Commercialization of Dredged-Material Decontamination Technologies

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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.

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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

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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.

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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 con-

cerned 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

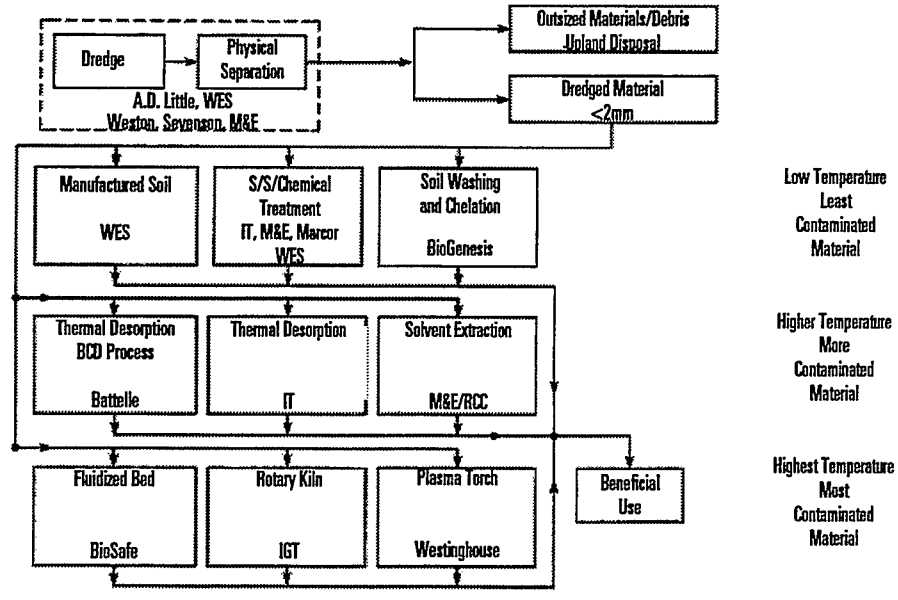
A matrix of technologies was selected for the initial bench-scale testing phase. They included low-, medium-, and high-temperature methods. A block diagram showing how they can be combined into a treatment train

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.

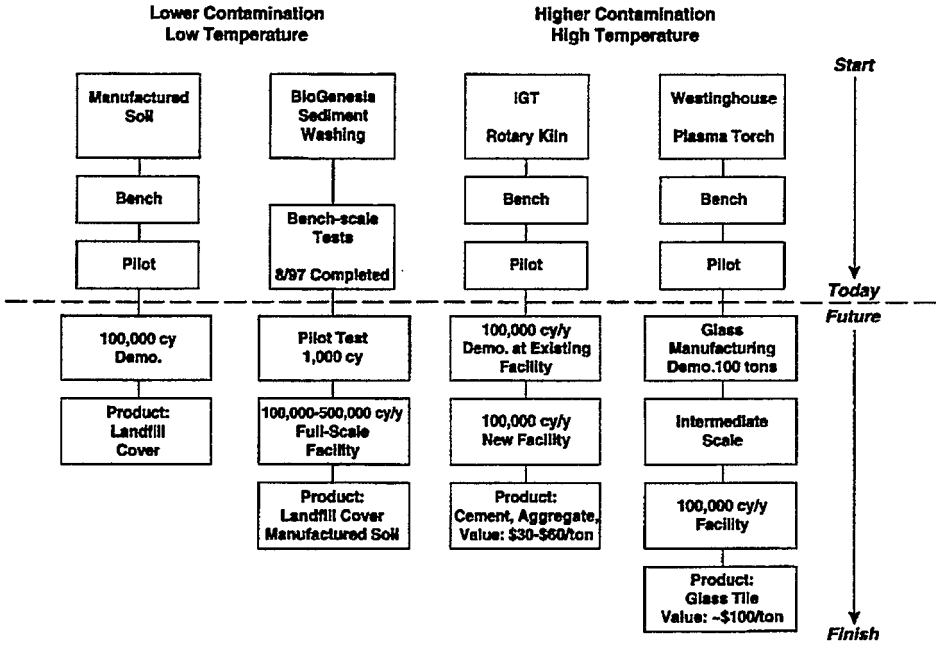
The testing program led to a treatment train that included both low- and high-temperature technologies that could satisfactorily treat dredged material with different levels of contamination.

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.

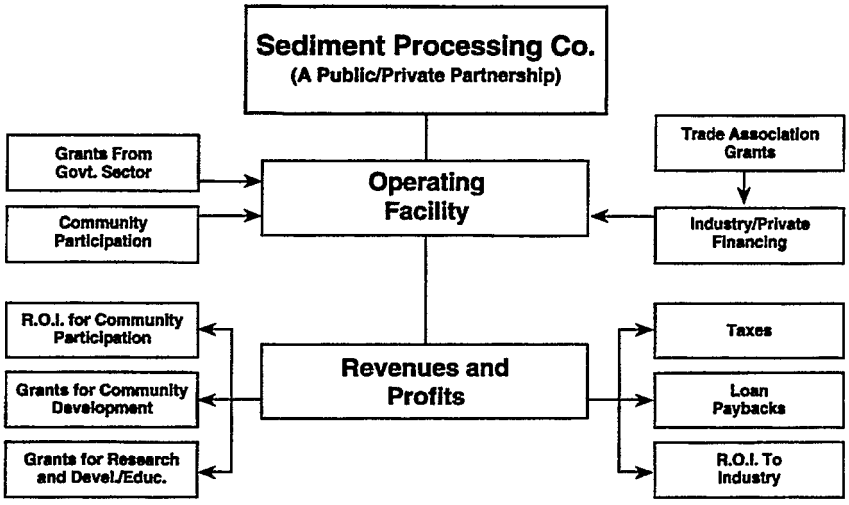
Costs for the various technologies discussed here have been refined continuously during the term of the project. The use of sediment-washing and manufactured-soil production is similar to a solidification/stabilization process, albeit with different additives. Thus, total costs of this disposal option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

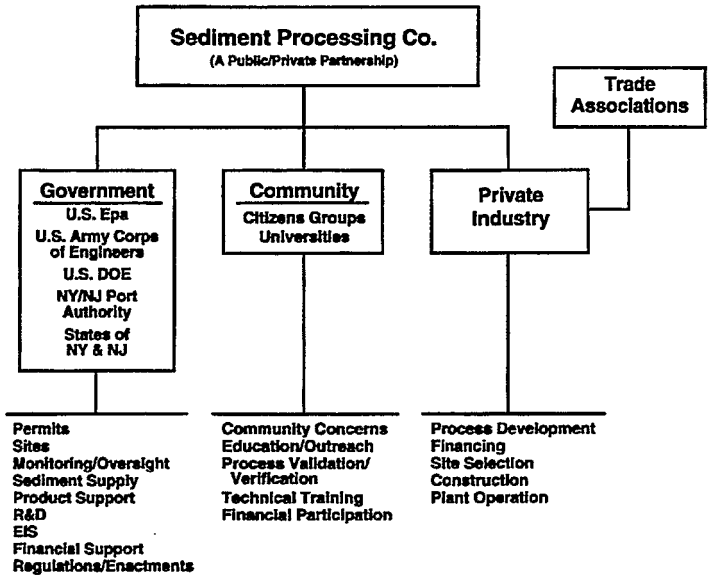
Exhibit 3. Conceptual Plan for Organization of Public-Private Consortium for Operation of Dredged-Material Decontamination Facility



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 ap-

proach 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.

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