment). A formulation is currently being developed using raw materials readily available within the vicinity of the site to make a topsoil product (i.e., topsoil for ornamental landscaping, etc.).The decontaminated sediment is being mixed with raw materials to create approximately 100 to 200 cyds of manufactured soils.

Verification

Bench-scale studies are being conducted to design and test a horticultural planting medium, which incorporates the cleaned dredged material with conventional soil amendments. Specific end-product prototype media are currently being evaluated under the Market Evaluation. At this time, the products are assumed to be landscape planting, turf establishment, and container usage (i.e. potted plants). Physical testing (grain size analysis, density, moisture content, etc) of the manufactured soil is being conducted to evaluate the blending process.

The overall approach to the bench-scale study is to develop mixture ratios for physical, chemical and growth testing to evaluate the effect of decontaminated sediment in the varying amounts on the end product. Lettuce plants will be grown in the test mixtures and observed for symptoms of toxicity. The resulting foliage will be tested for uptake of heavy metals, and organics. Lettuce was the choice for growth tests, because standard growth protocols are available. Additionally, growth rates, visual observations, foliar analysis ranges for nutrients and heavy metals are also available. Physical, chemical, and nutritional analysis of the mixtures will be conducted. The test plant will provide base level viability data and plant uptake data within the time constraints of the study. This is to ensure a high quality product, and support expected product performance levels.

Markets

As part of the Beneficial Use Evaluation, potential markets for soil products are being identified to ensure an acceptable output for the manufactured topsoil. In order for the State of New Jersey to issue an Alternative Use Determination for the manufactured soil, BioGenesis/Weston will need to provide a demonstration of the chemical and physical appropriateness of the material for the product as well as an ability to move the end product.

The data generated from the market survey will be used to determine the economic applicability of the manufactured topsoil product to the existing regional topsoil market. It will provide an economic as well as volumetric assessment of the markets for the manufactured topsoil products and fill products, regionally and nationally. At the conclusion of the market evaluation, there will exist a database for each of the products, which includes the estimates of the volume of product markets, the value of that market, and a group of clients that are currently purchasing similar product. The production of a topsoil material as output from a full scale facility with a production rate of 500,000 cy per year is estimated to be well within the volumes of the current regional wholesale market for comparable product.

CONCLUSION

The Pilot Operations that ran from January to March of 1999 were successful in generating the information and data necessary to take the process to full scale. Currently the system is being designed for its full-scale operations, to enable capacity of 275,000 cubic yards per year. Construction is scheduled to begin in the Summer of 1999.

The contaminated material into a clean resource concept is a reality. The manufactured topsoil distribution networks are being established, and wholesale clients are being identified for bulk sale arrangements.

By 2000, the public/private teammates will have successfully completed the mission of bringing a technology from bench scale to full scale. BioGenesis/Weston have planned by 2001 to provide the NY/NJ Harbor region with a commercial decontamination component able to treat contaminated sediments at 500,000 cy/yr to add to its disposal options for sediments.

PROCEEDINGS

OF THE

WESTERN DREDGING ASSOCIATION
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Louisville, Kentucky

CONSTRUCTION-GRADE CEMENT PRODUCTION FROM CONTAMINATED SEDIMENTS USING CEMENT-LOCK™ TECHNOLOGY

A. Rehmat[1], A. Lee[2], A. Goyal[3], M. C. Mensinger[4]

ABSTRACT

The Institute of Gas Technology (IGT) has developed the Cement-Lock™ Technology B a versatile, cost-effective, and environmentally friendly manufacturing technology B for producing construction-grade cements from a wide variety of contaminated waste materials, such as sediments, concrete and building debris, town gas site soils, Superfund site soils, sludges, chemical wastes, petroleum refinery wastes, and incinerator residues. Organic and inorganic contaminants are present in these wastes across a broad range of concentrations. In the Cement-Lock process, contaminated materials and proprietary modifiers are fed to a reactive melter operating under oxidizing conditions where all the organic compounds are completely destroyed and converted to innocuous carbon dioxide and water. Chlorine and sulfur compounds are sequestered and heavy metals are locked within the molten matrix to completely immobilize them.

During processing, the melt (Ecomelt™) is imparted with latent cementitious properties that allow it to be transformed into construction-grade cement. The Cement-Lock Technology is unique because it not only decontaminates the sediment but also converts it into a beneficial commercial commodity, namely, construction-grade cement. The effectiveness of the technology for remediating contaminated sediments has already been verified in bench- and pilot-scale test programs. Currently, a large-scale sediment decontamination project is underway in the New York/New Jersey harbor area to demonstrate the technology at a processing capacity of 30,000 cubic yards per year.

The work is supported under Contract No. 725043 with Brookhaven National Laboratory with funding provided, in part, through the Water Resources Development Act of 1996 (Section 226) through Interagency Agreement No. DW89941761-01-1 between the U.S. EPA-Region 2 and the U.S. Department of Energy.

Keywords: Dredging, dredged material, beneficial use, manufacturing process

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INTRODUCTION

Sediments must be routinely dredged from the New York/New Jersey harbor to maintain water depths for shipping channels, berthing areas for commercial vessels, and to insure safe navigation. In the past, most dredged sediments have been barged out into the open ocean and dumped. These dredged materials often contain a variety of contaminants from different anthropogenic sources including polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), insecticides, chlorinated dioxins and furans, and heavy metals. The concentrations of some of the contaminants in the sediment are high enough to render the sediments hazardous to benthic organisms through biotoxicity and/or bioaccumulation. Further, the ocean dumping area commonly known as the "Mud Dump Site" was closed to further dumping of contaminated material as of September 1, 1997. These contaminated dredged sediments must be rendered innocuous to the environment before being disposed of, or, as in the case of the Cement-Lock™ process, converted into a salable product for beneficial use.

In addition to the contaminated sediments, many different types of contaminated wastes can be treated via Cement-Lock Technology. Several million tons of wastes are being generated annually around the world. The wastes are often either being landfilled or stockpiled in nearby localities. Depending upon the nature of these wastes, they can pose environmental problems that warrant an economical and environmental compatible disposal. In addition to contaminated sediments, these wastes include concrete and building debris, town gas site soils, Superfund site soils, sludges, soils and debris from DOD and DOE sites, chemical waste, petroleum refinery waste, and incinerator residues.

The Cement-Lock Technology being developed by the Institute of Gas Technology (IGT) and its wholly owned subsidiary, ENDESCO Services, Inc., offers a one-step solution for remediating these contaminated materials in which the organic contaminants are completely destroyed, inorganic contaminants are immobilized, and the resultant solid product from the treatment can be put to beneficial use. The technology is flexible enough to accommodate the complex and varying nature and levels of contaminants and their widespread spatial distribution within the estuarine environment. The Cement-Lock Technology simultaneously immobilizes the heavy metals and destroys the organic contaminants such as PCBs, PAHs, dioxins, furans, chlorinated pesticides, and herbicides.

CEMENT-LOCK™ TECHNOLOGY DESCRIPTION

The Cement-Lock™ Technology is an advanced management system for remediating contaminated dredged sediments from estuarine and river environments, hazardous and non-hazardous wastes, and municipal solid wastes (MSW). In addition to decontamination, Cement-Lock converts the wastes into construction-grade cement, which can be sold on the open market. Depending upon the waste stream and its composition, other beneficial products could be produced, for example, steam for power generation. Further, there are no secondary hazardous waste streams produced during Cement-Lock processing as in some other treatment processes.

The beneficial use of sediments and wastes through the application of Cement-Lock Technology has many advantages over conventional waste processing. These include: a) additional revenues generated from the sale of construction-grade cement product, b) the ability to accept materials with fairly low tipping fees because of the secondary revenue streams, and c) environmental superiority when compared to conventional incineration technologies.

The Cement-Lock Technology should not to be confused with either cement manufacturing plants or with MSW incineration technologies. The Cement-Lock Technology is considerably simpler than a Portland cement manufacturing plant and bears little or no resemblance to the actual complex cement plant. Unlike a cement plant, the Cement-Lock Technology does not have the extensive sizing requirements for the materials being processed; it does not have the extreme temperature requirements of a cement plant; it does not produce waste streams (such as cement kiln dust); it does not require complex energy management to save energy; it does not produce high NOx; it does not have stringent requirements for materials of construction; and finally, the starting raw materials are entirely different.

Nor is the Cement-Lock Technology an incineration process either. Rather it is a thermo-chemical manufacturing process that utilizes the inherent properties of sediments and wastes as feedstocks for producing economically attractive products (Figure 1). Conventional MSW incinerators do not produce a salable product. Rather, they generate ash that may contain leachable heavy metals, which must be disposed of as hazardous waste. Further, MSW incinerators have been shown to generate dioxins and dioxin precursors.

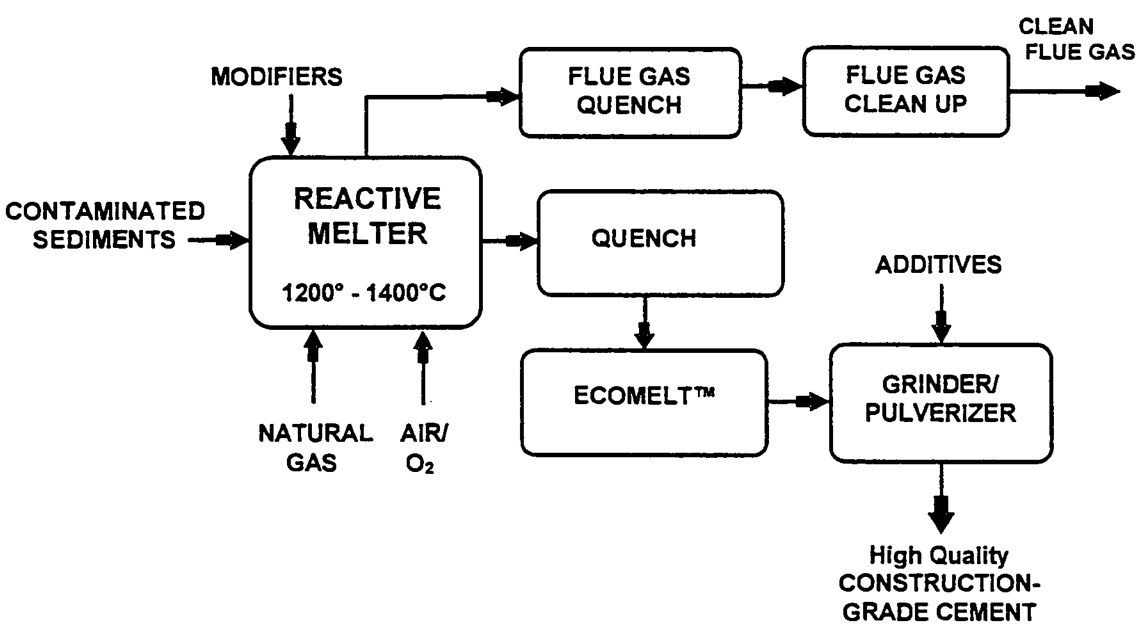

Figure 1. Schematic Diagram of the Cement-Lock Process for Treating Dredged Estuarine Sediments

The Process

Contaminated materials are reacted in a melter with suitable modifiers in proportions required for producing materials with latent cementitious properties. The proprietary modifiers are inexpensive materials that are commonly used in conventional cement manufacturing. The melter for carrying out this process is operated at temperatures in the range of 1200° to 1400°C (2192°-2552°F) or temperatures sufficient to completely melt the sediment-modifier mixture. At these temperatures in the presence of oxygen, organic contaminants originally present in the sediment are completely destroyed and converted to innocuous carbon dioxide (CO_2) and water (H_2O). Chlorine present in some of the organic compounds (dioxins, furans, PCBs, pesticides, etc.) is converted to hydrogen chloride (HCl), which can be readily scrubbed from the flue gas by direct injection of powdered lime. The flue gas could also be passed through a solid media filter containing calcium oxide (operating at 540° to 595°C; 1004° to 1100°F) to capture HCl. Preliminary laboratory-scale tests (Goyal *et al.*, 1999) have also demonstrated that some of the chlorine will be sequestered within the stable matrix of the melt. Sodium and potassium chlorides (NaCl and KCl) from seawater will be volatilized and captured in the downstream flue gas processing stages.

The melt, which contains the heavy metals present in the contaminated sediment, is quickly quenched. The metals are locked into the matrix of the melt that completely immobilizes them. The solidified melt can be crushed and pulverized by conventional methods or it can be drawn into micrometer-size fibers by fiberization techniques. The fibers can then be easily pulverized and mixed with another appropriate additive to yield construction-grade cement as a product for beneficial use.

Flue gas from the melter enters a secondary combustion chamber (SCC), where it is subjected to an additional two (2) seconds residence time at temperature to ensure complete combustion of any organic compounds. The flue gas exiting the SCC is cooled by direct water injection to a temperature of about 177° to 204°C (350° to 400°F) to prevent the formation of dioxin and furan precursors. Powdered lime (CaO) is injected into the flue gas to capture HCl, SO_2 and other acid gases. The flue gas then passes through a bag house to capture the spent lime, fine particulates, and NaCl and KCl volatilized from the estuarine sediments. From the bag house, the flue gas passes through a fixed bed of activated carbon to capture volatile metal species. In an alternative process configuration, powdered activated carbon can be injected into the flue gas stream to capture volatile metals and be removed by a second bag house. The clean flue gas is vented to the atmosphere.

All of the components required for applying the Cement-Lock Technology to the remediation and beneficial use of dredged sediments have been adapted from commercially available equipment. No equipment development was required. The following sections describes the major process equipment, the feed system, the reactive melter, and the melt fiberizer or granulator.

Feed System

The system for feeding dredged estuarine sediments into the reactive melter is a simple screw conveyor. Dredged sediments containing 60-weight percent water are scooped from the barge and dumped into the screw conveyor feed hopper. The rate of sediment feeding into the reactive melter can be controlled by regulating the screw rotation rate. Depending upon the pumpability of the sediments (from different geographical locations), it may be possible to use a sludge pump (reciprocating piston) to transport sediments from the barge to the reactive melter. Since sediments are essentially sandy, silty, or clayey in nature, the only feed pretreatment required is to remove large objects (such as automobile parts, timber, fencing, etc.) from the feed using a scalper.

Reactive Melter

Any suitable natural gas-fired melter can be adapted to the Cement-Lock Technology. IGT has considered three vendors for providing melters, which are described below. The current pilot-scale testing was conducted in a rotary kiln melter.

1) A rotary kiln-type melter as manufactured by ABB or Svedala Industries is suitable for the Cement-Lock Technology. The rotary kiln-type melter is very forgiving of variations in the size of feed materials that it can process. Through the years, rotary kilns have been installed in hundreds of locations worldwide.

The rotary kiln melter employed for the pilot-scale testing was designed and built by ABB. During pilot-scale operation, sediment containing 60-weight percent water was readily processed without predrying. ABB has subsequently quoted and is willing to provide the required guarantees for a rotary kiln melter with a processing capacity of 100,000 cubic yards per year of harbor sediment.

2) The reactive melter developed by Ausmelt Technology Corporation, is a vertically oriented, refractory-lined cylinder. The melter is constructed with water-wall cooling to minimize refractory thickness. A layer of frozen slag coats the internal walls of the melter to extend refractory life. Feed material and modifiers are fed into the melter through a port at the top of the melter. The energy required to melt the sediment-modifier mixture is supplied through a submerged lance, which is comprised of concentric tubes for feeding air or oxygen and natural gas into the melt. The lance can be moved up or down depending upon the depth of the melt. Typically, air (or enriched air) is fed through the outer shell of the lance thereby cooling the lance somewhat. Natural gas is fed through the inner tube.

Combustion products bubble vigorously throughout the melt. The flow of gas from the lance instills a circulating pattern through the melt ensuring complete mixing. During initial melter operation, the lance becomes coated with a layer of frozen slag, which extends its life. When the lance must be replaced, a spare can be installed within about 30 minutes.

3) Other melters, such as the submerged combustion melter, commercialized in the Ukraine for mineral wool manufacturing and being developed in the U.S. by the Institute of Gas Technology, is

also suitable for Cement-Lock Technology. A pilot-scale submerged combustion melter has recently been installed and tested at IGT's Energy Development Center.

Melt Granulator or Fiberizer

The melt (Ecomelt™) from the reactive melter flows from the reactor into a flowing stream of quench water or high-velocity air which quickly freezes the melt and effectively disperses it into fibers or granules. In IGT's pilot-scale tests, the water-quencher effectively produced fibers from the melt. The fibers were readily crushed to the particle size required for blending with the final additive to produce the construction-grade cement product.

Fiberization techniques are well known in industry, however it appears that specific industries have developed their own proprietary processes. Fiberglass and mineral wool are produced utilizing existing fiberization techniques.

BENCH AND PILOT STUDY DATA

Several bench-scale studies have been conducted with the following contaminated materials using the Cement-Lock Technology.

- Dredged sediments from the Newtown Creek estuary in New York (NY/NJ Harbor)
- Dredged sediment from the Detroit River
- Contaminated building debris (concrete)
- Fly ash

Pilot-scale studies have also been conducted with the following contaminated materials using the Cement-Lock Technology.

- Dredged sediments from the Newtown Creek estuary in New York (NY/NJ Harbor)
- Hydrocarbon-contaminated soil
- Municipal solid waste

The harbor sediments are contaminated with polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, insecticides, chlorinated dioxins and furans, and heavy metals. The river sediments also contain similar contaminants. The concrete waste was spiked with oil and chromium.

The results of the laboratory- and pilot-scale test programs for evaluating the Cement-Lock Technology have been very favorable. The results obtained with the dredged estuarine sediments, dredged river sediment, and contaminated building debris (concrete) are summarized below.

- All hazardous organic contaminants, including oil and grease, PAHs, PCBs, pesticides, insecticides, chlorinated dioxins and furans, were destroyed to well below regulatory limits. The destruction of organic contaminants is shown in Table 1.

- All heavy metals were immobilized within the cement matrix. The construction-grade cement (the end product) passed the U.S. EPA TCLP (Toxicity Characteristic Leaching Procedure) test (Table 2). The leachability of metals is several orders of magnitude below regulatory limits.
- Samples of mortar were prepared from the cement product, sand, and water according to ASTM (American Society for Testing and Materials) C 109 procedures. The compressive strengths of these mortar samples were determined according to the ASTM procedure after 3, 7, and 28 days of curing (Table 3). The compressive strength tests were conducted by Construction Technology Laboratories, Inc. (CTL - the research arm of the Portland Cement Association, USA). The mortar produced from the cement product exceeded ASTM compressive strength requirements. It can replace Portland cement for general construction applications.
- The process did not generate any secondary hazardous waste streams.
- The pilot-plant data were consistent with the laboratory-scale data in terms of organic destruction, leachability, and the quality of the cement generated from the estuarine sediment.
- The total metal contents in the cement product from the Cement-Lock Technology are usually within the range of total metals found in ordinary Portland cement.

These findings confirm that the final product from the Cement-Lock Technology meets all environmental requirements and the cement produced from this technology is of commercial quality.

DEMONSTRATION PROJECT

Following successful testing of the Cement-Lock Technology at the laboratory- and pilot-scale levels, a 30,000 cubic yard per year (yd^3/yr) capacity demonstration-scale plant is being constructed in the New York/New Jersey harbor area. The primary objective of this program is to demonstrate integrated operation of the Cement-Lock process while converting contaminated dredged estuarine sediment into construction-grade cement. The demonstration facility will be completely integrated with a ready-mix concrete plant that will utilize the cement produced from the plant. The demonstration will also confirm the environmental benefits of the technology through sustained operation; it will also demonstrate that the plant meets all the regulatory requirements and that no secondary waste streams are generated during processing, and the plant does not adversely impact the air quality in the surrounding neighborhood.

The rotary kiln melter for the demonstration-scale project was ordered from Andersen 2000 (Peachtree City, Georgia). The melter (Figure 2) is 10 feet in diameter and 30 feet long. The entire system consists of raw sediment storage bunker, hoppers for modifiers, screw conveyors for moving material to the melter, a pug mill for blending all of the feed materials before charging, the rotary kiln melter, quench/granulator, secondary combustion chamber, flue gas quench system, lime injection, bag house, and activated carbon adsorption system. Other equipment items, such as the Ecomelt grinder and construction-grade cement blender will be rented for the demonstration project.

Table 1. Organic Contaminant Destruction Achieved With Different Waste Materials

	Estuarine Sediment			River Sediment			Concrete		
Contaminant	Untreated Sediment	Cement Product	DRE*	Untreated Sediment	Cement Product	DRE	Untreated Concrete	Cement Product	DRE
	mg/kg(dry)		-- % --	mg/kg(dry)		-- % --	mg/kg(dry)		-- % --
Oil & Grease	--	--	--	18,000	< D.L.**	> 99.99	5,000	< D.L.	> 99.9
SVOCs	370	0.22	99.93	51.2	< D.L.	99.99	--	--	--
	µg/kg(dry)			µg/kg(dry)			µg/kg(dry)		
PCBs	8,585	< D.L.	> 99.99	1,100	< D.L.	> 99.99	--	--	--
	ng/kg(dry)			ng/kg(dry)			ng/kg(dry)		
2,3,7,8-TCDD/TCDF	262	< D.L.	> 99.99	--	--	--	--	--	--
Total TCDD/F	2,871	< D.L.	> 99.99	--	--	--	--	--	--
Total PeCDD/F	4,363	< D.L.	> 99.99	--	--	--	--	--	--
Total Hx/Hp/OCDD/F	34,252	< D.L.	> 99.90	--	--	--	--	--	--

* Destruction and removal efficiency.

** Less than detection limit of the analytical procedure used.

Table 2. Metal Immobilization in Construction-Grade Cement Produced from Different Waste Materials

	Untreated Material			TCLP* Cement Produced From			
Metal	Estuarine Sediment	River Sediment	Concrete	Estuarine Sediment	River Sediment	Concrete	Regulatory Limit
	mg/kg (dry)			mg/L			
Arsenic	39	7.8	--	< 0.005**	< 0.01	--	5
Cadmium	27	9.5	--	< 0.001	< 0.002	--	1
Chromium	298	138	500	0.15	< 0.072	0.097	5
Copper	--	180	--	--	< 0.01	--	--
Lead	542	218	--	< 0.002	< 0.01	--	5
Mercury	2.9	0.55	--	< 0.0004	< 0.0004	--	0.2
Selenium	6.2	--	--	< 0.003	--	--	1
Silver	13	--	--	< 0.001	--	--	5

* Toxicity Characteristic Leaching Procedure.
** Less than the detection limit of the analytical procedure used.

Table 3. Compressive Strength of Construction-Grade Cement Produced From Different Waste Materials

Test Period Days	Cement-Lock Cement From: Estuarine Sediment Lab-Scale	Estuarine Sediment Pilot-Scale	River Sediment Lab-Scale	Concrete Lab-Scale	ASTM Requirements: Blended Cement C 595	Portland Cement C 150
	psi (MPa)					
3	1,950 (13.4)	2,230 (15.4)	2,245 (15.5)	2,530 (17.4)	1,890 (13.0)	1,740 (12.0)
7	2,730 (18.8)	2,885 (19.9)	2,910 (20.1)	3,370 (23.2)	2,900 (20.0)	2,760 (19.0)
28	4,620 (31.9)	5,270 (36.3)	4,600 (31.7)	5,475 (37.7)	3,480 (24.0)	4,060 (28.0)

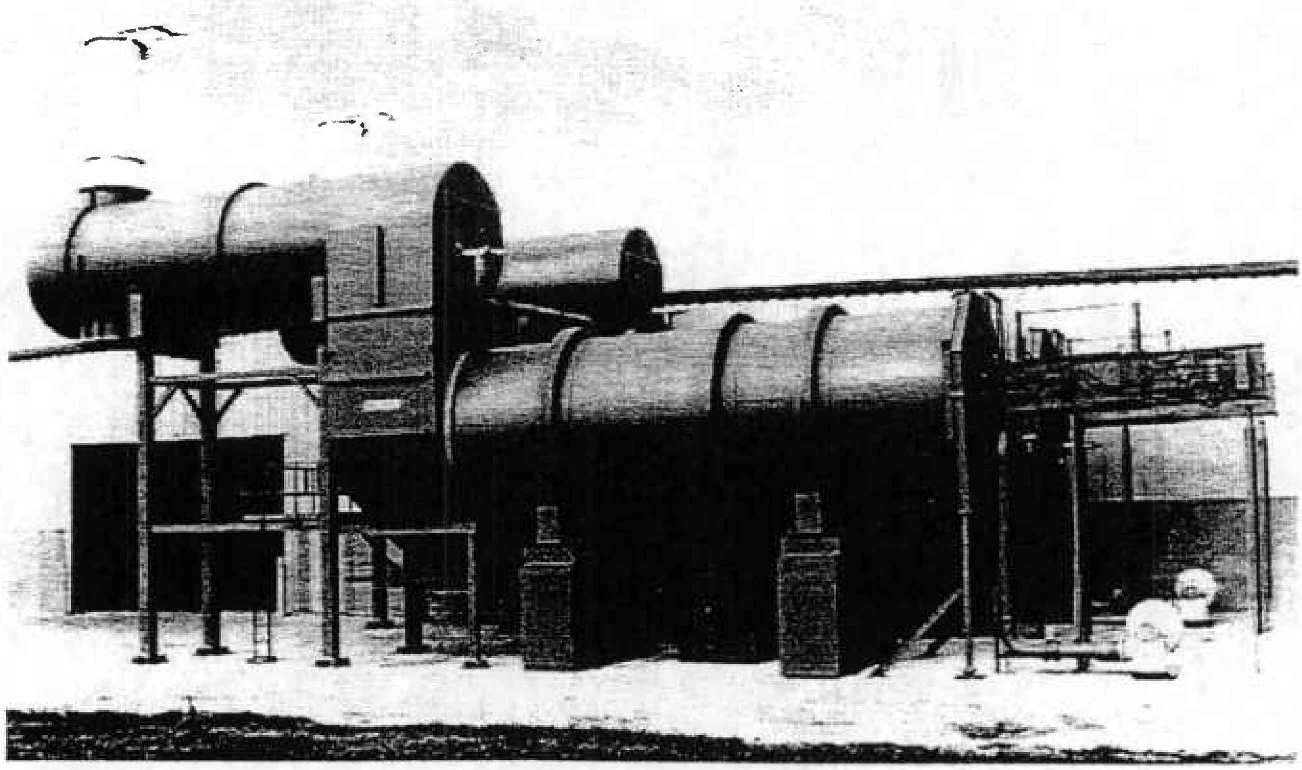

Figure 2. Andersen 2000 Rotary Kiln Melter for the Cement-Lock™ Demonstration Project (Two kilns shown)

The demonstration plant will be capable of processing other materials including contaminated soils, petroleum refinery wastes, and various other industrial wastes. Also, with process enhancements and improvements, the capacity of the demonstration plant can be increased to 100,000 cubic yards per year.

Significant public input has already been incorporated into this project based on numerous public outreach meetings.

The next stage of Cement-Lock Technology development will be the construction of a commercial-scale plant having a treatment capacity of 500,000 cubic yards per year of contaminated sediments and wastes. Other opportunities are also being pursued with different clients in the U.S. and around the world.

CEMENT QUALITY

The cements produced from contaminated sediment, brownfield debris, and fly ash have been tested by the Construction Technology Laboratories (technical arm of the Portland Cement Association, USA), a private cement manufacturing company, the State of New Jersey Department of Transportation, and another independent testing laboratory in New Jersey (on behalf of a private client). In all cases the cement product exceeded compressive strength requirements per ASTM C 150 standards; therefore, it can be used in general construction projects. The cement readily passed the EPA leachability test demonstrating that the heavy metals are locked within the cement matrix. Also, the total heavy metal contents in the cement product are within the range found in the conventional Portland cement. Gaining market acceptance for Cement-Lock cement is expected to be straightforward for these reasons.

ECONOMICS

Process economics are extremely favorable. Revenues are derived from both ends of the process. Currently, tipping fees for dredged sediment in the NY/NJ Harbor are in the range of \$35 to \$50 per cubic yard. Tipping fees for other waste materials that can be directly co-processed with sediment in the Cement-Lock Technology range from \$70 to \$500 per ton of material. The construction-grade cement product commands a market price between \$50 to \$70 per ton. The processing cost is approximately \$50 per ton. Therefore through waste co-processing, a full-scale plant has the potential for significantly reducing the cost for sediment treatment through offsetting costs. Equally important, the Cement-Lock Technology remediates the contaminated materials and demonstrates beneficial use for otherwise wasted materials.

CONCLUSIONS

The Cement-Lock Technology has been successfully demonstrated at the laboratory- and pilot-scale levels with various types of waste materials. A 30,000 cubic yard per year capacity plant is being constructed to demonstrate integrated operation of the technology at a larger scale. The demonstration facility will be completely integrated with a ready-mix concrete plant that will utilize the cement produced from the plant. Other opportunities are being pursued with different clients in the U.S. and around the world.

ACKNOWLEDGMENTS

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REFERENCE

Goyal, A. *et al.*, "Remediation and Beneficial Reuse of PCB-Containing Wastes Using the Cement-Lock Technology," Final report for the Gas Research Institute under preparation.

PROCEEDINGS

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WESTERN DREDGING ASSOCIATION NINETEENTH TECHNICAL CONFERENCE

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Louisville, Kentucky

THE BENEFICIAL USE OF DREDGED MATERIAL TO MITIGATE ACID MINE DRAINAGE

Shawn O'Donnell[1] and John Henningson [2]

ABSTRACT

Prior to the Surface Mining Act, activities in the Appalachian coal basin resulted in a legacy of environmental degradation, especially acid discharge directly into waterways. The impact of this environmental burden effects such sensitive ecosystems as the Chesapeake Bay, which receives thousands of pounds of acid daily from both Pennsylvania, Maryland and West Virginia. The magnitude of this impact is estimated at 250,000 acres in Pennsylvania alone, which carries a reclamation price tag of $15 billion. The financial and physical resources necessary to address a problem of this magnitude are enormous. Large scale closure of abandoned mined land has not been possible because of insufficient spoils to eliminate the hazard. For those sites fortunate enough to get closed, sufficient resources are typically not available to restore biota. To address socio-economic problems of this magnitude, researchers and planners need to look to other, non-traditional, sources of materials to restore these mined lands. These materials include: fly ash, bottom ash and gas scrubber sludge from power plants; slag from iron and steel manufacture; and sediment from harbor maintenance dredging projects.

This paper presents one such mined land reclamation program using dredged material and fly ash, together with an activator, to prepare a low-strength, compacted cementitious grout to close abandoned Pennsylvania coal mines. The important physical properties of this amended dredged material are an unconfined compressive strength of 50 to 300 psi and a hydraulic conductivity of 10-5 to 10-6 cm/sec. An artificial soil was prepared for restoration of biota from mixtures of recycled cellulose, to hold water; fly ash, to act as a source of minerals; lime, to act as a neutralizing agent (a soil sweetener); and organic material, to provide nutrients for bacteria in order to establish a self-regenerating nitrogen source. The results of a 30,000 cy pilot project conducted in 1998, using material dredged from the Municipal Marina in Perth Amboy, NJ were very promising. The next phase is a larger scale project to refine solids handling techniques and improve the cost effectiveness of the process. It is proposed to use 150,000 cy of the 1.25M cy of sediment to be dredged from the Claremont Channel in Jersey City, NJ to complete this demonstration project. This project will also provide material for other beneficial use demonstrations in New Jersey including capping a brown field site, grading a golf course and creating an inter-tidal habitat.

Keywords: dredging, amended dredged material, fly ash, grout, low strength structural fill

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INTRODUCTION

Bark Camp Abandoned Mine Site Demonstration Project

The Bark Camp Mine Site Demonstration Project is an abandoned site in Clearfield, Co., PA where extensive coal mining occurred on leased property owned by the Commonwealth of Pennsylvania (Scheetz et al. 1995). With the termination of mining in 1984, the responsibility for the environmental consequences of the mining has reverted to the Commonwealth. The site is located near Penfield in northern Clearfield County and consists of 1400 acres of PA Game Commission, Bureau of Forestry and Department of Environmental Protection land. The challenges at the site are: a) acid mine drainage (AMD) from deep mining amounting for up to 0.18 million gallons per day from Bark Camp #1, and a much smaller flow (25,000 gal/day) from Bark Camp #2; b) two open deep mines; c) an accumulation of refuse from coal processing that occurred on the site; and d) an exposed high wall remaining as the result of surface mining. Bark Camp Run traversing the site supports a native fishery but receives an influx of AMD as it passes through the site rendering the stream severely degraded.

The restoration of the Bark Camp site will require: a) the reclamation of the high wall; b) encapsulation of the tipple refuse; c) injection into the deep mines; and d) remediation of the Bark Camp stream. The high wall at Bark Camp consists of approximately 11,000 lineal feet of exposure extending 40 feet high to a bench and then to an additional 60+ feet above this bench to the hill side. Tipple refuse estimated at approximately 40,000 tons of coal screening materials and other refuse is present on the site plus additional refuse material was originally used to fill in the Bark Camp Run valley for construction of the tipple site. These screenings act as an additional source of further AMD development.

Reclamation and remediation activities utilizing a fly ash-based grout have successfully demonstrated the efficacy of this approach. Tipple refuse was added in lifts to cementitious grouts as the grouts were placed against the high wall in order to stabilize and recontour the slope. The refuse was placed so that it is intimately encapsulated in the grout thus keeping it in direct contact with a material with neutralization potential and prohibiting water from contacting the refuse. As the remediation of the high wall was completed it was covered with soils and planted. To date, as part of this fly-ash grout demonstration, approximately 100,000 tons of fly-ash grout have been placed, soil applied and revegetated.

Finally, the open, void space in the deep mines will be closed by pressure – injecting a cementitious grout. The Bark Camp #1 mine is extensive, stretching for over six miles with a wide lateral expanse. In contrast, the Bark Camp #2 mine is much smaller, extending for nearly a mile and a half with much less lateral expansion.

Studies show that from 6-10 million tons of grout will be required to complete the restoration of the Bark Camp Site. This volume is so large that the use of ordinary construction materials is cost prohibitive. However, many alumino-silicate materials, which are produced in very large volumes as waste products, are available. Fly ash produced from the combustion of coal in utility power plants and fluidized bed combustion facilities served as pozzolanic materials for phase I of this demonstration project. Several approaches for using cementitious materials, based on coal combustion by-products in the remediation / reclamation of acid producing sites, have been demonstrated. Schueck, et al. (1993, 1994, 1996), Fontana (1993), Scheetz et al. (1993, 1994, 1997, 1998) and Zhao (1995) have reported on the use of ashes from fluidized bed combustion in the remediation of tipple refuse piles. In this approach, the naturally cementitious ashes were pressure grouted in the refuse piles. In this case, by-product alkaline earth additions were used to activate the latent pozzolanic potential of the coal ashes. The demonstration at Bark Camp has recently entered into phase II of the study in which stabilized dredge material is being used for structural fill to reclaim and remediate the exposed high wall. The Bark Camp Demonstration Project will continue at the site for 10-15 years before restoration is complete.

Dredged Material

Dredge material is a "giga-scale" waste product in the same class of material as fly ash and slag that is generated by industrial activity and, because of its composition and extremely large volume, generates significant environmental and economic challenges related to its disposal. Dredge material is an unconsolidated, earthen material taken from harbors and rivers that has particle sizes that range from clay to silt and occasionally to sand (see table 1 for classification). These materials form from erosion of surrounding upland areas and are transported by rivers and streams. Nationally, approximately 500 million tons of sediments are dredged annually. As an example, the New York/New Jersey harbor, a naturally shallow water harbor, accumulates sediments at the rate of one foot per year, which amounts to the need for annual maintenance dredging of approximately 7 million tons. On the other hand, areas along the Savannah River in Georgia accumulate sediment at the rate of 12 to 15 feet per year.

Table 1. Size Classification of Sediments

Size	Fragment
2 mm	Sand
1/16 mm	Silt
1/256 mm	Clay

Sediments accumulate in aquatic lowlands and, in similar fashion, chemical constituents which may pose a threat to the environment and the health and the welfare of the public, may accumulate along with the sediments. Until 1992, most of the dredged material from the New York/New Jersey region was acceptable for ocean disposal. Changes in federal and state regulations now restrict ocean disposal of certain dredged sediments containing low to moderate levels of chemical constituents that may pose a threat to the environment and human health in an aquatic environment. These changes have caused the volume of sediments removed from the region to temporarily decrease dramatically in recent years. Additionally, these restrictions on ocean disposal have created a critical need for long-term upland management options for large quantities of dredged sediments.

Prior to these present day environmental regulations, PCB's and other chemicals were routinely discharged into this nations waterway and found their way into the sediments of many harbors; one of the most notably was the Hudson River estuary. With the secession of uncontrolled environmental discharge, very little, if any toxic materials are now recorded during these maintenance-dredging operations involving ocean disposal. With regard to the dredge material utilized for mine reclamation, the contamination levels in the dredge material are significantly below those levels classified as hazardous or toxic under state or federal laws. However, because of the possibility of contaminants, extreme care is being taken to ensure that no contamination is incorporated into this demonstration project.

Claremont Channel Dredging Project Overview

This is a multi-part project that is associated with improvements in the Claremont Channel in Jersey City. The project is envisioned as a partnership between the State of New Jersey, the City of Jersey City, Hugo Neu Schnitzer East (HNSE) and Liberty National Development Corporation. The project encompasses numerous activities including several innovative demonstrations as follows:

- major site improvements in the HNSE facility on Claremont Channel in the Jersey City waterfront, including noise control, site regrading for storm water control, new loading equipment, dock rebuilding and rail extensions;
- the dredging of the Channel;
- the creation of an inter-tidal habitat;
- the use of an innovative mixture of dredged material with PROPAT®, a recycled product manufactured by HNSE, for the bulk fill and grading of a new golf course at Port Liberte', a residential development adjacent to the Channel;
- the use of amended dredged material for capping and grading additional acres of the golf course;
- disposal at the Newark Bay Confined Disposal Facility (CDF); and
- filling portions of an abandoned mine in Pennsylvania with amended dredged material.

The estimated overall cost of this project is approximately $52 million. Hugo Neu Schnitzer East's contribution will be $30.5 million, or 60% of the total cost. It is proposed that the State of New Jersey provide the balance in a combination of funds and access to other disposal options, such as the CDF in Newark Bay. The balance of this paper will focus on the use of dredged material in the Pennsylvania Mines.

DREDGE MATERIAL TESTING PROTOCOL

Before any materials are removed from the harbor, the targeted dredge material area is sampled to below the depth of sediment removal. The sampling protocol has been established by a bi-state agreement between New York and New Jersey and signed-off by the Commonwealth of Pennsylvania. If any areas within the dredge material site are found to contain elevated levels of contamination, that area is re-surveyed on a finer grid scale to identify and isolate the contamination. This material will be specially handled and transported to a hazardous materials disposal site (Tavolaro, et al. 1987).

Once approved, the dredge material is recovered and transferred to a process treatment facility where it is stabilized in order to condition it for transfer to the Bark Camp Demonstration Site in central Pennsylvania. After the stabilization, it is again sampled for confirmatory purposes and placed on rail cars. At the Demonstration Site, additional fly ash and a chemical activator are added to the stabilized-dredge material and it is sampled and analyzed a third time before placement as a structural fill.

The Bark Camp Demonstration Project is being conducted pursuant to specific Quality Assurance & Quality Control (QA/QC) measures as required by the various state regulatory agencies involved. These measures are implemented throughout the project to provide assurances to protect the public health, welfare, and the environment. In addition to the many day-to-day operational QA/QC measures implemented, an extensive testing protocol is undertaken to physically and chemically characterize and monitor the dredge materials and industrial by-products used to create the manufactured fill product.

Quality Control measures for this project included characterizing the chemical and/or physical properties of the raw dredge material and any additives utilized in the treatment process prior to commencing dredging. The physical and chemical properties of the additives are determined from testing, and analytical results provided by the generators of these materials. Vendors supplying coal ash products are required to demonstrate that the ash materials meet the Pennsylvania Department of Environmental Protection (PADEP) Module 25 chemical criteria for ash placement in mine reclamation. Additionally, Material Safety Data Sheets (MSDS) that are available for these materials are provided and kept on file in the administrative office at the Bark Camp facility.

The chemical analysis protocol for the dredge material intended for Bark Camp consists of three stages. These include the core sampling and analyses of in-situ dredged material samples (Stage I); the sampling and analysis of the dredge material at the portside, offloading facility, which is intended to confirm that the material being shipped is similar to the in-situ materials (Stage II); and the sampling and analysis of the treated materials at the Bark Camp facility to assure that the manufactured materials comply with the criteria established in by the PADEP (Stage III).

The sampling and analysis of the dredge material utilized at Bark Camp is conducted in accordance with the requirements of the PADEP Beneficial Use Order (BUO) issued for the Bark Camp Demonstration Project. The BUO includes the requirements of the New Jersey Department of Environmental Protection (NJDEP) guidance manual entitled, "The Management and Regulation of Dredging Activities and Dredged Material in New Jersey's Tidal Waters," October, 1997. The New Jersey manual (referred to as the "Guidance Document") specifies sampling and analytical requirements for upland disposal and beneficial re-use of dredged materials in the State of New Jersey. The manual specifies sampling procedures and frequency requirements, target analyte lists, analytical test methods to be used, and acceptable method detection limits for in-situ sediment samples.

A dredge site specific Sampling and Analysis Plan (SAP) for the in-situ sediment is prepared for and submitted to the NJDEP and PADEP's review and approval. Individual core samples of the in-situ sediment are taken to the proposed project depth plus allowable over-dredge. Composite samples are prepared from the individual core samples. The individual core and composite samples are subjected to the analysis specified in the Guidance Document and the approved SAP.

Bench tests utilizing the dredge material from the in-situ testing and various percentages of proprietary additives are performed to simulate the creation of the manufactured fill. The bench test product samples are analyzed in order to chemically and physically characterize the manufactured fill and to determine the ability of the fill from each mix design tested to stabilize chemical constituents found in the in-situ dredge material.

The analytical and test results for the Stage I in-situ sediment samples are submitted to the PADEP and state of origin of the dredge material for their respective review and approval.

Quality Assurance measures (Stages II and III) for the Bark Camp project are implemented to confirm that the chemical and/or physical properties of the pre-amended dredge material transported to Bark Camp and the manufactured fill were similar to that of the in-situ sediment sample properties.

Stage II testing occurs at the portside facility, and is performed to confirm that the pre-amended dredged material is physically and chemically similar to the dredge material sampled in Stage I. This confirmatory sampling is performed pursuant to the BUO, at a frequency of one composite per 25,000 cubic yards of dredged material. The analytical and test results are reported to the PADEP for its review and information.

The final stage (Stage III) of the QA process is performed after the final amendment of the dredge material at the Bark Camp facility. One (1) composite sample of the manufactured fill is obtained pursuant to the BUO requirement of one composite sample per every 25,000 cubic yards of material. The composite sample is chemically analyzed and geo-technically tested pursuant to the specific requirements specified in the BUO for the manufactured fill. The analytical and test results are reported to the PADEP for its review and information.

The dredge material testing protocol includes, but is not limited to, total analysis as well as TCLP and/or SPLP analysis for RCRA constituents (organic and inorganic), PCB's and dioxins and furans. Dredge material accepted and utilized at Bark Camp may not contain levels of chemical constituents rendering it classified as 'Hazardous' or 'Toxic' material. Additionally, the manufactured fill must possess certain physical properties including a permeability of not more than 10^{-5} cm/sec, and a compressive strength of 35 psi or greater.

PERTH AMBOY PILOT PROJECT

The states of New Jersey and New York have offered their support of the Bark Camp Demonstration project. The Port Authority of New York and New Jersey (PANYNJ) is responsible for assuring that the channels and harbors serving these states are maintained and navigable. The PANYNJ, in cooperation with state government, has committed to designating specific dredging locations within the harbor for the Bark Camp demonstration project. The initial dredging location within the harbor designated for the Bark Camp project was the City of Perth Amboy Municipal Marina, located on the Arthur Kill waterway, in Middlesex County, New Jersey. Figure 1 is a map of the New York/New Jersey harbor with the Perth Amboy Marina located. The Perth Amboy Marina dredging project is representative of how future projects associated with the Bark Camp Demonstration project will be conducted, and is described below.

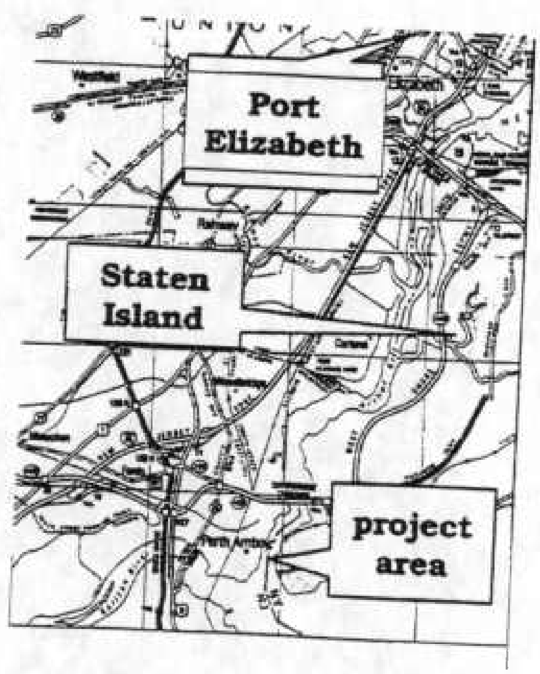


Figure 1. Map sketch of the New York/New Jersey harbor noting dredge material location.

Dredging Operations

For this project, dredging was conducted with a computerized, environmental, closed clamshell bucket. Experience has shown that this system result in higher solids to water ratio dredge material than is achievable by other techniques. The placement of the bucket can be controlled to +/- 6 inches, and each bucket's location can be tracked.

Processing

Off-loading of the dredged material was performed at Consolidated Technologies, Inc.'s transfer and processing facility located on the Arthur Kill waterway in Elizabeth, New Jersey. Off-loading was accomplished utilizing a 50-ton crane equipped with a clamshell bucket. As necessary, the loaded

barges were moored at the Elizabeth facility to allow the sediment to settle for de-watering of the barges prior to off-loading. Water decanted from the loaded barges was pumped through a particulate filter to portable frac-tanks. After an adequate period of settling, the water in the tanks was tested for compliance with discharge criteria contained in the Water Quality Certificate. Upon confirmation, the decanted water was discharged from the tanks to the Arthur Kill waterway.

The dredge material was off-loaded into a large receiving hopper and through a series of screens to separate debris from the sediment. The debris was staged for transport and disposal at an alternate, approved disposal facility. The dredge material was placed into a pug mill where it was mixed with coal fly ash to pre-amend (physically stabilize) the material for transport to Bark Camp. The raw material was solidified to a solids ratio of 40/60 to ensure that no free liquids were present in the material. From the pug mill, the pre-amended material was loaded into gondola rail cars for transport to the Bark Camp Facility.

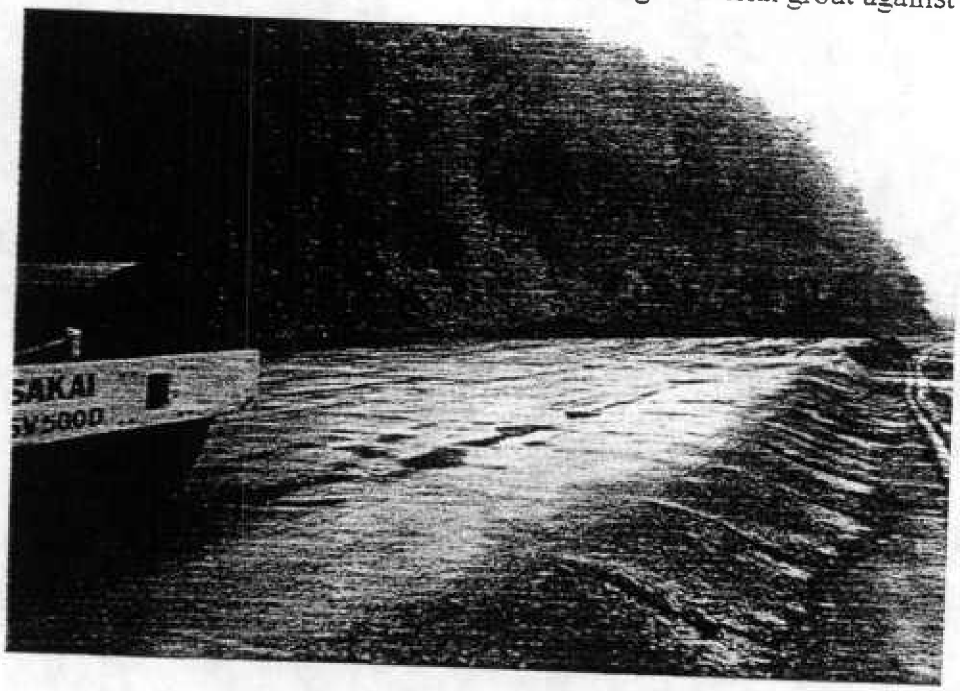
At the mine site, the dredge material was off loaded from the rail cars by a backhoe and transported to the processing site by truck. Here, it was again processed through a pug mill with additional fly ash and a lime activator to attain a water-to-solids ratio of approximately 30/70. On a demonstration basis, approximately 1,000 to a maximum of 4,000 tons per day can be processed in this manner. The activated, processed dredge material is allowed to stand for 24 to 48 hours for a pre-cure before being transported to the highwall where it is placed and roller compacted into place. This process is illustrated in Figure 2.

Dredged Material To Controlled Low Strength Cement For Structural Fill

The cementitious solids (i.e. manufactured fill) that results from the process just described relies upon the pozzolanic reactions between the fly ash, the alumino-silicates in the dredge material and the lime activator. The properties of the resulting solids can best be described as a "controlled low strength fill." The ultimate properties of the cementitious solids, however, are dependent upon the varying nature of the dredge material and the fly ash used in the process.

Two physical/chemical characteristics are monitored for this project, unconfined compressive strength and permeability. Strengths range from 115 to as much as 300 psi in 28 days and permeabilities range from 10^{-5} to 10^{-7} cm/sec.

Figure 2. Photographs of the placement of the dredge material grout against a highwall.



Manufactured Fill Being Placed at Bark Camp

Manufactured Fill Being Placed at Bark Camp

CLAREMONT CHANNEL DREDGING AND DISPOSAL PROGRAM

The upgrading of the Claremont Channel for improved traffic through dredging is critical to the future financial viability of HNSE and the preservation of 125 direct jobs and over 4,000 jobs indirectly related to this business, such as vendor services, parts suppliers and professional services.

The trend among overseas customers is towards the use of vessels drawing between 35 and 45 feet of water. The current nominal depth of the channel is 28 feet at low water; many areas have a shallower depth due to silt. This lack of water access is not only a hindrance to HNSE, but a real impediment to developing a multi-user facility. Figures 3 and 4 show the location of the Claremont Channel and key aspects of the improvement project.

Dredging

Dredging will improve access and safety. The proposed design would dredge a deeper channel 200-300 foot wide and 34 foot deep within the existing channel, and add a turning basin at the midpoint. This basin is needed to improve safety in operations. Currently, ships back up for nearly a mile from the main channel in the Hudson River, aided by tug boats. The turning basin would allow ships to turn before loading, and to exit the channel moving forward. The volume of material to be dredged would be approximately 1.25 million cubic yards. The cost of dredging is estimated at $5 million.

Dredging will be done by a modern clamshell. This equipment greatly reduces the volume of return flow water and the requirements for its treatment, when compared to the traditional hydraulic dredge. It also reduces the loss of sediment to the water column as the bucket is withdrawn.

The dredged material will be placed in barges and unloaded and/or treated on shore. A key consideration will be the screening of scrap metal. This will be achieved by a series of screens and grates placed on the barges and the shore where the material will be unloaded. Water quality during dredging must comply with the requirements of the USACOE Permit and associated NJ Water Quality Certificate.

Processing Facility

As noted previously, the dredged material will be used in several different beneficial ways. It is proposed that a permanent , sediment processing facility be constructed on the western portion of the HNSE property to process the 900,000 cy of dredged material to be used for beneficial upland use in Pennsylvania and New Jersey.

The proposed facility would remove debris, decant free water and process the sediment with several types of admixtures depending of the ultimate use. Demonstrations as grout at the Bark Camp, PA mine closure site and as capping material and as bulk fill at the Pt Liberte' site are

Figure 3. Claremont Channel Location

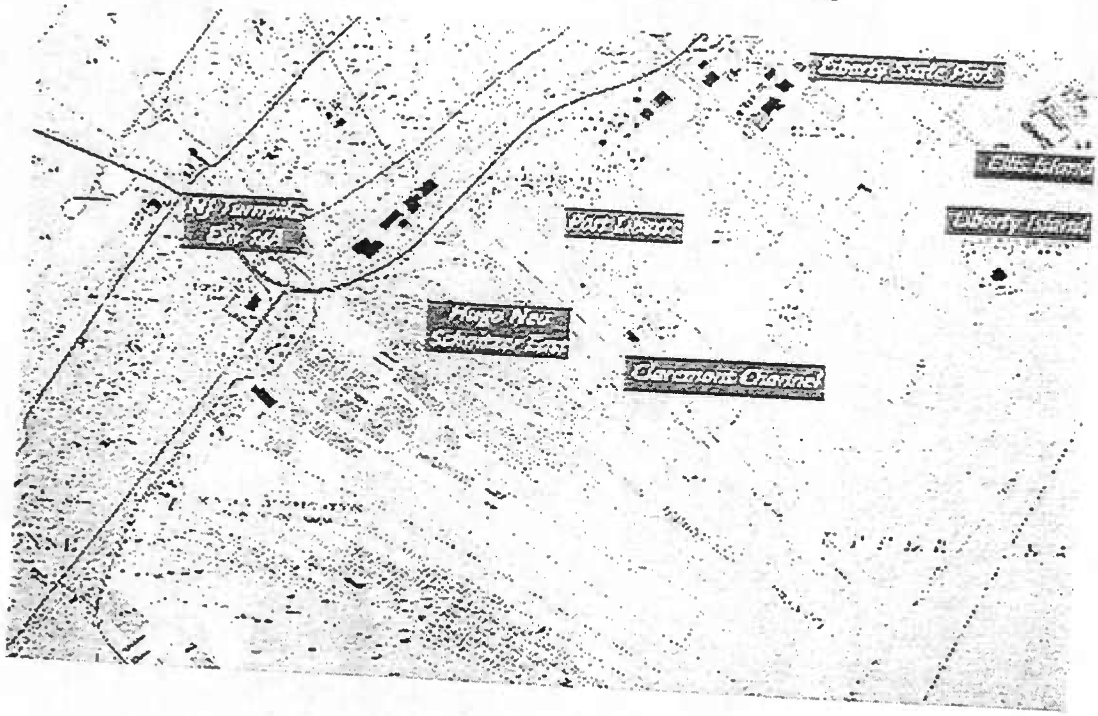
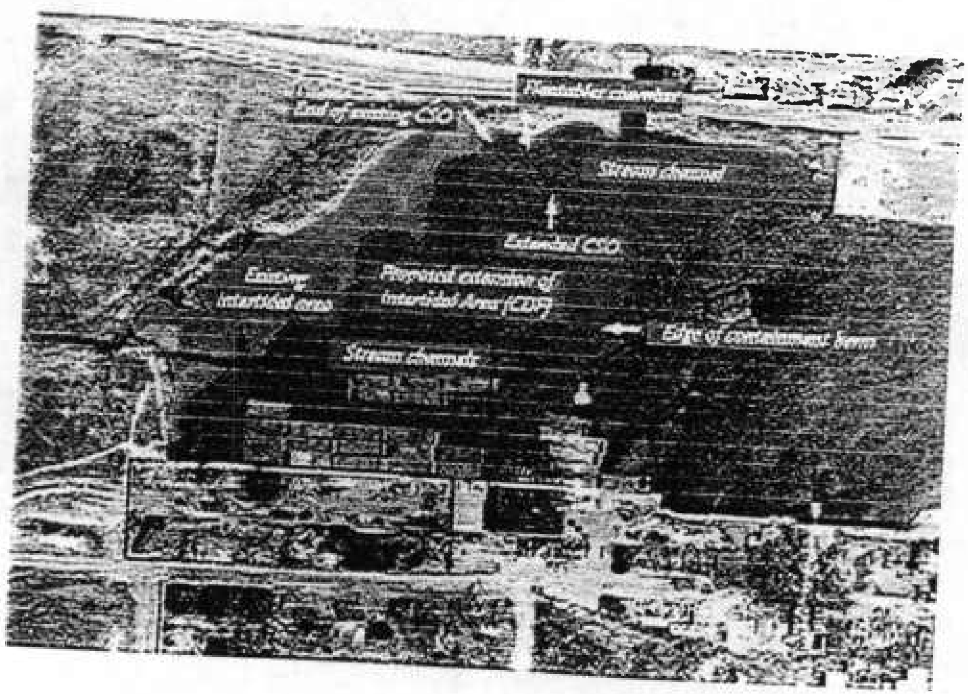


Figure 4. Key Project Elements



proposed. The facility would be capable of processing up to 4,000 cy of dredged material per day. The ultimate uses of the material are described in the following sections.

Golf Course Capping and Grading

The proposed use for the bulk of the dredged material (800,000 cubic yards) will be as capping and grading material for a golf course at the nearby 100+ acre Port Liberte site, immediately to the North of Claremont Channel. The majority of the site, formerly known as US Department of Defense Supply Depot One, functioned as a petroleum storage facility. The remainder of the site consists of commercial and industrial uses and a former paint manufacturing facility to be remediated. The site is being redeveloped as a mixed residential and golf course use by Liberty National Development Corporation.

The developer's Remedial Action Work Plan requires capping contaminated soil areas with a low permeability cover to reduce infiltration. A golf course would then be built on top. The New Jersey Department of Commerce, Maritime Resources, has suggested using the dredged materials from the Claremont Channel as cover for the golf course. The dredged material would be used for two different purposes: to cap contaminated areas and as bulk fill for grading. The capping material must have a compressive strength of at least 30 psi, a bulk density of 85 lbs per cubic ft., and a permeability of less than 10^{-6} cm / sec. The bulk fill must have a compressive strength of at least 30 psi and a bulk density of less than 85 lbs per cubic ft. Both uses will require processing the material to reduce the free water content, to stabilize contaminants, and to obtain a density appropriate to the use.

Most (650,000 cy) of the material will be processed by mixing it with pozzalanic additives routinely used to amend dredged materials for upland placement. By adjusting the mixture, the dredged material can be made suitable for use as capping material or simply be used as fill for grading.

Approximately 150,000 cubic yards of dredged material will be mixed with PROPAT® as a demonstration project. PROPAT® is a trademarked product manufactured by Hugo Neu Schnitzer East from recycled materials by processing the non-metallic interior materials from automobiles. PROPAT® has been approved as alternative daily landfill cover in several states and was approved in New Jersey as a cushioning material above a landfill liner in Pennsauken. Given its soil-like properties, PROPAT® may serve as an effective dehydrating agent for the dredged material, which consists of 60 to 70% water when extracted, thus improving its handling and application. The product's fiber content may also improve the strength of the admixture.

PROPAT®'s suitability for the proposed use as an additive, its field practicality and its cost effectiveness need to be demonstrated in order to obtain an Acceptable Use Determination from the New Jersey Department of Environmental Protection. A program consisting of bench scale, pilot scale and full scale demonstrations has been proposed to the New Jersey Department of Commerce, Maritime Resources, for funding. The bench scale demonstration is currently underway.

The physical and chemical properties of the PROPAT®/dredged material mixture can be obtained through bench-scale laboratory tests. However, a demonstration of the conditioned material's capabilities in the field can be best accomplished through a pilot-scale demonstration, utilizing full-size processing and earth-moving equipment.

The specific scope of pilot-scale testing will depend on bench test results. It is proposed that the pilot demonstration would be set up in a 1/20th acre parcel adjacent to the HNSE facility to test three different mixing options: mechanical mixing in a test cell on a small barge; mixing in a pug mill on land; and using mobile equipment for mixing at the upland test cell.

It is estimated that each option will require approximately 200 cubic yards of material, which will be disked, rolled and compacted using standard construction equipment. After curing, the material's consistency, strength, permeability and leachability would be tested in the lab using plug samples collected from the different test cells.
The final, full scale demonstration would be designed and implemented based on the results of the pilot tests. It is envisioned that its implementation would involve the following: extracting the dredged material; processing it with PROPAT®; trucking it to Port Liberte; and placing in bulk as fill/grading material.
The estimated cost of using the dredged material to cap contaminated soil areas and develop a golf course is $18 million for processing the dredged material, including capping and grading. Of this total cost, $5 million would be associated with the PROPAT ® demonstration.

Mined Land Reclamation

Consolidated Technologies, Inc. (CTI) is undertaking a 500,000 cubic yard beneficial use project to demonstrate the use of dredged material for reclamation of abandoned mines for the Commonwealth of Pennsylvania. Pennsylvania is confronted with severe environmental problems related to over 250,000 acres of unreclaimed mine lands. Acid mine drainage and fall hazards from exposed highwalls are among the many concerns. Approximately 30,000 cy of amended dredged material from the City of Perth Amboy, NJ Municipal Marina was previously used at the Bark Camp Site.

CTI will take an additional 150,000 cubic yards of the material from the Claremont Channel as part of their beneficial use project at a cost of $6.75 million. The sediment will be processed at the Hugo Neu site using proprietary techniques developed by CTI for creating manufactured structural fill for remediation and reclamation of abandoned strip mines. It will then be shipped to the demonstration site in western Pennsylvania via rail and placed in the mine using the procedures described perfected previously as a result of the Perth Amboy Pilot Project.

Inter-tidal Habitat

It is estimated that 100,000 cubic yards of the dredged material can be placed in a proposed intertidal habitat that will extend the existing shoreline at the West end of the Claremont Channel. This area is a gently sloping beach composed of silty sand and of high water marshes with spartina and phragmites flanking a storm drainage ditch. The adjacent upland is shrub growth consisting of pioneer tree species. The area is currently used by a variety of waterfowl and shorebirds.

It is reported that nearby benthic habitat is poor, due to the organic and pathogen content of periodic sanitary discharges from the 54" Richard Street combined sewer outfall (CSO). CSO discharges are made into very shallow water, due to the location of its invert elevation above mean low water, and also include unsightly and unsanitary floatable matter.

The proposed intertidal habitat will be filled with the dredged material to mean low water level (MLW), and will be capped with 2-3 feet of site sand, clean fill, or stabilized material. The intertidal habitat will be contained by a natural berm, preferable to a bulkhead for esthetic and habitat reasons. The berm's face will be stabilized with concrete rubble rip-rap, recycled from the replacement of an existing pier on the HNSE site. This artificial reef will provide cover for young fish and benthic food chain organisms.

The proposed design includes extending the Richard Street CSO to a deeper part of the channel to improve mixing, dilution and flushing of discharges. The City of Jersey City plans to construct a structure to contain floatables under a separate program. The cost of this habitat improvement is estimated at $4.5 million, including CSO upgrades.

CONCLUSIONS

Innovative approaches, such as the one described here, when used for the remediation of abandoned mineland, represents a win-win-situation for all parties concerned. Moreover, as long as the proper precautions are taken to ensure that no labile contaminants are present in the cementitious grouts, it will represent a very important approach to the solution of several, major, environmental problems. The need for extremely large volumes of low-cost structural fill materials can be met by many of the "giga-scale" materials produced by industry, such as fly ash and the dredge material that is the subject of this publication. The availability of this material on a continual basis has the potential to significantly impact the needs within Pennsylvania for low-cost fill. At the same time, it would eliminate health and safety issues in the 250,000 acres of abandoned mines and restore vast areas of land for recreational use. Furthermore, it would put put extremely large volumes of residual materials to beneficial use and divert them from landfill disposal.

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DREDGED MATERIAL MANAGEMENT IN NEW JERSEY: A MULTIFACETED APPROACH FOR MEETING STATEWIDE DREDGING NEEDS IN THE 21ST CENTURY

F.M. McDonough[1], G.A. Boehm[2], and W.S. Douglas[3]

ABSTRACT

New Jersey is a maritime state with 76 ports and terminals along its coastline. Dredging and environmentally safe disposal of dredged sediments has been set forth in State policy and provides New Jersey Maritime Resources (NJMR) with the flexibility to manage dredged materials on a case-by-case basis in a comprehensive matrix of primarily beneficial and environmentally sound uses. Traditional management options such as ocean disposal are no longer available. This paper provides a review of overall management strategy and recent innovative dredging projects, including aquatic confinement, upland containment, and brownfield remediation.

New Jersey projects include the Newark Bay Confined Disposal Facility (CDF), coal-mine reclamation, ocean remediation at the Historic Area Remediation Site (HARS), landfill and brownfield remediation in Elizabeth and Kearny, beach replenishment in Cape May and the construction of roadway embankments. Based on an anticipated volume of 7.8 million cubic yards of contaminated material from the Port of New York and New Jersey deepening projects plus 2 million cubic yards from non-deepening projects until the year 2002, NJMR management projects have a remaining project capacity of approximately 14 million cubic yards. An anticipated volume of 6 million (non-contaminated) cubic yards annually from State navigation channels will be managed under a new Statewide Dredging Plan that was approved by the State's Dredging Projects Facilitation Task Force.

NJMR has identified future dredged materials management options utilizing a geographic information system (GIS). Additionally, NJMR has also begun to address sedimentation rates and toxic discharges to New Jersey's waterways through innovative technologies such as AirGuard™, Scour™, in-situ and whole sediment decontamination, and a State Toxics Trackdown and Reduction Workplan.

Keywords: beneficial use, remediation, innovative technologies, sediment, disposal

INTRODUCTION

In 1637 the King of England declared the first port of entry in the British Colonies. The port was located in a small New Jersey community along the Delaware River called Salem. Since then, New Jersey as a maritime state has continued to be a major port of call from Trenton on the

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Delaware to Hoboken on the Hudson. While passenger ships no longer steam to New Jersey's 76 terminals, the State serves an import and export cargo industry valued in the tens of billions of dollars.

In the third largest port in the United States, the Port of New York and New Jersey, 85% of the commerce occurs in New Jersey waters (where containerization was invented) and more than 30 billion gallons of petroleum products transit the Port every year. Along the 127 miles of coastline, with its 116 State navigation channels, the fifth largest commercial fishing industry on the East Coast serves America and the world with finfish and shellfish harvests valued in excess of $1 billion annually.

The Delaware River channel reaches 106 miles from the ocean to the largest freshwater port in the world, the combined ports of Philadelphia and Camden. The River serves the second largest petroleum center in the country at 10 terminal facilities and refineries. Three thousand vessels annually ply the river carrying steel, fruit, lumber, fresh meat, and other products.

Maintaining these channels has always been a tremendous challenge for the State of New Jersey. In New York Harbor alone there are 240 miles of Federal navigation channels. In the late 1800's when the sailing ships of the time began to exceed the natural depth of the harbor (18 feet), *The New York Times* called for immediate dredging. In the 1990's, much the same cry was heard as the results of more sensitive testing methodologies determined that much of the dredged material in the Harbor could not be disposed of in the ocean. Compounding the situation, adequate funding was not available for dredging and disposal. The general population no longer appreciates its ports as it did in the early part of the century. Having moved to the suburbs and left the shoreside cities and ports behind, the average citizen has forgotten how the imported cars, fruit, cocoa, wine and beer arrives on our shores.

Finally, it was the New York Harbor dredging crisis in 1993 which galvanized the citizens and their political leaders into action to protect our waterborne transportation and maintain our navigation channels. Dredging and environmentally safe management of dredged materials has since been set forth in State policy and legislation. Traditional management options, such as ocean disposal, are no longer available or extremely limited. Highly flexible policies have been designed to manage dredged materials in a comprehensive matrix of beneficial and environmentally sound uses. This paper examines innovative dredging projects, technologies, and planning currently employed in New Jersey.

THE CONTAMINANT CHALLENGE

New Jersey sits on a geological shelf which stretches out 32 miles beyond the shore before dropping off into the Atlantic. Its major ports, the Port of New York and New Jersey, and the Ports of Philadelphia and Camden are riverine ports subject to substantial siltation. The Delaware River which leads into the Ports of Philadelphia and Camden, and numerous other ports and terminals along the river's edge, is essentially shallow water scoured only by its own movement and the dredges which travel from Trenton to the ocean. The Port of New York and New Jersey has an average depth of 18 feet and is located on an estuary fed by the Hudson, the Hackensack, the Passaic, the East River and numerous other watercourses which fill the estuary with one million metric tons of silt each year.

Dredging our channels is a never-ending task. We are an industrial region and the sediments as the natural sink for industrial pollutants, bear the legacy of the inadequate waste management practices of the past.

On the New Jersey side of the Port of New York and New Jersey, we face the challenge of the removal of approximately 1.82 million cubic yards of contaminated material annually. Historically, the management method of preference was ocean disposal. For almost 80 years the Port of New York and New Jersey primarily disposed of dredged material by transporting it to an ocean disposal site about six miles off the New Jersey coast. Known as the Mud Dump Site, this was one of more than a dozen ocean disposal sites for various materials from the metropolitan area. However, improved laboratory technologies and analysis of an increased number of contaminants revealed that much of the material being transported to the Mud Dump Site created the distinct possibility of biological uptake in the aquatic animals that subsisted, habitated in, and passed through the Mud Dump region, an area of almost 23 square miles.

In 1993 the fishing and environmental communities brought this practice to a halt in a lawsuit which challenged ocean disposal of contaminated dredged materials. Ultimately, the Federal government closed the Mud Dump Site forever and created, in its place, a remediation site which coincided with all the original disposal areas called the Historic Area Remediation Site (HARS).

Fortunately, the Governor was well ahead of this and had decided early on to adopt the policy of beneficial upland use for dredged materials. To meet this goal she directed a number of independent but interrelated actions. In 1994, while the lawsuit wound its way through the courts, newly-elected Governor Christine Todd Whitman created a team to develop short-term non-ocean alternatives while a fully comprehensive approach to dredged materials management was crafted. The result was implementation of a short-term disposal option (a subaqueous confined disposal facility in Newark Bay) and creation of a complex management strategy employing high and low technology options managed by a highly directed team of professionals within State government. This is the multifaceted management system which will resolve disposal challenges for the 21^{st} century.

THE APPROACH

The Governor tasked her Commissioner of Environmental Protection to draft a single regulatory document which would provide for the environmentally safe management of all dredged materials. To write *The Management and Regulation of Dredging Activities and Dredged Materials in New Jersey's Tidal Waters*, commonly called the "Technical Guidance Manual", a highly skilled Task Force of two dozen experts from every technical field within the Department of Environmental Protection worked for more than a year. The manual divided the State into several zones based on the types of dredged materials involved and the potential levels of contaminants. The document sets testing criteria, sampling requirements, and upland management protocols.

The Governor then created New Jersey Maritime Resources in the New Jersey Department of Commerce and Economic Development. The mission of the Office is to provide agency support and coordination, programmatic planning, and research and development to ensure sustainable economic development of New Jersey's $50 billion maritime industry including its ports and terminals, boat building, marine trade services, commercial and recreational fishing, military operations, waterborne transportation, navigation and government services, and education, science and technology.

Funded by a public/private partnership known as Prosperity New Jersey, NJMR immediately set about publishing comprehensive plans for dredging and disposal of dredged materials throughout the State. The Office reached out to its maritime industry constituents to develop a cooperative working relationship and conducted a conference to encourage private sector involvement in developing solutions. More than 230 industry representatives participated and the private sector has been a major factor in our success.

NJMR remains the lead agency in developing dredging programs, new technologies and beneficial use alternatives for dredged materials.

In the meantime, the Governor, working with the Governor of the State of New York, created the necessary funds and a Joint Dredging Plan between the two States which would ensure that initial steps were taken toward the long-term. $130 million was set aside for the two States to utilize in regulatory initiatives, technology development, sediment engineering, processing technologies, beneficial use, contaminant reduction and trackdown, pollution prevention, and harbor studies.

The New Jersey Legislature adopted legislation to create a $185 million bond fund for dredging of the navigation channels in the Port of New York and New Jersey, the development of CDFs, and the demonstration of decontamination technologies. The bill also created a $20 million fund for dredging navigation channels statewide. In November of 1996, the voters approved the Bond Act by a 2 to 1 margin. These funds, in addition to the Joint Plan funds, are managed by New Jersey Maritime Resources.

Then and perhaps most importantly for the permitting process, the Governor, through her Commissioner of Environmental Protection, created a single office within the New Jersey Department of Environmental Protection (NJDEP) to manage permitting of dredging and dredging-related projects. The Office of Dredging and Sediment Technologies combines expertise from a number of different fields to provide comprehensive one-stop review of proposals.

The Office of Dredging and Sediment Technologies, not coincidentally, is located within the NJDEP Site Remediation Program. This provides a fully integrated relationship between dredging and upland beneficial use options for dredged materials including site remediation, landfill capping, and construction fill. No matter what the proposed option: decontamination, manufactured soil, demonstration technologies, etc., this single Office contains the expertise to provide qualified and rapid response. Unlike the typical regulatory response, this Office is willing to step up to the plate and provide pre-application advice to the applicants to ensure that when a project is ultimately submitted, a permit can be promptly issued.

Finally, New Jersey Maritime Resources drafted a Statewide Dredging Plan to manage all dredging and dredged material disposal activities in the State of New Jersey. Mirroring the plans for the Port of New York and New Jersey, the Statewide Dredging Plan reviewed future requirements, developed a priority list for meeting those requirements, and identified options for the disposal of the dredged material utilizing as its guide the new statewide policy for beneficial use.

Unique projects, such as those described in this paper, provided an opportunity for the creation of upland disposal facilities and upland beneficial uses which incorporated local goals and included recreational, environmental, and educational components to ensure that each project had the necessary public support. The Penultimate Act was the endorsement by the Governor of a coalition of business leaders throughout the State of New Jersey to work with the Federal Administration and the Congress to ensure that Federal funding was available for all of the many Federal navigation projects throughout the State.

THE FUTURE

New Jersey has a tradition of utilizing a number of different methodologies for disposal and beneficial use of dredged materials from State navigation channels and facilities located along the Delaware River. Those management options include beach replenishment, confined disposal facilities, in-water disposal, and more recently, multiple use CDFs. Within the last decade, upland CDFs were even mined to produce soil for fill in construction projects. Dredging of certain channels where the material is both clean and of the correct grain size, has been routinely conducted by private contractors seeking sand for use in the marketplace. However, in certain locales such as the Port of New York and New Jersey a single option--ocean disposal--was relied on almost exclusively.

Because of the seemingly unlimited capacity for disposal in the ocean and the unavailability of other traditional disposal options such as upland CDFs, attempts to develop alternatives to ocean disposal generally failed. It wasn't until the dredging crisis of the early 1990's that real incentive existed to create innovative non-ocean alternatives. While New Jersey has been the leader in the development of those alternatives, the mind-set of many remains a search for the "silver bullet" disposal option.

Yet, political pressure, environmental activism, and the success of the non-ocean alternatives developed by the State of New Jersey are slowly but surely convincing even the diehards that reliance on a single disposal option is a thing of the past. The future is now reflected in a multifaceted approach to sediment management. Prior to 1993 almost 99% of all dredged material from the Port of New York and New Jersey was deposited in the ocean as reflected in Figure 1.

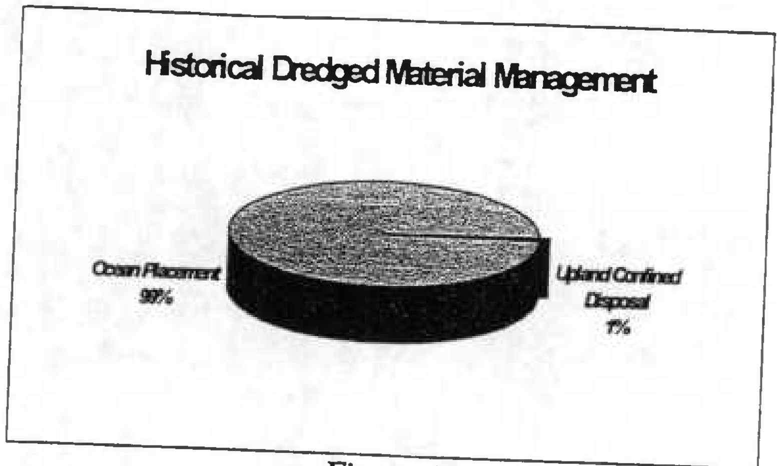


Figure 1

The shift to non-ocean alternatives is dramatically reflected in management operations conducted between 1995 and 1998 as shown in Figure 2.

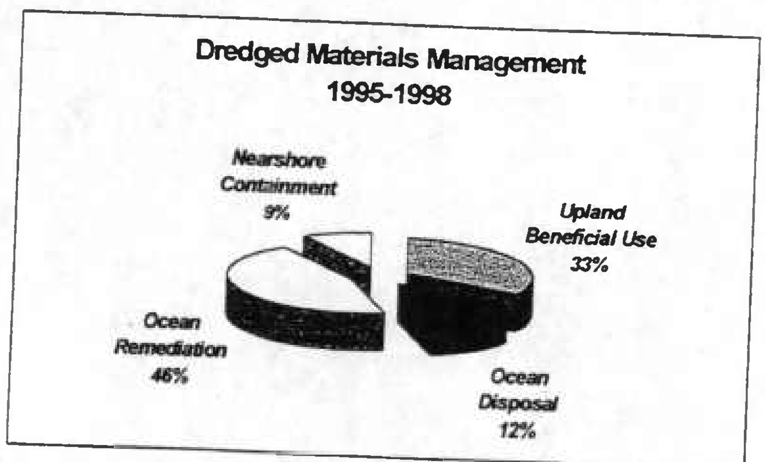


Figure 2

As Figure 3 reflects, in 1999 ocean disposal has been completely eliminated in the Port of New York and New Jersey. The only material now destined for the ocean is utilized for HARS remediation and then only after rigorous testing.

Figure 3

Comprehensive Management

New Jersey's sediment management plan is reflected in Figure 4. This combination of initiatives represents a comprehensive approach to the management of all dredged materials, especially contaminated dredged materials, and a series of initiatives designed to reduce sedimentation and eliminate contamination. The chart reflects strategies that are either already in operation, or in the research and development phase close to implementation. Each is also designed to compliment the other strategies recognizing, again, that no single approach nor even a limited collection of approaches will provide a fully successful management strategy.

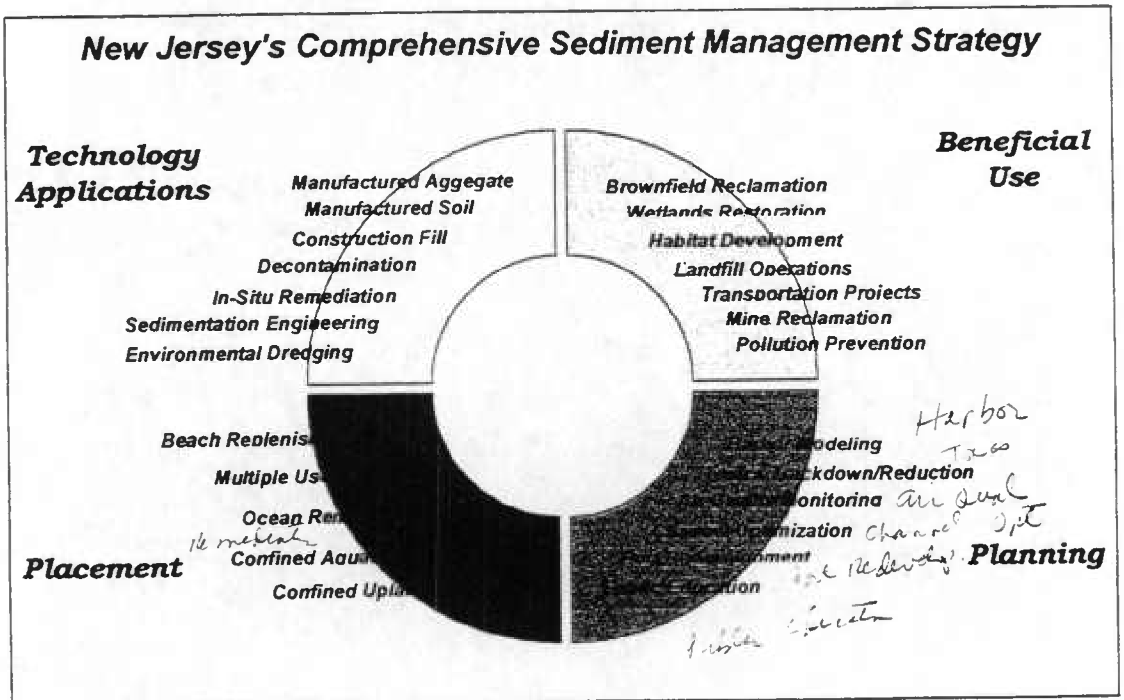


Figure 4

While the comprehensive sediment management plan applies statewide, the obvious genesis of the plan is the contaminated sediments found in the Port of New York and New Jersey. Table 1 reflects the types and levels of contaminants found in dredged materials in New York Harbor, particularly in Newark Bay. Comparing the sediment quality in Newark Bay to guidelines for the protection of aquatic life (Effects Range Low, Effects Range Median) one can see why the fishing and environmental community expressed concern over ocean disposal. However, when the same data are compared to the guidelines developed for protecting terrestrial ecosystems and human health (NJ Residential/Non-Residential Clean-up Criteria), it becomes apparent that environmentally sound upland management practices are possible. The techniques utilized can generally be categorized as high technology, low technology, and traditional approaches.

Table 1
Levels of Contaminants in Dredged Materials*

Chemical	Minimum Conc.	Maximum Conc.	Effects Range Low	Effects Range Median	NJ Residential Cleanup Criteria	NJ Non-Residential Cleanup Criteria
Antimony (mg/kg)	0.20	43.9	Not available	Not available	14	340
Arsenic (mg/kg)	1.2	67.4	8.2	70	20	20
Cadmium (mg/kg)	0.13	29.0	1.2	9.6	1	100
Chromium (mg/kg)	6.60	860.0	81	370	Site Specific	Site Specific
Copper (mg/kg)	0.44	2470	34	270	660-900	660-4000
Lead (mg/kg)	5.60	2500	46.7	218	400	600
Mercury (mg/kg)	0.10	12.4	0.15	0.71	14	270
Nickel (mg/kg)	7.10	369	20.9	51.6	250	2400
Silver (mg/kg)	0.11	42.3	1.0	3.7	110	4100
Zinc (mg/kg)	20.50	1900	150	410	1500	1500
Chlordane (µg/kg)	1.04	210	Not available	Not available	Site Specific	Site Specific
Total DDT (µg/kg)	3.77	1325.7	1.58	46.1	2000	9000
LPAH (µg/kg)	131.8	1368200	552	3160	Site Specific	Site Specific
HPAH (µg/kg)	668	1115000	1700	9600	Site Specific	Site Specific
Sum PCBs (µg/kg)	18.76	17200	22.7	180	Site Specific	Site Specific
2378TCDD (ng/kg)	0.20	13500	Not available	Not available	Site Specific	Site Specific.
2378TCDF (ng/kg)	0.31	480	Not available	Not available	Site Specific	Site Specific

*Analysis conducted of Newark Bay samples by NJ Maritime Resources

High Technology

High technology initiatives include employment of techniques which will reduce or eliminate sedimentation in the navigation channels and berths, decontamination technologies which remove the contaminants from the excavated dredged materials, in-situ remediation technologies, the Toxics Trackdown Plan being executed by the New Jersey Department of Environmental Protection, air quality monitoring programs to ensure that all of our upland beneficial use projects meet human health and environmental standards, and harbor modeling which will allow us to better understand the dynamics of our Harbor.

Low Technology

Low technology projects include the processing and use of contaminated and non-contaminated dredged materials for landfill operations and closure, hazardous site remediation projects which utilize both clean and contaminated dredged materials for capping, transportation projects in which dredged materials are processed to create manufactured soil for berms, grading, and fill, and the Pennsylvania Mines Reclamation Project which utilizes processed dredged materials to reclaim strip mines in Pennsylvania while reducing and eliminating acid leachate from those mines.

A full description of each of the technologies currently being employed or about to be employed in New Jersey is contained in Appendix 1.

Traditional Approaches

Traditional projects utilize clean dredged materials for remediation of the former ocean disposal site, removal of dredged materials from the Harbor in an environmental dredging program, utilization of in-water CDFs for placement of contaminated dredged materials, and the use of existing upland dredged material disposal facilities for multi-use projects.

Beneficial Use of Contaminated Material

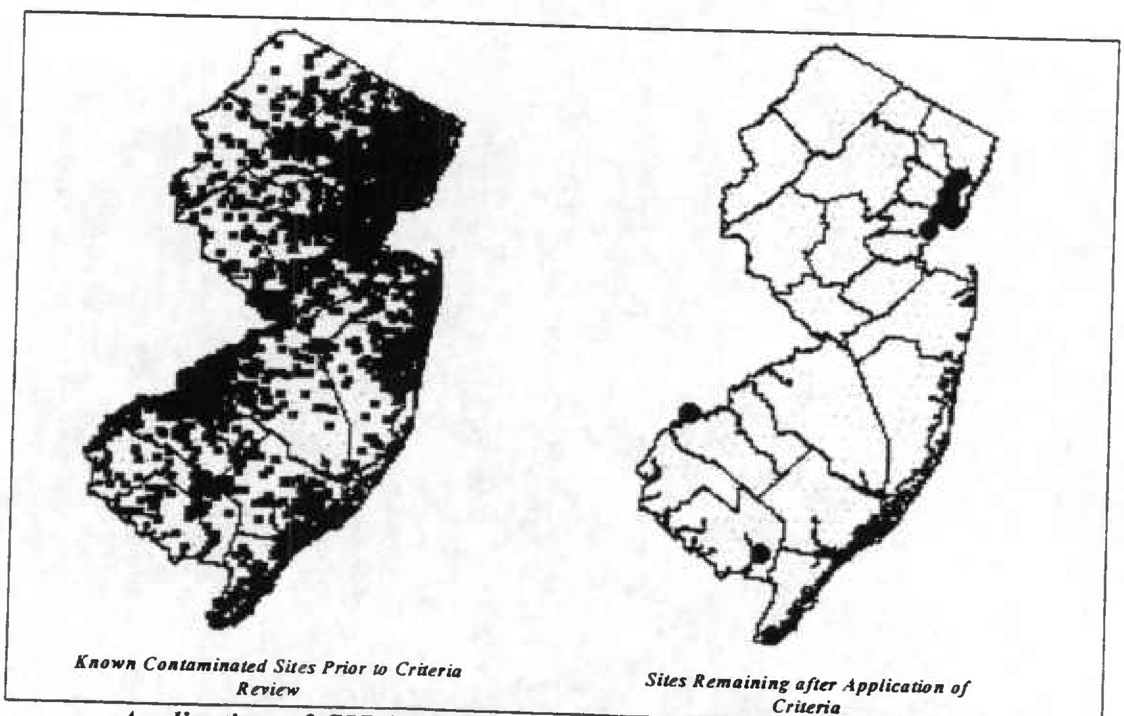
While upland CDFs are available in other parts of the State of New Jersey, no such facilities exist in the Port of New York and New Jersey. Redevelopment of brownfields and proper closure of landfills presented the most obvious opportunities for beneficial use of dredged materials. The first priority for the Port was to develop upland beneficial uses for dredged materials in construction, site remediation and landfill operations. However, the negative public perception created by significant media attention to contaminated dredged materials in New York Harbor resulted in an immediate obstacle to general use of dredged materials for beneficial purposes. This is true even though some of the contaminated dredged materials would meet the residential clean-up standards in the State of New Jersey, and all dredged materials would meet most non-residential site clean-up criteria. Regardless, a formula was needed which would provide the necessary public confidence that contaminated dredged materials would not be found in "my backyard."

The "formula" for beneficial use of dredged materials took the form of a list of criteria, established by combining both practical considerations and the Governor's policy against use of dredged materials near residential areas. Sites were plotted and, utilizing predicted volumes of contaminated and non-contaminated dredged materials proposed for dredging over an eight year period in the Port of New York and New Jersey, NJMR staff were able to identify sufficient capacity to satisfy disposal requirements. These sites for placement of dredged materials had to be close enough to waterways and roadways to allow cost effective access, yet far enough from schools, houses of worship, and residential areas to provide a buffer. The best sites were determined to be those that had previously been industrialized (brownfields) or solid waste landfills. Only sites greater than 40 acres were considered economically viable.

While development of the formula was relatively straightforward, a list identifying sites meeting these criteria had never been developed. Utilizing the GIS developed by NJDEP, maps of the closed and/or abandoned solid waste landfills and known contaminated sites in New Jersey were made using Arcview software. Inputting coverage of land use, navigable waterways, residential areas and houses of worship allowed NJMR to perform a spatial analysis that resulted in identification of the sites which would meet strict criteria. The result of this analysis is reflected in Figure 5.

During the time that NJMR was developing a list of viable sites, an unrelated legislative approach was being developed that would encourage redevelopment of brownfield and landfill sites throughout the State. Landfills were typically identified as those which were "orphan" landfills or former landfills where there was insufficient funds to reopen and close them in accordance with current standards. Brownfields were identified as any commercial or industrial site that is currently underutilized and where there has been or suspected to have been, a discharge of a contaminant. Legislative initiatives generally provided for liability protection for those who would remediate, tax incentives for remediation, reimbursement for a portion of clean-up costs, paid innovative clean-ups, protection from third party claims, and lessor/successor protection. This legislation provided the protections necessary for private investors to come forward and propose plans for the use of dredged materials in redevelopment projects.

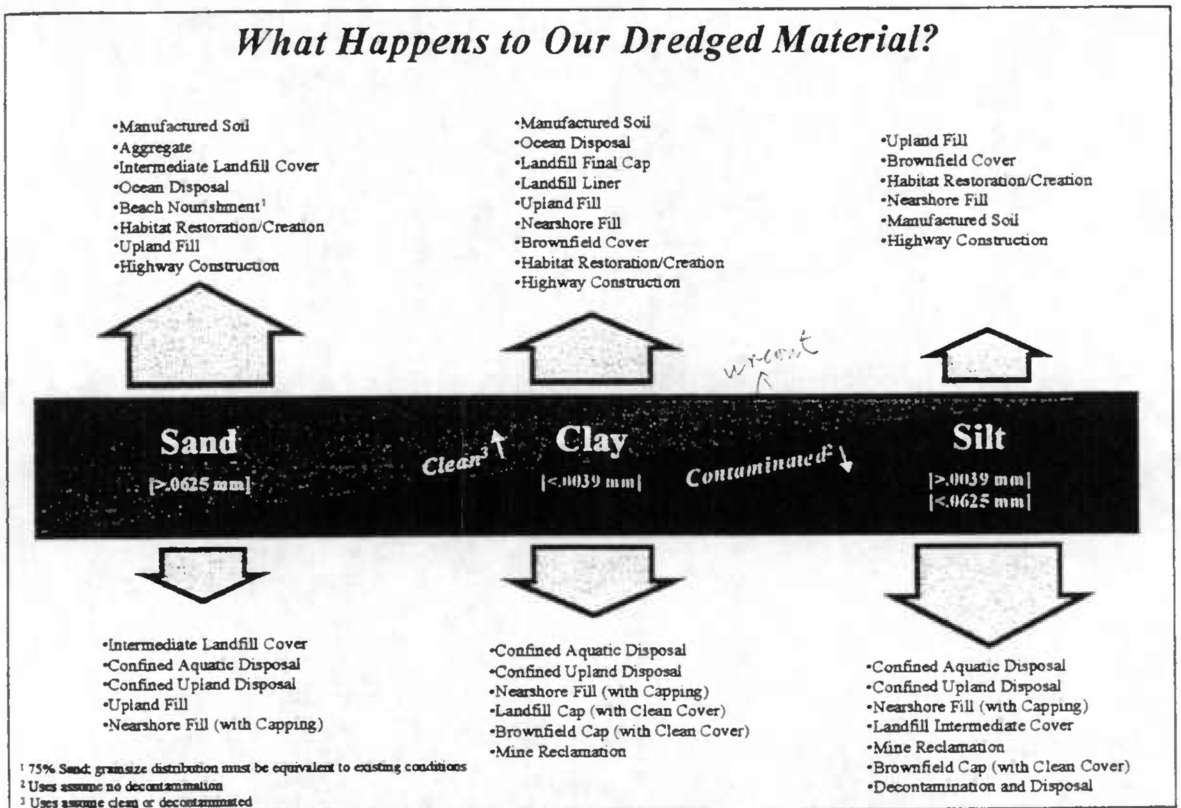
Another effort undertaken by NJMR was the development of a database of dredging projects throughout the State, and the annual projected volume of dredged materials that would require management. Information on capacity available at dredged materials management areas was also added to the database. This database, integrated with the spatial analysis performed using GIS, allowed NJMR to demonstrate available capacity for all dredged materials in the Harbor through 2005, with ample new sites for additional capacity which may be explored both publicly and privately.



Application of GIS for Screening Known Contaminated Sites List
Figure 5

Processing Facilities

While the private sector stepped up to the plate to develop beneficial use of dredged materials for upland activities, New Jersey continued to refine the potential uses for dredged materials as shown in Figure 6.

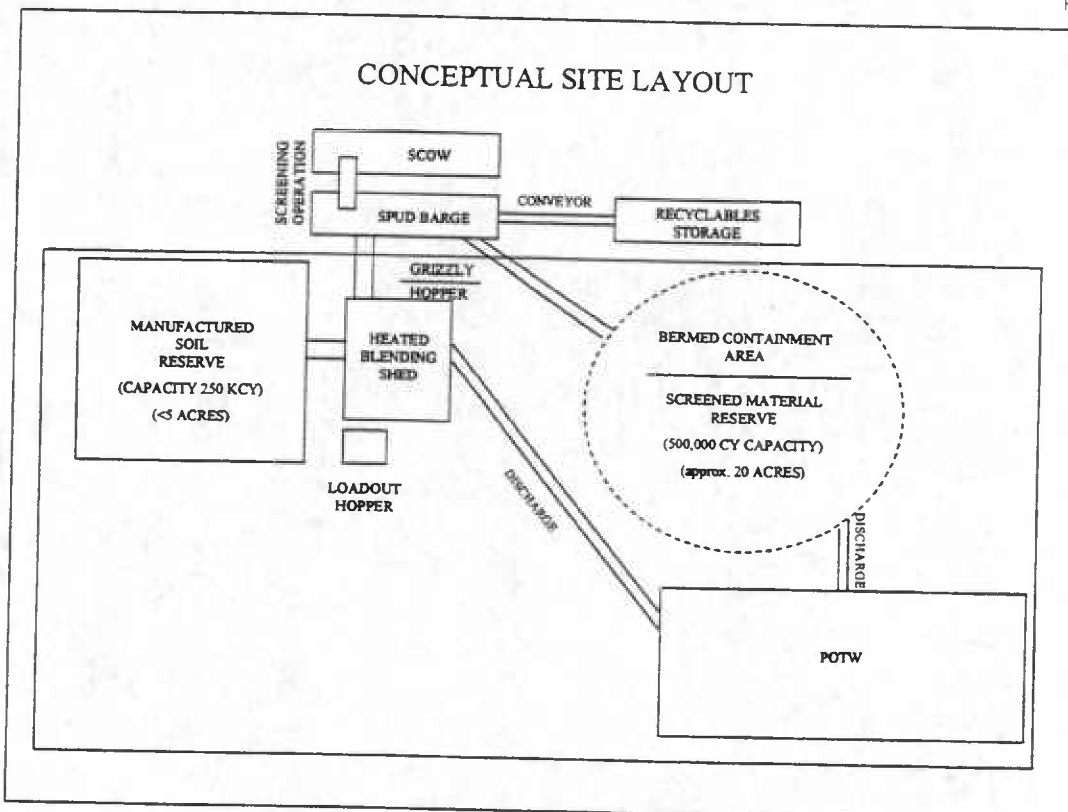


What Happens to Our Dredged Materials?
Prepared by NJ Maritime Resources
Figure 6

But the handling of dredged material proved to be a unique challenge. For example, dredged material from New York Harbor is 65% water, contains a high level of nutrients and is, of course, saline. It is not hard to picture the difficulty of dealing with sloppy, wet material in the payload bed of a truck or a rail gondola car. Moreover, environmental windows, which prevented dredging during certain fish habitat and migration times, made it difficult to develop a steady stream of dredged materials for various upland projects. This presented challenges to the private sector which needed that flow to profit. Furthermore, dredged materials in marinas and at terminals included large amounts of debris such as scrap metal, logs, pilings, and other objects which made the handling of the silt extremely difficult and expensive. Initially, the private sector tried pumping the dredged material over long distances to the site being reclaimed, then mixing the dredged material with admixtures to stabilize and create the necessary compaction rates for the intended use. Tires, bicycles, car doors, and other foreign objects destroyed the pumps in quick order. It is rumored that one private sector entrepreneur initially made more money recycling scrap metal than processing dredged materials.

In the end, new techniques for in-barge screening at dockside became the preferred method for ensuring that the dredged materials went though the process smoothly and expensive equipment was not destroyed by foreign objects. As the private sector learned from its investments, processing facilities became more economical, more efficient and mobile. Now they can be moved from location to location.

However, the State of New Jersey requires a facility which could guarantee processed, stabilized and enhanced dredged material for the landfill, site remediation, and transportation projects it was managing. Thus was born the idea of the State-owned, privately operated processing facility reflected in the design prepared by NJ Maritime Resources in Figure 7. This facility will process, stabilize and blend dredged materials to create manufactured soil at the rate of 500,000 cubic yards per year. The facility includes storage area to ensure that processed dredged material will be available twelve months of the year for ongoing State projects.



Processing Facility
Figure 7

Beneficial Use of Clean Dredged Material

In the Port of New York and New Jersey the United States Army Corps of Engineers, the Port Authority of New York and New Jersey, and the State of New Jersey are currently engaged in several significant deepening projects. The Kill Van Kull, which is the major waterway leading to the terminal facilities located in Port Newark and ElizabethPort, is currently being dredged to 45 feet. The Arthur Kill, which leads to many of the petroleum facilities in New Jersey as well as Port Authority terminals at Howland Hook on Staten Island, is scheduled to be deepened to 41 feet. Port Jersey Channel on the upper New York Bay will be dredged to 41 feet starting this summer, and a study is currently underway to deepen channels to 50 feet.

Collectively, these projects will produce millions of cubic yards of clean dredged material which can be utilized for a number of beneficial purposes. Rock is currently the subject of competition for various artificial reef and shoreline protection programs. Clean silt and sand will be utilized to help restore the Historic Area Remediation Site by capping the contaminated materials which had been deposited for more than 80 years in that 23 square mile area.

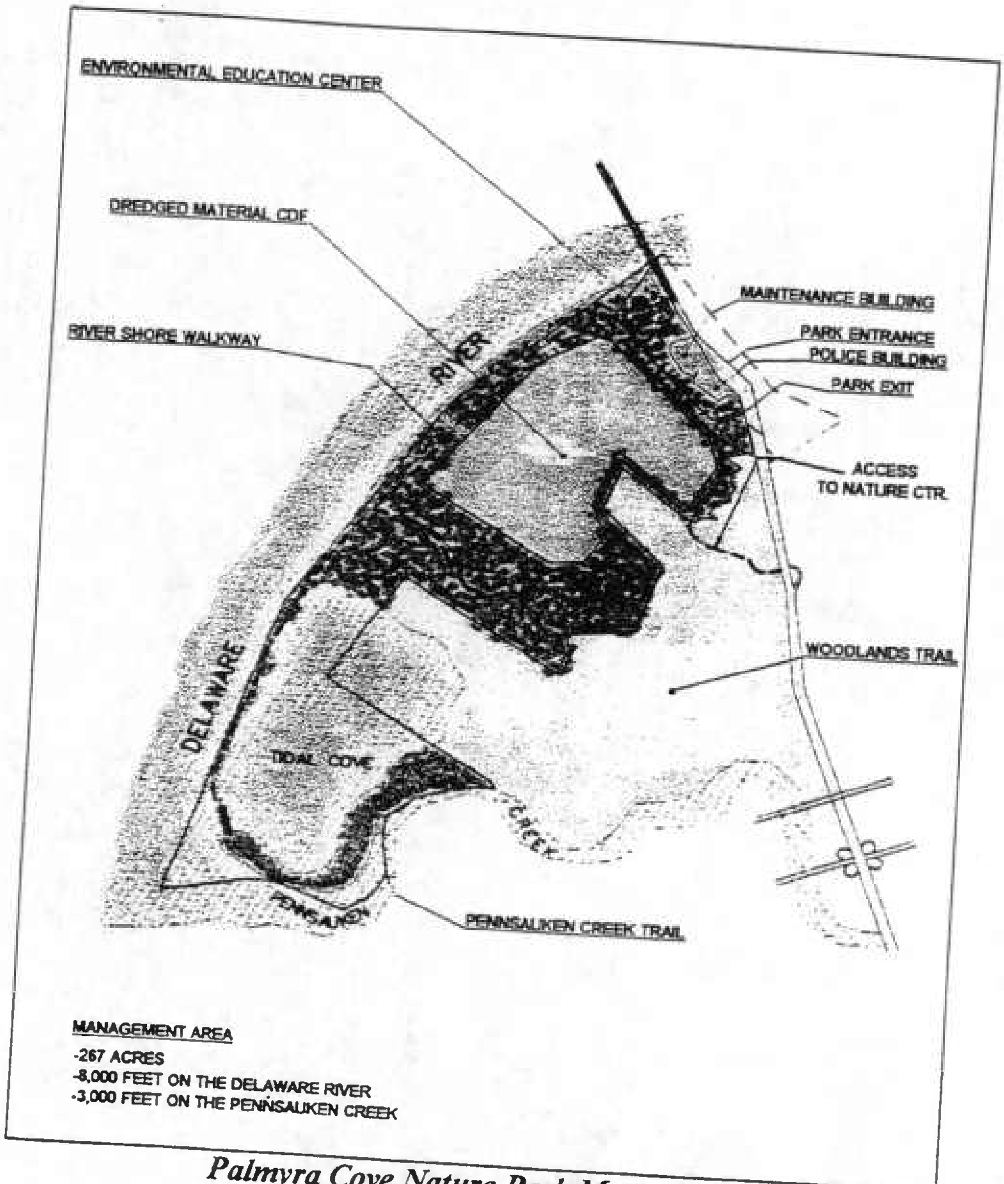
The most unique of these projects is the dredging of almost 10 million cubic yards of red/brown clay. This material has a general permeability rating of 10^{-7} or 10^{-8} making it a perfect capping material for the proper closure of orphan landfills in and around New Jersey's waters. So New Jersey has embarked upon a major demonstration project utilizing red/brown clay to cap abandoned landfills and construct slurry walls, preventing contaminated leachate from running into the Harbor. It is estimated that each improperly closed landfill discharges up to 400,000 gallons of contaminated leachate per acre into the Harbor annually. Thus New Jersey's red/brown clay program will serve several noble purposes: dredging navigation channels, properly closing abandoned landfills, and pollution prevention. The first demonstration project will start this summer and the program is expected to be replicated throughout the State of New Jersey at both abandoned and operating landfills.

The clay can also be utilized to provide a solid cap over the contaminated areas at the HARS and, if the material is not proven to be a good fit for habitat development, it could be further capped with clean dredged materials to provide the necessary habitat.

Confined Disposal Facilities-Multiple Use

As noted several times in this report, upland confined disposal facilities are in operation throughout the State of New Jersey. However they are traditional CDFs and they have become the subject of intense local public debate particularly with the deepening of the Delaware River. That project will excavate some 33 million cubic yards over several years and will require the continued use of a number of existing CDFs as well as the construction of new ones. Opposition to many of these facilities has increased in recent years as the fear of exposure to "contaminated materials" has heightened. While this fear may be misplaced regarding the Delaware River Project, New Jersey has developed an extremely active approach to the continued use of its existing facilities as well as the development of new ones.

By creating multiple-use facilities, New Jersey expects to educate individuals on the benefits of dredging through direct use of those confined disposal facilities for other purposes. The Palmyra dredged materials disposal facility on the Delaware River is the premiere example as shown in Figure 8. This unique facility was developed by a partnership of Burlington County officials, the Burlington County Bridge Commission, NJDEP, and others to create a natural habitat, as well as a beneficial use facility for storage and dewatering of dredged materials.



Palmyra Cove Nature Park MasterPlan
Designed by ACT Engineers
Figure 8

Facility plans include boardwalk trails, wildlife observation decks, shore access, fishing facilities, a nature preserve, an environmental education center, an education program on the necessity and benefits of dredging, and picnic areas. Moreover, the dredged materials deposited on this site will be mined for beneficial use projects throughout Southern New Jersey. In fact, materials from this site already have been utilized for construction of the entertainment amphitheater in the City of Camden. All future CDFs will be analyzed for the purpose of developing multiple use benefits for the local citizenry.

In the meantime, New Jersey Maritime Resources has embarked on a multi-faceted education program. Working with the New Jersey State Chamber of Commerce, the New Jersey Business and Industry Association, the New Jersey Alliance for Action, the Regional Business Partnership, the International Longshoremen's Association, the New York Shipping Association, terminal owners and others, a series of classroom education programs, media initiatives, and public speaking activities have been developed to remind the citizens of the benefits of our maritime industry and to ensure that the information that is provided is accurate and appropriate.

Planning Initiatives

Among the recommendations of the Governor's Dredged Materials Management Team, and the provisions of the Bi-State Joint Dredging Plan was the requirement for a careful examination of existing dredging requirements and a concerted effort to minimize those requirements. Currently, in the Port of New York and New Jersey, the US Army Corps of Engineers, the Port Authority of New York and New Jersey and the two States are conducting a Harbor Navigation Study to determine the appropriate depths for the existing channels in the Harbor. While the study is expected to result in the deepening of certain channels, it may also identify those channels which justify only current depths or even reduced maintenance.

New Jersey has also embarked upon an ambitious channel optimization plan which reviews each channel to identify opportunities for redesign which will reduce the amount of construction and maintenance dredging. Even public notices by private applicants for dredging permits are scrutinized closely to identify future dredging requirements and to encourage the development of comprehensive maintenance dredging plans for those facilities.

Probably the most significant study in New York Harbor is the Toxics Reduction Workplan developed by New Jersey to implement the contaminant trackdown and reduction goals of the Harbor Estuary Plan. The purpose of this study is to identify the sources of contaminants of concern to the Harbor and to begin to abate those sources through a toxics reduction strategy of increased monitoring, site cleanup/closure and environmental dredging. While hot spots in surficial sediment chemistry can easily be identified, there is no sound method to predict the overall impact of remediation strategies on the quality of the dredged material. To address this shortcoming, the State of New Jersey, working closely with the State of New York and federal agencies, is developing a state-of-the-art contaminant fate and transport model. This mode will enable managers to predict the outcome of contaminant reduction strategies on the quality of dredged materials in the future. This will ensure that limited funds are utilized most efficiently to achieve the greatest environmental gain.

Commensurate with these studies, is a series of important habitat development/redevelopment and wetlands restoration projects currently under development. Toxics trackdown, natural resources restoration, and pollution prevention are the three legs of the stool that will ultimately result in sediments clean enough for any purpose or disposal methodology.

CONCLUSION

If any conclusion can be drawn from the multiple disparate efforts identified in this paper, it is that the key to success is political will, creativity, and commitment. The political will is evident in the State's determination to establish the necessary processes which ensure the success of a relatively complex series of initiatives.

Creativity is reflected in the broad scope of technological initiatives now being employed or developed throughout the State. Commitment is reflected in the extremely short period of time within which the State of New Jersey traveled the great distance between no dredging, no disposal, and no funding, to a full and comprehensive dredging regime, funding, and even excess disposal capacity for the near-term.

Also key to New Jersey's success was the decision to entrust economic development issues and environmental protection in the hands of dedicated professionals working in partnership to achieve a common goal.

In the past, dozens of initiatives and years of study, while ably done by highly competent technicians, were characterized by a singular lack of connectivity and leadership. Simply put, there was no single thread connecting them all and the political leadership was not focused on the issue. Crisis created focus and filled in the missing ingredients. Now we are presented with, not only a comprehensive approach, but a coordinated approach and an ability to access and integrate all of the programmatic information that the public and private sectors are developing.

New Jersey's multifaceted approach for meeting statewide dredging needs in the 21st century can be characterized as a program which allows for continued progress even if one or more facets encounter unforeseen obstacles. The remaining elements of the program will continue to sustain our maritime industry while fine-tuning is applied to the faltering segment. Just as dredging is a never-ending task, so too is continuous and diligent attention to every component in the package. The approach developed by Governor Whitman provides precisely that level of management.

– Landfill Elizabeth [illegible]

– unpermitted landfill

over 800,000 – [illegible] dm w/ lime kiln dust, fly ash & Portland cement – make into structural fill for a mall

– 5K [illegible] reclaiming brownfields

1.2 mcy – mix [illegible] in barge

– [illegible]

– [illegible] state [illegible]

abandoned mine

Consolidated [illegible] EPA mandate for [illegible] clean [illegible]

[illegible] lime kiln dust [illegible] mill

[illegible]

DOT [illegible] transportation - has soil washed been installation using amended D.M. - trying to get construction std.!

APPENDIX 1

High Tech Initiatives

- Turbo Jetting – An alternative strategy to dredged materials management is to prevent the settling of particles in berthing areas, thereby reducing or eliminating the need to dredge there. One way to accomplish this is by using a high volume jetting system to agitate the water near the sediment surface periodically, thereby preventing the settling of fine particles. The SCOUR™ system is a high volume, low velocity pump that pulls surface water through a pipe and directs it out across the sediment-water interface. Multiple units are installed in a series across a pierhead, and are turned on for a short period at the start of ebb tide during each tidal cycle. The resulting water flow carries the fine particles deposited during the last slack tide out of the berthing area with the outgoing tide. One such project is currently under development by NJMR.

  Entrainment of fish larvae and sediment resuspension are of concern to regulators regarding this technology. Therefore NJMR has worked extensively with the NJDEP to produce a monitoring plan to determine the impact, if any. Regardless of the outcome, a conceptual cost/benefit analysis will weigh the environmental costs of this technology versus other available management options before a final decision will be made.

- Pneumatic Barriers – A similar strategy sponsored by NJMR employs the use of a series of bubble walls which act to keep particles in suspension, and prevent the buildup of sediments in berthing areas. Air is forced through a series of pipes on the bottom of the berth, oriented to maximize disturbance of water in areas that typically have high deposition. These barriers have already proved effective in floatables control throughout the Harbor, but have not yet been demonstrated to be effective in the control of sedimentation. This system has the added benefit of increasing dissolved oxygen throughout the water column, encouraging aquatic life. Ironically, some operators have expressed concern that attracting aquatic life may result in increased macrofouling of pier structures and water intakes.

- Soil Washing – This decontamination technology is based on the same principles as a washing machine. Sediment is mixed with water in a slurry and agitated in large mixing vessels. Chemicals are added to aid in destruction of organics and dissolution of bonds tying contaminants to the sediment. The "washwater" is then decanted and treated using standard techniques. Clean sediment can then be beneficially used to manufacture topsoil, structural and non-structural fill, and capping/cover material as needed. Two such projects have been selected to participate in the NJMR Sediment Decontamination Demonstration, projected to commence this year. As with all decontamination technologies, extensive public outreach is necessary to ensure that citizen concerns are allayed.

- Thermal Destruction – This decontamination technology relies on high temperature rotary kilns to "bake" the sediments. Organic contaminants are destroyed by the heat and the metals are permanently incorporated into the physical matrix of the sediment. The resulting mineral matrix is then used as a base material for the manufacture of lightweight aggregate or blended cement. Two such projects have been selected to participate in the NJMR Sediment Decontamination Demonstration, projected to commence this year.

- Enhanced Mineralization – This decontamination technology, known as Georemediation™ enhances the natural process of attenuation of contaminants in sediments and soils. A proprietary mixture of catalysts is mixed with the sediments and allowed to react for up to 28 days. During this time the organic contaminants are broken down into non-hazardous forms and the metals are incorporated permanently into the crystalline matrix. A pilot and demonstration project are scheduled for this year as part of the NJMR Sediment Decontamination Demonstration.

- In-situ Remediation – Due to the potential environmental hazards posed by disturbing highly contaminated sediments in certain locations, the State of New Jersey has been searching for technologies to decontaminate sediments in place. Several techniques have been proposed and are in the bench-scale phase of testing. The most promising uses zero valence iron powder to catalyze the destruction of bonds between the sediments and the contaminants. A series of tubes containing the zero valence iron powder are placed directly into the contaminated sediments. Contaminants are then transferred to the iron powder within the tubes. The tubes are then removed and the highly concentrated pollutants are disposed of appropriately. NJDEP is conducting one such demonstration project that is funded by NJMR.

- Toxics Trackdown – One of the long-range strategies for dredged materials management in the Port depends on the reduction in the amount of dredged materials that require specialized management due to contamination. In order to effectively reduce the amount of contamination being added to the sediments, the sources of those contaminants must be defined and prioritized. The States of New Jersey and New York, working through the Harbor Estuary Program, have developed a cooperative monitoring program to determine the sources and magnitudes of contamination to the water, sediment and biota of the NY/NJ Harbor Estuary. New Jersey's Workplan is being implemented by NJDEP and funded by NJMR.

- Harbor Modeling – In order to develop an effective management strategy for contaminants in the Harbor, a comprehensive fine-scale contaminant fate and transport model must be developed. This model will need to take into account all the point and non-point sources in the Harbor along with the complex hydrodynamics and be able to predict the concentrations of contaminants of concern in water, sediment and biota over a multi-year timeframe. Data collected in the toxics trackdown program may be used to calibrate and validate this complex model. Efforts are underway to develop a Request for Proposals for this project.

- Air Quality Modeling – One of the persistent issues associated with the innovative use of dredged materials in the Harbor region is public perception of risk posed by contamination in the sediments. While individual projects have revealed no human health hazard, an extensive monitoring program is being developed to identify and quantify volatile and semi-volatile pollutants released into the air during dredged materials handling and placement operations. The chosen monitoring site will reference local ambient air quality as a point of comparison.

Fugitive emissions are also being assessed as part of a demonstration project on the use of dredged materials in transportation projects.

Low Tech Initiatives

- Landfill Operations – Dredged materials can be used in a variety of ways to facilitate operations at solid waste landfills. Silty dredged materials can be amended with sand, woodchips, or biosolids to create intermediate cover. Alternatively, dredged materials can be mixed with cement-based admixtures to provide fill and capping for closure operations. Other admixtures, including a recycled product made from shredded car interiors (Propat™), are currently under development. Because landfills are required to have leachate collection systems and other engineering and institutional controls, all but the most contaminated materials can be used effectively. Clean dredged material composed of consolidated heavy clays can be used as landfill liner material, as final cap, or in slurry wall construction.

- Site Remediation – One of the most successful uses of dredged materials is in site remediation activities. Contaminated sites frequently have either institutional or engineering controls, rendering them excellent for all but the most contaminated dredged materials. Usually the contamination on site is orders of magnitude greater than the contamination in the dredged material, which results in an immediate improvement in environmental conditions on the site when dredged materials are used. Dredged materials can be combined with admixtures to create engineered structural fill, nonstructural fill, slurry walls, and final cap depending on their physical characteristics.

  The first successful operation of this type, the ORION project in Elizabeth, NJ, proved to be an excellent learning experience for the industry. The issue of material handling was the most troublesome. The contractor had extensive problems with debris and pumping equipment. The eddy pump system originally employed was replaced with conventional bucket dredging. Screening for debris was accomplished by sifting material through a grizzly prior to entering the pugmill. Other issues included permitting and contracting. Due to the unpredictable nature of site remediation projects, public/private partnerships are essential for these projects to progress. The ORION project was successfully completed, a second project is underway in Kearny, NJ, a third site is fully permitted and a fourth project is in the permitting stage.

- Transportation Projects - The State of New Jersey is currently developing the use of dredged materials in transportation projects. A project is underway to develop engineering standards for the use of dredged materials in roadway embankments. Due to the high cost of fill in the metropolitan area, use of amended dredged materials may prove to be highly cost effective. Final topsoil cover and roadway materials will reduce or eliminate any potential for generation of contaminated leachate. Models are being developed to predict environmental impact from the use of dredged materials, if any. An important concern being addressed is variability in admixture ratios in the final product. Dewatering of raw dredged materials may be required to ensure uniformity of engineering properties.

- Beach Replenishment – One of the oldest uses of dredged materials is for nearshore operations. The use of clean sandy dredged materials for beach replenishment is encouraged and will be utilized in the Delaware River Deepening Project as well as a small beach and dune project in South Jersey being funded by NJMR. Replenished beaches are not only attractive to tourists, but they provide critical infrastructure protection for existing development and regional economic benefits.

- Mine Reclamation – There are numerous abandoned surface coal mines throughout the Commonwealth of Pennsylvania. Due to the extensive environmental damage caused by these mines, the USEPA has mandated that the Commonwealth of Pennsylvania close the mines and control acid leachate. One strategy for closure and remediation is through the use of processed dredged materials. NJMR recently funded a highly successful project demonstrating the effective use of dredged materials mixed with cement and ash to fill the old mines and restore the landscape to the original grade.

PROCEEDINGS

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DECONTAMINATION AND BENEFICIAL REUSE OF DREDGED ESTUARINE SEDIMENT: THE WESTINGHOUSE PLASMA VITRIFICATION PROCESS

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ABSTRACT

Operation of the New York/New Jersey Harbor requires regular dredging. The offshore dumping facility has been closed due to regulations on ocean dumping of contaminated sediments, forcing the Harbor to consider alternative treatment and disposal options. The current report describes development of the Westinghouse Plasma Vitrification Process for decontamination and beneficial reuse of contaminated sediments. Phase I bench testing characterized the sediment and provided verification that good quality glass could be prepared with addition of less than 15% fluxing agents. Kilogram quantities were prepared, and tested for decontamination efficiency; organics were destroyed to 99.9999% efficiency, and the product passed the TCLP leaching test for all heavy metals by several orders of magnitude.

Phase II pilot testing followed, including large-scale sediment pretreatment (screening, dewatering, and blending). Four metric tonnes (Mg) of pretreated Harbor sediment were melted at approximately 0.8 Mg/hour in a full-sized plasma melting reactor powered by a Westinghouse Marc-11 plasma torch. Processing characteristics were evaluated, and detailed heat and material balances were prepared, including offgas and wastewater characterization. All gaseous and liquid effluents met discharge requirements.

Pilot plant data were then used to prepare preliminary plant designs for a 76,000 cubic meter per year Demonstration Plant (100,000 yd^3/yr) and a 380,000 cubic meter per year full-scale facility. This study included material handling, pretreatment, vitrification, offgas treatment, and pollution control systems, and predicts an overall 99% reduction in waste volume compared to the original sediment. Preliminary costs were developed for the integrated sediment processing (including amortized capital), with a range between \$90 and \$120/Mg depending on the cost of electricity.

Finally, Phase III testing demonstrated conversion of an additional 1.4 Mg of vitrified sediment into commercial architectural tile, using technology developed by Futuristic Tile of Allenton WI. This tile represents a high-value product with a large potential demand, sale of which could more than offset all of the cost of sediment decontamination, even before credit is taken for a tipping fee.

KEYWORDS: Glass, tile, dredged material disposal, demonstration testing, process design.

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INTRODUCTION

Many of the major harbors in the United States have become contaminated with a wide variety of toxic chemical species as the result of industrial discharge, sewage, and spills from commercial ship traffic. Since routine dredging of many of these harbors is required to allow access to modern deep-draft commercial shipping, large quantities of contaminated sediments must be removed from the harbor bottoms and subsequently dealt with. Disposal of dredged sediments, once a simple process of offshore hauling and dumping in deep coastal waters, is no longer simple due to toxic contamination and increasingly stringent regulation of ocean dumping.

In the specific case of the New York/New Jersey Harbor (see Figure 1), ocean dumping at a site southeast of the harbor (the "Mud Dump") has been the primary alternative for sediment disposal since 1977. These sediments consist of a mixture of fine sand and silt, with some natural organic material. Toxic contaminants (both organic and inorganic species) are ubiquitous, however. The 1994 EPA Contaminated Sediment Management Strategy has defined contaminated sediments as those materials "which contain chemical substances at concentrations which pose a known or suspected threat to aquatic life, wildlife, or human health." Much of the sediment quality in the Harbor is poor, due to pollutant inputs from the Hudson, Hackensack, and Passaic River watersheds, from atmospheric deposition, and from industrial waste water discharges and combined sewer overflows. Although much progress has been made in the reduction of point sources of new pollutants, large inventories of toxic materials still exist which feed into the Harbor. These especially include sewage residues in the Gowanus Canal, industrial and petroleum wastes in Newtown Creek, and a variety of industrial sites along the Passaic River (including the notorious Diamond Alkali site, formerly used for manufacture of Agent Orange, and the source of much of the dioxin and furan contamination in the Harbor).

Sediments have been classified since 1977 by the Marine Protection Research and Sanctuaries Act (MPRSA) according to their degree of contamination. Preliminary estimates in 1977 indicated that up to 40 percent of New York/New Jersey sediments would classify as MPRSA Category III (the highest level of contamination), and would not be permissible for ocean dumping (although most of the sediment does not qualify as EPA Hazardous Waste when considered for land disposal). The presence of dioxins and furans is especially difficult to deal with because of stringent bioaccumulation regulations. Since that time, the Mud Dump has been closed to further dumping.

Agencies responsible for Harbor management are therefore faced with rapidly escalating costs to maintain harbor access, since sediments must be disposed of by some alternative (and invariably more expensive) procedure. Options include:

- Disposal within the Harbor in subaqueous pits, which is allowed within environmental regulations, but is politically sensitive.
- Landfilling, with cost appropriate to the level and type of contamination. The large volume of material to be disposed of, the costs of landfill construction and maintenance, and the general unavailability of suitable land near urban New York City all make this approach very expensive.

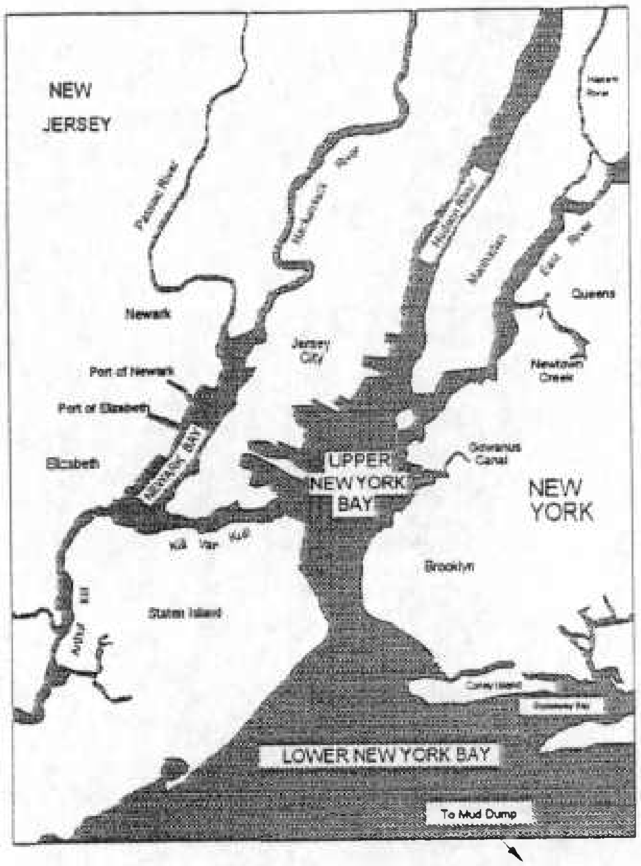

Figure 1 - New York/New Jersey Harbor

- Stabilization by addition of some additive such as cement to reduce contaminant leaching, followed by surface disposal. This approach provides some degree of beneficial reuse, since stabilized sediment may be used for land development applications such as filling spent mines or capping of industrial "brownfield" sites.
- Decontamination by some alternative technology, preferentially including reuse for some beneficial purpose to partially or completely defray the cost of decontamination, and to obviate the need for waste disposal.

Decontamination of harbor sediments is complicated by the *very* large volume of sediments involved (roughly four million cubic meters annually in the case of the New York/New Jersey Harbor), and the complex suite of contaminants which may be present. Sediment from New York/New Jersey Harbor contains low concentrations of a wide variety of heavy metals (including Ag, Cd, Cr, Pb, Sb, Se, Tl, Be, As, Hg, and Zn). Any effort to decontaminate the sediment must therefore contend with removal of a diverse range of inorganic chemical species of widely varying oxidation state, chemical solubility, high-temperature volatility, and concentration.

Sediments also contain an even broader range of organic compounds including pesticides from farmland runoff, hydrocarbons from oil spills, industrial solvents, polyaromatic hydrocarbons (PAH's), polychlorinated biphenyls (PCB's), dioxins, and furans. These compounds range from easily extracted or thermally desorbed light hydrocarbons to very stable and essentially nonvolatile dioxins. The wide spectrum of physical-chemical properties of these organic species make both thermal and chemical extraction processing challenging. Toxic microbiological agents such as *pseudomonas*, *streptococcus*, *clostridium*, and fecal *coliform* may also be present, further complicating handling and treatment.

THE WESTINGHOUSE PLASMA DECONTAMINATION PROCESS

Given the difficulty of designing a process for physically or chemically separating all of these toxic contaminants from the vastly larger body of non-toxic mineral sediment, an alternative process for sediment decontamination was investigated and developed by Westinghouse Electric Corporation. This process provides for near-quantitative destruction of toxic organic and microbiological contaminants, immobilization of heavy metals, and conversion of the sediment into a high-quality glass material suitable for a variety of beneficial reuse, specifically including production of architectural tile. This development effort was supported by the EPA Region 2, through an appropriation from the Water Resources Development Acts (WRDA) of 1992 and 1996. The program was administered through Brookhaven National Laboratory (BNL), and overseen by the Brookhaven Rensselaer Environmental Partnership/Multi-State Alliance (BREP/MSA).

The process is based on Westinghouse Plasma Torch technology. Air is passed through the electrodes of the torch, superheating it to temperatures approaching 5000°C. Harbor sediment, screened and partially dewatered, is injected into the plume of the torch, heating it extremely rapidly. All organic species are combusted and destroyed, even refractory organics such as dioxins. The mineral phases in the sediment are heated to the melting point, and fuse into a homogenous glassy liquid. Fluxing agents such as lime and soda ash may be added to adjust the viscosity of the final melt. The molten glass is then quickly quenched to maintain the vitreous characteristics, incorporating and trapping heavy metals in the glass matrix in a highly leach-resistant composite. The final quenched glass product is then suitable for a wide variety of applications, ranging from low value products such as road aggregate and sandblasting grit, to high value products such as glass fiber or sintered architectural tile.

DEVELOPMENT OF THE PLASMA VITRIFICATION PROCESS

Development of this process has occurred over a 2½-year period, beginning late in 1996 with a Phase I effort to characterize the Harbor sediment and determine the feasibility of converting it to a leach-resistant glass with complete destruction of toxic organics. Characterization studies were carried out at the Westinghouse Science and Technology Center (WSTC) in Pittsburgh PA. Whereas many decontamination processes would focus only on the concentrations and distribution of contaminant species, the vitrification process also required knowledge of the mineral oxide composition of the sediment in order to formulate a strategy for vitrification (conversion to glass).

Table 1 presents results of both X-ray diffraction analysis (for mineral phases) and chemical analysis (for metals). The bulk of the sediment consists of sand (quartz) and clay minerals, with iron silicate. A large quantity of organics is also present, with 9 to 10% total carbon and substantial sulfur. The organic content provide the dried sediment solids with considerable

Table 1 - Mineral and Metals Analysis for New York/New Jersey Harbor Sediment

Element or Mineral Phase	Chemical Formula	Weight Percent (Dry Basis)
Quartz	SiO_2	66 to 75
Muscovite (Mica)	$K_2O{\bullet}2MgO{\bullet}Al_2O_3{\bullet}8SiO_2{\bullet}2H_2O$	11 to 15
Kyanite	$Al_2O_3{\bullet}SiO_2$	3 to 13
Hydrated Aluminum Silicate	$19Al_2O_3{\bullet}173SiO_2{\bullet}9H_2O$	6 to 7
Cronstedtite	$4FeO{\bullet}2Fe_2O_3{\bullet}3SiO_2{\bullet}2H_2O$	4 to 6
Organic Phase	Petroleum residues	3 to 13
Silicon	Si	20.7 to 25.0
Carbon	C (organic plus inorganic)	8.9 to 10.3
Aluminum	Al	5.5 to 5.7
Iron	Fe	4.5 to 5.0
Sodium	Na	1.2 to 1.3
Potassium	K	1.7 to 2.1
Sulfur	S	0.5 to 1.8
Calcium	Ca	1.2 to 1.4
Magnesium	Mg	1.0 to 1.3
Titanium	Ti	0.5
Copper	Cu	0.2
Zinc	Zn	0.2

heating value, measured at 3.7 to 4.5 MJ/kg (which improves the overall efficiency of the plasma vitrification process). Sodium chloride is also found, primarily from brine in the estuarine Harbor water. Analyses are presented on a dry basis; as-dredged sediment was found to be 30 to 35% solids by weight.

A detailed contaminants analysis was also performed on the sediment, providing a baseline for assessing the efficacy of the decontamination process. Results are shown in Table 2. Included in the organic phase (7.3% total organic carbon) are nearly 30 regulated PAH species, as well as a range of chlorinated pesticides. Total dioxins are measured at 6.5 ppb, and ten toxic heavy metals are present above detection limit.

Given the mineral composition shown in Table 1, the next step in developing the process was to establish the design glass formulation. The sediment as shown is high in alumina and silica, which when melted alone would form a viscous melt with high fusion point. Handling of the molten product was therefore expected to be difficult unless the viscosity were reduced. Modeling of the melt viscosity was therefore done using the method of Riboud *et al.* (1981), in which the melt viscosity η (Pa-sec) is represented by the following function of temperature T (°K):

Ter
Pro

Table 2 - Toxic Organic Compounds in New York/New Jersey Sediment

Contaminant	Weight Fraction (Dry Basis)
Sulfides	7.8E-3
Total Organic Carbon (TOC)	7.3E-2
Polychlorinated Biphenyls (PCB's)	5.2E-6
Chlorinated Pesticides	4.6E-7
Polyaromatic Hydrocarbons (PAH's)	1.2E-4
Total Dioxins	6.5E-9
Total Furans	1.7E-8
As	3.3E-5
Cd	3.7E-5
Cr	3.7E-4
Cu	1.2E-3
Hg	1.3E-6
Ni	3.0E-4
Pb	6.2E-4
Zn	1.7E-3

$$\eta = A\ T\ exp(B/T) \qquad (1)$$

$$ln(A) = -17.51 - 35.76\ \Sigma_i\ x_i\ (Al_2O_3, Cr_2O_3) + 5.82\ x(NaCl) + 7.02\ \Sigma_i\ x_i(Na_2O, Na_2S, K_2O) + 1.73\ \Sigma_i\ x_i(CaO, MgO, FeO, MnO, PbO, ZnO, CuO) \qquad (2)$$

$$B = 31140 + 68833\ \Sigma_i\ x_i(Al_2O_3, Cr_2O_3) - 46351\ x(NaCl) - 39519\ \Sigma_i\ x_i(Na_2O, Na_2S, K_2O) - 23896\ \Sigma_i\ x_i(CaO, MgO, FeO, MnO, PbO, ZnO, CuO) \qquad (3)$$

where x_i is the mole fraction of each species i. The balance is assumed to be SiO_2.

For ease in handling, the target glass composition was designed to exhibit a pour viscosity of less than 100 Pa-sec at 1250°C, a temperature readily obtained within a plasma-fired shaft furnace. To accomplish this goal, a mixture of fluxing agents were added to the sediment. The viscosity was initially modeled using Equations (1) through (3) to identify predicted melt viscosities, and then coupon melt samples were prepared to confirm that the composition formed a fully vitreous product (entirely glassy, with no precipitated crystalline inclusions). Coupon tests of twelve candidate glass compositions were carried out with the assistance of Savannah River Technology Center (SRTC), at the Savannah River National Laboratory, Aiken SC. It was determined that test Composition #7 containing 83.2% (dry basis) Harbor sediment, 11.2% CaO flux (provided as slaked lime), and 5.6% Na_2O flux (provided as soda ash, Na_2CO_3) exhibited both the desired melting point (see Figure 2) and a fully vitrified final product. The resulting glass was lustrous and black (deep green-gold in thin cross-section), contained a high loading of sediment, and used a high ratio of lime to soda ash to achieve fluxing (soda ash being the considerably more expensive of the two fluxes).

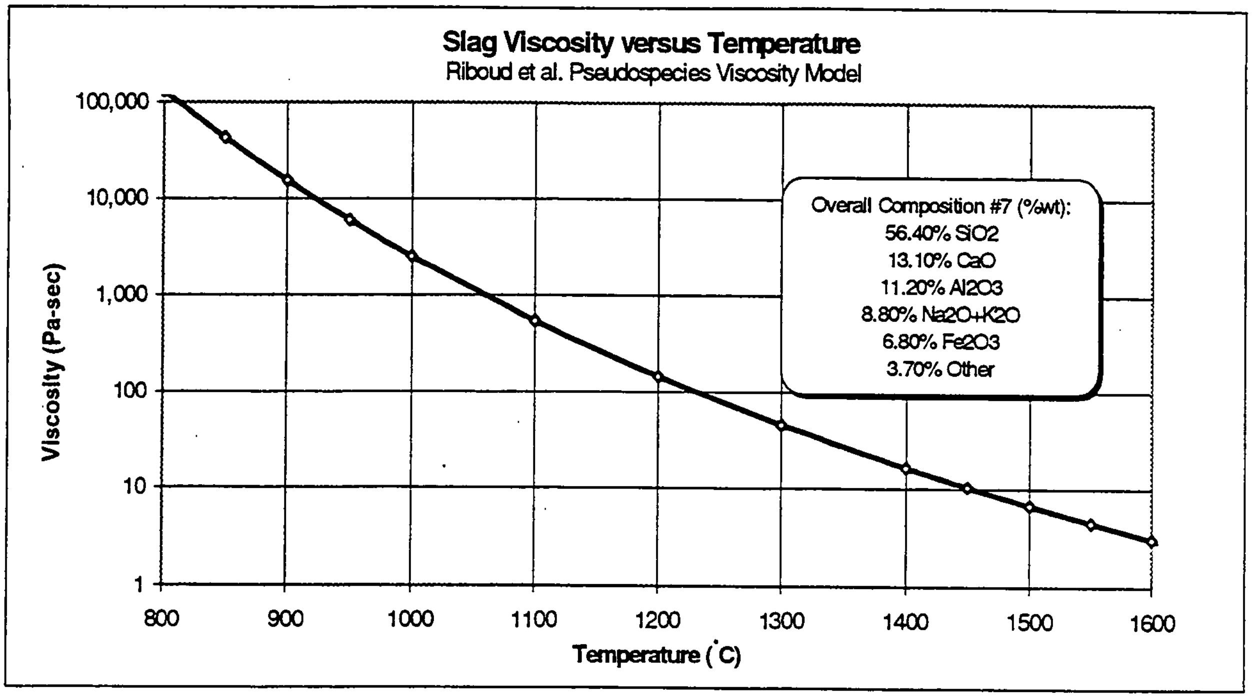

Figure 2 - Computed Viscosity-Temperature Profile for Target Sediment Glass Composition

CHARACTERIZATION OF THE PRODUCT GLASS ENVIRONMENTAL QUALITY

Larger samples of sediment-derived glass were then generated to permit leach testing and detailed analysis for various toxic contaminants. To produce 10 kg of glass for this purpose, samples of sediment were first rinsed with fresh water to remove the bulk of the salt, and then dried at low temperature (to minimize evolution of volatile organic compounds, or VOC's). Dried sediment solids were then blended with flux, and delivered to Ferro Corporation in Cleveland OH for melting in 1 kg crucible batches. Melt testing was carried out over a range of temperatures from 1250 to 1450°C. Approximately 12 kg of glass were produced in this way, with 7.5 kg shipped to Brookhaven National Laboratory for detailed analysis.

Analysis was done at BNL for 121 organic compounds. Of these, only five were identified in the final product above detection limit. As shown in Table 3, destruction efficiencies were at least 99.8% for all organic categories, 99.9999% overall, and exceeded 99.99% for dioxins, believed to be the most refractory (heat resistant) of all of the compounds present. Leach of the glass product was also carried out, testing using the U. S. EPA Toxic Characteristic Leaching Procedure, or TCLP. Of all the metals analyzed for, only lead was detected in the TCLP leachate; the concentration was only between 2 and 5% of the EPA regulatory limit.

Table 3 - Decontamination Efficiencies for Sulfides and Toxic Organic Species

Chemical	Units	Product Glass	Untreated Sediment	Destruction Efficiency
Total Organics	g/kg	0.048	119.0	99.9999%
Sulfides	mg/kg	0.50	7,800	99.994%
PCB's	µg/kg	1.28	5,260	99.976%
Pesticides	µg/kg	<Detection Limit	462	>99.35%
PAH's	µg/kg	259	137,000	99.81%
Dioxins	ng/kg	<Detection Limit	6,440	>99.99%
Furans	ng/kg	0.41	16,480	99.78%

SEDIMENT PRETREATMENT

Given the success of the bench testing program, a plant design material and energy balance was then developed, as shown in Figure 3. In addition to defining the optimum plasma processing conditions and the glass-flux formulation, consideration was given to pretreatment of the sediment. Ideally, all of the salt would be removed from the sediment prior to vitrification, since NaCl is volatilized during the melting process and provides both a corrosion problem and the potential for solid salt deposits in the offgas system. The first step in the pretreatment process is therefore washing the sediment. Fresh water is added during a prescreening process, which removes large debris and ensures that no particles pass through which could clog the sediment injection nozzle into the plasma melter. Note that for New York/New Jersey Harbor sediment exhibits a very fine particle size distribution, with 98.4% less than 1 mm, 96% less than 400 µm, and 50% less than 10 µm. Less than 1.6% of the total dredged material would therefore be rejected due to excessive particle size (greater than one millimeter), most of which consists of sticks, leaves, and various artificial debris.

Once rinsed substantially free of salt, the sediment is then be partially dewatered. Since electrical power is the largest single cost in the plasma vitrification process, it is beneficial to remove as much water as possible prior to injection into the melter. If too much water is extracted, however, the sediment becomes dry and clay-like, and is very difficult to pump into the melter. Viscosity measurements and pumping tests determined that approximately 50 to 55% solids represents the upper practical limit to slurry pumping. This solids concentration can readily to achieved by large, industrial plate and frame filtration equipment. Agglomeration of the sediment fines is enhanced by addition of $Ca(OH)_2$ (which later calcines to CaO, providing part of the flux). The dewatered sediment is then blended with the balance of the fluxing agents CaO and Na_2CO_3, and fed to the melter.

The material balance for major streams in Figure 2 is presented in Table 4. The sediment processing rate is 63 Mg/hr, equivalent to the program target of 500,000 cubic yards (382,000 m^3) dredged sediment per year. Chemical feeds to the plant (besides air and water) include:

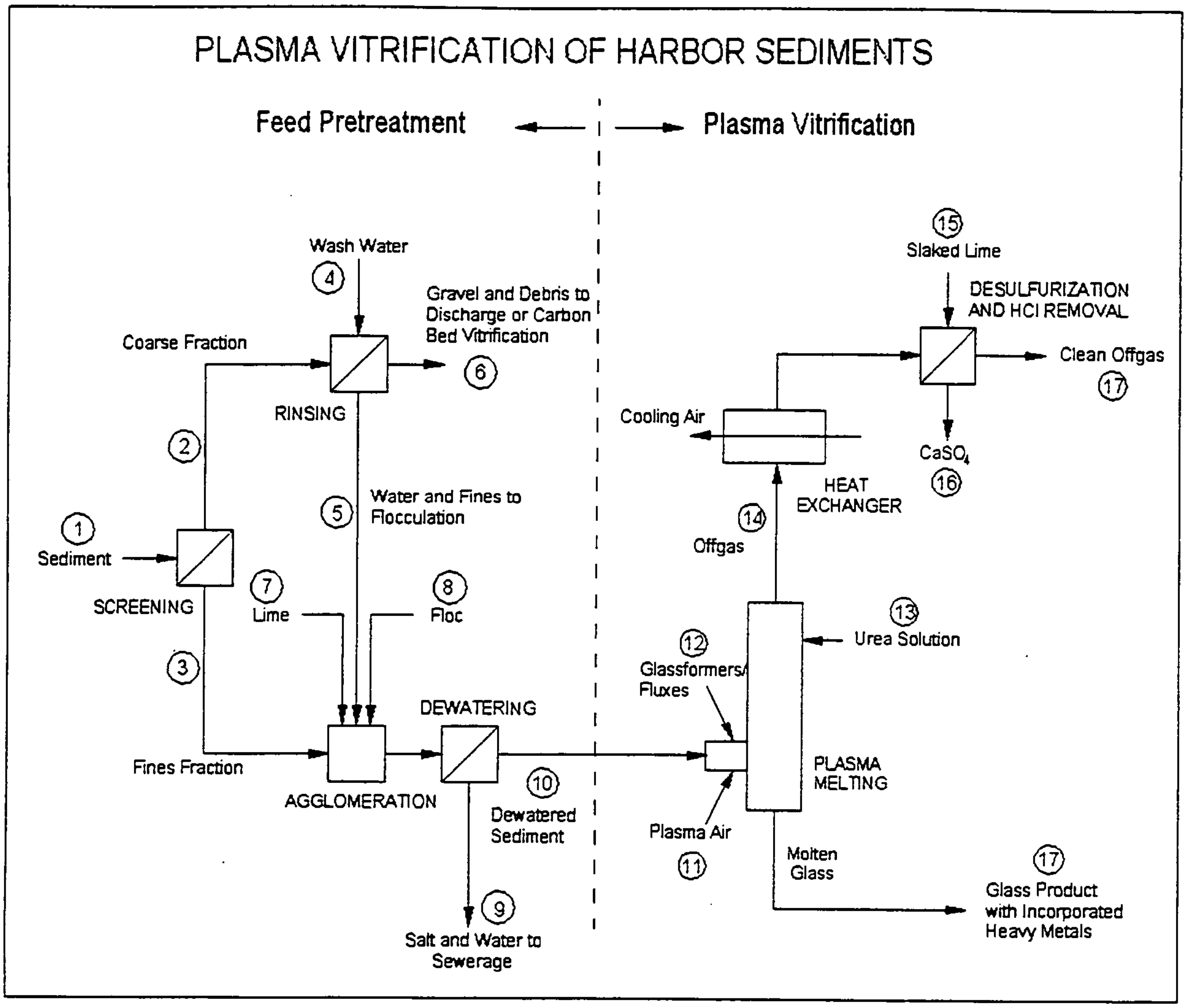

Figure 3 - Process Flow Diagram for Sediment Pretreatment and Vitrification Plant

- 1.0 Mg/hr $Ca(OH)_2$ (hydrated lime) for agglomeration of fines prior to filtration,
- 0.01 Mg/hr of organic flocculating agent,
- 4.3 Mg/hr of Na_2CO_3 (soda ash) for flux,
- 1.3 Mg/hr of CaO (slaked lime) for flux,
- 2.0 Mg/hr additional slaked lime for sulfur emissions control, and
- 0.07 Mg/hr of urea for NO_x control.

The process produces 21.5 Mg/hr of molten glass, which is quenched quickly and granulated.

As shown above in Figure 3 above, the overall process produces very little solid waste. The total waste which must be disposed of consists of only 1% of the original sediment volume. A small fraction of the sediment is rejected as oversize; this material would probably be landfilled, consisting primarily of debris and gravel rinsed of surface contamination. Offgas treatment consists of dry absorption for removal of sulfur oxides and acid gases (HCl), generating a small calcium sulfate/sulfite stream to landfill. Note that coal-fired power plants generate much larger quantities of the same $CaSO_4/CaSO_3$ scrubber waste, which is routinely landfilled.

Table 4 - Material Balance for 500,000 yd^3/yr Sediment Pretreatment and Vitrification

	Stream	Flowrate (kg/hr)	Notes
1	Dredged Sediment	62,730	33%wt solids
2	Oversize Fraction	1,820	Particle size ≥1 mm; also 33% solids
3	Fines Fraction	60,910	Particle size <1 mm
4	Rinse Water	4,540	
5	Rinse Water and Fines	5,330	
6	Washed Debris	1,030	Assumed 1.6%wt of feed
7	Hydrated Lime [$Ca(OH)_2$]	1,150	Agglomerating agent at 0.12 kg/L
8	Flocculating Agent	10	Added at 1 gm/L of slurry
9	Rinse Water to POTW Sewerage	141,900	0.2%wt solids (mostly NaCl)
10	Dewatered Sediment	35,120	60%wt solids
11	Plasma System Air	41,800	Includes 5,620 kg/hr for pneumatic transport of fluxing agents
12	Fluxing Agents [Soda Ash + Lime]	5,610	77%wt Na_2CO_3 + 23%wt CaO
13	Urea Solution [$CO(NH_2)_2$]	1,360	5.0%wt solution for NO_x control
14	Melter Offgases	59,750	0.4%wt solids carryover
15	Slaked Lime [CaO]	1,990	22%wt slurry for sulfur control
16	Calcium Sulfate [$CaSO_4$]	820	To landfill
17	Clean Stack Gas	46,940	Meets discharge limits for SO_x and
18	Glass Product	21,540	86% sediment metal oxide loading

Rinse water is essentially clean except for possible trace concentrations of organics, and can simply be discharged back to the harbor (being no more contaminated than water than drains from the excavation bucket during dredging). Most of the RCRA metals in the sediment are trapped in the glass matrix, as shown in Table 5 (data taken from Test #3, described in the next section). Most of the metals which partially escape the melter would report to the $CaSO_4/CaSO_3$ stream. The concentration of these metals in the calcium sulfate would remain very low, and would this material to be landfilled without special precautions.

PILOT SCALE DEMONSTRATION OF THE DECONTAMINATION PROCESS

Phase II of the EPA program consisted of pilot scale demonstration of the integrated process (pretreatment plus vitrification), treating 16.7 Mg of contaminated sediment from Newtown Creek. Large-scale pretreatment and process development assistance was provided during Phase II by Sevenson Environmental of Niagara Falls NY, experts in handling and dewatering of soils and sediments. The pretreatment steps outlined above were carried out for the full 16.7 Mg of sediment, using portable washing, screening, filtration, and blending equipment brought to and installed by Sevenson at the Westinghouse Plasma Test Center (WPTC) in Madison PA.

Table 5 - Retention of RCRA Heavy Metals in Glass Product During Vitrification

Metal Species	Concentration in Glass (ppm)	Fraction Retained in Glass
As	5.3	66.8%
Ba	26.9	99.8%
Cd	1.0	61.3%
Cu	1061.2	97.2%
Hg	<Detection Limit	(Not Measurable)
Ni	255.5	98.9%
Pb	106.7	79.8%
Se	1.6	79.4%
Zn	1232.9	72.6%

Pretreatment operations are summarized in Table 6. A total of 13.4 cubic meters of raw sediment were processed during July and August of 1997, starting from an initial 37% solids content. The initial sediment was black and tarry, with a strong creosote odor. Screening and washing eliminated 85% of the salt and 5% of the sediment mass, consisting mostly of debris and trash. Note that this fraction was higher than the oversize fraction in the Table 4 material balance; much of the debris was material discarded into the rolloff during sample collection (wood, plastic film, tools, protective clothing, etc.). Filtration with the aid of calcium hydroxide agglomerating agent produced a dewatered sediment product containing 52% solids. A total of 1,555 kg of fluxing agents was added (including the $Ca(OH)_2$), representing about 20% of the final melter feed on a dry basis (83% loading of sediment metal oxides into the final glass). The final 52% solids melter feed was a gray clay-like material which could be pumped by high pressure injection pumps.

Table 6 - Pilot Test Pretreatment System Performance Summary

Pretreatment Parameter	Value
Sediment Processed (m^3)	13.4
Sediment Solids Processed (kg wet basis)	16,700
Sediment Solids Content (%wt)	36.7
Oversize Cuttings Removed (kg dry basis)	328
Rejection of NaCl During Washing (%)	85.6
Rinse Water Consumption (liters)	28,700
$Ca(OH)_2$ Filtration Aide Consumption (kg)	460
Mass of Dewatered Sediment Produced (kg)	11,000
Solids Content of Dewatered Sediment (%wt)	52.0
Volume of Filtrate Water Generated (liters)	32,700
CaO Flux Added (kg)	285
Na_2CO_3 Flux Added (kg)	810
Plasma Melter Feed Generated (kg)	13,600

Vitrification testing was carried out between October and December, 1997, with a total of three tests. Most of the material processed was melted during Test #3 on December 5, during which a total of 3,980 kg of feed was converted to glass over 7.7 hours at an average rate of 533 kg/hr, with peak production as high as 800 kg/hr.

A schematic of the full-scale plasma melter design is shown in Figure 4 (as designed for the full scale plant, but functionally similar to the unit tested at Westinghouse PTC). The melter consists of a cylindrical furnace with refractory lining. Near the bottom is the injection port (one in the WPTC design, three in the full-scale plant design), referred to as the "tuyere" for its similarity to the air injection ports of a blast furnace or metal-melting cupola. At the outer end of the tuyere is mounted a Westinghouse plasma torch, rated at 2.3 MWe full power for the WPTC tests, or 5 MWe for the full-scale design. Full production in the larger design is accomplished by construction of five independent plasma melter trains of three torches each, arranged radially around the melter.

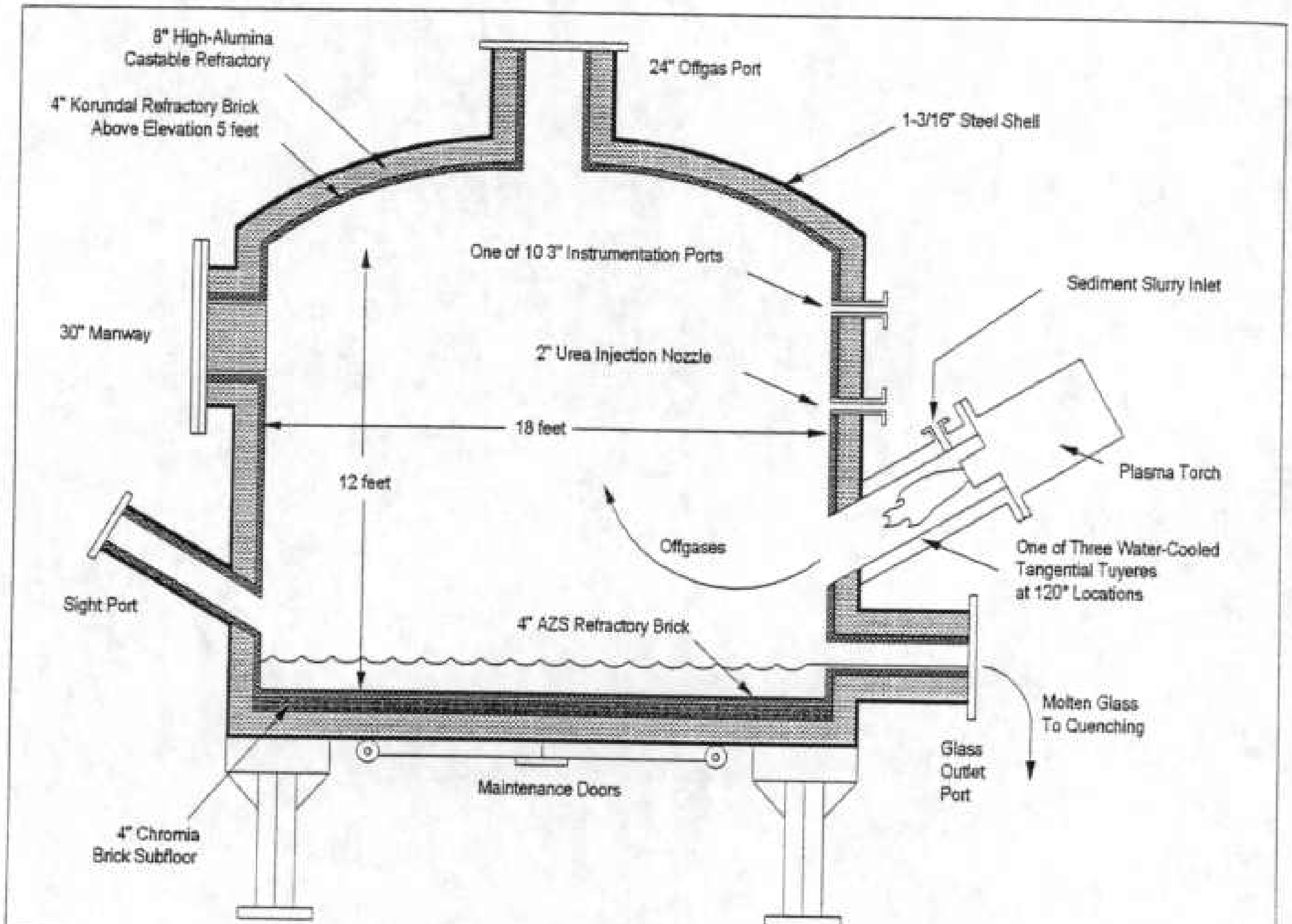

Figure 4 - Plasma Melter Schematic

Sediment and flux mixture is pumped as a slurry through an injection nozzle directly into the [illegible]ne of the plasma torch. The water content of the dewatered and blended feed is adjusted by the requirements of the pumping system. Higher solids content produces more economical operation since less water must be heated and evaporated, but more difficulty is introduced in transporting the viscous slurry to the tuyere. It was noted that the viscosity behavior of the sediment is highly non-Newtonian, behaving as a Bingham plastic material. Pumping proved to be the largest single difficulty encountered during the demonstration testing, when the slurry solids content was higher than optimal.

Air flow through the tuyere totals approximately 12.7 m^3/min, divided between torch air (passing through the plasma torch electrodes) and shroud air (serving the mix the plasma plume with the incoming sediment slurry, and to cool and protect the tuyere walls from the superheated plume). During Test #3, the plasma power averaged 1600 kWe. The specific energy consumption for processing of the sediment was therefore 10.8 MJ/kg of sediment feed slurry. Similar or better energy efficiencies would be expected in the full-scale plant.

As sediment enters the tuyere and mixes with the superheated plasma plume, it is rapidly dried and the organic surface deposits are combusted. Large agglomerated clumps disintegrate into fine, dry particles which are carried down the duct and thrown against the walls of the tuyere. Because of extremely rapid heat transfer, calcination of flux materials and melting of metal oxides occur within the tuyere, forming a homogeneous glass melt before the material enters the melter crucible (bottom). The liquid is continuously tapped from the crucible, with an exit temperature of approximately 1250 to 1350°C. Molten product may be cast into large masses, roll quenched into thin sheets for later crushing, or water quenched to form a fine aggregate.

BENEFICIAL REUSE OPTIONS

Vitrified sediment provides a safe and stable wasteform for landfilling (or, theoretically, ocean dumping), but the properties of vitrified harbor sediment are such that a wide range of possible beneficial reuse options also exist. Among the simplest involve use as roadbed aggregate, an end use currently being practiced for vitrified ash ("glasphalt"). The requirements for roadbed aggregate are not well defined, but both the processing cost and product value are low. If the particle size is controlled to some degree, the glass may also be used for sandblasting applications. In this market, sediment glass would compete directly with products such as Black Beauty®, a registered trademark of Reed Minerals (a division of Harsco Corporation). Black Beauty® is made from fused coal ash, and is chemically very similar to vitrified harbor sediment.

Somewhat higher value products which have been considered include:

- Roofing granules (requiring control of both particle size and Fe(II)/Fe(III) ratio for ultraviolet absorption characteristics; the iron ratio in New York/New Jersey Harbor sediment glass is favorable for this application, however).
- Replacement glass cullet (although considerable market demand for cullet exists, the market for Harbor sediment cullet would be limited by the black color of the high-iron glass).

- Additive to brown bottle glass (where the color would be advantageous; application for beverage bottles would be difficult to market given the origin of the material, however).
- Filler material for artificial onyx bathtubs and similar fixtures (where the color is irrelevant since the surface gel coat is the only visible material; the market is limited, however).
- Rock wool insulating fiber (requiring control of product viscosity to allow spinning into fibers, and relatively expensive processing equipment; the market value is nearly \$200/Mg, however).

At the high-value end of the spectrum, the New York/New Jersey Harbor sediment produces a glass which has physical and chemical properties similar to "E-Glass" which is one of the major commercial fiberglass compositions. Samples of Phase I Harbor sediment glass were forwarded to a major U.S. fiberglass manufacturer for evaluation. Samples were spun into greenish gold fibers, and exhibited both good forming properties (1000 Pa-sec fiber-forming temperature of approximately 1200°C) and excellent strength characteristics (490,000 psi single-fiber strength, only slightly below that of "E-glass"). Environmental TCLP testing of the fibers was also found to be no issue.

The major issues associated with fiberglass concerned product uniformity. The plasma melting process was designed to rapidly decontaminate and fuse the sediment, with short residence time to minimize energy costs and equipment size. Feed glass to a fiberglass spinning operation is required to be exceptionally homogeneous, with near-zero concentrations of incompletely melted or crystalline material. One fiber break per day in a spinning machine is considered a serious problem. To provide this degree of homogeneity, the molten glass would have to be held for a considerable length of time at elevated temperature to ensure complete dissolution of crystalline phases ("fining"). Both the capital and energy cost of equipment for this process as well as for fiber spinning is substantial. Also, it is difficult to guarantee the uniformity of the glass chemical composition, since the source will vary from day to day within the Harbor environment.

A far more robust application and one requiring much lower capital investment is fabrication of commercial architectural tile. Three major types of ceramic tile are currently marketed, low-grade wall tile, high-grade wall tile, and floor tile; each grade has different requirements for abrasion resistance and water absorption. The least expensive tile is composed of talc ($3MgO{\bullet}4SiO_2{\bullet}H_2O$), ball clay, and wollastonite ($CaO{\bullet}SiO_2$); sediment glass could readily substitute for natural talc, yielding an estimated product credit of up to \$170/Mg. Higher grade tiles use feldspar ($Al_2O_3{\bullet}6SiO_2{\bullet}K_2O$) in place of talc for increased resistance to water absorption. Substitution of sediment glass for feldspar potentially increases the product credit to \$250/Mg.

The tile market is also favorable, with approximately 75% of all ceramic tile being consumed by new construction. Demand should be good in the New York City urban area, providing a local market requiring minimal transportation costs. At current production figures, a 380,000 m^3/yr sediment decontamination facility could generate 166,000 Mg/yr of glass product, equivalent to as much as 5% of the current ceramic tile market. However, due to the relatively low anticipated cost of the glass, vitreous tile must be viewed as a high-quality, low-cost substitute for current tile products, where market impact would be minimized as vitreous tile replaced other lower quality or higher cost products.

Based on this market analysis, Westinghouse collaborated with one company currently producing vitreous tile from waste materials, namely Futuristic Tile LLC (soon to be known as Environmental Stone Products) of Allenton WI. Futuristic Tile accepts from municipalities scrap recycle clear ("white") bottle glass and "three-mix." (Note: current technology for glass recycling allows up to 90% of mixed green/brown/white glass to be automatically sorted into three pure-color streams. The remaining 10%, primarily broken material too small to be sorted, is known as "three-mix"). The mixed glass stream is first crushed, cleaned, and sized. It is then blended with additives designed to adjust the melt viscosity, sintering temperature, and thermal expansion coefficient. The glass powder is then fed into ceramic molds using a feed distributor known as a "dozer." This forms the bottom layer of the tile.

Clear glass is also crushed and cleaned, and sized to a smaller particle diameter (<1 mm). Using patented technology, the white fines are blended with coloring pigments (other metal oxide powders), and formed into granules which are then distributed into the mold to form the top layer. Between 30 and 40 colors are available, and by controlling the "dozer" distribution pattern, colors may be distributed in such a way as to visually mimic a wide range of natural stones in the final product (granite, marble, gneiss, etc.). The mold is then passed through a kiln under carefully controlled residence time and temperature profile, producing the finished tile product in roughly one square meter sheets. These are then cut to size, depending on the application. The complete flowsheet for tile production is shown in Figure 5.

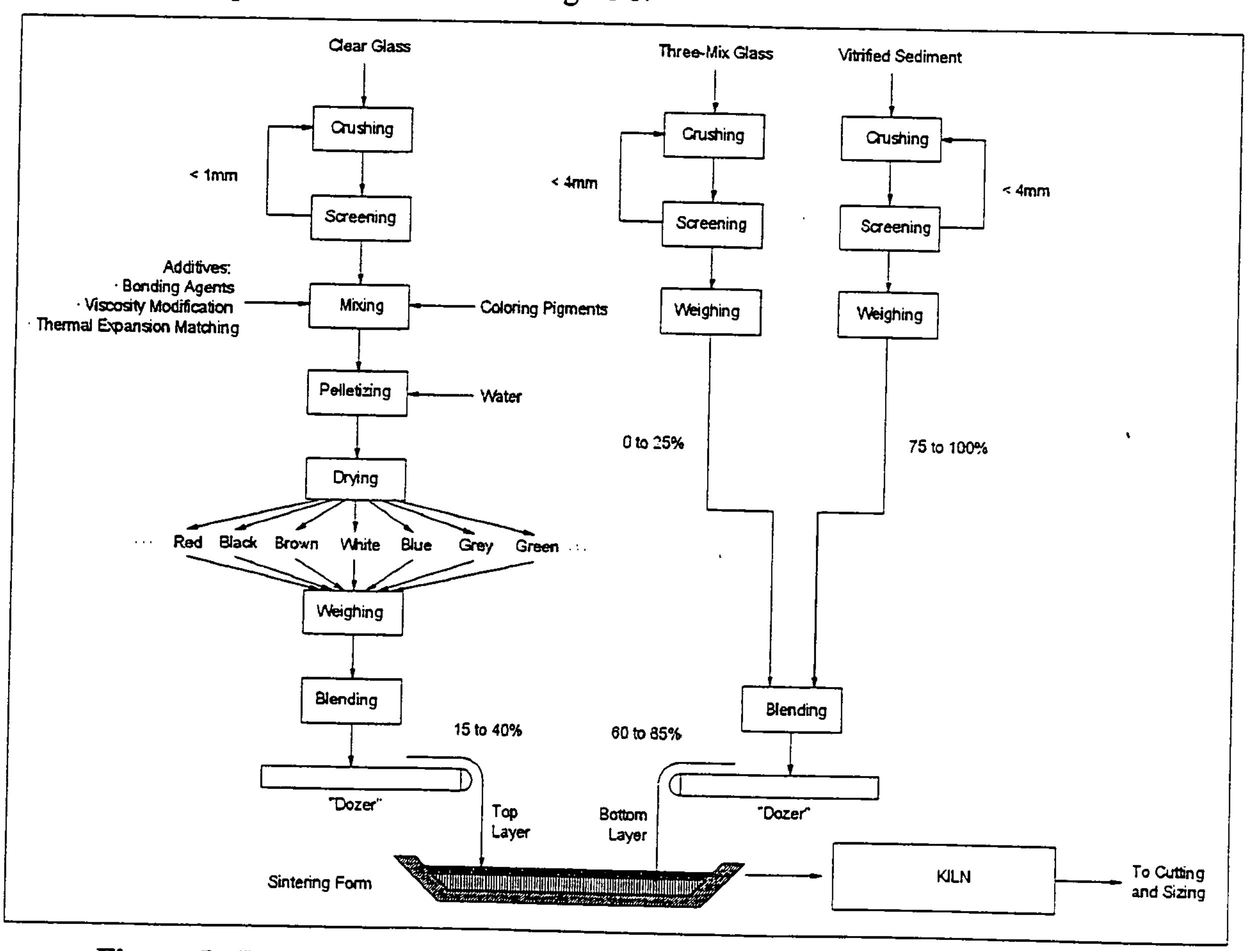

Figure 5 - Process Flow Diagram for Futuristic Tile Manufacturing Process

Futuristic Tile, working with Westinghouse, determined that vitrified sediment may be substituted for "three-mix" glass in the bottom structural layer of the tile. Initial testing with Phase I sediment glass produced good quality tiles using 100% sediment glass for the bottom layer. Based on the results of these exploratory tests, a Phase III program was initiated in which an additional 1,400 kg of sediment glass was prepared at PTC, crushed to <¼", and shipped to Futuristic Tile for conversion to tile.

The Phase III sediment glass was blended with slightly less flux than the Phase I samples, and therefore required a higher sintering temperature than for typical Futuristic Tile recycle glass operation. Because some of the pigments are temperature sensitive, and because higher sintering temperatures increase energy costs and require longer residence times, Futuristic Tile decided to blend the vitrified sediment with "three-mix" to obtain an optimized tile product. It was found that excellent quality tile could be prepared using bottom layer mixtures between 75 and 80% sediment glass, with the balance being "three-mix" (no other additives). Overall, the bottom layer represented 60 to 65% by weight of the total tile, so that a given Phase III tile was approximately 45% weight Harbor sediment glass.

Note that this sediment loading is low relative to what could be produced in commercial operation. Futuristic Tile has routinely produced tile with as low as 15 to 20% top glass. As was noted above, the Phase I glass with slightly higher flux levels produced good bottom glass with no dilution by "three-mix." With only small increases in flux, the final tile could contain 80 to 85% sediment glass.

During Phase III testing, 1,000 kg of sediment glass were converted into approximately 2,200 kg of tile. Experience with production-scale quantities of sediment glass as tile feed, Futuristic Tile engineers have concluded that not only does this glass produce good quality tile, but that there is a significant processing advantage for using it in place of "three-mix." The quality of recycled glass is highly variable, depending on the degree to which a municipality sorts and segregates glass from non-glass materials. The presence on metallic debris (jar lids, bottle tops, etc.) require additional sorting and screening effort on the part of the tile maker. Organic material such as plastic and paper not successfully removed during sorting and crushing are generally destroyed during kiln operation, but may also introduce flaws and bubbles in the product, leading to breakage and scrap. Futuristic Tile has therefore concluded that sediment glass would be a "preferred feed material" to recycled glass, improved productivity from which would help to offset the higher cost.

A photograph of the four stages of conversion from raw sediment to final tile is presented in Figure 6. The figure illustrates the original harbor sediment, its appearance after dewatering and mixing with flux, samples of the aggregated sediment glass after plasma processing, and two examples of Futuristic Tile product made from the glass aggregate during February, 1999, Phase III testing. The tile has been subjected to product quality tests, and has been shown to be equal to or superior to the product which Futuristic Tile generally produces.

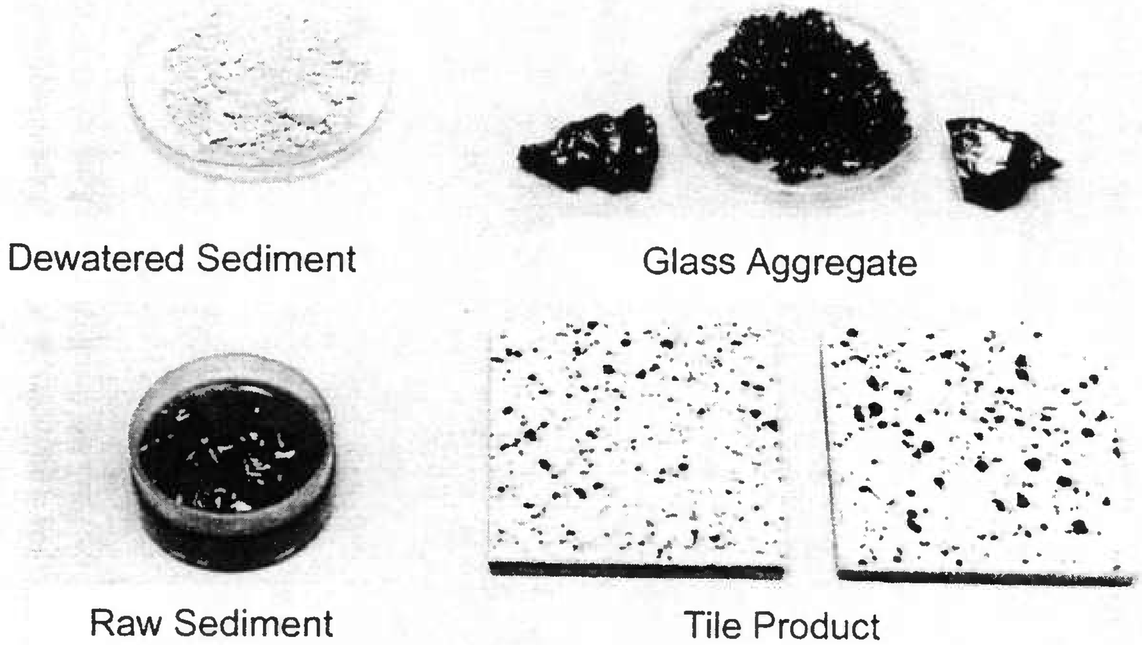

Figure 6 - Conversion of Raw Sediment into Finished Vitreous Tile

FULL-SCALE PLANT DESIGN AND TREATMENT COSTS

Following the success of the pilot plant demonstrations, a full-scale preliminary plant design was developed, based on the material balances shown in Figure 3 and Table 4. A summary of important parameters from this study is shown in

Table 7. Two designs evolved from the Phase II studies, one for a 76,400 cubic meter (100,000 yd^3) per year demonstration facility, and a second for 382,000 cubic meter (500,000 yd^3) per year full-scale production; the latter plant is presented in the table.

Capital and operating costs were also developed, based around the previously presented flowsheet and material balance. These are also summarized in Table 7. The cost of electricity is the largest single factor in determining gross operating cost, representing 65 to 75% of the total figure. A range of electrical costs from $0.03 to 0.05 per kilowatt-hour were examined in sensitivity tests, although discussion with utility representatives in the New York City area indicated that at high volume the cost per kilowatt-hour could even be lower. Taking a nominal electrical cost of $0.04/kWh, the processing cost for the sediment is estimated to be $81/Mg. Including amortization of capital costs, the total gross processing cost for sediment treatment from receipt of barged sludge to delivery of granulated sediment glass (suitable for tile manufacture) becomes

Table 7 - Summary of Full-Scale Sediment Treatment Plant Operating Parameters

Parameter	Value (per metric tonne of dredged sediment)	
Plant Capacity	500,000 yd^3/yr (461,000 Mg/yr)	
Turndown Capacity	12,800 kg/hr (20% of full load)	
Excess Capacity Built into Equipment Design	5%	
Sediment Delivery	Barge transport	
Plant On-Line Operating Factor	0.92	
Total Electrical Power Requirement	84 MWe (98% for plasma torch operation)	
Capital Cost Estimate	$81.4M	
Area 100: Pretreatment	$18.7M (23%)	
Area 200: Plasma Melters	$44.0M (54%)	
Area 300: Glass Quenching and Handling	$2.3M (3%)	
Area 400: Offgas Cleaning	$12.9M (16%)	
Non-Process Areas	$3.5M (4%)	
Land Requirement	8.2 acres (12 acres with glass product plant)	
Operating Cost	$30.5 to 44.1M/yr	$66.2 to 95.7/Mg
Chemical Raw Materials	$5.5M/yr	$11.9/Mg
Electricity (assuming $0.03 to 0.05/kWhr)	$20.5 to 34.1M/yr	$44.4 to 74.0/Mg
Other Utilities	$0.2M/yr	$0.4/Mg
Solids Disposal (oversize and $CaSO_4$)	$0.5M/yr	$1.1/Mg
Labor	$2.2M/yr	$4.8/Mg
Maintenance	$1.6M/yr	$3.5/Mg
Amortized Capital Cost	$12.2M/yr	$26.5/Mg
Total Sediment Processing Cost	$42.7 to 56.3M/yr	$92.6 to 122.1/Mg
Credit for Tipping Fee	($23.1M/yr)	($50/Mg)
Net Cost of Processing (Without Product Credit)	$19.6M/yr to 33.2M/yr	$42.5/Mg to $72.0/Mg

* Assumption that higher product manufacturing cost is associated with higher sale value.

$107.4/Mg. It is assumed in this analysis that "brownfield" industrial property for construction of the plant would be made available near the Harbor at no cost.

The net cost of processing with beneficial reuse must consider both the tipping fee received for treatment and disposal of the sediment, and the production costs and revenue associated with the final product. For the nominal case, it is assumed that essentially zero production costs are invested, and that the final product is roadbed aggregate, using the granulated sediment glass directly. (Note that for this application, a fully vitrified product may not be required, and that less expensive flux with less soda ash would probably be acceptable; no credit is taken for this detail). Roadbed aggregate typically sells for $7.50/ton, which converts to $2.33/Mg of dredged sediment (see material balance inTable 4).

A tipping fee for disposal of sediment must be assumed in order to project a net cost for treatment of the dredged material. For this purpose, a reference cost of $45/ton ($50/Mg) is assumed. This figure is based on current reported cost of disposal of sediment by stabilization and transfer to spent coal mines in Pennsylvania. Using the nominal $107/Mg vitrification cost, the nominal net cost of treatment is $55/Mg of dredged sediment.

In considering the economic viability of higher value products, one must consider the capital and operating costs for fabrication of that product, the "cost" of the sediment glass as compared to alternative feed materials (such as "three-mix" in the case of architectural tile), and impacts on the production process as a result of changing to sediment glass as the feedstock. As indicated above, demonstration tests with Futuristic Tile have shown that use of vitrified sediment will result in improved tile quality and productivity, due to the purity and consistency of the sediment glass. If an integrated sediment-to-tile process is considered, economic analysis by Westinghouse and Futuristic Tile indicates that the process will be profitable based on the reference design and tipping fee.

Note that with deregulation of the electric utility industry, the assumed $0.04/kWr electricity cost may reduce to $0.03 or even $0.02/kWh. The treatment cost to produce the vitrified aggregate would then reduce substantially to between $42 and $25/Mg of dredged sediment, resulting in greater economic margin for the overall sediment-to-tile production process.

As indicated above, any aggressive treatment option which truly destroys organic contaminants and immobilizes heavy metals will be more expensive than a procedure which seeks only to encapsulate contaminants, followed by landfilling (be it in an abandoned mine or engineered landfill). Although the economics of sediment vitrification followed by tile production appear to be favorable given a tipping fee based on competition with cement stabilization and landfilling, the overall economics of such a process improve with the degree of contamination of the material being treated. As contamination becomes more severe, the options for stabilization and disposal become fewer, and the treatment costs rise. The effective tipping fee against which the plasma vitrification process is to be compared therefore grows, making the overall process economics increasingly favorable. Even if low cost subaqueous burial within the Harbor (for example) were permitted for sediment with low contaminant levels, vitrification could remain the logical and economic approach to treatment of "hot spots."

This process is obviously not limited to harbor sediments, although this was the specific problem that WRDA and EPA resources were invested to solve. Many cases of Superfund sites exist where vitrification could be applied to treatment of highly contaminated sediments or sludges. The combination of near-quantitative destruction of organic contaminants, immobilization of heavy metals, and favorable economics for beneficial reuse of vitrified material make this process attractive for a wide range of applications.

CONCLUSIONS

Treatment and disposal of contaminated estuarine sediments will pose an increasingly costly problem to harbor managers and to communities which have a major investment in shipping as a livelihood. While many alternative treatment options such as cement stabilization plus landfill disposal are less expensive than the plasma vitrification process, these options depend on the continued availability of large areas of "free" land for disposal This represents an increasingly risky assumption for long term solution of the problem, the costs of which can only increase as public pressure against waste landfilling grows and land availability near such sites as New York City dwindles. In addition, such disposal options do not destroy any of the contaminants, but only move them to another, less sensitive, location. The ultimate liability still persists, which for many processes and sites has historically resulted in much larger legacy costs associated with later remediation.

The plasma vitrification process permanently and completely destroys all of the organic contaminants in the sediment, generating no organically-contaminated waste liquid streams in the process. The only wastes are treated oversize debris (which are partially decontaminated by washing) and a small stream of solid $CaSO_4$ which can be readily landfilled. The glass produced from this process has been demonstrated to be environmentally safe, meeting all EPA leaching requirements for the small quantities of heavy metals immobilized in the glass matrix. Coupled with options for beneficial reuse such as architectural tile for the environmentally safe glass product, this process provides an attractive option for permanent disposition of contaminated harbor sediments. A broad range of other applications are also apparent, including highly contaminated Superfund soil, sediment, sludge, and industrial waste remediations.

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Maintaining Access to America's Intermodal Ports/Technologies for Decontamination of Dredged Sediment

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MAINTAINING ACCESS TO AMERICA'S INTERMODAL PORTS/TECHNOLOGIES FOR DECONTAMINATION OF DREDGED SEDIMENT: NEW YORK/NEW JERSEY HARBOR

by

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1. INTRODUCTION

One of the greatest drivers for maintaining access to America's Intermodal ports and related infrastructure redevelopment efforts over the next several years will be the control and treatment of contaminated sediments dredged from our nation's waterways. More than 306 million cubic meters (m^3) (400 million cubic yards [cy]) of sediments are dredged annually from U.S. waterways, and each year close to 46 million m^3 (60 million cy) of this material is disposed of in the ocean (EPA 842-F-96-003). The need to protect our environment against undesirable effects from sediment dredging and disposal practices is gaining increased attention from the public and governmental agencies.

Meeting this need is a challenging task not only from the standpoint of solving formidable scientific and engineering problems, but also, and more importantly, from the need to implement complex collaborations among the many different parties concerned with the problem. Some 40 years ago, C.P. Snow pointed out the problems involved in communicating between the two cultures of the sciences and the humanities (Snow, 1993). Today, it is necessary to extend Snow's concept to a multicultural realm with groups that include governmental, industrial, environmental, academic, and the general public communicating in different languages based on widely different fundamental assumptions.

The handling of contaminated sediments in the Port of New York/New Jersey (Port) exemplifies this problem. This paper describes a <u>multicultural team</u> that has formed as the result of a Congressional mandate for the development of procedures suitable for the decontamination of sediments in the Port under the Water Resources Development Act (WRDA) of 1992 (Section 405C) and 1996 (Section 226).

The WRDA Program is the responsibility of the U.S. Environmental Protection Agency (EPA) - Region 2 and the U.S. Army Corps of Engineers (USACE) - New York District, with the U.S. Department of Energy (DOE) - Brookhaven National Laboratory acting as the Technical Project Manager.

Both EPA and USACE have stepped up their efforts to manage contaminated sediments and dredged materials. With the recent release of EPA's Contaminated Sediment Management Strategy, and the ongoing efforts of the USACE Waterways Experiment Station Dredging Operations and Environmental Research Program, as well as individual USACE District initiatives, the development of economically and technologically feasible sediment treatment and disposal alternatives is being aggressively pursued.

The WRDA Program has progressed through demonstrations of varying technologies at bench and pilot scales and is now being moved to construction of commercial-scale facilities. The step-wise procedure has resulted in a reduction of the number of participants through specific selection criteria, including technical performance, demonstration costs, public-private cost sharing, beneficial reuse of treated material, and corporate evaluations of the business potential for sediment decontamination.

One of several multicultural teams growing from the WRDA Program includes the federal groups previously mentioned and three commercial sector entities. BioGenesis Enterprises, Inc. (BioGenesis) and ENDESCO Services, Inc., a wholly owned subsidiary of the Institute of Gas Technology (ENDESCO/IGT), provide technologies suitable for decontamination of sediments with varying contamination levels. Roy F. Weston, Inc. (WESTON®) provides the engineering, construction, and operational skills needed to move the technologies to the commercial marketplace. Federal funding from the WRDA legislation provides assistance to the commercialization process, but the private sector will provide the capital needed for facility construction and operation. It is believed that this type of cooperative approach will be useful in the New York and New Jersey Region and may have features of interest to other Port communities throughout the country that are faced with problems caused by the need to dispose of contaminated sediments.

2. CONTAMINATED SEDIMENTS IN THE NEW YORK/NEW JERSEY HARBOR

New York/New Jersey (NY/NJ) Harbor contaminated sediments constitute a major crisis to the economic well being of the region. NY/NJ Harbor has a natural, undredged depth of 5.8 meters (19 ft). Ships need a depth of 12 to 14 meters (40 to 45 ft) for safe navigation. The difference between natural and required depths requires that 3 to 5 million m^3 (4 to 7 million cy) of sediment be dredged and disposed of every year for safe navigation and commerce. Exhibit 1 shows the NY/NJ Harbor Federal Navigation Channels that require dredging. According to the New York and New Jersey Port Authority, the Port generates more than $20 billion in revenue and is responsible for more than 180,000 jobs. Thus, any prolonged interruption in dredging would adversely affect the regional economy. The Port is currently faced with an operational crisis brought about by stricter regulations that reduce the amount of dredged material that is considered suitable for ocean disposal in the coastal Atlantic Ocean.

In a final rule that became effective on September 29, 1997, EPA de-designated and terminated the dredged material ocean disposal site (Mud Dump Site) and simultaneously designated the Historic Area Remediation Site (HARS). Exhibit 2 shows the location of the former Mud Dump Site. The HARS is restricted to receive only dredged material suitable for use as Material for Remediation. This material is defined as "uncontaminated dredged material (i.e., dredged material that meets current Category I standards and will not cause significant undesirable effects, including those effects caused through bioaccumulation)."

Sediments and soils found in and around the Port have been contaminated with a large variety of toxic materials produced by human and industrial activities in the region from colonial times to the present. Sediment contaminant concentrations in the NY/NJ Harbor rank among the highest in the nation (NOAA, 1995). Squibb et al. (1991) concluded that concentrations of a variety of toxic contaminants in these sediments are sufficiently elevated in many locations to cause adverse effects on the biological community. Heavy metals (Hg, Cd, Pb, Ni, Cu, Zn, As), chlorinated pesticides (including DDT metabolites, chlordane, dieldrin, and endrin), polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and dioxins/furans are major contaminants of concern in the Port region. Toxicological assessment studies, such as the U.S. EPA Regional Environmental Monitoring and Assessment Program and the NOAA/U.S. EPA Multi-Agency Sediment Toxicity Survey of the Newark Bay Complex, have all shown significant mortality to the marine amphipod *Ampelisca abdita* when exposed to sediment from the Harbor (NOAA, 1995). Furthermore, several contaminants detected in the Harbor sediments, as well as in the tissue of fish and shellfish, have resulted in fishing advisories in the NY/NJ Harbor. Bioaccumulation testing of dredged material has identified many of these same contaminants. Generally, the material is chemically stable and is found to pass the toxicity characteristic leaching procedure (TCLP) for testing the leachability of contaminants.

The physical characteristics of the sediments found in the Port are generally very fine-grained silts and clays (80 to 95%) with a small fraction of larger grain sizes and large-size debris. The bulk material has a gel-like consistency. The total organic content of Harbor sediments ranges from 3 to 10%. The solids content of the as-dredged material is 30 to 40% when obtained using a conventional clamshell bucket dredge.

Scientific visualization and scatter data modeling techniques have been applied in analyzing sediment sampling data from the NY/NJ Harbor (Hong et al., 1998). High-resolution data sets were visualized to determine the spatial patterns from surface sediments down to core depth where data were available. Specific "hot spots" have been visualized for a range of contaminants such as dioxins, PAHs, and metals. Exhibit 3 is an illustration of a 3-dimensional contaminated sediment visualization image from the Passaic River, New Jersey, characterizing dioxin concentrations from the sediment surface to a depth of 6 ft.

Current proposals for solutions to the dredged material disposal problem include continued unrestricted ocean disposal of uncontaminated material to the HARS, the use of confined disposal facilities (both upland facilities and containment islands), subaqueous borrow pits, and processing/treatment of contaminated materials. A complete solution to the dredging problem will no doubt include a combination of many or all of these alternatives. Decontamination of dredged material is one component of an overall dredged material management strategy. It can reduce the magnitude of the contamination and may provide a treated product with a beneficial reuse, thus simplifying disposal and, if salable, reduce the overall cost of treatment.

2.1 WRDA Program Background

Currently there are limited alternative disposal options for contaminated sediment, and as a result, the continued economic operation of the Port is threatened. The WRDA Program is intended to demonstrate decontamination technologies for sediment treatment and to create a viable treatment train capable of processing sediment volumes on the order of 382,300 m^3 (500,000 cy) per year. The work is divided into several phases; treatability studies of commercial and nonproprietary technologies at volumes of 19 to 38 liters (5 to 10 gallons) for bench-scale, and up to 19 m^3 (25 cy) for pilot-scale. Exhibit 4 shows the locations in the NY/NJ Harbor where sediment samples were taken for the bench- and pilot-scale tests. Both bench- and pilot-scale phases of the project were completed in December 1996. The technologies investigated included several types of thermal destruction and desorption processes, stabilization/solidification, sediment washing, advanced chemical treatments, solvent extraction methods, and manufactured soil production.

Results obtained in the treatment tests have been presented previously (Stern et al. 1996 and 1997; Jones et al. 1997 and 1998). Because of the complexities of mixed contaminants (metals, organics, etc.), different end-uses of the post-treated materials, and the importance of developing a sediment delivery system (materials handling) to move the dredged material into the physical plant, WRDA's objective from the onset was to develop a "treatment train" approach to processing and decontaminating dredged material. This approach puts together several key components that entail dredging, processing of the sediment, beneficial use of the post-treated material, and environmental/human health assessments. Under WRDA, the specification of a treatment train and potential implementation of a large-scale facility capable of processing up to 382,300 m^3 (500,000 cy) of dredged material per year is already underway. The development of an overall conceptual plan for implementing a large-scale treatment facility is now in progress.

WRDA has categorized the technologies that have been tested in the bench- and pilot-scale phases of the Program. They fall into the following categories: 1) those that are carried out at ambient or at least low temperatures; 2) those that are carried out at intermediate temperatures that do not destroy the organic constituents; and 3) those that are carried out at high temperatures above the decomposition point of the organic compounds. The wide variety of contaminants and differing concentration levels make it plausible to search for technologies that can be applied to specific concentration levels. In addition, the low-temperature technologies may be more acceptable to the local and regulatory communities, making obtaining building and other environmental permits easier. The higher temperature technologies may be more applicable to the most contaminated sediments that are found outside of navigational channel and depositional areas. These areas may lend themselves to "hot spot" remediation. High-temperature technologies may also produce beneficial use products that have higher resale values than solidification/stabilization.

3. TECHNOLOGIES FOR THE DECONTAMINATION OF DREDGED MATERIALS

The variety of contaminants and the wide range of contamination levels found in dredged material in the NY/NJ Harbor emphasize the need for developing several types of decontamination technologies for a comprehensive treatment process. This is exemplified by two approaches supported under the WRDA Program (see Exhibit 5) for large-scale decontamination facilities. One technology is a sediment washing method developed by BioGenesis. The other process developed by the Institute of Gas Technology uses high temperatures to completely destroy organic materials, while binding metals into a cementitious matrix (Cement-Lock™ process). In both cases the processed materials have beneficial uses that produce a revenue stream, which can be used to offset the decontamination processing costs.

The essential properties of the dredged material are the grain size distribution and the major element composition. A typical grain size distribution is shown in Exhibit 6 for dredged material taken from Newtown Creek, NY. Material from other locations with respect to grain size distribution in the Harbor is similar. Examination of the data shows that most of the sediment is less than 2 millimeters in size. The small particles are easily handled during the washing or cement-making procedures. Oversized material can be sorted into material that should be sent to a landfill or reduced to the smaller sizes needed in the two processes. The major element composition is silica and overall is suitable as input material for the production of cement or as the basis of a soil.

A schematic diagram and photograph of the equipment used by BioGenesis in a recent demonstration are shown in Exhibits 7 and 8. The contaminants found in the sediments were reduced by approximately 90% for silts, clays, and sands. The results are shown in Exhibit 9 (BioGenesis℠ Two-Cycle Treatment Process). The dredged material suitable for processing depends on the criteria for its end use. If an artificial soil is chosen, then the initial contaminant levels must be less than a factor of 30 greater than the appropriate soil criteria for the disposal site. This factor includes both the contaminant's reduction efficiency and the reduction resulting from the addition (dilution) of the original materials required for soil formulation.

A schematic diagram and photographs of the IGT Cement-Lock™ equipment used for a pilot-scale test of cement production are shown in Exhibits 10 and 11. The input material was similar in grain size, composition, and contamination to that used in the BioGenesis℠ test. The operating temperature range of the thermal processing for the test was between 1200° and 1500°C (2200° and 2700°F). These conditions are sufficient for achieving complete destruction of all organic contaminants. The reduction efficiency is shown in Exhibit 12.

In summary, essentially all of the organic contaminants originally present in the dredged sediment were destroyed to below the analytical detection limit as a result of the high-temperature Cement-Lock™ Technology processing. DREs in excess of 99.99% have been achieved in both the bench-scale and pilot-scale testing. It is expected that organic compound DREs in excess of 99.99% will be consistently achieved in the production-scale Cement-Lock™ plant that will be built in Phase III of the WRDA program. In addition to the extreme thermal conditions that exist in the melter (Ecomelt Generator), organic compounds will be subjected to 2 seconds residence time at 1200° C (2200° F) in the secondary combustion chamber. This is the process requirement for 99.9999% destruction of PCBs.

The product from Cement-Lock processing of dredged sediment is blended cement. As part of the WRDA program, the Cement-Lock blended cement was tested according to American Society for Testing and Materials (ASTM) protocol to evaluate its compressive strength. The compressive strength exceeds the ASTM requirements for portland cement. The cement can be used in concrete for general construction applications.

4. COMMERCIAL OPERATIONS

Detailed design plans for large-scale treatment facilities have now been completed that will meet the WRDA goal of achieving operation at 382,300 m^3 (500,000 cy) per year in the next 12 to 30 months. One of the major hurdles in placing any facility into an operational condition will be the issuance of permits from state and local authorities. The sediment washing permitting process should be relatively straightforward, since there are no gaseous side streams and the contaminants found in a liquid side stream can be removed by standard water processing techniques.

The use of a high-temperature process will require comprehensive air permits. Initial discussions in public groups have indicated that this type of process may be acceptable, if it is completely environmentally responsible from the public standpoint. From a purely technical standpoint, both technologies can be engineered to be completely environmentally responsible.

Technologies that are environmentally safe and that effectively decontaminate dredged material are not enough. They must also be economically viable and in this regard dredged material is now being stabilized with cement and fly ash and used for construction material and cover at several locations in New Jersey. Currently, the total cost for dredging, treatment (stabilization), and disposal ranges from $40 to $50/cy. Current total disposal costs in the Newark Bay confined disposal facility are approximately $35/cy. We anticipate that the costs for sediment washing and cement production will be competitive when full-scale operation is achieved and when the economic benefits of beneficial uses are considered. Preliminary estimates for the demonstration-scale level for processing costs range from $50 to $70. Larger scale demonstrations planned in 1998 (minimum of 7,600 m^3/10,000 cy each) will provide economic information for scale-up volumes as well as information on potential return for beneficial reuse. The target range of costs for full-scale/commercial-scale operations is to be at or below $35/cy.

There is good reason to believe that lower costs can be achieved for the Port to remain competitive. Competition from other East Coast ports also needs to be considered. Environmental regulations for handling of dredged material are not uniform and can be much lower than the NY/NJ Harbor benchmark. If other ports attract deep water shipping away from the NY/NJ Harbor, then the whole transportation pattern in the region could change and completely change the current needs for dredged material management in the Port. From an examination of the two technologies, it is believed that costs that are low enough to meet the market cost as it is currently projected can be achieved.

The actual costs for decontamination in the future will be determined by effective responses to requests for proposals from USACE, the Port Authority of NY/NJ, and private dredging clients.

5. BENEFICIAL REUSE

In order to evaluate the potential beneficial reuses for treated sediment, one must understand the characteristics of the material following treatment. First, dredged material from the NY/NJ Harbor consists mainly of fine-grained materials (silts and clays). The treated material, therefore, cannot be used directly as structural fill. The organic material contained in the treated dredged materials is removed or destroyed. This includes contaminants as well as other naturally occurring organic material. The treated material, therefore, is typically not good as a growth substrate.

Given these characteristics, potential direct beneficial reuse pathways for the treated sediment are limited. The treated material, however, can be mixed with other materials to obtain a useful end product. The amendment of the treated materials will require additional processing; therefore, the revenue from the end-use product will offset costs of processing and provide an additional source of revenue. Some potential end uses for amended treated dredged material include:

- Manufactured soil - High-end growth use (i.e., potting soil).
- Manufactured soil - Low-end growth use (i.e., top soil).
- Nonstructural fill material (daily landfill cover).
- Shoreline stabilization.
- Restoration/fill for underwater areas.
- Wetlands/habitat restoration.
- Blended cement.

In order to offset dredged material treatment costs and provide a cost-competitive overall treatment approach for management of NY/NJ Harbor sediments, beneficial reuse pathways need to be utilized. In addition, beneficial reuse of dredged materials is "environmentally sustainable and responsible" in that contamination contained in the materials is reduced to a level acceptable for use instead of disposal.

As stated previously, the total cost for dredging, stabilization with cement fly ash, and use as construction material currently ranges from $40 to $50/cy. Current predictions of full-scale/commercial-scale operations of the BioGenesis℠ Sediment Washing process and the IGT Cement-Lock™ Process put the processing costs in this same range; however, in order to be cost competitive and offer a more cost-effective operation for full-scale commercialized use, the operation costs must be reduced or offset.

Presented in Exhibit 13 is a summary of potential beneficial reuse products for the BioGenesis^{SM} soils washing and ENDESCO/IGT Cement-Lock™ treated dredged materials. Included in this listing is an evaluation of the treatment requirements (i.e., regulatory standards applicable for the treated sediment) as well as estimates of the value of the end product. The end-use products that can be produced from each individual source of dredged materials will be dictated by the initial contaminant levels, the treatment costs needed to meet the applicable standards for the particular end use, and the costs associated with amending the treated dredged material to be marketable.

Beneficial reuse of treated dredged materials is a "sustainable and environmentally responsible" approach to handling dredged materials. Depending of the full-scale treatment costs, beneficial reuse of treated dredged materials will provide a revenue source to make treatment technologies more economically competitive. As full-scale treatment costs are refined, treatment becomes less costly, and beneficial reuse products are utilized, the net cost of treatment of contaminated sediments will be reduced.

6. CONCLUSIONS

There has been significant progress to date in the WRDA Program to evaluate and demonstrate decontamination technologies for contaminated sediments. The progress is based on a collaborative effort between federal, state, and local governments, academia, private industry, and the community. Many technologies have been evaluated from technical and economic perspectives. Both non-thermal and thermal technologies (i.e., BioGenesis^{SM} and ENDESCO/IGT Cement-Lock™) are components of an overall treatment train approach to handling sediments with different levels of contamination and physical characteristics. Emphasis has been placed on treated sediments with established beneficial reuse markets. The WRDA Program has conceptualized the treatment facilities required for commercial-scale operations. The future goal of the WRDA Program is to finalize large-scale treatment economics based on currently planned demonstration projects in 1998. The ultimate objective of the Program is the commercial use of one or more of these technologies up to 382,300 m^3 (500,000 cy)/year capacity.

7. ACKNOWLEDGMENTS

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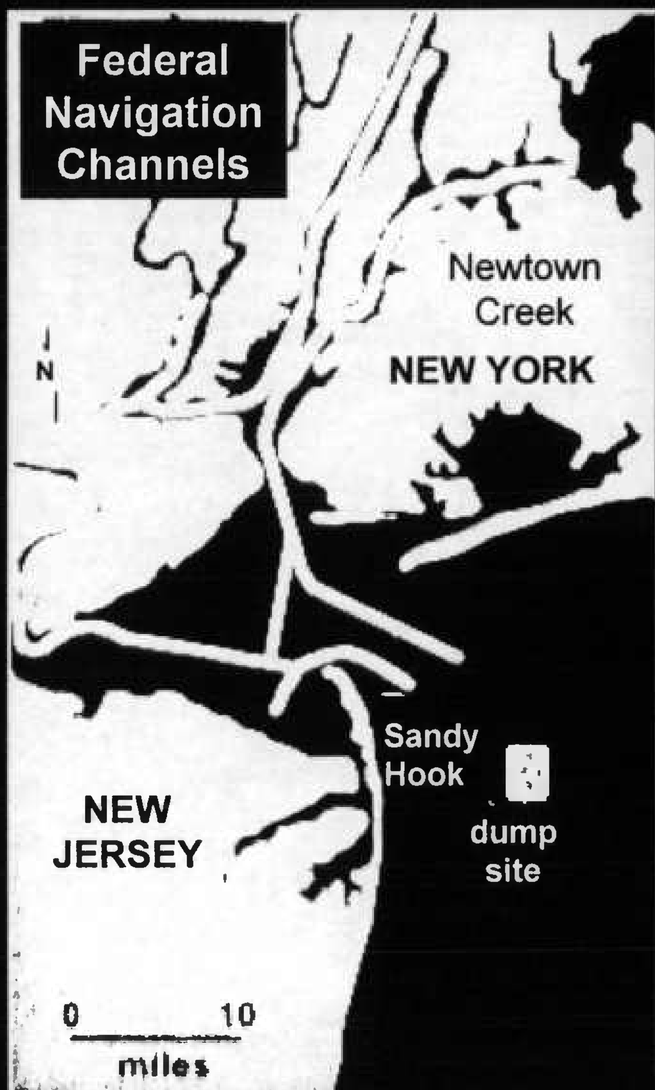
Michael C. Mensinger – Mr. Mensinger is a Chemical Engineer and Director of Technology Development for ENDESCO Services, Inc., a wholly owned subsidiary of the Institute of Gas Technology. He currently directs technical activities and manages the experimental development of IGT's Cement-Lock™

Technology for converting contaminated sediments, sludges, and soils into salable products, such as blended cements. He has been instrumental in the development of the Cement-Lock™ Technology from inception through pilot-scale testing and beyond, and is co-inventor of the technology.

Charles L. Wilde – Mr. Wilde is Executive Vice President and Chief Operating Officer of BioGenesis Enterprises, Inc., an environmental firm specializing in production of oil cleaning chemicals and soil remediation and the inventor of the BioGenesis ℠ Sediment Washing process. He is an expert in petroleum matters, with focus on storage, distribution, testing, and pollution control, and has extensive experience in government regulation and contracting, planning, budgeting, and systems analysis.

Exhibit 1

NY/NJ Harbor Estuary



- 4 to 7 million cubic yards of sediment are dredged from the channels annually
- Much of this sediment contains pollutants
- Various options are being pursued for management of this sediment

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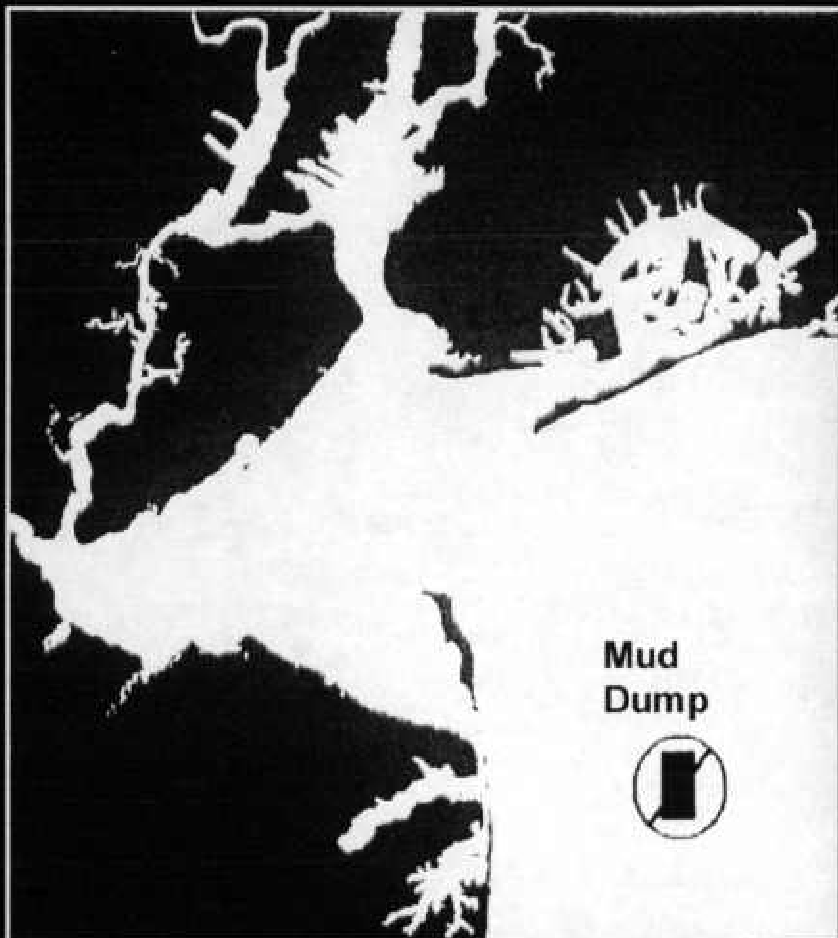
Exhibit 2

What is Done with the Dredged Material?



Dredged Material Management Plan
U.S. Army Corps of Engineers - New York District

- > 90% to Mud Dump Prior to 1992
- 35% to Mud Dump 1992 to 1997
- 25% to Mud Dump after 1997

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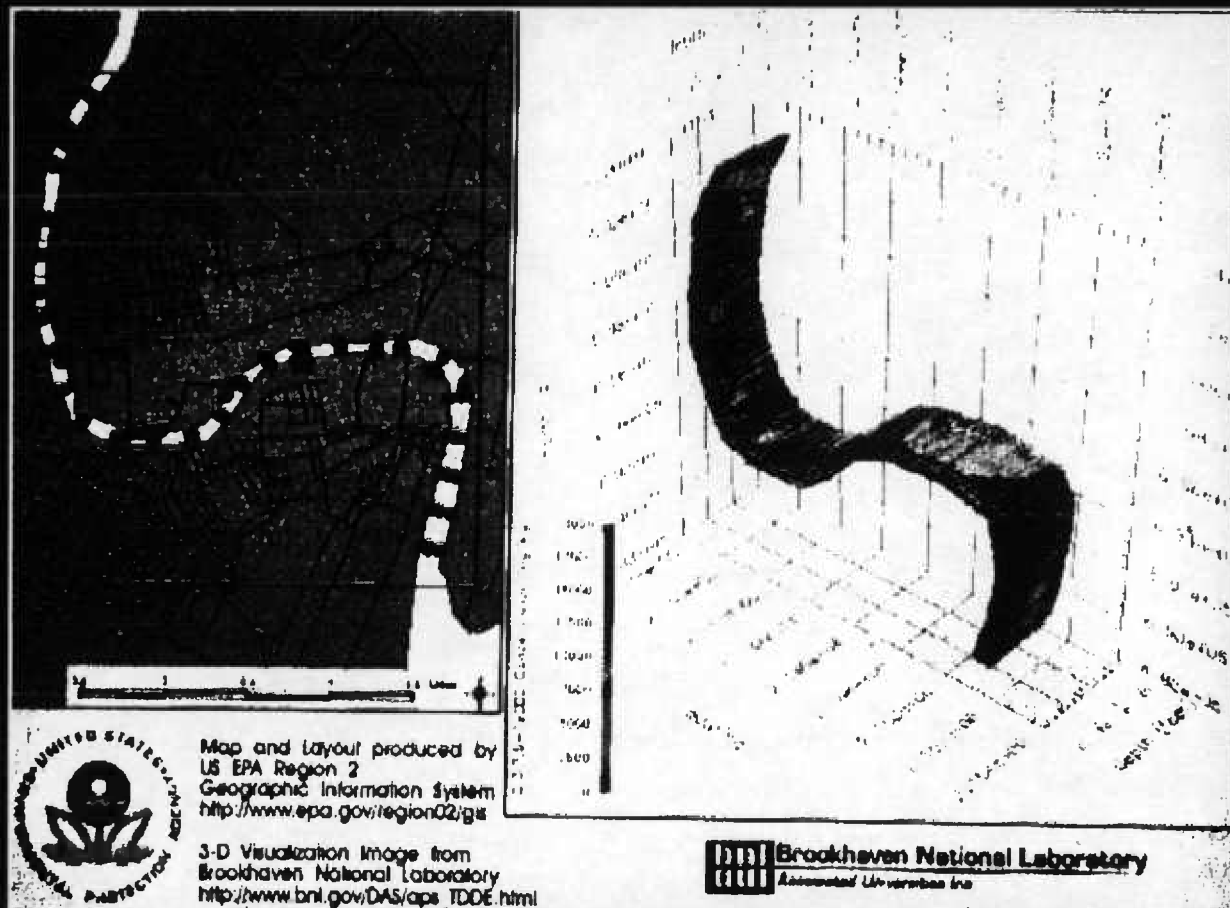
Exhibit 3

Contaminated Sediments
3-D Visualization Image



Hong Ma et al. 1998

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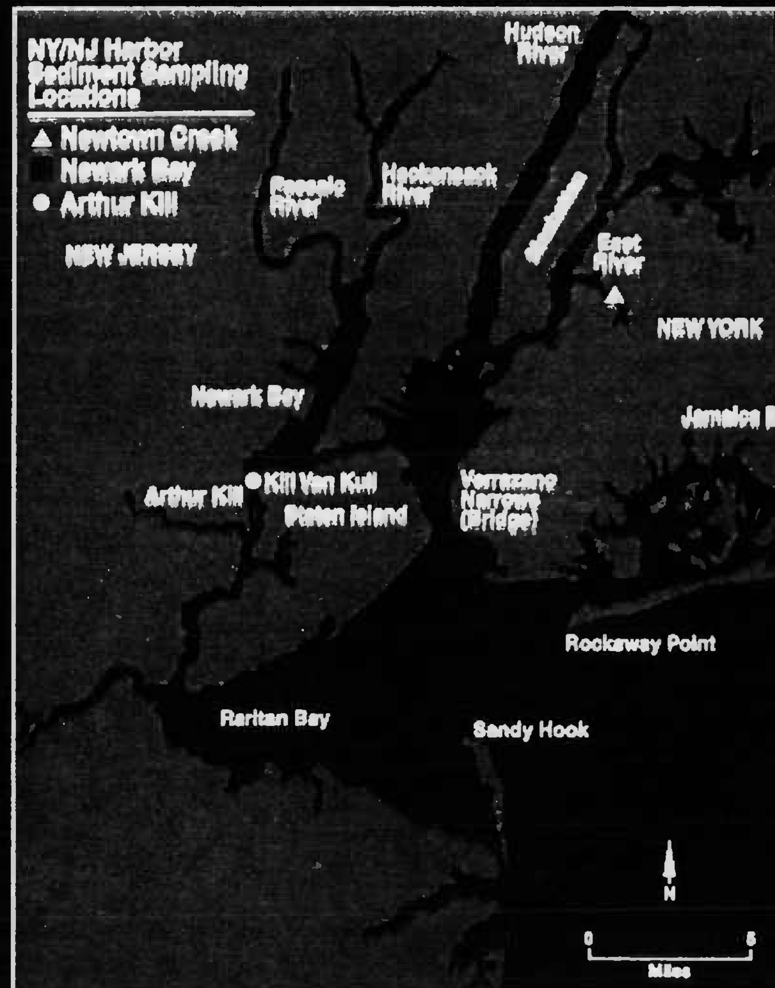
Exhibit 4

WRDA Sediment Decontamination Sediment Sampling Locations for Technology Investigations



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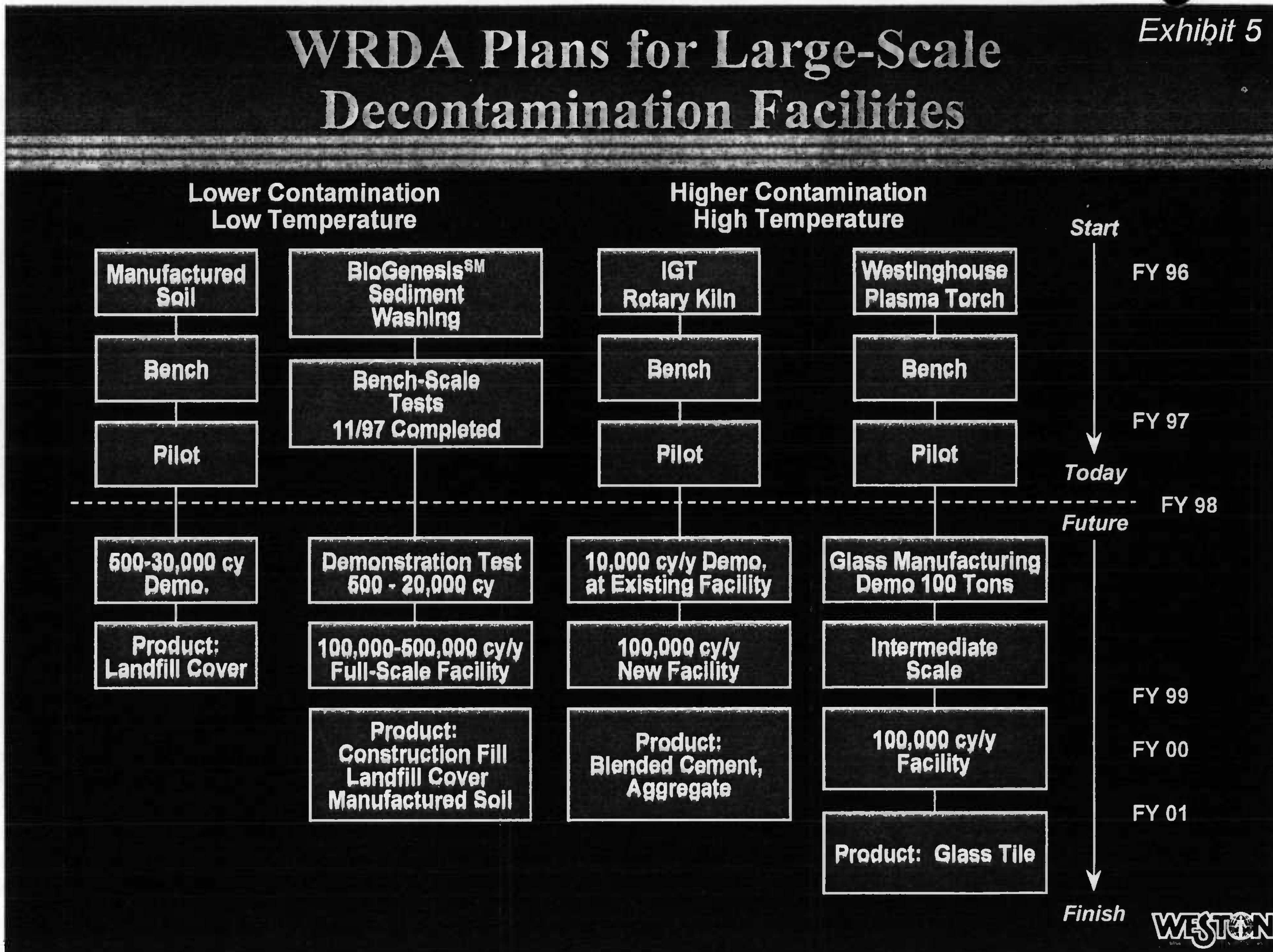
Exhibit 5
WRDA Plans for Large-Scale Decontamination Facilities
Lower Contamination
Low Temperature
Higher Contamination
High Temperature
Start
FY 96
Manufactured Soil
Bench
Pilot
BioGenesis SM Sediment Washing
Bench-Scale Tests 11/97 Completed
IGT Rotary Kiln
Bench
Pilot
Westinghouse Plasma Torch
Bench
Pilot
FY 97
Today
FY 98
Future
500-30,000 cy Demo.
Product: Landfill Cover
Demonstration Test 500 - 20,000 cy
100,000-500,000 cy/y Full-Scale Facility
Product: Construction Fill Landfill Cover Manufactured Soil
10,000 cy/y Demo, at Existing Facility
100,000 cy/y New Facility
Product: Blended Cement, Aggregate
Glass Manufacturing Demo 100 Tons
Intermediate Scale
100,000 cy/y Facility
Product: Glass Tile
FY 99
FY 00
FY 01
Finish
WESTON

Exhibit 6

Summary of Physical-Chemical Properties of Raw Sediment from Newtown Creek

Sample Designation		IGT-37 As Dredged Sediment
Particle size, wt % (dry basis)		
Medium gravel	(> 4.75 mm)	11.03
Fine gravel	(2 - 4.75 mm)	2.54
Very coarse sand	(0.85 - 2 mm)	1.78
Coarse sand	(0.425 - 0.85 mm)	3.21
Medium sand	(0.24 - 0.425 mm)	5.03
Fine sand	(106 - 240 mm)	9.38
Very fine sand	(75 - 106 μm)	2.84
Clay		28.23
Silt		35.96
		100.00
pH		7.25
Total Solids, wt % (dry basis)		44.6
Total Sulfides, mg/kg (dry basis)		5,900
Total Organic Carbon, wt % (dry basis)		7.50
TPH, mg/kg (dry basis)		16,100

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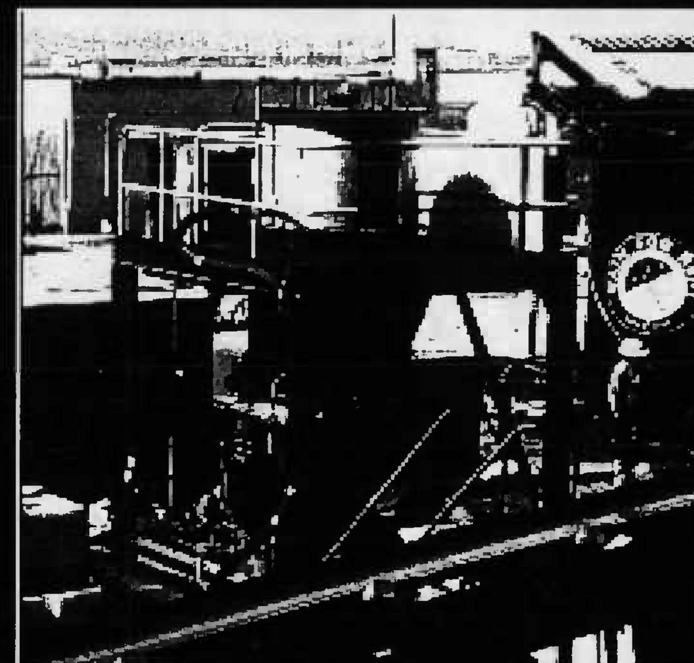
Exhibit 8

BioGenesis[SM] Pilot Plant Washing Equipment

Washing Gondola



Sediment Washer

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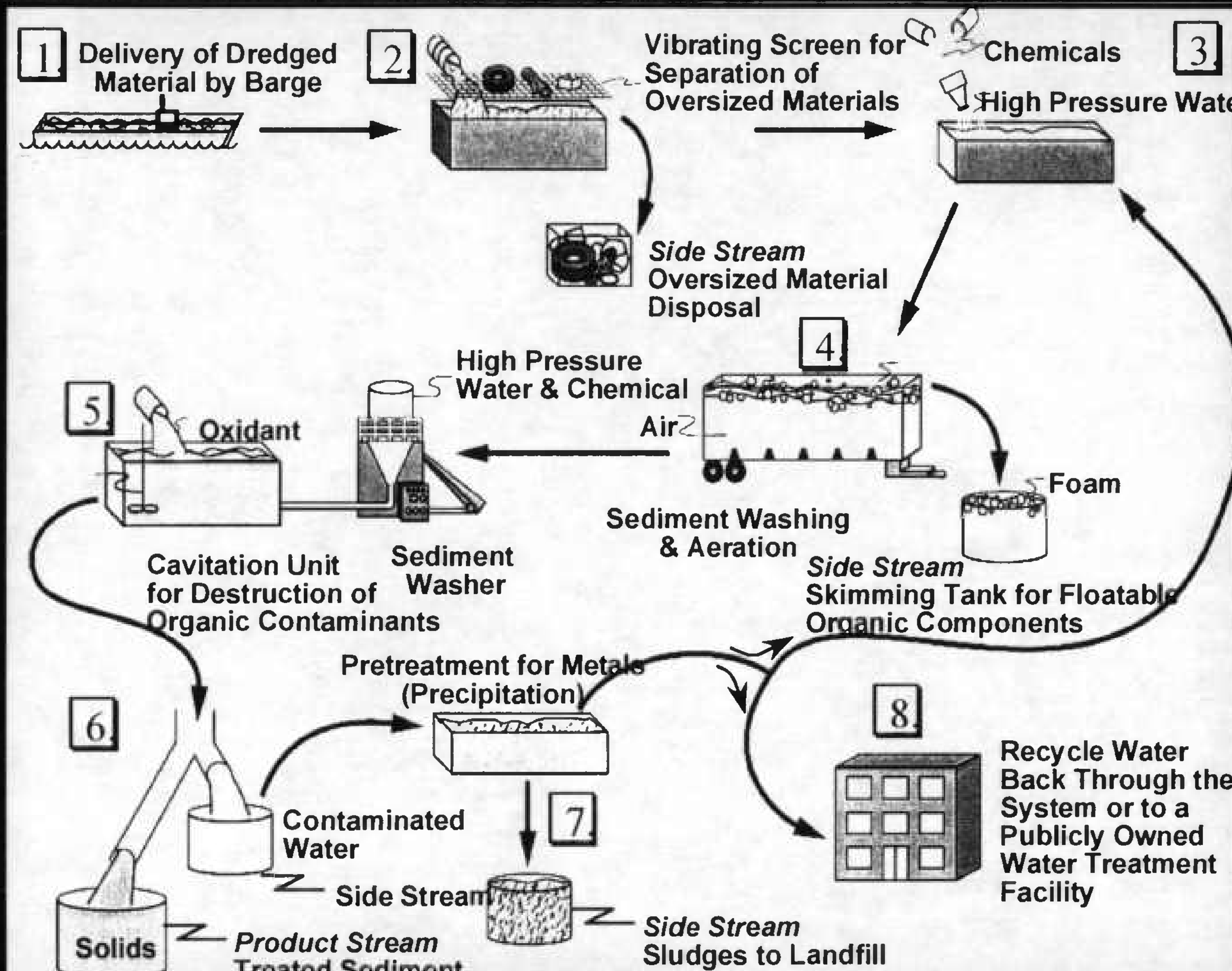
Exhibit 7

BioGenesis℠ Sediment Washing Process



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BioGenesis℠ Sediment Washing Two-Cycle Treatment Efficiency - Final Solids Analysis (11/97)

Contaminant	Untreated	Treated	Overall Removal Percent
TOC (%)			
Organic Content	9.2	2.0	78%
PAHs (ug/kg)			
napthalene	913	138	85%
acenaphthylene	326	34	90%
acenaphthene	434	34	92%
fluorene	533	51	90%
phenanthrene	2241	743	67%
anthracene	1612	177	89%
fluoranthene	7358	537	93%
pyrene	6767	177	97%
benzo(a)anthracene	3563	234	93%
chrysene	3781	286	92%
benzo(b)fluoranthene	3496	158	95%
benzo(k)fluoranthene	1155	204	82%
benzo(a)pyrene	2666	236	91%
indeno(1,2,3-cd)pyrene	1595	ND (MDL 26)	98%
benzo(ghi)perylene	1453	ND (MDL 27)	98%
Total PAHs	37895	3175	92%

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Exhibit 9 *(Cont'd)*

BioGenesis[SM] Sediment Washing Two-Cycle Treatment Efficiency - Final Solids Analysis (11/97) (Cont'd)

Contaminant	Untreated	Treated	Overall Removal Percent
PCB (ug/kg)			
MonoCB	175 EMPC	ND (MDL 7.5)	96%
Total DiCB	191EMPC	ND (MDL 8.2)	96%
Total TriCB	429	ND (MDL 8.8)	98%
Total TetraCB	718	ND (MDL 6)	99%
Total PentaCB	487	ND (MDL 6.2)	99%
Total HexaCB	456	ND (MDL 8)	98%
Total HeptaCB	165	ND (MDL 10)	94%
Total OctaCB	39	ND (MDL 14)	Not Determined**
Total NonaCB	13	ND (MDL 25)	Not Determined**
Total PCB	2673	93.7	96%
METALS (mg/kg)			
As	22	12	42%
Cd	18.2	1.4	92%
Cr	226	63	72%
Pb	454	60	87%
Hg	13	0.3	86%

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Treatment Efficiency

Contaminant	Untreated	Treated	Overall Removal Percent
PCB (ug/kg)			
MonoCB	175 EMPC	ND (MDL 7.5)	96%
Total DiCB	191EMPC	ND (MDL 8.2)	96%
Total TriCB	429	ND (MDL 8.8)	98%
Total TetraCB	718	ND (MDL 6)	99%
Total PentaCB	487	ND (MDL 6.2)	99%
Total HexaCB	456	ND (MDL 8)	98%
Total HeptaCB	165	ND (MDL 10)	94%
Total OctaCB	39	ND (MDL 14)	Not Determined**
Total NonaCB	13	ND (MDL 25)	Not Determined**
Total PCB	2673	93.7	96%
METALS (mg/kg)			
As	22	12	42%
Cd	18.2	1.4	92%
Cr	226	63	72%
Pb	454	60	87%
Hg	13	0.3	86%

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Exhibit 10

IGT Cement-Lock™ Process

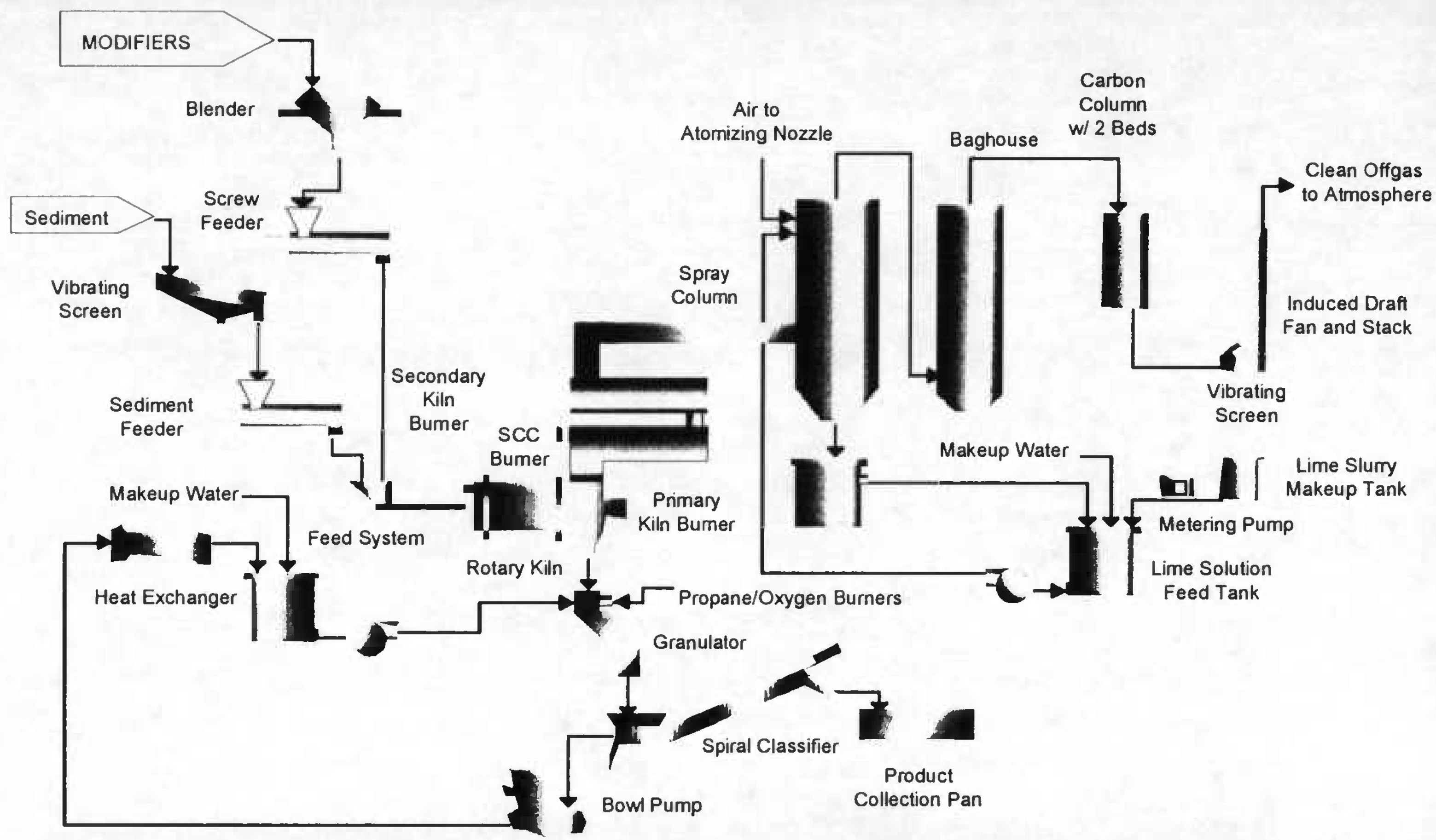

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Exhibit 11

IGT Cement-Lock™ Pilot Plant Equipment

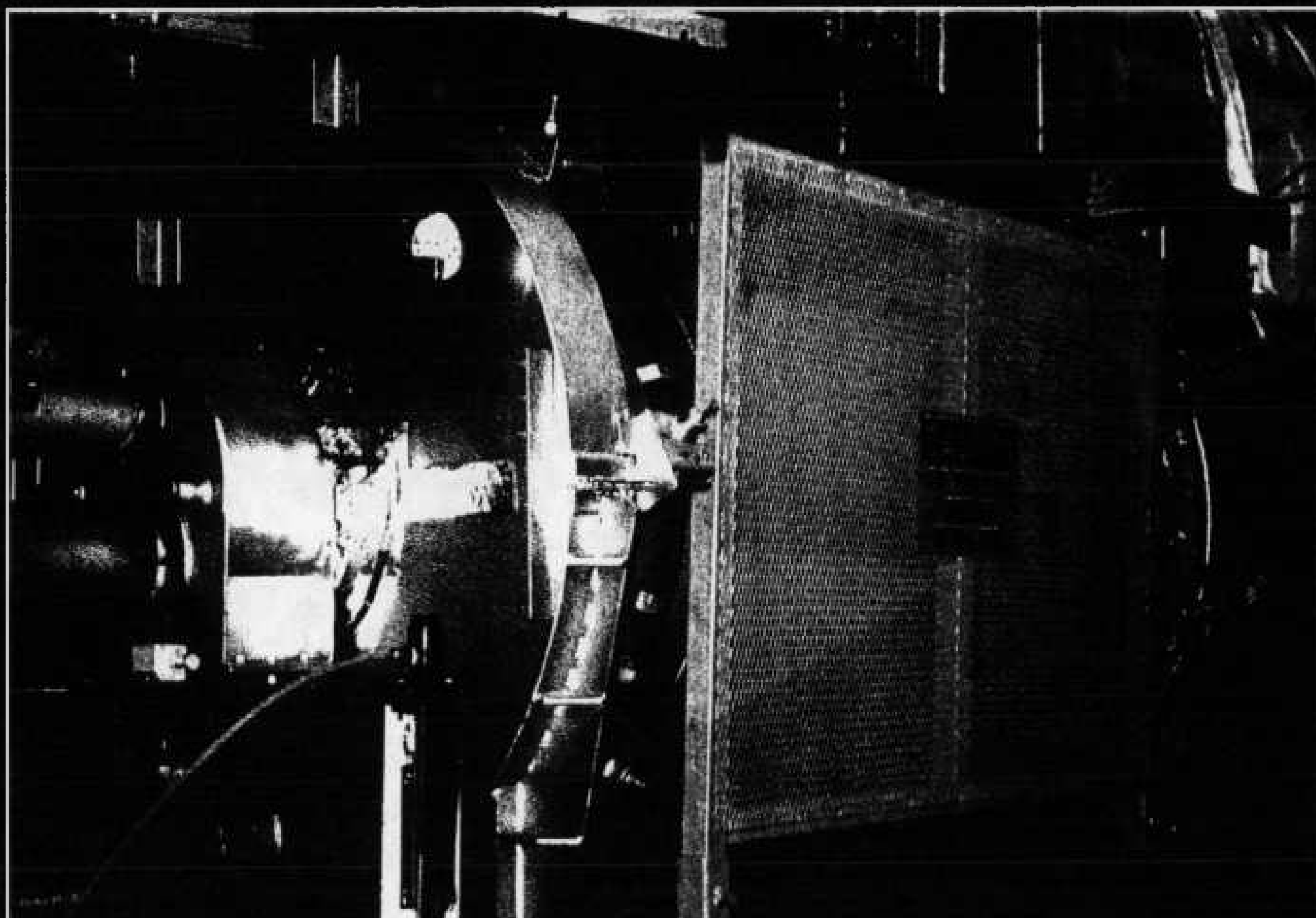

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Exhibit 12

Summary of Organic Contaminants in Dredged Newtown Creek Sediment, Blended Cement Products, and IGT Cement-Lock™ Destruction and Removal Efficiencies for Bench-and Pilot-Scale Tests

Contaminant	Units	Untreated Sediment		Blended Cement		DRE*	
		Lab-Scale	Pilot-Scale	Lab-Scale	Pilot-Scale	Lab-Scale	Pilot-Scale
PAHs (SVOCs)	ug/kg	116	370	0.3	0.22	99.24	99.93
PCBs	ug/kg	5.270	8.585	0.75	<D.L.**	>99.96	>99.99
2,3,7,8-TCDD/TCDF	ng/kg	381	262	<D.L.	<D.L.	>99.99	>99.99
Total TCDD/F	ng/kg	2.260	2.871	<D.L.	<D.L.	>99.99	>99.99
Total PeCDD/F	ng/kg	3.231	4.363	<D.L.	<D.L.	>99.99	>99.99
Total Hx/Hp/OCDD/F	ng/kg	38.945	34.252	18	<29	99.88	>99.90

* Destruction and removal efficiency

** Less than the detection limit of the analytical procedure used

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Exhibit 13

Summary of Potential Beneficial Reuse Products

Treatment Technology	Treatment Abilities	Beneficial Reuse Product	Amendment Requirements	Regulatory Standards	Product Value
BioGenesis[SM] Sediment Washing	Reduction in Organic and Inorganic levels	Nonstructural Fill (Daily Landfill Cover, etc.)	Bulking materials	NY/NJ Non-residential Standards	\$3 to \$8/cy
		Low End Manufactured Soil (Top Soil, Wetlands restoration, Brownfields, etc.)	Bulking materials, organic additives	NY/NJ Residential and/or Nonresidential Standards	\$7 to \$17/cy
		High End Manufactured Soil (Potting Soil)	Bulking materials, organic additives	NY/NJ Residential Standards	\$100/cy
IGT Cement-Lock[TM]	Reduction in Organic levels and stabilization of Inorganic levels	Blended Cement	Cement	NY/NJ Residential and/or Nonresidential Standards	\$50 to \$70/ton
		Construction	Cement	NY/NJ Residential and/or Nonresidential Standards	\$10 to \$20/ton

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