CONFERENCE PROCEEDINGS 19

National Symposium on Contaminated Sediments

Coupling Risk Reduction with Sustainable Management and Reuse

TRANSPORTATION RESEARCH BOARD

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National Symposium on Contaminated Sediments

Coupling Risk Reduction with Sustainable Management and Reuse

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The views expressed in the presentations and papers contained in this report are those of the authors and do not necessarily reflect the views of the steering committee, the Transportation Research Board, the National Research Council, or the sponsors of the conference.

The conference was sponsored by the Transportation Research Board, the Marine Board, the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, and the U.S. Maritime Administration.

Cover design by Tamara Lee

Dedication

The Symposium Steering Committee dedicates this Proceedings to the late Joseph L. Zelibor, Jr., who served as the Marine Board staff officer on the NRC study report that was the basis for the symposium. In the words of one committee member, "Joe was one of the most dedicated and energetic individuals I had the privilege to work with.... He was always a quick learner regardless of the project he faced, whether it was dredging, marine mammals, or risk assessment...."

Although Joe had moved over to the Space Studies Board by the time the symposium activity got under way, another committee member stated that "Joe was [the one] who kept it alive ... the flame that would not go out ... until it finally happened."

His sudden and untimely death is a tragic loss to his family and to the many friends and colleagues he had within the NRC and the community it serves.

Joseph L. Zelibor, Jr.

Preface and Acknowledgments

At the request of the Marine Board and with the approval of the National Research Council, the Transportation Research Board (TRB) hosted the **National Symposium on Contaminated Sediments: Coupling Risk Reduction with Sustainable Management and Reuse** on May 27-29, 1998, in Washington, D.C. The goal of the symposium was to promote discussion of the issues raised and recommendations presented in the NRC report *Contaminated Marine Sediments in Ports and Waterways: Cleanup Strategies and Technologies*, released in March 1997.*

Although there are no simple solutions to the problems created by contaminated marine sediments, the problems can be managed effectively using a systematic, risk-based approach that incorporates incremental improvements in decision making, remediation technologies, and project implementation. Sponsors of the symposium were interested in educating and promoting dialogue among the diverse stakeholders involved in sediment management and in finding potential solutions. This was accomplished through a combination of expert panels, case study presentations, and roundtable discussions. The formal program was augmented by breakout discussion groups, which encouraged dialogue among the various stakeholders on specific issues of most interest to them. The key points from these discussions were then presented at plenary sessions.

* The executive summary of the NRC report is provided in Appendix D.

Another important component of the symposium was a number of staffed poster displays and demonstrations, highlighting a broad range of strategies and technologies that have been successfully implemented or that are in development. The focus was on specific research and case studies relating to the development and application of technologies and methodologies for management of contaminated sediments; specifically, decision-making processes, remediation technologies, and project implementation. Appendix A presents a synopsis of the displays.

The material in these proceedings has been condensed and edited to assist the readers, who do not have the benefit of the visual aids used both in the presentations and in the poster displays and demonstrations. Names of all speakers and participants appear either in the text or in the appendices. While there were more speakers, moderators, respondents, and exhibitors than can be recognized, the contributions of the following individuals are gratefully acknowledged:

- Steering Committee co-chairs Spyros P. Pavlou and Louis J. Thibodeaux; Committee members W. Frank Bohlen, Lillian Borrone, Billy Edge, and James Wenzel for their work in developing the program, soliciting speakers and panelists, and chairing sessions;
- Sponsor liaisons Joe Wilson from the U.S. Army Corps of Engineers, Craig Vogt from the Environmental Protection Agency, and Michael Carter from the Maritime Administration for their assistance in coordinating federal agency participation;

• Thomas Wakeman III from the Port Authority of New York and New Jersey for his support in developing the program and helping review and organize the poster displays and demonstrations;

• David Caulfield, Wayne Young, Issa Oweis, Rachel Friedman-Thomas, John Connolly, and Edward Neuhauser for developing and presenting case studies;

• Industry and agency representatives who served as panelists for plenary sessions and facilitators and rapporteurs for the breakout sessions;

• The organizations that offered poster displays and demonstrations of projects and technologies; and

• The late Joseph L. Zelibor, Jr., who was involved in the original NRC study effort, suggested the symposium activity, and provided advice and support throughout the process.

Special thanks are given to the U.S. Army Corps of Engineers, the Environmental Protection Agency, the Maritime Administration, the Hazardous Substance Research Center South & Southwest, Aluminum Company of America (ALCOA), the Chemical Manufacturers Association, E.I. duPont de Nemours and Company, General Electric, Kennecott Utah Copper, Niagara-Mohawk Power Corporation, the Olin Chemical Charitable Trust, and URS Greiner/Woodward-Clyde, Inc., for their financial support.

Contents

Introduction

Chairmen's Summary

Spyros P. Pavlou, *URS Greiner, Incorporated*
Louis J. Thibodeaux, *Louisiana State University*

History

In 1993, in response to requests by a number of federal agencies—including the U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers, Maritime Administration, U.S. Navy, U.S. Geological Survey, and National Oceanic and Atmospheric Administration—the Marine Board of the National Research Council (NRC) assembled a committee to evaluate the state of practice in the management and remediation of contaminated marine sediments in the United States and provide recommendations for future action.

The committee's evaluation, conclusions, and recommendations were documented in a report, *Contaminated Sediments in Ports and Waterways: Cleanup Strategies and Technologies*, published in March 1997. A summary of the conclusions and recommendations also was published in the May–June 1998 issue of *TR News*, which focused on ports and waterways. The article is included as a sidebar to this section of the Proceedings.

During the committee's deliberations, it became clear that the success of contaminated sediment remediation projects depends heavily on consensus building in decision making among diverse stakeholders (e.g., port managers; transportation officials; industrial managers; federal, state and local regulators; resource managers; environmental advocates; and the general public). It also became clear that there were limited venues in which these stakeholders could address issues collectively in a nonadversarial setting.

The committee, therefore, recommended to the supporting agencies that its findings, conclusions, and recommendations be discussed in an open forum, a national symposium, to obtain stakeholder feedback and perspectives on what is needed for future planning and decision making.

At the request of the Marine Board, the Transportation Research Board (TRB) assumed the responsibility for organizing and hosting the symposium. A technical steering committee was convened to guide development of the technical program and identify stakeholder groups and potential speakers. The National Symposium on Contaminated Sediments was held on May 27–29, 1998, at the National Academy of Sciences in Washington, D.C. Joedy Cambridge was the TRB program officer managing the activity.

The goal of the symposium was to engage stakeholders in a productive exchange of ideas and foster a partnership for cooperative problem solving. Stakeholder responses and perspectives were presented by representatives of ports, the chemical and mining industries, environmental groups, regulatory and resource agencies, and the legal community.

Symposium Highlights

As noted in the NRC report, the committee focused its efforts on the following tasks:

- Review, evaluation, and ranking of sediment remediation technologies in terms of implementability, effectiveness, practicality, and costs;
- Aspects of project implementation, including source control, cost sharing, and beneficial uses of contaminated sediments; and
- Use of a risk-based approach for improving decision making, including the availability of decision-analysis tools.

This summary highlights stakeholder responses to, and comments on, the committee's recommendations and the remainder of the NRC report, together with participants' perspectives on the symposium themes—risk reduction, sustainable management, and reuse.

Risk reduction, in the context of the NRC report, pertains to more than the attainment of post-remediation chemical residuals in the sediments that protect human health and the environment. Risk reduction is viewed as part of the overall decision-making process for contaminated sediment management, particularly the evaluation of the trade-offs between risks, costs, and benefits associated with the selection of a preferred management alternative among a number of available options.

Sustainable management implies continuity and adaptability through an evolving knowledge base. As symposium participant Thomas Wakeman said, "Managers adapt; regulators do not."

Reuse is tantamount to beneficial use. Can contaminated sediments be promoted as bad materials that can be made good?

Technologies

In Situ Technologies

The report concluded that high-volume, low-cost technologies should be a first choice in sediment remediation. In situ technologies (e.g., natural recovery, capping, and containment) are effective methods for contaminated sediment management. Natural recovery is a viable and optimal solution when contaminant concentrations are low. If natural recovery is insufficient, then capping may be appropriate. The Comprehensive Environmental Response, Cleanup, and Liability Act (commonly known as Superfund) should be amended to allow capping as a permanent remedy. In situ chemical treatment has conceptual advantages, but further research and development (R&D) is required. The same is true for bioremediation: R&D is needed to resolve microbial, geochemical, and hydrological issues.

Symposium participants expressed support for the committee's recommendations, but also recognized that a very limited database is available on in situ technologies for use in determining long-term efficacy (i.e., only five or six sites were discussed). Participants also offered the following additional comments on in situ technologies:

Available data should be placed in a central repository that is easily accessible for use in decision making and promoting acceptability of the technologies. There must be an understanding of the effectiveness of in situ technologies in reducing risk (in both the short and long term). There is a need for long-term monitoring to evaluate the contribution of source control to loading reduction, enhance understanding of natural attenuation (i.e., degradation processes within caps), and help control contaminant release due to failure of capping or containment.

Acceptability criteria must be developed that can be applied on a site-by-site basis and can define long-term risk reduction. Good science is lacking. Guidelines for standardizing cost data need to be developed, and cost data need to be released to stakeholders and the public (i.e., to explain what is being done to achieve a desired level of risk reduction). The strongest resistance to the use of in situ options relates to the disincentive for long-term monitoring by principal responsible parties (PRPs). The problem is the potentially open-ended cost commitment, and associated uncertainty in costs, under the current regulatory framework (i.e., the project cannot come to closure).

There is a need to develop effective risk communication tools to improve public perceptions. Citizen and community forums were effective in achieving understanding and implementing in situ options at some sites. The public needs to be educated on the science of in situ technologies to avoid poor decision making based on ignorance.

Dredging and Disposal

According to the report, precision dredging at near–in situ densities should be made widely available to limit the capture of clean sediments and water and to reduce the volume of material. Methods for preserving the capacity of existing confined disposal facilities are needed. Contained aquatic disposal on or near contaminated areas appears to have a high potential for acceptability, which must be explored fully. There is a need for R&D on cap design to enhance biohabitat improvement. There also is a need for long-term monitoring methods to evaluate contaminant degradation under caps and control potential contaminant releases.

Symposium participants generally concurred with the NRC recommendations. Participants expressed support for the implementation of performance-based contracting and longer-term contracts in the dredging industry, so that companies would have more security and therefore could take on the risk of developing innovative approaches. Concern was expressed that companies should not bear all the costs of innovation, particularly given the difference between dredging for navigational purposes versus cleanup.

Ex Situ Treatment

The report concluded that ex situ treatment is justified only for relatively small volumes of highly contaminated sediments. Unit costs of advanced treatment may decline slightly as they move through the demonstration phase, but they are unlikely to become competitive with less expensive containment technologies. Cost data on full-scale remediation technologies must be improved, and R&D should focus on ex situ technologies for the cost-effective treatment of large sediment volumes. There is a need for bench- and pilot-scale investigations to demonstrate the effectiveness of ex situ technologies, including bioremediation.

Symposium participants indicated that the treatment cost estimates in the 1997 NRC report [up to \$1,000/yd^3 (\$1,310/m^3)] are outdated. The current state-of-practice estimates are \$50 to \$70/yd^3 (\$65 to \$92/m^3). Long-term contracts would result in more economies of scale.

Project Implementation

The report concluded that the burden for source control should be transferred to states and polluters, for the following two reasons. First, states benefit from dredging and customarily are engaged in wetlands management. Under Section 303 of the Clean Water Act, the EPA and the states set total maximum daily loads for waterway segments and develop allocations for pollution. A similar approach can be applied to sediment pollution control. Second, ports already bear an inequitable share of the responsibility for remediation and disposal. There is a need to develop cost-sharing formulas for dredging and disposal. By adopting a consistent cost-sharing approach founded on cost-benefit considerations, the cost-effectiveness of dredging and disposal can be improved.

This issue turned out to be a point of contention between the port and chemical industry representatives at the symposium. The former asserted that ports provide services in a way that ensures a return on their investment. Therefore, ports must know the risks, the costs of reducing the risk, and the benefits of managing contaminated sediments—because someone has to pay. Those who benefit should pay and those who created the problem also should pay. The chemical industry representatives disagreed with the view that polluters should pay and ports should be given more leverage. They advocated a fair allocation of risk and costs, particularly given that disposal actions taken 20 or 30 years ago were considered legal at the time. Both sides, however, acknowledged that partnering among stakeholders is essential for effective problem solving.

During the course of discussions, symposium participants offered the following additional comments: Before considering source control, sources first must be identified. Sources include point discharges (e.g., industrial and municipal outfalls) and nonpoint discharges (e.g., groundwater, atmospheric deposition, inflow of natural background constituents) into surface water systems. Sources must be prioritized in terms of mass loading; waste allocation formulas must be developed; and cost trade-offs between source control and contaminated sediment management must be evaluated. Source control is linked to the acceptable risk criteria that must be met to protect human health and the environment. An effort must be made to avoid focusing on a single discharger or specific industry, and the public must be involved in the process. This approach will foster cooperative problem solving rather than finger pointing and rhetoric. Ongoing sources must be tracked down and interdicted.

According to the report, the precision of site assessments can be improved through the use of remote sensing (e.g., acoustic coring). R&D should be initiated to advance the state of the science in site assessment technologies (e.g., advanced survey methods, chemical sensors for surveying and monitoring). Data gathering must focus on specific needs. A manager needs to understand the site dynamics and factors influencing the transport, bioavailability, and spatial and temporal variability of the contaminants of concern to achieve minimum-cost projects that meet cleanup objectives and allow for the establishment of optimal remediation schemes. All sampling is dictated by that requirement. Administrative interim controls (e.g., health advisories, signs), coupled with natural recovery, may be appropriate in certain situations.

The report also suggested that beneficial uses of contaminated sediments may resolve complex disposal dilemmas and can offset clean-up costs. Therefore, beneficial uses of contaminated sediments (e.g., islands for seabird nesting, landfills for urban developments, beach nourishment, wetlands, shoreline stabilization, topsoil for landfill covers, construction fill) should be explored further, and regulatory agencies should continue funding R&D for innovative beneficial-use alternatives. In addition, the agencies should revise policies to allow for placement strategies that incorporate beneficial uses and should develop incentives to encourage the implementation of these alternatives.

This topic provoked considerable discussion during the symposium. Major questions raised included the following:

- How should beneficial uses be promoted? Funding is needed for demonstration and marketing, collection and organization of data, and classification standards and protocols to foster public confidence.
- What are the barriers to deriving the benefits? The barriers include public skepticism, lack of organized information on all aspects of commercialization, and lack of legislative authority and designation of sediments as nonwaste materials.

Actions to be taken include the following:

- Congressional designation of sediments as nonwaste;
- EPA designation of sediments as recovered material that meets specific standards and can be considered in the federal procurement process;
- EPA evaluation of the benefits of using sediments on brownfield;
- Development of standards for sediment products as well as for manufacturing processed sediments; and
- Funds to support demonstration projects.

Priority uses identified included mine reclamation, raw material manufacturing, wetlands construction, brownfields redevelopment, beach nourishment, and soils for farmlands.

Decision Making

The report concluded that stakeholder involvement early in the decision process is important in heading off disagreements and building consensus. Symposium participants agreed and offered the following additional comments: Partnering is the common thread to successful decision making. Public outreach, communication, and perception are also important in gaining public acceptance of contaminated sediment remediation projects. Information must be disseminated in an understandable format and communicated at the level of the audience; it also must be believable and trustworthy. Face-to-face meetings must be held to help build relationships. Clear communication is imperative: For many people, "risk" means danger, "disposal" denotes garbage, and "ignorance" equals fear.

According to the report, a systematic risk-based approach offers the best chance for cost-effective management. Uniform procedures should be developed to address human health and environmental risks associated with disposal, containment, or beneficial reuse of contaminated sediments. Risk analysis can be applied more widely in selecting and evaluating management alternatives and remediation technologies. Projects should be evaluated based on performance and success in achieving desired risk reduction. The relationship between contaminant bioavailability and risk should be quantified.

This approach was supported by many of the symposium participants, but with caveats. There must be recognition of the limitations of assumptions, uncertainty in estimating risk, and different perceptions regarding acceptable risk. A risk-based approach is more difficult to communicate to the public than is compliance with prescribed administrative standards or criteria. Sediment quality assessment protocols do not project potential ecosystem impacts. Prognostic modeling quantifying the relationship between bioavailability and risk was identified as a method for determining whether a given remedial action is effective for achieving a desired level of risk reduction, particularly as it pertains to sediment removal.

The report concluded that trade-offs among risks, costs, and benefits can be analyzed to improve decisions and the selection of preferred alternatives. Information on the state of the science of decision tools (e.g., risk analysis, cost-benefit analysis, risk-cost optimization, cost-risk-benefit [CRB] trade-off procedures) should be communicated to stakeholders at the outset of a project. Stakeholders should be considered an integral part of the cooperative problem-solving process and should support pilot projects to demonstrate the use and effectiveness of decision-making tools.

Although this logic was accepted by many symposium participants, the need to demonstrate CRB methodology in a real situation also was recognized. There is a need to account explicitly for direct and indirect costs for different management options and to quantify benefits so that a trade-off evaluation becomes a useful tool in selecting a preferred alternative. However, a detailed cost-benefit analysis may not be attainable within the schedule for completing a project, because the benefits may be difficult to quantify or translate into monetary terms.

Strategies and Technologies for Cleaning Up Contaminated Sediments in the Nation's Waterways

The National Research Council Study

By Spyros P. Pavlou and Louis J. Thibodeaux

Contaminated marine sediments pose a threat to ecosystems, marine resources, and human health. Sediment contamination also interferes with shipping activities and growth of trade resulting from delays in dredging and the inability to dredge the nation's harbors due to controversies over risks and costs of sediment management. Given that approximately 95 percent of total U.S. trade passes through dredged ports, potential economic impacts due to sediment contamination may be severe.

The management of contaminated sediments is complex and difficult. The factors that contribute to the complexity are many, exacerbate the problem, and result in non-cost-effective management actions with controversial outcomes and marginal benefits. These factors include

- High public expectations for protecting human health and the environment;
- Multiple stakeholder interests and priorities;
- Conflicting and overlapping jurisdictions of federal, state, and local regulatory authorities;
- Relatively low levels of contamination;
- Large quantities of affected sediments;
- Uncertainty in quantifying and managing risk; and
- Limitations of handling and treatment technologies.

An overview of a study performed by the National Research Council's (NRC) Committee on Contaminated Marine Sediments is provided here. The 15-member committee included national experts from academia, industry, and the professional services sector. The committee was established in the spring of 1993 and completed its work in the summer of 1996. The committee's deliberations were published in a report released by the NRC in March 1997. This report was a basis for discussions and presentations at TRB's National Symposium on Contaminated Sediments: Coupling Risk Reduction with Sustainable Management and Reuse held in Washington, D.C., in May 1998.

Scope of the NRC Initiative

The committee's charge was to

(1) Assess best management practices and emerging technologies for reducing adverse environmental impacts;

(2) Appraise interim control measures for use at contaminated sediment sites;

(3) Address ways to use and communicate information about risks, costs, and benefits to guide decision making; and

(4) Assess current knowledge and identify research needs for enhancing contaminated sediment remediation technology.

Technical information was reviewed and assessed. Committee members interacted closely with researchers, regulators, stakeholders, engineers and operators. Six case studies of contaminated sediment remediation were evaluated and one sediment remediation project site was visited. In addition, the committee conducted workshops on interim controls and long-term technologies, summarized site assessment methods, and evaluated the application of decision tools to the contaminated sediment management process. The results obtained from these tasks then were assembled and organized under three major categories: remediation technologies, project implementation, and decision making.

Remediation Technologies

Remediation technologies were grouped into four categories: interim control, in situ management, sediment removal and transportation, and ex situ management. The technologies were compared qualitatively in terms of state of maturity, frequency of usage, scale of application, cost per cubic yard, and use limitations. They were then scored and ranked according to four criteria:

effectiveness, feasibility, practicality, and cost. The committee also addressed the need for remediation technology research, development, testing, and demonstration. The following conclusions and recommendations were then formulated:

- Capping, containment and natural recovery are effective management methods for most contaminated sediments. Where remediation is necessary, high-volume low-cost technologies are the first choice, assuming they are feasible and succeed in attaining the required risk reduction for protecting human health and the environment. Because treatment is expensive, reducing volume is important.
- Treatment is usually justified only for relatively small volumes of highly contaminated sediments. Advanced treatment is too costly in the majority of cases, which typically involve low-level contamination.
- Cost data for full-scale remediation systems must be improved to allow for fair overall comparisons and development of benchmarks for R&D and systems design. Regulatory agencies should develop guidelines for calculating costs of remediation systems, including technologies and management methods. The agencies should maintain a database on the costs of systems that have actually been used.
- Natural recovery is viable and can be considered as an optimum remediation solution when contaminant concentrations are low. If natural recovery is not feasible, capping may be appropriate to reduce bioavailability. Monitoring is required to test the efficacy of capping. The use of capping might be advanced if it were viewed as a permanent remedy under Superfund.
- In situ chemical treatment has conceptual advantages but considerable R&D will be needed before successful application can be demonstrated. Similarly, using bioremediation to treat in-place sediments requires further R&D to resolve microbial, geochemical, and hydrological issues. Given the high costs of ex situ treatment relative to dredging, dredging technologies must be improved to enable sediment removal at near in situ densities and precise removal of contaminated sediments to limit the capture of clean sediments and water. In this manner, the volume of dredged material requiring containment or treatment can be reduced.
- Research is needed to improve control of contaminant releases, long-term monitoring methods, and techniques for preserving the capacity of confined disposal facilities (CDFs).
- The potential for constructing contained aquatic disposal (CAD) facilities on or near contaminated sites must be explored fully. Regulatory agencies should support research to improve design tools for preventing containment failure, improve monitoring methods for assessing long-term performance, control contaminant loss, and determine risk-reduction effectiveness through contaminant isolation.
- Regulatory agencies should support research for promoting the reuse of CDFs and CADs and for improving tools for the design and evaluation of their long-term stability and effectiveness.
- R&D on ex situ treatment technologies is warranted in the search for cost-effective treatment of large sediment volumes. Bench- and pilot-scale testing of ex situ treatment technologies—and eventually full-scale demonstrations in marine systems—are needed to improve cost estimates, resolve technical problems, and improve treatment effectiveness.
- Additional R&D and demonstration projects are needed to improve technologies and reduce risks associated with developing and implementing innovative approaches. The advancement of cost-effective and innovative technologies could be facilitated by peer review of R&D proposals and side-by-side demonstrations of new and current technologies. Regulatory agencies should develop a program to support such R&D and demonstration projects.

Project Implementation

Although improvements in remediation technologies would contribute to cost-effective contaminated sediment management, a variety of practical issues must be addressed to remove constraints in project implementation. These include responsibility for source control, site characterization needs and technologies, interim controls, and promotion of beneficial uses. The committee's conclusions and recommendations regarding these issues included the following:

- Since ports currently bear an unfair share of the responsibility for remediation and placement of contaminated sediments, project implementation should transfer the burden for source control to states and polluters. Federal and state regulators, together with the ports, should investigate the use of appropriate legal and enforcement tools to require the upstream contributors to the contamination to share equitably in the cleanup costs.
- New and improved techniques are needed to reduce the costs and enhance the precision of site assessments. The use of remote sensing technologies—including rapid and accurate sensors—might accomplish this goal. Regulatory agencies should support R&D to advance the state of science in site-assessment technologies. Objectives should include the identification and development of advanced survey approaches and new and improved chemical sensors for surveying and monitoring.
- Where sediment contamination poses an imminent danger, administrative and engineering or struc-

tural controls can be used to reduce risks to humans and to ecological receptors from exposure to contaminated sediments over the short term, until a more permanent remedy can be implemented.

• Beneficial uses of dredged contaminated material can provide socially acceptable disposal alternatives. These uses could include, for example, creation of islands for seabird nesting, landfills for urban development, beach nourishment, wetlands, shoreline stabilization, topsoil for landfill covers, and other potential marketable uses. Regulatory policies developed to allow for placement strategies that incorporate the beneficial use of contaminated sediments should be enhanced. Regulatory agencies involved in contaminated sediment disposal should develop incentives for—and encourage implementation of—beneficial-use alternatives. Funding should be continued for R&D of innovative beneficial uses of contaminated sediments and the development of technical guidance and procedures for environmentally acceptable beneficial reuse.

Decision Making

Factors influencing decision making include regulatory realities, stakeholder interests, site-specific characteristics and data uncertainty, and availability of remediation technologies. The committee examined all of these factors and developed the following conclusions and recommendations:

• Stakeholder involvement early in the decision process is important to head off disagreements and build consensus among all involved. When decisions are complex and divisive, obtaining consensus among stakeholders can be facilitated by using formal, analytical tools, such as decision analysis.

• The trade-off evaluation of risks, costs, and benefits, and the characterization of their uncertainties in selecting a preferred management alternative offers the best chance for effective management and communication of the decision-making process to stakeholders. Risk analysis is an effective method for selecting and evaluating management alternatives and remediation technologies. More extensive use of appropriate methods for cost-benefit analysis has the potential to improve decision-making.

• Regulatory agencies should sponsor research to quantify the relationship between contaminant availability and corresponding human health and ecological risks. The main goal is to evaluate sediment remediation projects using performance-based standards, i.e., risk reduction from in-place sediments, disturbed sediments, and sediments under a variety of containment, disposal, and treatment scenarios. This is critical to the successful trade-off evaluations of risks, costs, and benefits to make technically defensible decisions in selecting a management alternative.

• The use of systems engineering can strengthen project cost-effectiveness and acceptability. In choosing a remediation technology, systems engineering can help ensure that the solution meets all removal, containment, transport, and placement requirements while satisfying environmental, social, and legal demands.

• Federal, state, and local agencies should work together with appropriate private sector stakeholders to interpret statutes, policies, and regulations constructively, so that negotiations can move forward and sound solutions are not blocked or obstructed.

• Regulatory agencies should continue to develop uniform or parallel procedures to address human health and environmental risks associated with freshwater, marine, and land-based disposal, containment, or beneficial reuse of contaminated sediments.

• Regulatory agencies should develop and disseminate information to stakeholders regarding the availability and applicability of decision analysis tools; appropriate risk analysis techniques for use throughout the management process, including the selection and evaluation of remedial alternatives; and the demonstration and appropriate use of decision analysis in an actual contaminated sediment remediation case.

• Existing cost-benefit analysis guidelines and practices developed by regulatory agencies should be modified to ensure comprehensiveness and uniformity in method application.

Summary

There are no simple solutions to the problems created by contaminated marine sediments. However, the NRC study summarized here indicates that careful problem formulation and good information provide the foundation for good decisions in managing contaminated sediments. Incremental improvements can be made in remediation technologies, project implementation, and decision-making and can result in cost-effective, socially acceptable, and environmentally sound solutions.

Spyros P. Pavlou is technical director for environmental risk economics at URS Greiner, Seattle, Washington. Louis J. Thibodeaux is Jesse Coates Professor of Chemical Engineering at Louisiana State University. Both were members of the NRC Marine Board Committee on Contaminated Marine Sediments and served as co-chairs of the TRB A1T85 Steering Committee for the National Symposium on Contaminated Sediments. *This article originally appeared in the May-June 1998 issue of* TR News.

Welcoming Remarks and Charge to the Symposium

William A. Wulf, *National Academy of Engineering*
Louis J. Thibodeaux, *Louisiana State University*
Spyros P. Pavlou, *URS Greiner, Incorporated*

Science and Engineering Informing the Political Process

William A. Wulf

As president of the National Academy of Engineering, it is my pleasure to open this first session of the National Symposium on Contaminated Sediments. I would like to begin by saying a few words about the set of organizations we refer to as the National Academies. There are actually four organizations, and unless you have some rudimentary understanding of that, it can be somewhat confusing.

I will start with a bit of history. The Europeans have had a set of academies of science for about four centuries. These academies are primarily honorific societies—in England, it is called the Royal Society. One gets elected to the academy of sciences by the members, based on a lifetime of contribution to scientific discovery.

In the United States, a little past the middle of the nineteenth century, a group of Americans decided this nation also should have such an organization. They decided to create a private, not-for-profit corporation called the National Academy of Sciences, incorporated in Washington, D.C. At the time, Washington, D.C., did not have a city government. Because the city was governed at the time by the federal government, more specifically by the U.S. Congress, all corporate charters were granted by the Congress. Accordingly, this group of Americans went to the Congress and asked that a corporation be formed.

However, a funny thing happened on the way to the Senate. It turned out there were two competing groups, and both wanted to form the National Academy of Sciences. One of them obviously would lose. A senator who was in favor of, and represented, the losing group inserted some nonstandard language into the boilerplate for the corporate charter. It was intended as a "gotcha." That nonstandard language said the National Academy of Sciences would provide advice to the federal government on issues of science and technology whenever requested to do so, and it would do so without compensation. That latter phrase has been interpreted to mean not-for-profit.

That little "gotcha" phrase has developed into one of the most productive relations between an academy and a government in the world today. It turns out to be the envy of the European academies. We have a relationship between this set of academies and our federal government that exists in very few other places.

This all happened in 1863, in the middle of the Civil War. The charter was signed by Abraham Lincoln and has stood us in very good stead. Between 1863 and now, what started out as a single organization, the National Academy of Sciences, has become four organizations. Three of them you can think of as honorific societies, more or less in the model of our European colleagues. They are the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. The fourth, the National Research Council (NRC), of which the Transportation Research Board (TRB) and Marine Board are members, is the operating arm of the National Academies.

Hence, we have a dual role. Part of the complex is honorific societies, whereas the other part provides advice to the federal government. I want to emphasize that we are not part of the government. We are, in fact, fiercely independent. We see our role as providing highly independent, highly authoritative advice—and we do a lot of it. We produce about 200 reports a year, roughly one every working day. Each one of them tends to be a book about the size and type of the report that you will discuss during this symposium. At any given time, about 6,000 volunteers are working very hard on tough and complex issues such as the one you will focus on during the symposium. Contaminated sediments is an excellent example.

Generally speaking, the issues addressed by the National Academies are difficult problems with important societal consequences, and they often require that science and engineering expertise and opinion become part of the political process.

You all know a great deal more about the topic you will be talking about than I do. I was given a set of reading material to get myself up to speed on this topic and was asked to take on the job of describing the "CS problem." I have to tell you, my background is as a computer scientist, so I felt I knew the "CS problem" very well. Then I started to read this material, and it did not match at all.

The fun part of my job is that I get to learn about all kinds of new things. Sometimes the things I learn are exciting and enlightening; sometimes they are scary. What I learned in preparing these remarks falls more into the latter category.

As I said earlier, you know this topic much better than I do, but the notion that 10 percent of the surfaces underlying our waterways are seriously contaminated, sufficiently contaminated to pose risks, is pretty scary. The fact that some 3 million to 12 million yd^3 (2.3 million to 9.2 million m^3) of what is dredged up every year in clearing our waterways is sufficiently contaminated to require special handling is pretty scary. The societal consequences are pretty scary in terms of damage to the ecosystem, propagation of these contaminants up the food chain, and implications for the loss of recreational waterways.

These are things to which I have given little attention. If I had, I probably would have realized that contaminants hang around for a long time under the surface of the water. I thought that, after Rachel Carson and *Silent Spring*, dichloro-diphenyl-trichloroethane was no longer a problem. Well, I learned that it still is a problem in sediments. I learned that few parts of the country are unaffected. It was no surprise to learn that the problem is further complicated by a tangled web of legislation, multiple federal agencies with responsibility, and overlapping state and local jurisdictions.

This is a perfect example of the types of issues that the National Academies take on—a really important societal problem that requires that science and engineering inform the political process and that policies be put in place. You have been asked here today to help us make some sense out of this difficult situation.

On behalf of the presidents of the two other honorary societies, Bruce Alberts, president of the National Academy of Sciences, and Ken Shine, president of the Institute of Medicine, let me once again welcome you here.

Success Through Consensus Building

Louis J. Thibodeaux

I am a professor of chemical engineering at Louisiana State University and had the privilege of not only serving as the co-chair of the TRB Symposium Steering Committee but also serving on the NRC study committee that prepared the report we will be discussing. I will begin by giving you a brief history of how the NRC got involved in the issue of contaminated sediments.

It began in 1988, when a Committee on Contaminated Sediments was formed under the Marine Board, which is a unit of the NRC Commission on Engineering and Technical Systems. I recall very well the first meeting in Tampa, Florida, where I had been invited as a workshop participant. This committee produced a report in 1989 entitled *Contaminated Marine Sediments: Assessment and Remediation.** (I will summarize briefly some of the findings contained in that report and offer comments on where we stand today.

- *Adequate data do not currently exist for comprehensive pinpointing and prioritization.* As evidenced by an

* *Contaminated Marine Sediments: Assessment and Remediation.* National Academy Press, Washington, D.C. 1989. Available via the Internet at http://www.nap.edu/reading room, or call the National Academy Press (1-800-624-6242).

inventory recently released by the Environmental Protection Agency (EPA), this problem is being addressed.

• *In terms of risk to human health, transfer of contaminants from marine sediments to humans is poorly documented and underassessed.* As a researcher in this area, I know that over the last 10 years this problem has been at least partially resolved.

• *Despite the widespread extent of contaminated sediment problems, remedial actions directed at excavating, treating, or otherwise manipulating contaminated sediments have been extremely rare.* In the last 10 years, a number of technologies have been applied, including dredging, capping, and some other in situ technologies.

• *Little or no weight is given to sediment-mediated contamination of edible fish and shellfish in the hazard ranking system.* At that time, the hazard ranking system was strongly biased to groundwater problems, but since that time it has been amended to provide a better ranking for contaminated sediments.

After that report was published in 1989, contaminated sediment problems continued to come to the fore. At the urging of the EPA, National Oceanic and Atmospheric Administration, U.S. Army Corps of Engineers, and U.S. Navy, a second report was commissioned aimed at trying to assess what technologies existed to clean up contaminated sediment.

A second Committee on Contaminated Marine Sediments was formed in 1993 to produce the report before us today. The Executive Summary of the second report, *Contaminated Sediments in Ports and Waterways: Cleanup Strategies and Technologies,** has been provided to all symposium participants. This 1997 report concluded that technologies alone will not solve the problem; there must be a strategy. Although technologies are available, it is also necessary to factor cost-benefit, human health, and risk considerations into the decision process.

This symposium acknowledges that the success of contaminated sediment remediation projects depends heavily on consensus building. Although there are many stakeholders—including port managers; transportation officials; industry, federal, state, and local environmental regulators; environmental groups; and competing users for all these marine resources—there are few venues in which these stakeholders can address the issues collectively in a nonadversarial setting. We hope this symposium provides such a venue.

* *Contaminated Sediments in Ports and Waterways: Cleanup Strategies and Technologies.* National Academy Press, Washington, D.C. 1997. Available via the Internet at http://www.nap.edu/readingroom, or call the National Academy Press (1-800-624-6242).

Technical Forum for Productive Ideas

Spyros P. Pavlou

My co-chair summarized how we got here. I will offer a brief look into the future, which I believe can begin with this symposium.

The Symposium Steering Committee tried to develop concepts and issues that we would like to see propagated and discussed. The first is the issue of risk reduction; the second is sustainable management, or adaptive or continuous management; the third is reuse. Throughout the next two days, you will see these three terms being discussed, embellished, defined, and perhaps even rejected. However, the committee felt this would be an appropriate starting point. The symposium has been configured as a technical forum for the exchange of productive ideas, with members of the audience as contributors and partners in cooperative problem solving.

There are many issues to be addressed and solved. The two reports that Lou Thibodeaux discussed offered recommendations; however, they do not offer solutions to the problems. Through this symposium, we hope to take advantage of your collective experience and expertise to provide direction for the best way to deal with these problems now and in the future. We want to hear stakeholder response to the study report. We want to hear war stories, test cases, stories of successes and failures, and what should be done to promote better management of contaminated sediments. We want to hear your perspectives, your ideas, and your constructive criticisms. Above all, we want you to play an active role in contributing to this process.

Overview of the Study Report

Joseph L. Zelibor, Jr., *National Research Council*
W. Frank Bohlen, *University of Connecticut*
Donald F. Hayes, *University of Utah*

Adopting a Systematic Risk-Based Approach

Joseph L. Zelibor, Jr.

I would like to begin with a statement: Ports and waterways are of strategic importance to the economic well-being of the United States. According to the Maritime Administration, ports handled approximately 3 billion metric tons of cargo in 1992; supported the employment of 15 million Americans, which is about 17 percent of our total population; and added nearly $800 billion to the gross domestic product and another $525 billion to personal income. Ports contributed another $210 billion in taxes at all levels of government.

Contaminated sediments slow decision making and the implementation of dredging, which is needed to keep ports and waterways safe and efficient. Every year about 283 million yd^3 (216 million m^3) of material are dredged, of which about 5 to 10 percent are estimated to be contaminated. Beyond that, the management of contaminated sediments goes beyond port operations and can benefit other important things, such as recreational areas, fishery habitats, and the overall quality of life along our waterways and coastal areas.

Some time ago, I was at a congressional briefing on coastal engineering and heard some estimates batted around that the revenues generated in coastal areas from foreign and domestic tourism and other activities exceed the revenues generated from agriculture and energy. Clearly, the effective management of contaminated sediments is of strategic importance to the economic well-being of ports, waterways, and coastal areas.

I will provide you with an introduction to the 1997 National Research Council (NRC) report and try to focus on the findings relevant to the topics to be discussed in this symposium. I hope that you have had a chance to read the report, which assessed the best management practices and emerging technologies. Among the elements of the committee's task was the appraisal of interim control measures and methods of evaluating risks, costs, and benefits that can be used to help guide decision making. Overall, the report was intended to assess existing knowledge and identify the research needed to improve and develop technologies. Although the task was broad, it did not allow the committee to address all of the issues relating to contaminated sediments.

The committee met seven times over a three-year period, often with various liaisons from agencies such as the U.S. Army Corps of Engineers (USACE) and Environmental Protection Agency (EPA). The committee reviewed relevant reports and was briefed by federal, regional, state, and local officials; port authorities; and public interest groups. Committee members visited the USACE's Waterways Experiment Station in Vicksburg, Mississippi, and the Port of Tacoma, Washington. They held two workshops on dredging and remediation technologies. They also compiled case histories of six projects. A major part of the study process was a review and assessment of interim and long-term controls and technologies on the basis of maturity, applicability, limitations, costs, and research needs.

Although many people wish there were a "silver bullet," there is no single technology, now or on the horizon, for treating large volumes of contaminated sediments effectively and economically. Given this lack of a simple solution, the committee determined that a systematic, risk-based approach incorporating improvements in current practice is essential for the cost-effective management of contaminated sediments.

The committee focused on evaluating management practices and technologies but also found it essential to address a number of tangentially related issues, such as regulations, source control, and site assessment, because problems in these areas can impede best management practices and technologies.

As Dr. Wulf noted, the regulatory framework for contaminated sediments management is extremely complex. At least seven federal agencies and six comprehensive Acts of Congress influence remediation or dredging opportunities for managing contaminated sediments in settings ranging from the open ocean to inland reaches of estuaries and wetlands. The overlapping jurisdictions of federal, state, and local agencies further complicate the situation. For example, states are authorized to establish water quality standards within their jurisdictions and can block sediment dredging and disposal that violate these standards.

The committee compiled six case histories of contaminated sediments projects. These projects were selected as representative of particular conditions, regulatory constraints, and classes of contaminants. The delay between the discovery of a problem and implementation of a solution can range from 3 to 15 years or even more. The problem is often due to the adversarial nature of relationships among stakeholders and the convoluted regulatory path.

As many of you know, contaminated sediments can best be managed if the problem is viewed as a system, composed of interrelated issues and tasks. The overall goal is to manage the system in a way that optimizes the results. In particular, a systems approach is advisable with respect to the selection and optimization of interim and long-term controls and technologies. The committee grouped its conclusions and recommendations into three topic areas: decision making, remediation technologies, and project implementation.

It is important that decision makers be aware of, and understand, applicable laws and regulations. To this I say, "Good luck." I certainly do not know about, or understand, all of them. Outreach to stakeholders is critical. The early involvement of stakeholders is important for heading off disagreements and building consensus. Systems engineering can enhance the cost-effectiveness of contaminated sediments management. Three tools can be applied to inform and improve decision making. Risk analysis and cost-benefit analysis are familiar concepts but are not widely applied to contaminated sediments management. Decision analysis is a newer concept for resolving problems with multiple variables. It is hoped that all of these issues will be discussed and debated during the course of the symposium.

With regard to remediation technologies, the committee found that high-volume, low-cost technologies are the first choice, if feasible, when remediation is necessary. Because treatment is expensive, reducing volume is also very important. Treatment is usually applied to just a small volume of highly contaminated sediments. In most cases, advanced treatment is too costly for low-level contamination. There are also problems with the cost data associated with available technology. The problems include a lack of standardized documentation and the lack of a common basis for defining all relevant benefits and costs. In addition, research and development (R&D) and demonstration projects are needed to improve existing remediation technologies and reduce risks associated with the development and use of innovative approaches for treating marine sediments.

With respect to project implementation, the committee found that upstream generators of contaminants often cannot be identified and held accountable, leaving ports with the burden of managing the problem. They found that states, which benefit economically from dredging and customarily engage in watershed management, might assume more responsibility for source control. They also found that new and improved techniques are needed to reduce the cost and improve the precision of site assessments. Although few data are available on the effectiveness of interim controls, the committee found a number of measures that appear to be practical and likely to reduce risk.

Also of significance is the fact that dredged material has been used for many beneficial purposes. Some contaminated sediments have been transformed successfully into wetlands, and research is under way on the safe use of contaminated sediments for landfill covers, manufactured topsoils, and other applications. However, the funding for this research is limited, and technical guidelines have yet to be developed.

Finally, as we search for the elusive silver bullet, there are many opportunities for incremental improvements in decision making, remediation technologies, and project implementation. We hope that this symposium can help move us ahead to the next steps.

Making Site-Specific Assessments

W. Frank Bohlen

I am a physical oceanographer working on the problems of coastal sediment transport. I will addres the issue of site assessment, which is covered in Chapter 4 of the NRC report. I realize that talking about site assessment problems and criteria is a bit like carrying coals to Newcastle, because the majority of this audience may know as much, or more, about it than I do. However, it is important for you to get at least one person's perspective on the committee's bias with regard to site assessment, particularly given that this topic is a bit outside the charge to the committee, which initially was technologically oriented and looking for the technical "fix."

Very early in the committee's deliberations, we realized that we needed to spread our wings a bit and look at the larger picture, beginning with the fundamental issue of the site itself. Some of you may be well-advised over the course of this symposium to question what we mean by "contaminated." For the moment, we assume it means that, based on some criteria, someone said, "That stuff is contaminated." We believe that effective management of a site containing contaminated sediment begins with a reasoned, detailed, and systematic assessment of site characteristics.

An assay seeks to define the extent and character of the contamination, including probable sources, sinks, potential mobility, and ultimate bioavailability, which, after all, is what we are particularly interested in. Beyond their obvious technical and scientific utility, such data serve as a basis for determining the governing regulatory framework, identifying who the stakeholders are and their particular interests, and defining the optimal management protocols and remediation procedures. It is the foundation upon which all else should be built.

It is our experience, and I think it was more or less unanimous among the committee members, that quality site assessments are seldom done. It was also the impression of the committee that quality site assessments *can* be done; it is not beyond the state of the art. Central to the evaluation, however, is a fundamental understanding of the factors governing contaminant transport and availability. You have to know something about the system with which you are working.

Given the affinity of the majority of the contaminants of concern for fine-grained sediments, the transport often involves displacement of cohesive materials. The displacements are governed by a variety of interactions among local and regional, meteorological, hydrodynamic, biological, geological, geochemical, and perhaps even geopolitical factors. The interactions typically result in a transport system characterized by a high degree of spatial and temporal variability. Therein lies the rub. A high degree of spatial and temporal variability establishes some very particular constraints on the adequacy of sampling and survey protocols. How do you specify what is there, given the state of the art? Don Hayes, the next speaker, will talk about this issue in terms of the technologies available to dredge, or clean up in place, the contaminants of concern.

Taking a look at the various transport systems, for example, it should not be surprising that the factors governing transport on the California continental shelf and affecting the displacement of contaminants off Los Angeles differ substantially from the factors affecting transport at an Upper Hudson River site. The latter is a moderate-energy riverine environment impounded by a variety of dams and locks above Troy, heading down into the tidal river below Albany to Poughkeepsie and, beyond that, the estuary down to New York City, including the Port of New York and New Jersey.

The effects and characteristics of the system are compounded by significant variations in the sedimentary characteristic of the area. For example, a high-organic deposit of fine-grained materials, mixed sawdust, sands, and silts, interlaced with lathe debris from the historical lathing operation in the Upper Hudson, makes for an interesting deposit in terms of friability, transportability, and contaminant availability. Such a deposit could be found in a shoreside dump.

Contrast that system with a coastal environment, such as an inlet on Long Island Sound contaminated by a variety of constituents, mostly metals and sewage-related materials, with sediments characterized predominately by sands and dynamics affected by the inlet. Contrast that with a system such as the estuary of the Acushnet River, Upper New Bedford Harbor, an area of relatively low energy in terms of winds and waves but affected by significant tides and stream flows and the recipient of an historical discharge of polychlorinated biphenyls (PCBs).

Another example would be tidal flats, where the degree of aeration and exposure, or potential for volatilization, is very different from that of the California continental shelf or Upper Hudson. Contrast this with some of the Gulf Coast petrochemical areas receiving yet another variety of contaminants discharged into yet another set of different environments, with energy-grade lines running nearly horizontal [i.e., the channel slope changes by only 1 ft in 40 mi (0.3 m in 64.4 km) in an area with relatively low tidal energy, in fairly confined embayments such as a bayou, but receiving bursts, or very flashy discharges, of rainfall runoff.

Therefore, to assess what is going on from a temporal standpoint, you might put out a variety of instruments and leave them for some period of time. There are relatively few long time-series observations available to us in many of the environments of concern. If you put out a bottom-monitor array of instruments, you might be interested in looking at suspended material concentrations. In observing the velocity record, you might be interested in the current speed, time variations, characteristic M2 tide (i.e., semi-diurnal lunar component of the astronomical tide), characteristic spring/neap cycle (i.e., monthly variations in tidal range), and a number of aperiodic events. The systems we work with tend to be affected by an ambient velocity field perturbed aperiodically by the passage of moderate-to-high-energy storm events.

We hear a lot about storm events, and in some areas they are sufficient to cause mass failure of the deposit and orders-of-magnitude changes in material transport. However, that effect has to be scaled against the slow, persistent cycling of significant concentrations of material over each tidal cycle. In some areas (e.g., Long Island Sound), that slow, persistent cycling is as significant in terms of mass flux as are many of the storm events. The particular time scale of interest depends on the chemical time scales of concern, processing times, or biological uptake and processing times.

A plot may show the inherent nonlinearity of many of the relevant processes. The characteristics of the response of sediments vary significantly as a function of antecedent conditions, such as, in one case, the wind stress field. If you get the right wind, then you get a particularly energetic wave field. Alternatively, if you have a number of wind stress events, you might expect the first event after a quiescent period to be more effective in terms of stirring up materials than one that comes later. The third one may not be as effective in terms of the resuspension of materials. In other words, a variety of nonlinearities, as well as a variety of time scales, are inherent in the process.

Beyond the time scale, we might be interested in the spatial scales. A change in structure over relatively small spatial scales has profound implications in terms of the mobility of the material. It varies as a function of sediment type and, to some extent, the history of working of the sediment, the textural characteristics, which can vary significantly in space.

The committee kept coming back to the need for site-specific assessments, not only because of the variations from a spatial standpoint due to hydrodynamics, meteorology, and the rest, but also because of the characteristics and structure of the sediment column. The spatial variability, of course, can be complicated by perturbations. We also could have interfacial photographs that would give clear evidence of burrowing infauna and reworking of the sediments, and that burrowing and reworking would have a characteristic seasonal variability. Therefore, we may have some spatial and seasonal variations as well as variations due to local sediment characteristics.

Mapping of these characteristics on a larger scale is facilitated by the use of acoustic techniques. Not all of us have the patience, time, and money to go out and bounce an interfacial camera all over Long Island Sound or up and down the East Coast, but you can significantly cut the survey time if you use acoustic techniques, which we will hear more about in a later session. A low-frequency seismic profile over a dump site gives you some feeling for the effects of deposited material on the sediments and sediment structure. It also may show several acoustically opaque regions where you begin to lose the strata because of the presence of gas in the deposits. Another consideration is the production of methane and what it means in terms of the structure, fabric, texture, and transport of the materials as well as the irrigation and migration of contaminants in the sediment column. These effects can vary significantly in space and time.

Although we are dealing with moderately high content and often fine-grained sediments, which might appear to be easily eroded, the materials are, for the most part, relatively stable. The materials have a certain amount of consistency, coherence, and stability. One should not assume that, because we are dealing with fine-grained deposits, these materials are easy to move around. The mobility also can be affected significantly by burrowing infauna, which may be macro- or megafauna.

With this background as a bias, recognizing the inherent spatial and temporal variability in the system, the committee argued for the application of a systematic approach to site assessment. We argued that the best method is a tiered approach, and we provided you, in Chapter 4, with a "strawman" outline. By no means is it intended as the "do all and end all"; rather, it is intended to point to a couple of things that the committee felt were important, beginning with a review of historical data. The review of historical data on a site is often overlooked. None of us has the time to visit the library anymore; we hardly have time to use the World Wide Web. As result, we often go out and reinvent the wheel. Sometimes we get away with it, but often this approach slows down the project and increases costs.

An example provided in the NRC report is Marathon Battery. The fact that they were dealing with an archeological site was overlooked when they were working out their disposal options. As a result, they had to go back to the drawing board to work out a way to deal with an old gun emplacement. Another example is the reference to the Boston Harbor study and the discussion of the utility and value of historical data as a preface to newly acquired data. Many historical data not only will satisfy present-day quality assurance and quality control (QA/QC) criteria, but also will withstand wild-point editing and consistency checks and serve as a perfectly adequate basis for surveys intended to satisfy today's QA/QC criteria.

When you search for such data, a variety of files (e.g., federal, state, local, historic district) are often a fount of information. I never fail to be amazed at the amount of water quality data available for New York Harbor. If you can spend the time searching for data (which may not be put together quite the way you expect), the data can provide a good starting point. Hence, it is important to look at the historical data.

The next item to be addressed is whether contaminants are present. If not, then there is no problem. If they are present, then there is a need to decide if a full site assessment is worth the time and effort. It becomes necessary to gather data, do a literature review, and conduct an evaluation of site dynamics to see what is needed and note obvious data deficiencies. The primary emphasis is on the degree to which the contaminants may be available and may have significant effects on the ecosystem and public health.

If there are obvious data deficiencies (e.g., no bathymetry for the area, no good sediment map), then it becomes necessary to conduct initial field surveys to fill in the gaps. For example, you go to Lake Onondaga and look for accurate, high-resolution bathymetry, and even though the area has been studied extensively because of a variety of historical contaminants, you are hard-pressed to find the data. The surficial sediment maps are gross characterizations of what is out there. It is hard to believe this after probably 20 or 30 years of study, but it very well could be the case.

When you are through with the initial field surveys, you will have fundamental information. The initial field surveys tell you there is a problem; for example, there may be PCBs, dioxins, and metals of concern in the navigation channel that need to be dredged. It may be necessary, or useful, to push the current state of the art. This is where the need arises to conduct detailed field surveys. It was the committee's impression that techniques are available to provide us with the highest-resolution distribution of contaminants. We may not have the money to do it, but the techniques are available.

You may question some of the speakers at this symposium about capabilities to push the state of the art to provide high-resolution "surgical dredging," or dredging that will allow you take off a layer of material that may be just 1 or 2 cm in vertical extent. With the global positioning system (GPS) and differential GPS, we probably can get down to centimeter scales in the horizontal. You may hear arguments that we also can provide vertical dredging tolerances of centimeters. Coring techniques are possible, but as I hope I have made clear, the spatial variability does not favor the use of a just few cores to characterize a large area. You probably have to combine some amount of coring with higher-resolution acoustic techniques; however, it can be done and the argument may be that—even given the costs—it is warranted and should be done.

In summary, remembering that the systems we deal with are affected by significant spatial and temporal variability, an understanding of site history, existing conditions, and dynamics is needed for the design and implementation of a successful management plan. The process of site assessment is complex because of the variability, but it is possible—although it may be expensive—to obtain the information necessary to make informed decisions. There always will be some uncertainty, and you must determine what level of uncertainty is acceptable. If one waits until all uncertainty has been eliminated, then no decision ever will be made.

We believe that data gathering must focus on specific needs. (As a scientist, this causes me great pain.) Data gathering is not an end in itself; it must be process oriented. If someone is going to gather data, then someone else must ask why, because everything is rooted in a fundamental understanding. The manager must have a fundamental understanding of the dynamics affecting the transport and availability of the contaminants of concern, and all the sampling is dictated by that requirement.

Good site assessment results in minimum-cost projects that meet clean-up objectives and allow the implementation of optimal remediation schemes. It is the foundation for all of the work we do. The committee felt it was a very important part of the process.

Addressing Technologies and Controls

Donald F. Hayes

I am a faculty member in civil and environmental engineering at the University of Utah. It is my job to provide a brief overview of Chapter 5 of the report, which addressed interim and long-term technologies and controls. As we begin talking about technologies, I want to reemphasize a statement made earlier: There is no "silver bullet."

A nice thing about working on a report like this is that we did not have to deal with day-to-day issues. Frank Bohlen referred to this as the geopolitical context. To some extent, the committee members were able to look at things as if we were "emperors for a day." The committee organized the technologies and controls into categories, which are not perfect but are illustrative of where each one fits: interim controls; in situ management options; sediment removal and transport technologies; and ex situ management. To some degree, these categories represent increasing complexity, and one can anticipate increasing or decreasing risk in terms of the end product.

Many options are available for managing contaminated sediments. Although actions such as deep ocean dumping of contaminated sediments are illegal, I will mention a multitude of other practical and possible technologies. As Dr. Bohlen pointed out, it is important to remember that spatial variations within any single site can be very dramatic. Therefore, the same answer may not be the right answer for the entire site. When you combine that variation with the number of options available, the result, in almost all cases, is a very complex solution.

In my view, this suggests that a systems approach is the only way to investigate the alternatives fairly. Unfortunately, we do not always have quite enough information to do that in the way we would like, but the tools are still useful. I want to emphasize, as we go through the various categories, that the applicability (i.e., the number of applications) of a technology goes down as the complexity increases, primarily because the costs increase so dramatically.

As a committee, one of the first things we discussed and concluded was that the nation cannot afford to treat all sediments to a clean state, particularly because we may not even know what "clean" is. Nor would this make sense, because we seldom know what the end use is going to be. That issue is beyond the focus of my remarks; however, it is certainly something to be concerned about—trying to better define the real objective.

I will focus first on interim controls. Joe Zelibor mentioned the time frame from the beginning of a project to the point when something really happens. If you have been associated with these types of projects, then you know it is a long time, and nothing happens in a hurry. In this context, "fast track" is measured in years, and decades are the norm. This gives rise to the rational use of interim controls. If there is truly an ecological and biological impact occurring, then it is often necessary to intercede and do something to reduce the risk associated with the site *while* we are deciding what to do in the long term; hence, the introduction of interim controls.

A number of examples can be cited from around the country. An example of an administrative control is the posting of a "no swimming" sign to keep people out of an area. An example of a technological interim control is the use of sediment traps to reduce additional contamination or the addition of uncontaminated sediments to an area. Yet another example is removal of hot spots. If one spot is dramatically increasing the risk posed by the entire contaminated area, then it may be necessary to move faster and do something with a small portion of the site, leaving the larger decision until later. Other possibilities, such as temporary caps, have not been thoroughly examined.

There may be other in situ methods that also could reduce the risk. This is the first category of long-term remediation technology that I will discuss. As USACE officials and others in this audience know, there are contaminated sediments in channels, and channels are dredged on a regular basis. The most highly contaminated sites tend to be those that are not dredged and may not necessarily impede navigation. In these cases, in situ options are possible but—at least in my view—have not been looked at very carefully or scientifically.

The committee discussed at length the option of natural recovery and the distinction between it and "no action." Unfortunately, these options are too easily confused. Some argue that natural recovery is a decision, and along with that decision goes long-term monitoring to make sure the decision was correct. It is an action that says (a) the contaminants are there because they are at the lowest-energy area in the environment, (b) they are stable, (c) there is no evidence of ecological damage from their presence, and (d) they should be monitored to ensure they do not go anywhere and are not distributed by storms or other events. In some instances, this may be the best option.

If natural recovery is not an option or not the best option, then in-place capping may be a possibility, using some type of cover or cap or possibly in situ treatment. There are a few examples of in situ treatment, which involves adding various components to the sediments that will cause the contaminants to be more tightly bound and less bioavailable. There are concerns associated with this approach, including limited experience and uncertainty with respect to the risk.

There are a variety of dredging alternatives. Dredging is a proven technology that has been used extensively. My work has focused on contaminant release and resuspension and environmental impacts during the dredging operation. In many cases, the effects are far less than what may be expected. In general, the cost to pick up and move sediments is low compared to treatment cost; however, once you pick them up, you have to do something with them. Previous speakers touched on the issue of source control. One of the strange things about sediments is that, once you pick them up, you own them, whether you were the original source of the contamination or not.

There are concerns about contaminant losses and overall volume increases due to the addition of the water. There are issues of accuracy and precision. Reiterating what Dr. Bohlen said previously, there should be some correspondence between the precision of the site characterization and the precision at which we require the dredge to remove sediment. There is concern about overdredging, or taking sediments that are not contaminated but, once removed, essentially become defined as contaminated. There have been advances in this area, particularly in Europe. Some new dredges have been developed, such as bottom-crawling dredges, which reduce overcutting of the bottom because of their potential for high accuracy and precision. In general, this is a fairly well-developed science.

Once sediments are moved, something must be done with them. Certainly the most prevalent technology is ex situ containment. Contained aquatic disposal (CAD) is a fairly new technology based on the concept that, if we have to move sediment, then keep it in the environment the contaminants like, because they are probably more stable there. Although CAD has been applied in a few cases, it is still categorized as an emerging technology. It is not widely accepted by the public as being standard practice; certainly there is a need to increase the experience base and the data available on it.

On the other hand, confined disposal facilities (CDFs) have been used for years and can be categorized as proven technology. Although some people would argue about the capability of a CDF to contain the contaminants, we know how to implement it. Not all sites are necessarily designed for that purpose, but if that is the choice, then it can be done. The real problem is that CDFs are difficult to site—nobody wants one in the backyard. On the positive side, CDFs are generally affordable, or fairly inexpensive.

A wide array of ex situ treatment technologies is being tested, and the state of proof is debatable. Very few of these technologies have been proven in a full-scale environment. Consequently, little is known about what the real costs will be. We have done lab tests, bench tests, and pilot tests, and those data have been extrapolated; however, it is not known what the costs will be on a larger scale.

There are physical methods, chemical methods, and biological methods. Bioremediation is an up-and-coming area of interest that holds a lot of promise, but at present the science is immature in terms of whether it provides a true long-term solution. Physical methods are more common and have been used in the mining industry for a long time, but the costs are higher than most probably would expect. More experience is needed to prove whether some of these technologies will really work. They will be expensive because, at a minimum, thermodynamic energy is required to remove the contaminants from the sediment, and that costs money. It is doubtful that a silver bullet can be found; more full-scale experience is needed, and concerns about disposing of the residuals must be addressed.

I will close my remarks by focusing on the issue of cost, which is perhaps the biggest problem we face. Administrative interim controls, such as signs, are inexpensive relative to other options. There is less experience with technological interim controls; however, some could be quite expensive, especially hot-spot dredging. Moving on to long-term controls, cost estimates for in situ management are largely guesses because there is limited experience on which to base them. Removal and transport costs probably fall in the \$10/yd^3 (\$13/m^3) range.

Ex situ containment is expensive, ranging from \$20 to \$50/yd^3 (\$26 to \$65/m^3) However, it appears less expensive when compared to the cost of ex situ treatment options, which start at around \$300/yd^3 (\$392/m^3) and can range as high as \$1,000/yd^3 (\$1307/m^3). This is a dramatic difference; in the long term, it suggests that, for large quantities of sediment, there is little choice but to focus on removal and transport and ex situ containment, with treatment applied to the small quantities that are highly contaminated.

In closing, I want to emphasize that decision analysis is an important tool because of the spatial variations and the wide range of costs. Because of the costs, it is important not to arbitrarily apply one solution to a very large volume of sediment. Care must be taken to apply the right solutions for the right portion of the area.

Stakeholder Response to the Study Report

Thomas H. Wakeman III, *Port Authority of New York and New Jersey*
John Haggard, *General Electric Company*
James Tripp, *Environmental Defense Fund*
Tony MacDonald, *Coastal States Organization*
Konrad Liegel, *Preston, Gates & Ellis*

NOTE: The National Research Council (NRC) study report stressed the importance of partnerships among stakeholders. It was evident to the committee that, if progress is going to be made in dealing effectively with contaminated sediments, then it will be with the participation and cooperation of all parties involved in and affected by the issues. The decisions must be made together. Accordingly, a distinguished panel of representative stakeholders was invited to offer different perspectives on the NRC report. Each panelist presented opening remarks to stimulate interaction with the audience.

Port Perspective

Thomas H. Wakeman III

The opening speakers mentioned two NRC reports. I want to mention an earlier report produced by the NRC in 1985, *Dredging Coastal Ports: An Assessment of the Issues.** This report essentially stated that there is a need for dredging, that port channels will get deeper, and that there are contaminated sediments. The second NRC report, released in 1989, confirmed the presence of contaminated sediments and the need to do something about them. The third report was issued in 1997, again stating that there are contaminated sediments in our ports, harbors, and other waterways, and we need to do something about them. I am afraid that, in five years or so, there will be yet another report that says we have contaminated sediments in our ports and harbors and we should do something about them.

I want to begin by reiterating a comment made earlier by Spyros Pavlou, who said we need to have clearly defined and mutually agreed-on objectives that are aimed at reduction of risk, reuse of material, and sustainable management. The problem is that we do not agree on the objectives.

For the port community, the objective is to maintain our business, which is providing a service in a way that ensures a return on our investment. Ports are generally not the generators of the contaminants that they often find themselves forced to deal with, but they do need some type of regulatory certainty. They need adequate technical ways to deal with these problems, and they need help with the enormous expense of removing these contaminant burdens from channels and waterways.

The most recent NRC report looked at the three areas covered before. Among other things, I noted that there are nine conclusions and four recommendations regarding decision making, which means the committee clearly considered this issue. There are 12 conclusions and five recommendations related to technologies, which means there was something to report on. There were five conclusions and five recommendations with respect to project implementation, which suggests very little has been done, and that does not help the port industry at all. From the perspective of the port industry, talk is delay—too often the solution is another meeting to talk about the problems instead of action to do something about them.

* *Dredging Coastal Ports: An Assessment of the Issues.* National Academy Press, Washington, D.C. 1989. Available via the Internet at http://www.nap.edu/readingroom, or call the National Academy Press (1-800-624-6242).

The study concluded that three key things needed to be done. The first is to forge partnerships and agree on where you are going. Here in Washington, the greatest bureaucracy in the world, you want to ask the federal agencies to partner? Recently, there was a maritime listening session hosted by the U.S. Coast Guard, Maritime Administration, U.S. Army Corps of Engineers (USACE), and a variety of other folks, but not the Environmental Protection Agency (EPA). Does the EPA not believe, or do others not recognize, that the EPA is part of the maritime industry? Federal agencies, particularly the EPA, need to learn how to partner within their own organization as well as with other agencies.

I want us to consider laws, regulations, and practices. Practices are what I want to see, because I like to see action. I am tired of having the environment compartmentalized. That was fine when we were writing laws in the late 1960s and early 1970s that said, essentially, "We will deal with air, we will deal with water, we will deal with contaminated sediments." We must recognize that it is a closed system. If you take something out of here and put it over there, then it is still here with us. If it comes off the China coast, then it will be here sooner or later. It is a closed system. We need to work together to look at the risks to the system, to ourselves, and to other critters that share the planet.

We need to have flexible, practical ways of dealing with these problems in my industry, because that will give us the opportunity to gauge the business risk of getting involved. As someone said earlier, "You touch it, you own it." Nowhere is this more true than in the port industry. I have about two floors of lawyers telling me, "Don't touch it." That is of no help if I have ship coming in drawing 47 ft (14 m). Nor is it cheap.

What does the port industry need? We need to agree on the objectives of this work. More reports will not cut it, at least not for me. We need to identify what the risks are to the best of our abilities, decide what it will cost to meet those risks, and then decide on what the benefits are, because someone is going to pay. I would prefer to see the people who benefit from the activity pay for it, but those who created the problem also should pay a share. The idea that the Port Authority of New York and New Jersey is the source of all goodness and cream is over. Partnering, to me, is not coming in with your hand out saying, "Give me money." The federal and state governments are also players, along with the ports.

I want to see action. Demonstration projects are necessary because this is a trial-and-error type of reality. The certainties of how contaminants partition in biological organisms and ultimately end up in humans is really a stochastic process. There is no deterministic equation of which I am aware that tells me exactly how much mercury I will get. There is also a need to think about the recycling component. Sediment comes from the mountains down into the bays, and if we do not move it, then we become a meadow instead of a harbor. Let us think about how to recycle it, the way any other industry now looks at recycling technologies.

In my view, developing partnerships is also a trial-and-error process. We do not have adequate models for how to develop partnerships. Mathematical equations are lousy at predicting what you will do, because we are value-driven creatures. Maybe a stochastic model will work, but it is still not deterministic.

There is a need to consider new laws and regulations that are based on risk. This is a tough challenge, particularly when you tell someone there is a one-in-a-million chance they will get cancer. Of course, the family that had the one-in-80-million chance of getting $100 million is very happy right now. I also want us to stop compartmentalizing the world and begin writing and applying legislation in a fashion that gets the maximum return on investment instead of the best press.

Industry Perspective

John Haggard

I have been involved in a number of "meat and potatoes" sediment problems and may have a different perspective than other presenters do. I want to thank the NRC for convening this symposium on what is a very important topic from many different perspectives. The 1997 NRC report provides a thorough, concise, and thoughtful review of what we as a country are doing to deal with contaminants in sediments within our waterways. It also lays a foundation, based on risk management principles, for evaluating objectively both the potential risks that may be posed by contaminated sediments and the methods of controlling those risks.

In reviewing the charge to the panelists, Frank Bohlen asked that we offer our unique perspectives as stakeholders and try to comment on the report's conclusions and recommendations. He also encouraged us to "get the juices flowing" by not avoiding controversy. I will try my best to do just that.

My perspective is that of an industrial company trying to manage sites where there are contaminated sediments that have been attributed to us and are derived primarily from past operations. The fact that these problems are a result of past practices as opposed to post-1970 practices is an important distinction that other stakeholders need to understand. We cannot turn back time.

My comments will focus on issues related to the management of contaminated sediments from the perspective of environmental restoration, which differs from that of port management and navigation. In my view, the unifying principle embodied in the NRC report is that risk analysis should guide the management decision, and I firmly agree with this. This is sound policy that allows the maximum use of existing science and allows site-specific information to guide decisions. This should be the basis of how we manage sites.

It now appears that not only the NRC, but also the EPA, in its recently issued contaminated sediment strategy, advocates this approach for managing contaminated sediments. There is an important concept that seems unique to sediment sites: The remedy that we impose on these sites can have a significant impact on the very things we are trying to protect. As a result, we must have a full accounting of both the benefits that might accrue from our action as well as of the impacts of our action. From my perspective, this is extremely encouraging and forms a basis of what should be a sound national policy.

I would like to be more specific about what I believe it means to use risk assessment in a remedial decision-making process for contaminated sediment sites. For many sites containing contaminants and sediments, the management decisions and sometimes confusing phraseology can be collapsed into a small number of simple questions—"simple" only in that they embody the risk-based concepts in a small number of fairly direct questions. If we can answer these questions for a given site, then risk managers can make reasoned decisions about what to do. The problem, as pointed out earlier, is the great difficulty of answering these questions at times. It is hard work, but in the end it is worth the effort.

The first question is: What are we trying to do? What are we concerned about? What is the end point we are trying to protect? This should be a risk-based end point. It should be one that has a fairly direct relationship to the protection of human health and a population of ecological receptors. The second question relates to the recognized fact that natural recovery is occurring at many of these sites. The question is: If we let the natural recovery processes continue, then how long will it take to reach the risk-based end points that we are trying to achieve?

The third and fundamental question is: Is there anything we can do to materially accelerate the achievement of those standards? This is critically important to the process. When we look at questions two and three, we are making time into a decision point. No matter what we do, we will not reduce the risk to acceptable levels at any of these sites by tomorrow. Interim actions may be taken, but there will be an element of time. Accordingly, if we take an action and reduce the length of time required to achieve these standards by a year at a tremendous cost, will it be worth it? What if it reduces the time by 100 years? That may be worth it. We never will see a real issue that is so black and white, but time becomes a critical management decision point.

The next two questions deal with rare events, such as floods. In situations where, even with natural recovery, there is concern about a traumatic event setting back the clock, such events have to be considered. More importantly, you have to consider whether you can do anything about it. It is appropriate to worry about the problem, but you also have to figure out what to do about it. When we look at sites where this issue has come up, we often find there is no evaluation. It is like having a 1,000-pound gorilla in a closet and hoping it does not escape. We need to start using what we know about sediments—both cohesive and noncohesive sediments—in terms of how they move and how that affects the impact of an extreme event. We have the technology to do that and should use it.

Lastly, we need to look at the impacts of these projects. How do we balance them? How do we account for them? We will see movement of material from one compartment to another as a result of actions, and we will see direct impacts on aquatic systems; all of these impacts must be accounted for.

There is a growing consensus, as evidenced by the EPA sediment strategy and the NRC report, that risk analysis should guide remedial decision making. The state of practice is basically out of step with this. As a result, there is an inability to address the key risk questions and determine whether a remedy was appropriate, and, more importantly, whether the expenditure of resources is having any real benefit at all.

Over the last five years, we have undertaken a systematic review of projects around the United States in which contaminated sediments were evaluated for removal. We found a number of interesting things. One, there has been relatively little technical and regulatory experience with the evaluation of contaminated sediment sites, particularly with risk-based concepts. However, there have been about 20 reasonably sized projects from which we can draw conclusions.

Fundamentally, we are finding that, when remedial actions have been selected, it is almost impossible to figure out why they were selected. What is the relationship between what we are doing and the risk we are trying to control? Ultimately, was there any hope at the start that the chosen remedy actually would control the problem? Trying to reconstruct this process becomes very frustrating.

In some cases, projects appear to be based on the misguided belief that the removal of a mass of contaminants will translate directly into the control of risk. This is a critical assumption, the validity of which is not addressed by the proponents of mass removal. It often is couched in, or dressed up as, the term "hot spot." When I hear, "We are going to deal with hot spots," I instantly translate that to: "This is a mass-removal project." The concept of hot spots needs to be dissected into risk, and that seldom happens.

As discussed earlier, the questions we must address to determine the proper course of action are relatively simple. The process of doing it, however, is hard work. This work seldom is done, and this is wrong. We also found that valuable project information seldom is generated or made available. Project documentation is extremely poor, making the independent evaluation of projects nearly impossible. More importantly, we are losing the opportunity to learn from experiences at other sites. What types of remedial approaches are working? Are we successfully controlling risks? What impacts accrue because of these remedies? What are the real costs? How long did it take, versus how long we thought it would take, to do these projects? The sharing of best practices is simply not occurring.

Given the potential social, public health, economic, and ecological concerns that arise during the remediation of these sites, it is strongly recommended that an independent policy and technical evaluation be undertaken of sediment sites for which remedial decisions have been made, to ensure that the use of risk methods is consistent with the NRC and EPA approach. Where remediation has occurred, it should be evaluated to determine what was learned about the capabilities and limitations associated with various techniques. If we cannot learn from our success, then we will have to learn from our failures, and we are missing a golden opportunity here.

Although I strongly agree with most of the conclusions and recommendations of the NRC report, there is one with which I strongly disagree. The report recommends, in the interests of economics and fairness, that the polluter pay and that ports be given more leverage over the polluter. Although this concept initially may appear to be appealing, I suggest that it is not necessarily fair; moreover, as a result of the disagreements that would occur, it would not result in a timely resolution of the problems facing our ports. This brings me back to the fact that most of the problems we have as an industry are based on historical actions that were legal at the time, performed and often done with government acceptance and knowledge.

In many ports, there are multiple contaminants and multiple sources of contaminants. The allocation of responsibility in these situations would be extremely complex and result in endless controversy, particularly, as is often the case, when a few high-profile industrial sources are attacked and the more-difficult-to-find, yet often more pervasive, sources are let go. Contaminants from sewage outflows are one good example. The fairness issue is at the center of this controversy.

The standards that ports are required to meet to manage or dispose of their dredged material are extremely stringent. The relationship between these risks and reasonable science is elusive. If the problems of ports are to be managed efficiently and in a cost-effective manner, as they need to be, then trying to bring actions against industries for long-abandoned practices will not be an effective solution. It will not be fair from the perspective of the industrial stakeholders, because we will be asked to foot the bill for an action over which we have little control. This will generate controversy, and it will not result in a timely solution to the problems.

In summary, I think the NRC report provides a sound policy framework for maximum use of the developed science and efficient allocation of resources. However, the state of practice is markedly out of step with the ideal. Too much emphasis is placed on mass removal versus risk control and on simplistic analysis. To advance the field, a review should be conducted by an organization independent of those performing projects, and changes should be implemented to ensure that the expenditure of our resources has a real benefit.

Environmental Perspective

James Tripp

I think this is a terrific report. As a lawyer, I found Appendix B of the NRC Report particularly worth while, in that it provides a very good, fairly detailed discussion of all the laws and regulations that apply to this complex array of problems.

I want to emphasize a few key points, the first being source control. The report discusses the importance of source control, not just the technology of decontamination. Source control, in this day and age, is absolutely vital. There may be historical quantities of contaminants in sediments that predate the implementation or adoption of a number of today's environmental laws, but that is no excuse for allowing conservative contaminants such as organic chemicals and metals to be discharged continuously in an area where they will find their way into our sediments.

In the New York area, there is a committee on sediment contaminant reduction. I chair the Dredged Material Management Integration Work Group, which has been highly supportive of the effort to get both New York and New Jersey—states that have a profound interest in the economics of the port—to commit more resources and pay more attention to the ongoing sources of contaminants.

In general, the environmental laws that govern sources of contaminants, the Clean Water Act (CWA) and Clean Air Act, for example, have not been used effectively to require monitoring and removal of low concentrations of conservative contaminants, which, over time, can build up in sediments. The focus tends to be more on the dispersion of concentrations, an approach that is not terribly useful when it comes to sediments. The economic importance of ports should be a motivating factor to get regulatory agencies more focused on regulating some of these contaminants.

My second point: Are there, in fact, viable technologies? Over the past three years or more, under the Water Resources Development Act and with support from the EPA, USACE, and Department of Energy, we in the New York area have carried out a big effort costing many millions of dollars to test—at bench scale and then at pilot scale—a number of decontamination technologies. Some of these are, or should be, very effective. The question is what will happen at the operational scale, and what will it cost?

Earlier, it was suggested that some of these technologies could cost hundreds of dollars, up to thousands of dollars, per cubic yard. I am a lawyer and not in charge of this program, but I do not believe the cost of doing state-of-the-art decontamination should be that expensive. I hope that these costs, if we could get some of these technologies off the ground, would be more in the range of \$50 to \$100/yd^3 (\$65 to \$130/m^3). The more basic question is how to get the technologies to an operational scale to see whether or not they can be effective.

The next issue relates to what John Haggard discussed. In many harbors (and this is certainly true of New York), upstream sources contribute to contamination in the port. There are polychlorinated biphenyls (PCBs) in the upper Hudson River. There are dioxins and a variety of other organic contaminants and metals in the lower Passaic River. There are polyaromatic hydrocarbons (PAHs) in the Arthur Kill. Because we just heard about PCBs, let me approach the question from a somewhat different point of view. I agree that there is a need for risk assessment, but whose risk? What about the distributive effects of risk? General Electric Company (GE) may say, "Why should we bear the risk?" Who, in fact, is bearing the risk today?

We heard from Tom Wakeman of the Port Authority of New York and New Jersey about the cost of removal and containment of PCB-laden sediments. For your information, the PCBs in the sediments in the lower estuary may be one-fiftieth of the level in some hot spots in the upper Hudson River, but those sediments flunk the ocean-dumping protocols. They have to be properly contained somewhere at a cost of perhaps \$40 to \$50/yd^3 (\$52 to \$65/m^3). Who pays? Who is responsible? Who bears that risk in terms of cost? In terms of the environment, should the ocean bear that risk? In terms of public health, if these contaminants are disposed of in upland areas, then what communities will be affected?

If you look at a harbor and can identify historical sources of contaminants in higher concentrations upstream—which, the law of gravity tells you, in due time will find their way down to an estuary and affect navigation, dredging, and fisheries—then one can ask this broad question: Would it be more cost-effective or cheaper in the long run (if we look ahead 10 to 50 years) to engage in focused, perhaps expensive, near-term efforts to reduce contaminant levels in these upstream hot spots? Would it be cheaper and more effective to do that rather than wait over a period of years or decades for those contaminants to wend their way down to the estuary, where the port authority, state, shippers, or public taxpayers will have to pay high costs to remove and contain those materials?

This is a legitimate question. How can we determine realistically whether it would be more cost-effective, or whether there are better remedial alternatives for dealing with upstream sources of PCBs in the Hudson River, dioxin in the lower Passaic River, or metals and

PAHs and those types of things? One approach is to let the Comprehensive Environmental Response, Cleanup, and Liability Act (Superfund) wend its way through the regulatory maze.

But another approach, now that we have some good pilot studies on decontamination technologies, would be to put out a request for proposals and ask the relevant firms, some of which may be represented here at the symposium, what they would suggest we do with these sites up the Hudson River where there are significant concentrations of PCBs in the sediments. Do you have a technology or process for removing or destroying those PCBs? Can you do this without transporting that sediment long distances and imposing on a community by putting that contaminated sediment in its landfill? Is there a technology, what will it cost, what would you propose, and what would this do in terms of reducing the downstream transport of PCBs over a period of years?

Rather than setting up another independent panel of experts, we should go to private-sector companies that have developed these technologies and know about the costs and benefits (because they are for-profit firms), and we should ask these questions and see what the answers are. If the answers are unsatisfactory, then maybe we cannot do anything; however, if we cannot do anything, then the question still remains as to who should bear the cost.

The incremental cost of disposing of contaminated dredged material in New York Harbor—the cost may be similar in other harbors—is on the order of \$35 to \$50/yd^3 (\$46 to \$65/m^3). Multiplying 3 million to 4 million yd^3/year (2 million to 3 million m^3/year) by \$40/yd^3 (\$52/m^3) or more is \$120 million to \$150 million—a huge cost. The question posed earlier by Tom Wakeman was who bears that cost? Should upstream industrial polluters—who allowed, and profited from, the discharge of contaminants—have to share in that cost? That seems a reasonable question. Otherwise who does pay? The shippers, port authority, environmental community, various land-based communities, and countless others.

I think one can reasonably say that a firm like GE should pay for one-fifth to one-sixth of that total cost. I cannot explain where that figure comes from, but it is a modest and discernible amount between \$20 million and \$25 million/year. It is a contribution to a cost that is being borne today. This is not an abstract cost, but rather a real-world cost that the states, federal government, and cities of New York, Newark, Elizabeth, and others are struggling to find a way to pay.

As I indicated earlier, the report also discusses the regulatory framework. The discussion of federal and state laws that apply to water is more extensive and, in a way, more satisfactory than is the discussion of federal and state laws and regulations that apply to land. It is true that dredged material comes from water, but the disposal sites for contaminated dredged material can be in bays (covered by the CWA; the Ocean Dumping Act; or the Marine Protection, Research and Sanctuaries Act) or upland sites, where the Resource Recovery and Conservation Act (RCRA) comes into play. But RCRA is not a very satisfactory statute in terms of dealing with on-land disposal of contaminated dredged material.

New York and New Jersey are among the states that have had to struggle with what types of standards should apply. What has happened, to some degree, is that the upland disposal sites have tended to be located in proximity to low-income communities, which brings us back to the question about risk. Who bears the risk when contaminants get handed around? In terms of the regulatory framework, we need to figure out a way of developing standards that can apply in some comparable sense to upland disposal as well as to in-water disposal. When there has been talk about disposing of contaminated material in upland sites, we suddenly start hearing about PCB (or some other type of organic chemical) volatilization, which simply was not an issue with in-water disposal.

Regulatory Perspective

Tony MacDonald

I enjoy this opportunity to get the discussion going, because that suggests I do not necessarily need to be fair or even accurate. Accordingly, I am prepared to throw out some thoughts and ideas. If you find my comments a little schizophrenic, it is because I read this report from two different perspectives. When it was being written, I was special counsel and director of environmental affairs at the American Association of Port Authorities. I am currently the director of the Coastal States Organization, representing governors of coastal states, including the Great Lakes states and U.S. island territories, on natural resource management issues and policy matters here in Washington, D.C. As you might imagine, that makes for a mixed perspective. Some of the things I say may annoy my former employers and colleagues.

I would like to start out by saying this is a great panel. Joe Zelibor, Frank Bohlen, and Don Hayes did a great job of outlining the key issues to be addressed over the next two days, and my fellow panelists have offered their perspectives on these issues. Tom Wakeman wants action, and he wants it now—not surprising coming from someone who has spent most of his life looking at San Francisco Bay and New York Harbor. John Haggard wants more and better information and a better understanding of the problems; a cynic might interpret that as wanting inaction.

Jim Tripp, who represents the environmental community and has been involved in these issues for a long time, wants a little bit of everything. He definitely wants the stakeholders to be involved, as he represents a very broad public. He definitely wants source control; he definitely thinks that technology may be less expensive than it seems to be. He thinks these costs are high, so he is sympathetic with the ports, but he certainly thinks someone (such as John, perhaps) might want to step up and bear some of those costs.

I am here representing the states. In a generic sense, my reaction is to say, "I am not quite sure what I want. You guys work it out." Therein is the nub of the problem, and perhaps that is why you will get federal reactions and will continue to get these reports. I will respond to the report in part from a state perspective and in part based on my own personal views.

I think Tom's call for action is great; in general, there is a lot of support for that. The report supports some of his objectives. Although it covers some very broad issues, it is actually a narrow report. It does support and give a scientific imprimatur to some issues that the port community has been espousing for a long time, most notably a greater recognition that source control is important; that in situ management does make sense in many cases and is scientifically and environmentally defensible; and that technology, although we want to look at it, is not a magic wand that will make things go away. One needs to look at this report in the context of when it was developed and the types of problems it was trying to solve. You also need to look at the introduction to the report.

It was enlightening to listen to Frank Bohlen's discussion of site assessment issues. This was not a report about assessment issues, and it specifically says that it will not address spatial and temporal variations, the definition of clean versus contaminated, and the comparison of bioavailability-based to concentration-based decision making. These issues are all beyond the scope of this report, but they are exactly the types of things that most of the folks here are paid to do on a day-to-day basis. They will continue to be the grist for disagreement among the stakeholder groups. Therefore, we need to address those issues to a degree, but we also need to recognize a couple of other things.

The recommendations in this report are the types of things around which it is easy for people to rally, even though they may interpret them differently. It is not unlike our support for sustainable economic development or sustainable environmental protection, because we all disagree on what those terms mean. We often pretend that we agree on risk-based assessments, but it is a very complicated business. Are we talking about comparative risks or scientific risks? Are we talking about what I am most interested in within the context of decision making—perhaps helping Tom with a decision or John with a decision (or perhaps indecision)?

There is more to risk communication. What do we know that will help the most important stakeholder (i.e., the public) better understand why we take a particular course of action? How do we engage people, such as governors and other state officials, to get more involved? Once we have a better assessment of that, we still may not agree on outcomes, but we are more likely to agree that this is the universe within which we will make decisions. Until we reach that point, I doubt there will be significant progress in this area. I also would like to point out that the people in the audience today have much more knowledge about these issues than even the panelists, and certainly more knowledge about these issues than either the public or the decisionmakers.

In my view, what Dr. Bohlen called the "geopolitical world" is, in many cases, the world in which the decisions get made. In that context, there is a misunderstanding or lack of understanding about the extent to which science, as some of you apply it in your work setting, is comfortable with uncertainty. From a geopolitical viewpoint, science is used to provide certainty for decision making. This is a fundamental philosophical difference that is not addressed by decision makers. They look to you, particularly those of you who are scientists, to provide the "hard science" so that they can make decisions. Meanwhile, you say, "Well, I am not sure, but this is the best we can do with a particular level of statistical confidence." Most people do not care about the details of quality assurance and quality control, although they want you to have it. My point is that, from the perspective of a state entity, I think we need to address these geopolitical issues up front and recognize both the limits of science and the long-term possibilities. We need to move toward action.

In my view, what is not addressed in this report—and must be recognized as we discuss the recommendations—is the assortment of institutional issues that underlie the decisions. There are real institutional problems, such as the ongoing issue of the respective roles of the USACE and EPA with regard to the management of dredged material. There are fundamental issues of institutional commitments, ethics, and other things that I think will be more of a problem in the long run. We can discuss the scientific and public policy legitimacy of cost-benefit analysis as it relates to decision making, but we also must recognize that this type of analysis is very different from the USACE's internal cost-benefit considerations affecting whether and how it moves forward with projects. We must consider how the USACE identifies a viable disposal alternative using its internal cost-benefit analysis approach, which is a mind-numbing exercise.

There is a failure to recognize what problem we are trying to manage. What is it that we are trying to manage? Institutionally, the USACE perceives itself more as managing a program, which is dredging harbors and channels. The USACE does not necessarily view this as a problem specifically of managing the sediments; the programmatic approach is much broader. You find within USACE regulations a great deal of forced consistency among the various programs, including inland navigation and flood control, which also creates institutional constraints to solving this problem.

Similarly, the EPA traditionally has focused on managing problems through a regulatory perspective, although increasingly the EPA is divided against itself. It is adopting the rhetoric of watershed management planning, the rhetoric of working with the states on performance partnership agreements to establish cross-programmatic priorities to adopt, at least in a generic sense, some of the recommendations that Tom Wakeman mentioned about environmental controls. Yet the EPA mission is fundamentally regulatory, and most agreements with the EPA have a clause at the end that says, "This is not to give up any of our traditional regulatory authority, but thank you very much for working with us on these issues." These things will continue to plague us as we try to address these issues.

I will conclude by making a couple of general observations. First, with regard to the states, I am paid to say that the states do not perceive themselves as "just another stakeholder." We have a very significant role to play, not only in regulating but also in trying to manage these problems and respond to the public concerns about these problems. This point is not recognized in the report, which contains inaccurate descriptions of the states' role with regard to water quality certification and particularly state consistency determinations under coastal zone management programs. From the outset, the report takes a federal and academic perspective. I think the decisions on management of sediment, contaminated or otherwise, will be made—and are being made—most effectively at the local level by local decision makers, including state and county governments. For example, the Great Lakes region is way out in front in addressing some of these issues on a regional and state-specific basis. That is where the action will be, and I urge you, when looking at these recommendations, to think in terms of how you can facilitate decisions at that level.

Second, I often see diagrams of the myriad environmental and state controls and regulations and so forth, accompanied by statements about what a problem that is. Presented like that, this issue becomes like the "simple" questions John Haggard presented earlier. They are simple as he presents them, because he knows what answers he wants. When you present those issues in a certain way, they are not complex. But we get what we want; we get what we ask for. At the moment, that is still what the public wants. They want to be able to respond to specific problems, and those regulations are probably the best way to do that.

Despite all the discussion about wanting to respond to things in more broad-based ways, I think our decisions will continue to be driven by media specifics, storm surges, and so forth. We must recognize that reality and deal with it in the short term while also coming up with a long-term scientific and regulatory approach to address those issues. In the long term, that is the real issue for the environment. The real public health issue is the insidious, creeping nature of these problems.

Legal Perspective

Konrad Liegel

I am a practitioner in Seattle, Washington, EPA Region 10, a region of the United States that has had, for more than a decade, a comprehensive, joint federal/state program for managing contaminated sediments. We in the Northwest like to think we are on the cutting edge of sediment management, whereas others around the country may feel that we are far more on the lunatic fringe.

From the previous members of the panel, we know that contaminated sediments profoundly affect ports, municipalities, industries, and transportation entities that have to work with sediments as part of dredging, source control, natural resource damage, and environmental cleanup activities. As an environmental attorney, the challenge for me is to advise you in how to shepherd a project through regulatory approvals so that it remains cost-effective, environmentally sound, timely (the biggest challenge of all), and fair with respect to your actual contribution to the contamination.

Like the other panel members, I am in general agreement with the conclusions and recommendations of the report, in particular the importance of the USACE and EPA continuing to work together to develop consistent methodologies to assess, evaluate, and manage sediments. There should be no difference between a dredging action and an environmental cleanup with respect to the particular sediments in question. I also want to emphasize, as Frank Bohlen did, the importance of involving relevant stakeholders at the beginning and throughout the process.

I want to digress for a moment to mention a project that a client started about 10 years ago. The client was a pulp and paper company, which had just purchased a plant in a Superfund region near Tacoma, Washington. The company had put in source control measures and was thinking about cleanup. The record of decision (ROD) for the Superfund site was about a year away. The company determined that the best approach for the contaminated material was to leave it in place, move some additional contaminated material to that place (it was a depositional environment), and then cap it, bringing it up to the intertidal elevations to produce a habitat. The agencies were uncertain, given the concerns about in situ capping and the fact that an ROD was on its way. Because the company had approached the environmental community early on and discussed the project, the environmental folks weighed in at the last moment, saying that, in this case, they believed the proposed remedy would produce habitat benefits and that action at this time was more important than inaction. The cleanup went forward. After 10 years of extensive monitoring, they have proven to be right. The contaminants have stayed in place, and the habitat is flourishing.

I want to call particular attention to the portion of the report focusing on beneficial reuse of sediments. In this case, the pulp and paper company built up habitat in that area while managing the sediment. I believe that the report, with its emphasis on risk management, fails to give sufficient recognition to the role of habitat. Sediments are habitat, as we well know, and in our region of the country—maybe because of habitat considerations, maybe because we are about to have a listing of Chinook salmon—habitat considerations are invariably complicated and delay remediation efforts. In considering how to deal with contaminated sediments, there needs to be an increased focus on the role of sediments as habitat.

One important conclusion that I derive from this issue is also deserving of more emphasis in the report. Specifically, decision making and project implementation would be improved if the goals of land use and resource management planning were combined more often to develop project plans that are both environmentally sound and economically attractive. What follows from this perspective that I feel should be added to a strategy for addressing contaminated sediments? First, there should be an emphasis on source control, because sediments, as we know, are a sink for contaminants. When it comes to sediments, an ounce of prevention is worth a pound of cure, a reality that is given insufficient emphasis. Second, it is important to allow for natural attenuation. Sediments keep building up in certain regions, and that means, through the processes of natural recovery and natural attenuation, the risk posed by contaminated sediments will diminish with time if they are left in place. Third, there should be a focus on beneficial reuse. When dredging, we should use this material for something rather than simply disposing of it. Fourth, we should look for ways to integrate cleanup with habitat restoration and industrial development, so that a project will get the most bang for the buck.

Because I am supposed to provide the legal perspective, I will conclude with a few observations on needed regulatory reform. There is not so much a need to legislate wholesale changes to existing laws as there is a need—and this was recognized in the report—to promote policies that interpret regulatory requirements based on the intent of the underlying laws. What do I mean by this? First, when it comes to Superfund, it is important to view in-place capping as a permanent control under certain circumstances. My earlier example of the pulp and paper company shows that, in certain instances, in-place capping can be a long-term, permanent solution that also has important habitat benefits.

Second, with respect to Section 404 of the CWA, although there is an emphasis on selecting the practicable alternative that has the least in-water effect, there is also an element of the 404(b)(1) analysis that is not looked at much. While you focus on the least damaging alternative with respect to the aquatic environment, you also should consider the environmental consequences of other practicable alternatives, so that, in the end, you look not only at the risk but also at the costs and benefits associated with all of those alternatives.

Third, as I mentioned before, we should use the laws to encourage projects that integrate sediment remediation, habitat restoration, and industrial redevelopment. Fourth, building on a point that Frank Bohlen made earlier, it is important to encourage the development of regional approaches to the management of contaminated sediments, because the needs and the dynamics in different regions are different. Through that process, we can allow for the development of consistent federal and state approaches to contaminated sediments rather than settling for conflicts among federal, state, and local approaches.

Finally, I will weigh in on the debate of who is responsible and who should bear the risk. I think we need to work toward no longer making ports a target of opportunity when it comes to sediment remediation. When it comes to dredging, this means confining the analysis of impacts to the dredging prism targeted by the ports; facilitating, in the case of Superfund or even in CWA Section 404, the ability to institute cost-recovery actions so that the costs are allocated fairly between the ports and the upstream dischargers; and looking at things in a watershed context and in a source-control context, so that—perhaps through the process of total maximum daily loads or the like, as indicated in the report—there is a means of progressively limiting the contribution of contaminants from upstream sources.

Technologies and Research and Development

Case Studies
Roundtable Discussion
Breakout Discussions

CASE STUDY

Acoustic Techniques for Mapping the Distribution of Contaminated Sediments

David D. Caulfield, *Caulfield Engineering*

I want to begin by stating that the committee did an excellent job on the National Research Council (NRC) report. Earlier, everyone was talking about site-specific issues, which I also will address. I want to emphasize that I started my professional life as an engineer. Fortunately, someone twisted my arm and put me in the U.S. Navy as a civilian for 10 or 15 years, an association that I have continued. The Navy is the key reason why I am here today. I also want to point out that, in discussions and presentations such as those at this symposium, you always hear about the need for action.

I will begin with the technical aspects of the case study. First, a comparison. Say that someone has built a building on a particular site. The building has a sewer plant and bathrooms in it. There is a whole pile of codes and standards that people use when they build buildings. Unfortunately, in our site surveying and in the way we currently handle sediments issues, there are no codes. But there is a very simple solution. There is the American Society for Testing and Materials (ASTM), the association for standards in the United States. There is a guideline for writing codes.

I will talk about one example of the need for site surveying standards. I am sure that similar types of standards could be converted for coring and chemical analysis. This might resolve many of the questions we are talking about today, such as who is to blame, where we should put the material, and so on, because then we would be talking about facts with which everyone agrees.

The history of this case study dates back to the late 1950s, when the Woods Hole Oceanographic Institution staff started doing research for the Navy on building the first subbottom profilers, which were designed for mapping bottom-bound sonar systems. At the Naval Research and Development Center in San Diego, Edwin L. Hamilton—who in 1960 had a budget of $250 million, which makes what we are doing today look quite small—had the task to map the bottom of the oceans for their acoustic response and then relate this to the physical properties of the bottom—namely the grain size, density, and bulk modulus. He found some general engineering trends and devised a way to categorize the oceans. It worked very well—so well that it has been used now for about 30 years.

I was fortunate to be a student working under Dr. Hamilton, and in the early 1980s, when we began working with the U.S. Army Corps of Engineers (USACE), we used his data to establish a library of historical data on acoustics, which includes a summary of the Navy tables and the 44 surveys by the USACE from 1987 to the present. It provides a general characterization of the material type. The bulk density is the specific grain-size density, which usually is adjusted by the local geology. The material also has a wet density. Clays, where all the pollution is, are usually low density. The sands, which are usually clean, are high density. Porosity is the amount of void space. Another characteristic is mean grain size.

We also use the term "bottom loss." If you put in a sound wave that has 1 unit in amplitude, and it reflects back at, say 0.5 units, then the bottom loss is 20 × $\log_{10}$ 0.5 = −6.02 decibels (dB). You can characterize the bottom reflection coefficient, normally called bottom loss, although some people still use the older engineering term "water content." The point is that these data are based on probably $300 million to $400 million in acquisition costs and span a time period of 40 years. These data are very repeatable and are for uncontaminated sediments.

Another term used to characterize sediments is acoustic impedance, which is like the resistivity in a resistor. It is basically the density multiplied by the sound velocity. A plot of impedance versus density for the U.S. continental shelf in the Atlantic Ocean turns out to be a rather nice curve, computed by Dr. Hamilton in 1972. All the data we have collected for uncontaminated sediments since then for the USACE have fit on the same curve. The other important measurement in acoustics is absorption, namely, an attenuation that is a function of frequency and material type. This is very important for classification.

You probably all know what a survey boat looks like: pingers in the front; a boomer, which is a low-frequency source towed behind, with a hydrophone array; an acquisition system; and, of course, the global positioning system (GPS). We were successful in the Trenton Channel (near Detroit, Michigan) portion of the Environmental Protection Agency (EPA) work in producing a final map that was accurate to within 1 m in three dimensions. An important, added feature of the quality control work, which relates to developing the standards, is that the coring rig was dropped right in between the two transducers. Hence, we were able to get the acoustic data exactly when we got the core data. Then, when the core data were sent for analysis of the physical properties (e.g., grain size, density), they also were subjected to an exhaustive chemical analysis. We analyzed everything, from the organics to the heavy metals to the polychlorinated biphenyls (PCBs).

Acoustics has been around since the early Navy days. There was a chief who, when I asked why I had to learn about acoustics, took his right fist and described very carefully why I had to learn it. Basically, sounds propagate from a sound source, and every time there is a change in acoustic impedance or material type you get a reflection. The major feature added with the EPA and USACE work, which is not a standard in the industry, is the fact that you add a calibration hydrophone. The work became a success because people have seen the changes. Frank Bohlen described various major spatial changes. How do you know this is true from a legal point of view so that you can defend yourself in court or at a permit hearing? By calibrating your acoustic system, just like you calibrate the cranes that built this building, you can work back to the baseline. The change is no longer a "guesstimate" or, more importantly, an interpretation; it is now a statement of engineering fact.

When you use sound source data, you use something called the sonar equation. If you calibrate with a calibration phone, then you know all the terms in the equation except the bottom loss, which is what you are trying to measure—the bottom reflection coefficient. You do your survey and compute all the numbers. The first step in the EPA work was the development of quality control procedures, which are very important. The overall objective is that you cover the survey distance. The key step is when you give actual measurements, along with the percentage of accuracy in how you measure every one of the acoustic parameters. When you finish the survey, you have it down perfectly, and there is no argument. The customer knows it; the permit people know it; the EPA people know it. Everyone knows exactly what goes into the answers.

A calibration record contains several things. First, there is the transmit signal coming to the calibration; second, there is the signal reflecting off the bottom. This is a simple geometric problem. As you lower the calibration phone, the bottom moves up and the signal to the calibration moves down, and you can identify the signals. Computer software automates the whole process; it is not difficult to operate the system. A ping can be taken right where the core was, and by using cursors, you can select various reflections. The software automatically does all the math and computes the bottom loss. With the bottom loss, there is a standard deviation. If you have high levels of organics or PCBs that have been there a long time, then there is a gas content, and the standard deviation is one of the indications for the gas content.

You also can compute the acoustic impedance as a function of depth and relate that to the material types. As I mentioned, absorption is important. This can be done using a Fourier transform (to convert time amplitude data to the frequency domain), which basically allows you to take a seismic section. The frequencies start at 400 Hz and go up to 5,000 Hz. The dynamic range is very wide, from 6 dB to 80 dB. The important point is that, in normal sediments, there is a fall-off at the high frequencies, depending on the material type (e.g., sands, clays). With contaminated sediments, this fall-off is orders of magnitudes greater, by as much as a factor of 10.

With gaseous sediments, there is a phase reversal when the signal reflects off the layer that contains gas. This is illustrated by using correlation techniques. If it shows a solid line, then there is no phase reversal; if there is a dashed line at the layer, then there is a phase reversal. The software picks out the major layers and plots the bottom loss. Other speakers have talked about spatial variations. For example, within a distance of about 10 m, there may be bottom loss variations on the order of almost 10 dB, which is like going from silty sands all the way to fine mud—a significant variation.

Cores normally are taken after the acoustic survey. For example, using the Hamilton approach to predict density, you may see 95 percent of the points fall within the 95 percent confidence interval. In other words, if the sediment is uncontaminated and you follow procedures correctly, then you can be 95 percent certain about the density.

A new finding of the EPA work at the Trenton Channel over the last three years was that we took the core data when we took the pinger data; based on the core data, the software said the bottom loss should have been X—like -10 dB—but actually it was -5 dB. We plotted the difference between what the bottom loss should have been and what we measured, and at the same time we plotted the core data. There are no measurements yet of the worst core case, so we combined the whole thing and looked at the total chemical, metal, and organic levels. The core that had the most was assigned a grade of 10, and we graded them down to zero for those with no contaminants. It was interesting to find that the deviation in bottom loss was directly proportional to the gross amount of pollution. I caution you that this is a site-specific curve. In other words, this type of curve must be developed for each location, because it depends on the historical contaminant deposition.

When we finished in the Trenton Channel, we were able to map the deposits. All the clays in the area were contaminated, as illustrated by the close agreement between the actual core data and the predictions. Before we arrived on site, they had taken 8 or 9 cores. We then took another 10 or 15 cores. The polluted stuff included polyvinyl chloride, and white suits had to be worn when handling it. The assumption was that a very large amount of polluted material would have to be removed. When we did the entire survey in detail, one area turned out to be rock, or hard sand. Thus, instead of dredging the entire area, we could make a risk assessment at some points. There were very polluted areas and spots with hardly any pollution at all. Only 25 percent of what they expected to remove actually had to be removed.

The thickness of each layer also can be mapped. Some layers are 2.5 m, whereas others are only around 0.5 m thick. It is obvious, as you heard this morning about the transport of materials, that some areas probably do not have to be dredged. Using either a sealed bucket dredge or one of the new bottom-trawling dredges, they may have to dredge only a small area. The state of Michigan is going in this summer to complete the job.

That was a quick summary of the technology available today to set up standards for surveying. Now I would like to recommend several things. If you know anyone who controls the funding, the USACE program that led to this success has been canceled. There are no funds for the staff in Vicksburg, Mississippi, to continue to make databases of all the surveys. Furthermore, the USACE's direct involvement in local surveying has stopped. That sets us back to where we were in 1985, when people were taking survey data that were good but were without any standard and were not calibrated. That is like having an independent contractor make different software for each of our nuclear submarines and destroyers and then trying to fight a war—you could not do it. The contractors may be good, but standards are needed. With the work being done at the EPA, we are just months away from being able to write a standard. If someone says to go ahead, then we can write a standard. That way, when we talk about the risks and measurements, we will have data on which everyone has agreed.

CASE STUDY

Disposal Technologies Used in the Chesapeake Bay

Wayne Young, *Maryland Environmental Service*

I will talk principally about two projects in the state of Maryland, the Hart-Miller Island facility and the CSX/Cox Creek facility. The Port of Baltimore is way up the Chesapeake Bay and definitely needs to dredge. It has to dredge 5 million yd^3/year (3.8 million m^3/year), of which 4 million yd^3 (3 million m^3) are in Maryland. Of that, 500,000 yd^3 (382500 m^3) are from the harbor area and, although considered under Maryland law to be contaminated, may or may not actually be contaminated. The outer parts of the harbor tend to be very lightly contaminated, whereas some of the inner areas tend to be more contaminated with zinc, chromium, and arsenic.

To show you where this fits into the overall context, I will talk briefly about the governor's strategic plan for dredged material management. This is an outgrowth of more than 25 years of searching for suitable placement sites for both contaminated and uncontaminated dredged material dating back to 1970, before Hart-Miller Island opened. There have been a number of activities since Hart-Miller Island, including the 1986–1990 master plan, which looked at more than 300 sites and fell on hard times because of a political process. Several options—one in particular, a deep trough or hole in the Chesapeake Bay—became an environmental "cause célèbre," and then-Governor Schaefer formed a task force. The master plan never was produced in its full final form. The task force shifted the emphasis to beneficial uses of dredged material, which formed the basis for the Maryland Port Administration (MPA) Dredging Needs and Placement Options Program and continues to form the basis for the governor's strategic plan and the U.S. Army Corps of Engineers' (USACE's) Dredged Material Management Plan.

The range of alternatives covers everything from traditional open-water placement to upland sites, beneficial-use options, innovative concepts, artificial islands, and ocean disposal. The extensive involvement of the community, interagency efforts at the federal and state levels, municipalities, Baltimore County, and other counties on the Eastern Shore resulted a balanced, multiphase plan that includes two sites for contaminated dredged material, Hart-Miller Island and CSX/Cox Creek. It also includes the restoration of Poplar Island; open-water placement at Pooles Island (continuing the practice there) on a small scale for the next three or four years; large-scale open-water placement; and, ultimately, an Upper Bay island for clean dredged material. Some of these are very-high-cost options, making open-water placement necessary as a low-cost option to balance the cost of some of the more expensive alternatives.

The beneficial use of dredged material has been attempted with only one success in the upper portion of the Chesapeake Bay. The reasons for the limited success are the following. First, we have covered a tremendous range of options, including habitat development and so forth, all for clean material. Only one, Poplar Island, currently is moving forward. Aberdeen Proving Ground has a lot of contamination, both in the water and on land. Under the sponsorship of the MPA, we had 16 different island sites, restoration sites, shoreline sites, and so forth, all of which are no longer being considered.

Although we potentially could get these projects covered by the Comprehensive Environmental Response, Cleanup, and Liability Act (Superfund) under protocols for the installation of restoration programs, there is another type of contamination here, unexploded ordnance (UXO), and there are no protocols for UXO. Thus, if the port or USACE were to go in and build a project and then it was decided that the UXO had to be removed, we would have to go back in and dig out the habitat project, and they would have to pay for it. That killed the project.

Another project that has not worked and is still on the drawing boards is in Baltimore Harbor, in the area of Sparrows Point. It involved taking some degraded bottom area and putting clean material on top of the contaminated sediment to form a habitat. The citizens in the area do not approve of this project, in part because a lot of this harbor area was filled in before by Bethlehem Steel, and the citizens opposed it. There is also a rule established by the Maryland State Legislature that prohibits any containment facility within 5 mi (8 km) of Hart-Miller Island. This rule, which was put in after Hart-Miller was built, offers another example of the political process and how it can affect planning. Because this project would require a containment facility, it is also on hold.

At Poplar Island, portions of the island have been lost because of erosion. For the past seven years, planning has been under way to bring it back as an island containment site, hence providing a beneficial use for clean material. That project was fast-tracked. It took about seven years to go from concept to full-scale construction. There was a dedication ceremony at the USACE, presided over by the government, a week ago. The project is under construction. It will hold 38 million yd^3 (29 million m^3) of clean dredged material.

A number of lessons were learned from the beneficial-use efforts. First, we have broad support for beneficial-use concepts. However, beneficial use tends to be loosely defined. When we tie the beneficial use to a specific location, we usually have opposition. The only place we did not have opposition of some form was Poplar Island. It was a popular fishing area, and some clamming areas were affected. With the assistance of the Maryland Department of Natural Resources (DNR), a new area was found and opened up for clamming. Now there is total support for the Poplar Island project.

One of the big problems, of course, is funding. These projects are very expensive, much more so than open-water placement. This project will cost on the order of $75 million or more just for construction, and then it has to be maintained. Therefore, we have had great difficulty bringing these beneficial-use projects on line. Why am I talking about that at a symposium on contaminated sediments? If we are having a problem with clean stuff, then you can imagine the problems you will have with contaminated material.

Hart-Miller Island has been in operation since 1984. It is a multiple-use site. It is probably a beneficial-use site, although most people do not consider it as such. It was a beneficial-use site before that term became popular, because there is an active park there. Hart-Miller Island is the disposal site for contaminated dredged material. Everything west of a certain line in the harbor is, by state law, defined as or considered contaminated regardless of its content, and it must be contained.

Hart-Miller Island is located outside of Baltimore Harbor, at the mouth of the Back River. It consists of more than 1,000 acres. The north cell is the active containment cell. The south cell, once used actively, has not been used since 1990 and is under development for passive recreation and habitat. It has a park. When the facility was constructed it reconnected Hart and Miller islands, which at one point were the same island. A beach also was constructed. It has an observation tower and draws up to 70,000 visitors in a good year.

Regarding Hart-Miller Island's economic contributions, obviously it is a disposal site for dredged material and has allowed the port to maintain operations uninterrupted. It is cost-effective placement. It has been built. The dikes have been raised, so we did not have to build a new facility. Raising the dikes was less expensive than building a new facility. There is also local acquisition of goods and services, so the local economy has benefited. In addition, the location of the approximately 1-by-2 mi (1.6-by-3.2 km) island provides a shelter against winter ice and storms, so it has benefited local property owners.

The recreational assets include the constructed beach, observation tower, and park facilities. There are 22 primitive campsites, which are used extensively during the summer. There are test plots out there now testing vegetation. This is a USACE project; the local sponsor is the Maryland DNR, with support from the MPA and technical support from the Maryland Environmental Service.

The environmental benefit of Hart-Miller Island is that it provides an environmentally sound containment area for Inner Harbor dredged sediments. The operation is monitored extensively, both on the facility and by the Maryland Department of the Environment (MDE) externally, to check on what is happening in the benthic region and so forth. There have been no benthic problems. There has been some increase in zinc levels in the area of the spillways. We occasionally have test results indicating some toxicity, but when the materials have been retested, the toxicity has gone away. The area alongside the dike is used extensively by crabbers when the crabs are migrating. In fact, one waterman told me he liked it better with the island there because now he knows where the crabs are going and he catches more of them.

We have avoided water quality impacts in the form of total suspended solids (TSS). We have strict monitoring criteria. The facility is operated under a state discharge permit, and we operate to those parameters for TSS and pH. For metals, we have extensive testing, which I will not go into in great detail.

The islands of Hart and Miller have been preserved. Before, they were eroding; now, the beach has been reconstructed. There is now more shallow-water habitat than there would have been otherwise. There is extensive use by migratory waterfowl. More than 267 species of birds have been observed at Hart-Miller Island, and when the dredged material comes in, perhaps because of the organisms and other things in the dredged material, tremendous numbers of birds use it, coinciding with their winter migration. In the development of the south cell, one of the concerns was that, when the north cell no longer is used as a dredged material containment facility, the shorebird habitat that is now provided on an interim basis will be lost. That has figured into the planning for the south cell to help rebuild shorebird habitat.

Then there are environmental study opportunities. The Hart-Miller Island project was started in 1969. The project was authorized, and the site was selected. Then there was a lawsuit, which was won by the port. The facility was constructed from 1981 through 1984, and the first inflow was in 1984. The port got a 50-ft (15.25-m) channel deepening project through, and all the money came in two years. This put tremendous demand on the facility, resulting in what then was to be a temporary raising of the dikes from 18 to 28 ft (5.5 to 8.5 m).

This gets to one of the lessons learned. We believe that, because Hart-Miller Island was there, it took the pressure off of finding a solution for the dredged material management problem. The facility was filled up to the 28-ft (8.5-m) dike. Now the dikes on the north cell have been raised to 44 ft (13 m), with extensive public involvement and a lot of controversy. Because of the demand for placement capacity, the facility is operated on a one-year dredged material management cycle to get optimal, or nearly optimal, consolidation of the material.

The port has funded a very aggressive crust management program. When the material comes in, the water is decanted and discharged in accordance with criteria overseen by the MDE. As soon as the material starts forming a bit of crust, we put exterior trenches in. We also run a pontoon excavator out into the cell to put depressions in. They are only 6 or 8 in. (15 or 20 cm), but they provide pathways for the water to get to the exterior trenches that run down to the spillways. When the crust can support it, trenching equipment is sent out; then we get a full crust and we are back to inflow. The trenching pattern is over the entire facility. It takes a fair amount of time to put that in place, but it helps keep the water off and the facilities rapidly drying.

When the material from the 50-ft (15-m) deepening project came in, crust management was not possible because the port had to get that material in or else lose the money. Once the crust management started, we gained the capacity back and inflow started again. Dave Bibo was instrumental in getting a two-year hiatus, which gains additional capacity for the facility. With aggressive management, we might get as much as 50 percent consolidation. During a drought year we got 60 percent consolidation.

The follow-up to Hart-Miller Island will be the CSX/Cox Creek facility, an existing dredged material containment facility that has not been used for some time, although it has been maintained for that purpose. An old refinery discharged water there. We are in the process of rerouting the stormwater discharge through a wetland. We have gone through all of the permitting for that. We have to get an additional permit for some nontidal wetland impacts, and we are coordinating with the MDE on that.

This facility will be dewatered, and the cross dike will be removed. A tow berm will be placed about 60 ft (18 m) outside because the bottom conditions are not particularly good; there are clay areas. For stability reasons, to get an adequate engineering factor of safety, the tow berm needs to be placed here. We are working with the regulators now on the water quality certification requirements for this facility. The regulatory field is changing. This is an impaired water body, so there is a lot of discussion as to what the appropriate criteria are, and this will be going on for some time.

This facility is a wetland. However, these wetlands are incidental to dredged material placement. The facility originally was constructed by the USACE. Then it was acquired by private companies, CSX Corporation and the refinery company, and it was used privately for material from the CSX and Cox Creek access points to their facilities. The facility was converted and the USACE determined that it was nonjurisdictional, which allows its reactivation. It will be used for maintenance-dredging material.

Once the traditional technologies allow the material to settle out and we decant the water, manage the crust, and fill the facility, then we will need another facility. It is getting more difficult to find these places, so the port is looking at recycling to see if contaminated material can be turned into an environmentally sound, unregulated product. Because it needs to dredge 500,000 yd^3

(382,500 m^3) of contaminated material every year, the port is using this number as a target. One problem, however, is finding a technology that is cost-effective and will produce an environmentally sound, unregulated product, whether landfill caps, topsoil with amendments, or whatever. It is a major effort to get rid of 500,000 yd^3.

A confined disposal facility (CDF) can provide interim habitat. However, you have to use it in a way that prevents you from losing it. If an endangered species moves in, then one potentially could lose the use of those facilities. If it turns into wetlands and you go back to reuse it, then you potentially could lose it. Perhaps this problem should be resolved from a regulatory perspective, so that those who build these facilities and operate them effectively do not lose their availability while providing habitat that is widely used by various species, perhaps displaced from elsewhere.

The regulatory field is changing. The total maximum daily load issue may have profound effects on all facilities that are impaired water bodies. We are not sure how that issue will relate to this facility, and we are working with the MDE on that. We believe the Clean Water Act, Section 401, is the appropriate regulatory authority. Hart-Miller Island is operating under a discharge permit because this approach was more effective back when the facility was started, and there was an agreement with the citizens that it would be controlled very tightly.

I mentioned that the availability of a CDF can relieve the pressure to find a long-term solution, and to some extent, that has happened. When you have something as large as Hart-Miller Island, it may appear that it will go on operating forever. But it will fill up. Thus, even when you are able to get a large facility built, you cannot stop looking for other alternatives—and looking hard—with extensive public involvement. Finding new locations in harbor areas is very difficult because these areas have been developed. Perhaps we could put sediment in brownfields. Strong public involvement is needed at all stages because this is a sociopolitical issue as well as an environmental, engineering, and cost issue.

With Hart-Miller Island, we have to deal with the rule that says we cannot have a containment facility within 5 mi (8 km). Yet to get a long-term solution, most of the island sites that are being considered are either all or partly within 5 mi of Hart-Miller Island. Strong public involvement and legislative involvement will be required if any of those sites go forward. This is a NIMBY ("not in my back yard") meets NIMBY situation. The bay community says, "Put that material upland." The upland folks say, "Don't put it here." Where do we put it? We have to put it somewhere. We have controversy over the sites no matter where we put it. Poplar Island was an exception; it got broad-based support because of a number of factors, but sites like that are few and far between.

Down in Houston they had good luck with one beneficial-use project, so there are opportunities. But these are for clean material. We need innovative alternatives and technologies for contaminated sediments. The port is looking into this. The cost seems to be high, although one company says that for \$10/yd^3 (\$13/m^3) it can make an environmentally safe, unregulated product. The port is interested in putting out requests for expressions of interest. The documentation is finished, but the request is on hold because the site they plan to use for recycling is the CSX/Cox Creek facility, and the upland site would be the staging area. There is an initiative to put a racetrack there, in Anne Arundel County. Until that is resolved, the request for expression of interest is on hold.

Even if we ultimately find a technology that is cost-effective and can make a product that is environmentally safe and unregulated, the technology is useless unless we can get rid of 500,000 yd^3 (382 500 m^3)of material a year. We still have to find a market for it. After we have used up the space available in the facility, then we are back to square one. We have to find someplace to put it. Getting into the product stream and marketing can be very difficult because we are going up against existing topsoil and gravel markets and so forth.

With all these technologies, information sharing is critical. This is a very expensive area. The ports and others need to work together so that information about successes and failures is shared. That way, resources are conserved, and people do not invest in someone else's mistake but rather in someone else's success, adapting it for their local area. Finally, funding for high-cost dredged material management options is very difficult to obtain, particularly when you have traditional options available, but at the same time you need the traditional options to balance those high costs.

CASE STUDY

Geotechnics of Utilizing Dredged Sediments as Structural Fill

Issa Oweis, *Converse Consultants*

My remarks deal with the structural aspects of the use of dredged sediments as opposed to the environmental aspects. The case is a site in Elizabeth, New Jersey. It is probably one of the largest, if not the largest, site in New Jersey now using dredged sediments to prepare a site for a large shopping mall, which will have about 1.5 million ft^2 (139,500 m^2) in retail space. The project has been heavily supported locally and at the state level. The environmental permitting was not the most significant part of the site development. The owner prepared a risk assessment. That particular aspect of the use of dredged sediment in New Jersey is not regulated by the solid waste group, although it is being reviewed by the group. That is very important.

This is a 160-acre (64.8-ha) site that used to be a garbage disposal site. It is about 30 years old and is commonly referred to as the Kapkowski site. It was purchased about seven years ago by a Danish company, which prepared the site, and it is being developed now by an Ohio company. The original plan was to stabilize the garbage using a combination of deep dynamic compaction as well as preloading. These are not new technologies; they are well proven. The question was how to grade the site to make it suitable for construction. That is how the use of dredged sediment came to be considered.

Originally, the plan was to dike the whole site and pump the dredged material into the diked area—basically the traditional method used successfully by the U.S. Army Corps of Engineers (USACE) at many sites and just discussed by Wayne Young. But it would take a long time, maybe seven or eight years, for the material to consolidate and be suitable for construction. Some thought was given to accelerating the drainage by putting in drainage nets, so that each layer of the dredged material pumped would consolidate the one beneath it. However, there was a concern that the effluent from the consolidation process would have to be treated, increasing the cost of the project.

The last option was to stabilize the dredged sediments, again using a very old technology but with a new twist that involved mixing the dredged sediment with lime, cement, and fly ash. The old TRB literature mentions that organic soils are not suitable for stabilization. What that really means is, they are not suitable for stabilization at a reasonable cost. We are talking about fine-grained material, which has a relatively large percentage of organics, about 7 percent, maybe as much as 19 percent.

Regarding grain size, the data for a lot of samples from New York Harbor, New York Bay, Newark Bay, and Arthur Kill show there is not a wide range in the gradation of the material. Anywhere from 50 to 95 percent passes through the number 200 sieve, which is silt size, or very-fine-grained material, and quite a bit passes through the 2-micron size, or the so-called clay size, at which the material begins to exhibit clay-like properties.

For all practical purposes, all the material, whether from New York or Newark Bay, could be considered the same material; in any event, New York sediments come to Newark Bay. It is all the same.

From an engineering classification viewpoint, the samples are mostly elastic silt. For those of you not in the soil mechanics business, the liquid limit is the moisture content at which the material starts to flow. The higher the liquid limit, the weaker the material; the lower the limit, generally speaking, the stronger the material. The plasticity index is the difference between the liquid limit and the plastic limit. The plastic limit is the moisture content at which the material starts to break, which means it becomes very stiff and brittle. The lower the plastic limit, the stronger the material.

I mentioned the term "moisture content." I must caution that many groups have different definitions of moisture content, depending on the discipline involved. The way I am using it here, moisture content is the weight of water divided by the dry weight, which is the traditional geotechnical (or soil mechanics) definition. However, to the environmentalist, the moisture content is the weight of water divided by the total weight, which is wet weight. Thus, from an environmental standpoint, the moisture content of pure water is 100 percent, whereas from a soil mechanics structural viewpoint, the moisture content is infinity. There is also a third definition, the volumetric moisture content, which is the volume of water divided by the total volume. This definition is used by hydrogeologists.

That leads me to one comment about the NRC report. Right at the beginning, you should try to define which moisture content you are talking about. A wrong assumption about the meaning can be disastrous in contract documents, depending on which moisture content you are talking about.

Without stabilization, the material is very weak. The USACE data from 1994 for Newark Bay shows that the material has a very high void ratio and is very compressible, although less so than peat or, in general, phosphatic clay. In any event, when it is dredged and put on a barge, it has a mayonnaise-like consistency, which is very weak. The problem with it is not only environmental but also structural. You cannot handle it; you cannot drive on it; you cannot walk on it. The mobility is a major concern in trying to dispose of it for structural use to support a building.

Obviously, there is a correlation between the organic content and the specific gravity. For very fibrous peat, the specific gravity is about 1.4. The material from Newark Bay, New York Bay, Arthur Kill, and New York Harbor typically has about 7 percent organic content by the American Society for Testing and Materials definition. To determine the organic content, you burn the material at very high temperature and measure the weight before and after. You occasionally find very high organic content, on the order of 15 percent. This is important, because we found that organic material hydrates more slowly than does inorganic material when mixed with cement and lime. The organic content basically inhibits hydration. This affects how long you have to wait before you start handling the material. This is not something new. It was reported in the literature in the early 1950s that, if you have high organic content, even in trace amounts, the strength will be very low because there will be less hydration.

In stabilizing the material with cement and lime, the key is to have enough lime to form a gel. These days, lime is very expensive. The material used as a stabilizer for the Elizabeth project is cement and fly ash. Cement is much cheaper than lime. At some point early in the project they used lime kiln dust, which has some lime, but not much. The key to the stabilization of the material is to maintain a high pH. That is not a new finding. That was found in the early 1950s in work at Louisiana State University and other institutions. If you maintain a pH of 12.4 or close to 12, then you get high strength after hydration.

If the material has a high organic content, then it has a tendency to absorb calcium ions. That does not leave much calcium for the hydration. There is a correlation between the strength and the absorption of calcium ions. If you have very low absorption, which means less organic content, then you have higher strength. That is very important in the stabilization of the dredged material. Obviously the material has to be strong enough to support the pavement of the parking areas for the shopping mall as well as access roads.

A variety of mixtures can be used. One has 20 percent lime kiln dust; another has 20 percent cement kiln dust; others have 7 to 8 percent cement; and still another has about 8 percent cement and 12 percent fly ash. You get different behavior based on what mix you use. The important thing is to be as close to the optimal density as possible, and not too far off the optimal moisture content. If you are too far off, then you have lower strength. If the material is too wet, then you cannot compact it and you have low strength; if it is too dry, then, when the material gets inundated, it just collapses if it is compacted. You have to strike a balance.

Looking at compaction for these mixes under different levels of energy (the standard energy is about 12,400 ft-lbf/ft or 600 kN-m/m), none of the densities is good enough. In the range of a dry density of 60 lb/ft^3 (973 kg/m^3), the material simply collapses when you saturate it. Even if you use only 95 percent of the standard energy, the standard density is not good enough to maintain a stable material for structural support. We also found that, as the material waits before you try to compact it, it takes more and more energy to compact it. The permeability of the material is quite low. In a way, this is good, because it will be more difficult for the water to go through. On the other hand, if it is fine grained, then it could crack very easily.

Consolidation curves show that the material is not very compressive but is well compacted. Up to a certain point, it exhibits the properties of overconsolidated soil. If you are below 3 or 4 tons/ft^2 (27 to 39 tonne/m^2) of bearing, then you have relative compressibility for the stabilized material of different mixes. Once you go beyond that, it will act as ordinary material.

It is very simple to normalize all these data into a meaningful form that can be used by the designer. We use a parameter called normalized density, or the density to which you compact the material divided by the optimal density and multiplied by the normalized moisture content (which is the optimal moisture divided by the moisture content to which you compact it). The higher the number, the greater the strength of the material. A preliminary design chart can be made to assess what type of strength you could expect based on a certain density and moisture content.

The same data can be plotted in the California bearing ratio (CBR), which is the standard test comparing the penetration resistance of the material to the penetration resistance of strong material such as crushed stone. The minimum CBR they can use for structural purposes is 10 percent; anything below that is no good. You can get some idea of the CBR if you have the moisture content.

In many compacted fill applications for conventional material, engineers use a nuclear density gauge to figure out the wet density in situ and the moisture content. We found out that the nuclear density gauge underestimates the moisture content of the material and therefore overestimates the dry density. Thus, a big lesson learned from this project is: Do not use a nuclear density gauge to measure the moisture content. Compared to a dry density value obtained using the most reliable sand density cone, a nuclear gauge overestimates by up to 20 percent, which, for structural purposes, could be a very serious difference indeed.

After it is mixed and placed for compaction, the material looks like ordinary structural fill. Again, I must caution that, based on most highway specifications, it does not fit the grain size requirement. Furthermore, with regard to the negative aspects of this material, it has a very low tolerance for frost-and-thaw cycles; we have to cover it with 2 to 3 ft (.6 to .9 m) of sand or non-frost-susceptible material. It is also somewhat expensive. In addition, it is quite corrosive. But that is not a big limitation because, with the concrete technology we have now, we can mitigate against high sulfates and chlorides and bury it in concrete.

The dredged material in a compacted state is performing very well. We have lots of data to show that it has a field CBR of over 10 percent, and that the unconfined compressive strength could be well above 20 or 30 lb/in.^{2} (138 to 207 kPa).

Roundtable Discussion

Testing New Technologies

Tommy Myers, *U.S. Army Corps of Engineers, U.S. Army Engineer Waterways Experiment Station*
Dennis Timberlake, *U.S. Environmental Protection Agency*

NOTE: The National Research Council (NRC) report made a number of recommendations for new technologies and research, many of them directed at the Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE). Since the report was published, staff members from these two agencies have met several times and begun working together on specific projects. Representatives of both agencies were asked to discuss their reactions to the 12 relevant conclusions and 5 recommendations, what actions are being taken in response, and whether there are any differences of opinion. The relevant NRC conclusions and recommendations are excerpted below, followed by the agency responses.

Engineering Costs of Cleanup

> Many contaminated sediments can be managed effectively using natural recovery, capping, or containment. Where remediation is necessary, high-volume, low-cost technologies are the first choice, if they are feasible. Because treatment is expensive, reducing volume is very important. At the current state of practice, treatment is justified only for relatively small volumes of highly contaminated sediments, unless there are compelling public health or natural resource considerations. Advanced treatment processes are too costly in the majority of cases of (typically low-level) contamination. The unit cost of advanced treatments will probably decline slightly as these technologies move through the demonstration phase, but it is unlikely to become competitive with the cost of less-expensive technologies, such as containment.
>
> Problems with available cost data include the lack of standardized documentation and the lack of a common basis for defining all the relevant benefits and costs. The data are inconsistent with respect to the types of costs included and the units of measure (e.g., cubic yards, tons, hectares), and geographical variations in costs are not taken into account. The problem stems in part from the lack of a formal structure for reporting cost data. Even if good cost data were available, measures of effectiveness must be improved before reliable comparative analyses of technologies can be made.
>
> (NRC Report, pp. 162–163)

Tommy Myers: Regarding the costs, we are in agreement that we need more cost information, particularly for treatment alternatives. That is the real issue. We have data on the traditional and conventional methods of dealing with dredged material that the USACE uses in its maintenance program.

We would like to add to the conclusions. We feel one weak point is an insufficient emphasis on total cost data. That is, the total cost of dredging, transportation, treatment or disposal, and, with regard to treatment, the management of the waste streams that are generated. I think Issa Oweis's presentation highlights the need for this. For example, the effluent or leachate that would be produced during consolidation, and the treatment costs for that, led to a decision not to use hydraulic dredging and filling and conventional dewatering.

We in the USACE, and I in particular, are somewhat skeptical about some of the claims of $10, $5, or whatever per yd^3 ($13 or $6.50/m^3) to treat materials and, as Wayne Young noted, get the materials to a point where they are not regulated anymore. We are very much concerned about that. On the other hand, we do not want to be obstructionist, and we encourage those working in the treatment areas to continue to achieve economy of scale, innovation, and reduced cost.

Dennis Timberlake: I agree with that. In most cases, dealing with hot spots and looking at high-technology options, we certainly could improve the technologies, but I think you are looking at small increments in cost performance.

One exciting thing about this field, the NRC report, and the discussions we have had is that sometimes you are challenged on basic assumptions. There is some demonstration work going on around New York Harbor now, with cost estimates that include treatment coming out very low, at less than $100/yd^3 ($130/m^3). I do not know all of the details. Part of me says that you cannot do it that cheaply. I am used to the Comprehensive Environmental Response, Cleanup, and Liability Act (Superfund) context, where it costs several hundred dollars per cubic yard. But I think we need to remain open. It will be interesting, as those projects move to larger-scale demonstration in the field, to see the real economics of those processes.

When I was reading through the conclusions, something kept nagging at me. We are talking about cost—low cost is obviously better—but we really are talking about the cost of implementing a specific solution. As Tommy Myers said, we should look at the whole range of costs. But there is more than just the cost of implementing a solution. Hopefully we also are talking about risk reduction and risk management. Thus, even if we had comparable cost numbers on a bunch of technologies, could we really compare two of them? How much do we really know about what we achieved by implementing a technology?

I know my research laboratory, and I think we do a poor job of documenting the amount of risk that actually was reduced by using a certain technology. We in sediment management are not as smart as we maybe like to think we are. You can talk about how cheap it is to implement a certain technology, but there is a cost associated with not taking care of certain pollutants that are in place. This gets to the whole cost-benefit issue. We talk about the cost of implementing a solution, but there is much more to the equation than just that.

Remediation Technology Options

> For many projects, natural recovery is a viable option. It may be the optimum solution where surficial concentrations of contaminants are low, where surface contamination is being covered over rapidly by cleaner sediments, or where contaminated sediment is modified by natural chemical or biological processes and the release of contaminants to the environment decreases over time. A better understanding of natural processes is needed, and models need to be verified through long-term monitoring.
>
> When natural recovery is not feasible, capping may be an appropriate way to reduce bioavailability by minimizing contaminant contact with the benthic community. The efficacy of capping needs to be monitored, not only to ensure that risks are reduced, but also to gather data that can be used to advance the state of practice. The appropriate use of capping might be advanced if it were viewed as a permanent solution in the Superfund context.
>
> Although there are conceptual advantages to in situ chemical treatment, considerable research and development (R&D) will be needed before successful application can be demonstrated.
>
> Using bioremediation to treat in-place marine sediments, although theoretically possible, requires further R&D because it raises a number of significant microbial, geochemical, and hydrological issues that have yet to be resolved.
>
> (NRC Report, p. 163)

Myers: I generally agree with the capping and treatment conclusions. I have some disagreement with the natural recovery conclusion. The report leads you to believe that natural recovery will be applicable at many sites that we are considering for remediation. Of course, natural recovery does not fit into the USACE program or into work related to maintenance dredging, when we have to move the material. I also wonder about the term "many." My gut feeling is that, at a few, very special sites, we will find natural recovery to be a good alternative that really works.

We in the USACE support capping. I believe it truly is the most cost-effective remediation alternative when it is applicable. It would not necessarily be applicable in shallow-water areas. There are many places—outside of environmental questions, navigation, or appearance of sites—where it may not be applicable; maybe the water is too deep. But capping is cost-effective in terms of the definition that economists use, looking at the marginal cost and marginal benefit. When you analyze it that way, capping is very environmentally protective and very inexpensive. It is not popular because we do not directly decontaminate or detoxify the sediment; we isolate it. It is a containment technology. We like it very much. We wish we could use it more in our program.

Regarding treatment, of course, we agree with those conclusions. We believe there is a lot of R&D needed. It relates back to the cost.

Timberlake: I echo what Tommy Myers said about natural recovery; I had the same reaction. My gut feeling is that there are probably a few places where it might be appropriate, but not many. It comes down to the wording. It is a viable option. When you make a decision about which risk management method to use, what real costs are you considering? If you are looking at just the cost of implementation, then maybe natural recovery is a great way to go. If you are looking at more "touchy-feely" types of costs down the road, then maybe it is not the best choice. We need to get a better handle on that type of thing.

With regard to capping, I run into the attitude that it is not a permanent solution. People have a lot of questions about the long-term capability of a cap to control the contamination. We have a lot of models and a lot of information to make the decision that capping is a good choice in a lot of cases, but in my opinion, there definitely is a need for long-term monitoring information, so that we can answer factually any questions about the long-term performance of caps.

Regarding in situ treatment, as the report acknowledges, there are lots of problems with how you deliver reagents and microbes to the sediment without causing resuspension, and how you control the process. I agree with all that. Our lab has a number of research projects aimed at developing in situ approaches. It is a long shot, but we see a huge payoff if we can develop technologies that can be implemented in place. As a first step, we are looking at a lot of our processes to be implemented within confined disposal facilities (CDFs). Technically, that would be an ex situ process, but it is quasi in situ because you are working on a large volume of sediments. It allows you to control some of the conditions for treatment.

Sediment Removal Technology

> Because of the high cost of ex situ treatment relative to dredging, dredges need to be made widely available that can remove sediments at near in situ densities and that have the capability for the precise removal of contaminated sediments, so that the capture of clean sediments and water can be limited, thus reducing the volume of dredged material requiring containment or treatment.
>
> (NRC Report, p. 165)

Myers: I generally agree with that conclusion but would add some precautionary comments. Precision dredging is an oxymoron right now. We are not able to do that in maintenance dredging—depending on how you define precision. If we are mapping characteristic concentrations in three dimensions and trying to achieve resolution on the order of 15 cm, then we can probably come close, but it typically would be more like 30 cm.

When you get resolution down to 15 cm or less, I have a question about our coastal sites. These are open, dynamic systems. Why do we think the contaminants will be there later—seven years later in Wayne Young's case—right where we measured them? That confuses me in particular. We know that sediment is moved around; that is why our channels fill up and we have to dredge to maintain them. Perhaps some of the buried stuff would still be there.

My precaution regarding the development of precision dredging technology is that we need to do this on the fast track, not over seven years. We need to do something similar to what David Caulfield was alluding to in the Trenton Channel, where, after the mapping is done, they get to dredging. In that case, it makes sense to me. Many times, a fast track is defined in terms of seven years; I am glad to hear that David Caulfield is getting something going a lot quicker. Maybe there is no reason why we cannot get things going faster and make use of the technologies.

In terms of USACE programs, we wonder if it is a smart R&D investment of our limited resources to do this. Of course, for our maintenance program, where we are doing geometry and not cleanup, precision dredging makes sense in some cases, and it may be worthwhile.

Timberlake: I was surprised that the conclusion did not say something about assessing effects, such as resuspension, related to dredging operations. That flag comes up a lot. It would be nice to have more studies that define the conditions under which you might make a problem worse, or say whether it is not an issue in some cases. I suggest that be added.

Ex Situ Technologies

> Research is needed to improve the control of contaminant releases, to improve long-term monitoring methods, and to improve techniques for preserving the capacity of existing CDFs.
>
> Construction of contained aquatic disposal (CAD) on or near contaminated sites is likely to be acceptable, but the applications have not been explored fully. Research is needed to improve design tools and long-term monitoring methods and to control contaminant losses and determine their effects and associated risks.

> Research and development of ex situ treatment technologies is warranted in the search for reasonable possibilities for the cost-effective treatment of large volumes of sediment. Bench and pilot testing of ex situ treatment technologies, and eventually full-scale demonstrations in marine systems, are needed to improve cost estimates, resolve technical problems, and improve treatment effectiveness.
>
> (NRC Report, pp. 165–166)

Myers: We agree that work is needed on CDFs. For the USACE and its maintenance program, and for port authorities with their navigation channels, this is still a good technology. It is a confinement technology, but a good one. We traditionally designed CDFs to confine solids, not necessarily contaminants, so there is room for improvement—and there has been an improvement. We caution you to advise others that we may have misplaced concern about the effectiveness of these facilities. When we hydraulically fill these facilities, the effluent is monitored to the conveyance point where it has to be discharged to meet state water quality standards. Water quality certification is required.

We have tools, tests, models, and procedures on the World Wide Web—everything needed to design a CDF to meet a water quality standard for the effluent during hydraulic filling. We even developed leaching tests to assess leachate quality inside a CDF in a pre-project mode (for design purposes), to determine if you want to use a line or not. We are developing tools for using those data to predict concentrations at a target receptor downstream of the CDF in the subsurface. We are moving in all these directions, so naturally we agree that research is needed. We also have laboratory work under way on the volatilization of hydrophobic organics from CDFs. We in the USACE do not have much in the way of long-term monitoring programs for CDFs; our work is focused more on pre-project assessment and design.

Contained aquatic disposal is, in a sense, another form of capping. We like CAD; we think it is very cost effective. Regarding the need for research on tools, we are working diligently to improve design tools for CAD so that we will have a cap that is thick enough to isolate the contaminants and prevent migration, behaves properly geotechnically, and withstands storm events—whatever storm events are specified by state or federal agencies, or if we can determine what the requirements would be. We are working steadfastly on the design tools, and a lot of progress is being made. Long-term monitoring to prove the adequacy of the design tools certainly is needed. We do not have a research program set up to provide long-term monitoring. We are probably talking about more than just a bureaucrat's career, or even a researcher's career, in terms of long-term monitoring for these options.

Dennis Timberlake alluded to some of the treatment work already going on. We are very much interested now in doing the R&D to investigate the use of CDFs to treat materials that someone wants cleaned, to get those materials to the unregulated state that Wayne Young referred to and give new life to our CDFs. Perhaps we can remove materials from the CDFs and recover that storage capacity. We certainly agree with the report that a lot of R&D is needed in this arena.

Timberlake: For CDFs and CAD, we need long-term performance monitoring, just so we know what we are dealing with. Otherwise, we can argue forever about what is appropriate and what is not. I think we need to make some progress on issues such as whether or not there are releases from CDFs or what the level might be.

Regarding ex situ treatment, most of the advanced technologies that we use were developed for Superfund-type treatment. I do not see major advances coming that would reduce the cost of implementation. I think the real breakthroughs will be in how the technologies are implemented. For instance, in New York Harbor, an economy of scale possibly will drive down the cost and make it reasonable. Coming up with partnerships and different things could be helpful. It is more than just a technical problem; it is how you use the technology.

Remediation Technology Research, Development, Testing, and Demonstration

> Additional R&D and demonstration projects are needed to improve existing remediation technologies and reduce the risks associated with the development and use of innovative approaches to testing marine sediments. The development and wide use of cost-effective, innovative solutions would be advanced by (1) the peer review of proposals for R&D on new technologies for handling, containing, and remediating sediments, and (2) the establishment of mechanisms for side-by-side demonstrations of new and current technologies.
>
> (NRC Report, pp. 167)

Myers: I could not quite understand the peer review comment in terms of a need. The R&D programs on sediment remediation do involve peer review, I believe, and it is sometimes quite extensive. I think we all agree that it is probably needed and appropriate for these types of programs.

Regarding the side-by-side demos, I think that is great. I am concerned that it might be beyond our resources, at least the public resources that are available now. A more prudent approach is to do bench-scale testing side by side, select two or three technologies for pilot-scale testing, and then demonstrate maybe one. Side-by-side field demos, depending on what you mean by a demo, will cost a lot of money. Traditional engineering practice has been to do bench-scale and pilot-scale demonstration before you go to full scale. I think that is very prudent and cost-effective.

I say that because Dennis Timberlake and I work for the public, and we constantly are reminded that we are supposed to make the best use of resources. We would like to do demos side by side all across this country, all the time and everywhere, and have billion-dollar research programs. That would be great but as a practical matter, I do not know if we will be able to do these things.

Timberlake: Picking up on that thought, I think side-by-side demonstrations would be wonderful. I think the best avenue to get that type of work done is through programs directed at specific regions. For instance, the Great Lakes had the Assessment and Remediation of Contaminated Sediments (ARCS) program. They had the resources to look at a number of technologies at a select number of sites. Now New York Harbor is in the same position, getting money to look at technologies for a specific problem.

The budgets made available for efforts like that dwarf my budget for R&D. It would be nice, as Tommy Myers said, to do this all across the country, but for now we need to try to take advantage of certain areas that are in the spotlight. For a time it was the ARCS program. Certainly the Great Lakes are still an issue, but now you hear a lot about New York Harbor. I think we should use those vehicles to get this type of information.

Recommendations for Improving Long-Term Controls and Technologies

> The EPA and USACE should develop a program to support R&D and demonstrate innovative technologies specifically focused on the placement, treatment, and dredging of contaminated marine sediments. Innovative technologies should be demonstrated side by side with the current state-of-the-art technologies to ensure direct comparison. The results of this program should be published in peer-reviewed publications so the effectiveness, feasibility, practicality, and cost of various technologies can be evaluated independently. The program should span the full range of R&D, from the concept stage to field implementation.
>
> The USACE and EPA should develop guidelines for calculating the costs of remediation systems, including technologies and management methods, and should maintain data on the costs of systems that have actually been used. The objective should be to collect and maintain data for making fair comparisons of remediation technologies and management methods based on relative costs as well as their effectiveness in reducing risks to human health and ecosystems.
>
> The EPA and USACE should support R&D to reduce contaminant losses from CDFs and CAD, to promote the reuse of existing CDFs, and to improve tools for the design of CDFs and CAD systems and for the evaluation of long-term stability and effectiveness.
>
> The EPA and USACE should sponsor research to develop quantitative relationships between the availability of contaminants and the corresponding risks to humans and ecosystems. The overall goal should be to enable project evaluation using performance-based standards, specifically the risk reduction from in-place sediments; disturbed sediments; capped sediments; CDFs and CAD; and sediments released following physical, chemical, thermal, and biological treatments.
>
> The EPA and USACE should support the development of monitoring tools to assess the long-term performance of technologies that involve leaving contaminants in or near aquatic environments. Monitoring programs should be demonstrated with the goal of ensuring that risks have been reduced through contaminant isolation.
>
> (NRC Report, pp. 167–168)

Myers: The recommendations on cost are a good idea. I think we have been somewhat behind the eight ball on that. There are cost data out there, but they are not updated and compiled and readily available. I suspect a lot of the cost is somewhat regional. It is nevertheless a good suggestion.

Regarding CDFs and CAD and risk, we are certainly taking that to heart. We have a program that some of you know about, the Dredging Operations Environmental Research Program, which comes out of headquarters. Joe Wilson is primarily responsible for getting that money and setting up that program; he is the technical monitor. This information is on the Web. This program is supposed to do research on design to balance operational and environmental initiatives and meet the complex economic, engineering, and environmental challenges of dredging and disposal in support of the navigation mission. That covers the availability of contaminants and risks, CDFs, operation, designs, CAD, costs, and monitoring tools.

Timberlake: Regarding the first recommendation, on developing a joint research program, we have moved toward identifying areas of common interest. I see that growing in the future.

Concerning cost guidelines, we have some efforts in my lab doing just that—coming up with guidelines on how to document or estimate costs for sediment remediation projects. The real problem is when you have the guidelines, how do you get people to use them? We have experience with remediation projects in the field, but we have done a poor job of learning from those projects from a risk-reduction or cost point of view. Just because you have guidelines does not mean they will be used. Maybe a larger problem is how to get people to follow certain guidelines or protocols.

The last two recommendations, dealing with the availability of contaminants and monitoring tools, fall within the mission of my lab but also involve other labs within EPA. We sometimes have a hard time working together. It comes down to sharing resources and that type of thing; we need to do a much better job of this. Regarding the availability of contaminants and risk, for example, we do a very poor job of documenting the risk reduction achieved with a particular management option.

We do this in series. People have been working for years documenting that contaminated sediment is a problem. Then they hand it off to engineers and others. Now we are working on risk management, but we stop at that point. We need to tie risk assessment into what we are doing in research on risk management to get a handle on how good a job we are doing.

BREAKOUT DISCUSSIONS

Enhancements and Impediments to Applying New Technologies

K. E. (Ted) McConnell, *University of Maryland*
Donald F. Hayes, *University of Utah*
Patrick Keaney, *Blasland, Blouck & Lee*
Larry Miller, *Port of Houston Authority*
Weldon Bosworth, *Dames & Moore*

ENGINEERING COST OF CLEANUP (GROUP A)

K. E. (Ted) McConnell

My group agreed that we should discuss a broader topic, which is the benefits and costs of contaminated sediments. We had a good discussion about both the costs and the benefits. I will focus primarily on our two conclusions, one concerning the engineering costs, the other concerning the nature of the benefits.

The group agreed that costs must include more than just engineering costs to be meaningful (e.g., resource damage costs, land values). Sediment management is an unusual arena in which costs typically are figured on a per-cubic-yard basis rather than by determining all of the parameters of the specific situation. In the case of contaminated sediments, costs are always site specific. A number of steps are involved in the process for a project, and a range of costs is involved in each step, depending on the variables. A generic cost-model needs to incorporate the various segments in the chain and standardize costs for each segment. Costs also need to be linked to risks and benefits.

What are the major sources of variations in costs? For dredged sediments in place, these factors include production rate and distance to the disposal site. A cost factor for all projects is sediment characteristics, which determine the applicable state and federal regulations. The necessity of addressing public concerns and public perceptions of risk also adds to the costs. In most cases, costs are regionalized, differing based on the geography of ports (e.g., shallow water, currents, periods when environmental concerns preclude or permit dredging).

With respect to engineering costs, an effort should be made to learn more about these costs in a systematic way by data gathering. The idea is that engineering costs vary in systematic ways. If we have a sense of how they vary, then the range of costs may look a lot narrower than it did on the chart in the NRC report. Our conclusion is as follows:

- Engineering costs for the multitude of types of cleanup of contaminated sediments are highly dependent on regional and project-specific goals and objectives.
- Costs must be incrementalized for volume for methods such as natural recovery, capping, and dredging (inclusive of disposal volume or beneficial sediment conditioning, production, disposal siting or end use, and location considerations).
- Therefore, uniformity of project elements is necessary to compute the total costs of different projects.

We also concluded that the benefits need to be identified in order to justify the higher costs of contaminated sediment management for all objectives. We categorized the chief benefits as follows: Environmental benefits include additional restored wetlands and increasing function of ecosystems. Recreational benefits include increased recreational fishing and increased use of public lands. There are also specific commercial benefits, such as

- Increased navigational commerce;
- Increased commercial fishing; and
- Increased opportunity for development, both commercial and recreational.

Public health benefits include a reduction in health care treatments for exposed individuals and the prevention of impairments due to reductions in the release of contaminants in sediments.

In general, there was a feeling that cost-benefit analysis is useful, but in some cases, you may have to forgo a complete analysis and either measure benefits when you can or measure the objective attributes. This leaves you in a world of multi-objective output. To perform a cost-benefit analysis, costs for specific approaches must be determined, and the elements that are factored in must be uniform or standardized. Costs need to be coupled with various scenarios (e.g., cap, dredge, dispose) and linked to goals and objectives (e.g., improved transportation, restoration of habitat).

Evaluation of Technology Options with Dredging (Group B)

Donald F. Hayes

The group talked mainly about two topics: sediment removal and transportation, and ex situ treatment technologies. We spent a lot of time discussing dredging. The consensus was that there are a few dredging technologies. There is still quite a bit of concern about sediment resuspension and contaminant release and our ability to predict and estimate them. It was also agreed—although there were a couple of dissenters—that performance-based contracting for dredging is the way to stimulate advances in the U.S. dredging industry. Along with that, longer-term, larger-scale contracts will give the dredging companies more security so they can take more risks.

I doubt anyone was surprised at the consensus on performance-based contracts. That is not the direction we were going in the past, but it is the trend now. I had some concerns about it, but I have been convinced that is the way to go. Some concern was expressed about how it could affect the costs for specific companies that have contaminated sites, and whether or not they should bear the full cost of that innovation, considering that navigational dredging and environmental dredging are two different approaches.

The Hazardous Substance Research Center South and Southwest put up a poster that includes a definition of environmental dredging. I do not recall exactly what it said, but sometime back I wrote a definition that basically stated a different purpose. In navigational dredging, the purpose is to get the material out as cheaply as possible; in environmental dredging, the purpose is to clean up first. There was some concern about the potential for performance-based contracts to have different effects, depending on the type of dredging. On the other hand, there was a belief that, in the long term, these performance specs would cause the dredging industry to respond; although it probably would limit the number of proposers, the result would probably be a better product.

The second thing we talked about was ex situ treatment. I spurred a little interest this morning when I stated that treatment costs were high, up to \$1,000/yd^3 (\$1,310/m^3). I have to change a couple of things. My job was to reflect what the report says, so I should have said the costs are in the range of \$50–\$1,000/yd^3 (\$65 to \$1,310/m^3). Furthermore, based on our group discussion, there seems to be not only hope but also evidence of the potential for decontamination technologies to cost less than \$100/yd^3 (\$130/m^3). Some suggestions are in the \$50 range; some are in the \$70 range (\$65 to \$92/m^3). These costs do include economies of scale, but the people proposing them suggest that they have a lot of experience and that these numbers are not just "pie in the sky" but actually can happen.

There is more than a little difference between the two sets of numbers. The NRC committee's intention was to include all of the pieces—the extra handling, disposal of residues, and so on—but that still does not account for the large difference. I am elated to hear the new numbers, and I hope they turn out to be true, because that would be the best thing for us. The NRC material was a bit dated. The report has been out for a year; it was done a year before that; and our data were some years old at that point. I am glad to hear that things are happening in that regard.

A point was made that, if we really want to bring these costs down, we should look again at long-term contracts and specific locations that could bring in some economies of scale. An example is New York Harbor, or some other location where you know how much sediment will be treated and someone can count on that for a long period of time. Then it is worth the capital investment, and maybe these costs really will come down to a level that will surprise and please us all.

There is one other topic I should mention. It was clear from the discussion that regulatory impediments exist in the mere definition of sediments, and that we should not impede ourselves unnecessarily by defining sediments as something bad. They can be cleaned, and some can be used for many beneficial purposes, as they are. There may not be a place for them in the marine environment; that may be a problem. But those same sediments in an upland environment may pose essentially no risk. Tagging it as unusable probably does not help any of us, and it closes some doors that might offer the best solutions for society as a whole. We felt there is a need to encourage beneficial use to the fullest extent possible.

Evaluation of Technology Options Without Dredging (Group C)

Patrick Keaney

In situ options include interim controls, both administrative and technological, and long-term controls and technologies, including natural recovery, in-place capping, and treatment. It quickly became apparent to everyone as we kept talking about the same five or six sites that the experience base for all in situ controls and technologies is very limited.

The group discussed a number of topics related to these technologies and identified the following issues that need to be addressed to improve the knowledge base and acceptance of in situ controls. It was recognized that there are informational gaps and barriers to implementation related to the effectiveness, applicability, and cost of in situ options. These data, when we develop and coordinate them, will help us make better risk-based remediation decisions and inform relevant stakeholders at the local level to facilitate consensus building on in situ options.

We broke this problem down into two major areas: information and data needs, and barriers to the implementation of in situ options. The information and data needs were divided further into two broad categories. First, considering the limited existing database, we need better coordination of the data that exist for the sites already out there. There was a call for someone to coordinate these data and put them into a central repository that could be accessed. Second, as in situ options are implemented in the future, what types of data do we need to move forward and what types of data should we be collecting to increase the acceptability of these remedial options?

With regard to the second category, data need to be collected to (a) gauge the effectiveness of in situ options in reducing risk, both short and long term; reveal long-term trends in source reduction, natural attenuation, and potential release; and improve the understanding of engineering failure analysis of in situ options; (b) assess the applicability of in situ options, develop guidelines for acceptability (i.e., what hoops must we get through to declare this an acceptable option at a site), and improve the definition of long-term risk reduction; and (c) delineate costs, develop guidelines for standardization of cost data, and increase awareness of the importance of releasing cost data to stakeholders and the public.

The second overall problem area—and probably the more lively area of discussion—concerned barriers to the implementation of in situ options. One barrier is the long-term monitoring component, which is essentially a disincentive to principal responsible parties (PRPs) under the current regulatory framework. Associated with that barrier are the costs, and the uncertainty about the costs, related to long-term monitoring.

Another barrier, which probably got the most discussion in our breakout session, was the public perception of, and risk communication related to, in situ options. We listed as needs the development of risk communication tools, review of case studies on how public participation and community involvement has been implemented successfully at sites, integration of citizens into the process and community forums at these sites, "risk translation" for the layperson, and general public education on the science of the in situ options. An example of that science would be degradation processes that may occur over time within a cap.

The third significant barrier to the use of in situ options was the lack of science. The perceived lack of science breeds uncertainty, which ultimately becomes a barrier to implementation in the eyes of the public, regulators, and industry. Three more barriers were identified that I doubt we will be able to affect. These were navigational impacts, environmental impacts, and contaminant-specific impacts. All three influence the decision-making process related to implementation of in situ options.

Responsibility for and Financing of Research and Development, Testing, and Demonstration (Group D)

Larry Miller

Our group was tasked with identifying responsibility for research and development (R&D) testing, and demonstration programs, and also identifying financing sources for R&D of new technology. We came up with three recommendations. The first was to increase research support at the federal level. I am preaching to the choir here to a certain extent. The second was to encourage industrial R&D, partnering, and teamwork. The third was to encourage R&D focusing on beneficial uses.

With respect to increasing research support at the federal level, I mean research support through dollars, not just a statement like, "We support your efforts, good luck to you." Money is needed through mechanisms such as the identification of contaminated sediments as a priority in competitive grants programs, including the Environmental Protection Agency and U.S. Army Corps of Engineers (USACE) initiatives and other multi-agency initiatives. Along with that, money is needed for fundamental process research, remedial technology development, and market research.

Regarding the encouragement of industrial R&D, we talked about partnerships and teaming. This is very important. Budgets are shrinking. You may have had the money in the past, but you no longer have it. Thus, it makes sense, and not just from an economic standpoint, to partner and team up to get the best bang for the buck. It is much better to do that than to have a program die or end up in a file cabinet. We also talked about remedial technology development forums and limiting liability for demonstration programs. By doing that, you encourage R&D at the industry level. If a company's risk is reduced, then its exposure is reduced, and it will be encouraged to enter into R&D projects.

I can identify with the third recommendation, encouraging R&D focusing on beneficial uses. We heard about the reuse or management of contaminated sediments. In Houston, we are using dredged material for beneficial uses such as recreating marshlands and building boater destinations and bird habitats. I am not saying that all material can be used in those situations. We have determined that there is a greater need for beneficial uses for dredged material in Houston than we have dredged material available. The same may be said in the long run by this group.

In sum, there are many reasons to move forward with R&D. Money is needed. Start at the highest level, the federal government, and work down to partnering and teamwork and encouraging R&D on beneficial uses at the industry level.

Regulatory Impediments to Applying New Technology (Group E)

Weldon Bosworth

Our group had a very wide-ranging discussion. Much of it dealt with regulatory impediments—although not the environmental regulatory impediments you might expect, but rather those associated with the procurement processes.

The underlying theme was that there is a big disincentive for the emergence and use of some of the more innovative solutions. The problem is the short-term nature of the procurement process. That is, contracting agencies such as USACE apparently are unable to commit for long-term, minimum-volume amounts and so forth, that would give a businessman financial incentive to develop innovative solutions. Certainly there is risk associated with starting and running a business, but risk tolerance can go only so far. A lot of people (maybe our group was stacked that way) felt we needed more of a long-term outlook.

As a corollary, it was suggested that perhaps a private means of developing a supply that could be contracted out by some public agency could serve to encourage innovative solutions. For example, a multiparty collection of dredged materials or sediment might be treated and perhaps administered somewhat differently than it would be in the federal procurement process.

Along the same lines, there was a discussion about the need to develop flexible performance standards for the treated dredged material. That is, if the material failed ocean-dumping criteria after treatment, then there would be a range of possible uses, from construction to other things. If there were flexibility to develop different criteria for using sediments, rather than a need for a new decision on an ad hoc basis every time something is treated, then at least the people who ran the decontamination process would have a more certain goal.

A good deal of talk revolved around risk taking. We probably have a lot of good ideas in this room about how we might try to implement innovative remedies. But the decision makers who ultimately determine whether or not they can apply a technology have a disincentive to take risks. Just because of the nature of the system, they probably have more of an incentive to stick with the tried-and-true alternative, which is to take the sediment out and move it somewhere and treat it.

How do you encourage risk taking? I do not know. There was a suggestion that, if you give the PRPs some discretion—some prerogative in meeting mutually agreed-on remedial action outcomes, cleanup goals, or performance criteria—then they might be willing to take the risk of implementing other types of solutions in situations where that normally would not happen if the regulators made the decision. Given that the PRPs are ultimately responsible anyway, because there is always a review of remedies, this would not be much different from the current situation. But they would be allowed at some point to say, "We want to do it this way; we are willing to take the risk."

More specifically, one of the regulatory impediments has to do with capping and the need, as one of the nine

Comprehensive Environmental Response, Cleanup, and Liability Act (Superfund) criteria, to consider the reduction in toxicity, mobility, or volume. At the enforcement agencies at least, regulators do not believe that capping will achieve these ends. Therefore, at least in Superfund cases, there is probably a low probability that capping will be the solution. If we do not have a situation in which we can implement this technology and then monitor it to document performance, where do we go? We are left with someone maybe writing a research proposal, having the incentive to do it, and spending a lot of time and money without even having an adequate example of a real-life implementation of that type of remedy.

We spent a lot of time talking about interagency cooperation and consolidated review of permits. There was an indication that perhaps more of this should be motivated by the states, because that is where the projects take place, and that we need more early involvement by all stakeholders. That type of thing is logical to anyone who has done permitting. We certainly would encourage it. This is not really a regulatory impediment.

The bottom line was that most people felt the regulations were there, and there was flexibility within them, but the administration of the regulations perhaps was dampening the flexibility for innovative solutions. Lastly, people felt the need to have some involvement by multiple stakeholders in developing protocols that can be shared with others seeking to implement remedies, so that there is more certainty in the path they are following as well as the feedback that comes from sharing successes and failures.

Decision Making

Case Studies
Roundtable Discussion

Case Study

Multistakeholder Decision Approach for Contaminated Sediment Management

Rachel Friedman-Thomas, *Washington State Department of Ecology*

I will discuss sediment management activities in Puget Sound, and in particular, multistakeholder decision-making approaches. I will begin by providing a context for why the sediment cleanup pilot project was undertaken in Bellingham Bay.

In Washington State, a program has been in place for about 10 years; Konrad Liegel alluded to it. The Puget Sound Dredge Disposal Analysis (PSDDA) program manages the dredging and disposal of clean dredged material. It is a joint federal-state program run by the Environmental Protection Agency (EPA) Region 10, Seattle District of the U.S. Army Corps of Engineers (USACE), Washington State Department of Ecology, and Washington State Department of Natural Resources. The program manages the unconfined, open-water disposal of clean dredged material. It works in a consensus-driven manner, through which we have established testing methods and monitoring. We have identified and used eight different disposal sites in Puget Sound. It is a highly accountable program; the public has been involved from the outset, both during the development process and on an annual basis, working with us as we renew and update methodologies and provide status information.

In the early 1990s, a number of issues made it clear that we needed a similar model for managing contaminated sediments. Our modus operandi up until that point was site-by-site cleanup decision making, very liability-oriented decision making, which was stalling a lot of our efforts. Money was moving out of the environmental improvement arena into legal support, if you will. In effect, because we were not making progress with cleanup, we were not moving in the best direction for the public. In case you are not aware of it, there was a series of lawsuits and counter-suits between some of the agencies that were involved cooperatively in the PSDDA program. That highly adversarial interaction was not working for us. Because of that, the four agencies involved in the PSDDA program decided that we needed to do something differently in the management of contaminated sediments.

In 1996, we entered into a partnership with a number of folks to develop and implement a bay-wide approach to aquatic land management. Tony MacDonald made an interesting point about the power and efficacy of local decision making. That was a real impetus for our interest in developing this pilot model. We recognized the effect that local government can have on decision making, and we wanted to marry the interests of a local government with the federal and state interests to develop policy concurrently as well as conduct actions. A driving issue was the fact that the regulated and environmental communities have been dissatisfied for a number of years with how the federal and state governments coordinate.

As you heard earlier, myriad federal regulatory authorities intermix, cross over, and confuse. When that is coupled with state and local requirements, we step all over each other. The stakeholders were saying, "Get your acts together." They also were interested in speeding up what was perceived as a very protracted permitting process. They wanted us to evaluate conflicting aquatic land uses. They wanted us to minimize residual risk through our cleanup decision making and minimize transaction costs by coupling economic development with environmental improvement.

Taking all of those driving issues into account, we landed in Bellingham Bay, which is a fairly small, urban embayment in the northern part of Puget Sound. It represented an array of sediment contamination issues and habitat loss. There is a very large mercury-contaminated sediment site here. There is an unpermitted landfill growing out in the bay. There is more mercury associated with some discharges. There are ferry operations issues. Although it may not sound like New York/New Jersey Harbor or some of the other areas, it offered enough diversity that we could try to integrate navigational issues, public access issues, habitat, cleanup, and source control.

The Bellingham Bay Work Group is composed of 16 members, including representatives of the port, the city of Bellingham, and the county government. We also have a private entity—the principal party responsible for that major spot of mercury contamination. We have two tribes involved in the project. We have all of the customary federal and state players as well.

Through a consensus-driven decision process, the first thing we did in this pilot project was to develop a vision and some process objectives. We talked about a new approach, a number of elements that we would like to integrate in the bay. These objectives were a good start toward laying out the big picture. This was a valuable activity because it spawned our buy-in, if you will, on the selection of the five elements about which we wanted to make decisions. Another activity was the development of a process flow.

After we developed our vision and objectives and identified our elements, one of the first steps was to compile all of the existing data that we could find about all of these elements, as a baseline. Then we were all on a level playing field in terms of information. One of the things I keep hearing in this session, whether the subject is data or cost information, is that without enough information, there is not a leg to stand on for decision making.

We came a long way, and then we realized that we lacked an approach for tackling tough decision making, prioritization, or eventually selecting projects. We decided to use a multiple-stakeholder decision approach, which helped facilitate decision making across multiple elements and among multiple parties. We have used this technique in Washington State in the past to do everything from establishing criteria for our state Superfund law to siting disposal facilities. Through this process, we found that you can arrive at an implementable, effective, and acceptable decision. From the standpoint of decision theory, this technique allows you to use all the parties' core values, whether regulatory, proprietary, tribal, or private. It eliminates the need to move to the margins as a result of trade-offs.

After about one year of working together as a group and overcoming a lot of trust barriers, we conducted a two-day exercise at which all parties articulated all of their goals for a project, ranging from protecting human health to maintaining economic vitality in the region. We ended up with perhaps 45 goals, which we then packaged. That packaging required a number of iterations. We eventually packaged seven goals, none of which initially carried any more weight than the others. But we decided that working with seven goals would be too unwieldy, so we ranked them. We did it using a simple relative numeric model, in which, in effect, everyone's voice had equal rank.

Our overarching goal was to be inclusive of mandatory regulatory requirements as well as the goals that the work group identified as most important. The balancing goals, if you will, are the practical considerations that affect how easily an action or alternative can be implemented and that were identified as not most important, but still important, by a large number of the work group members. We could apply these seven goals to any type of decision, from prioritizing sediment clean-up sites (there were eight) to prioritizing habitat restoration projects.

The seven broad goals were categorized as primary goals (i.e., the initial screening steps) and secondary goals, which were used in conjunction with the primary goals to evaluate a screened set of actions and identify the priorities for any given element. The primary goals are to protect human health and safety, protect and improve ecological health, and protect and restore ecosystems. The secondary goals are to implement actions that are consistent with or enhance cultural and social uses in the bay and surrounding vicinity; maximize material reuse in sediment cleanup, minimize the use of renewable resources, and take advantage of existing infrastructure where possible; implement actions that are more expedient and more cost-effective through approaches that achieve multiple objectives; and enhance water-dependent uses of commercial shoreline property.

How did we apply these goals in our disposal-site selection process? We were committed to maintaining the three broad categories of upland, nearshore, and aquatic sites. We developed a number of exclusionary criteria based on distance, suitable land types, and so forth. We could not consider an eelgrass bed, for example. We ended up with a list of 68 potential disposal areas in a multicounty area. We took that list and conducted a multistep exercise.

First, we went back to our seven goals and developed evaluation criteria, which then could be translated into scoring guidelines. We subjected those 68 sites to our scoring guidelines to come up with a midsized list of 36 upland, 15 nearshore, and 17 potential contained aquatic disposal (CAD) sites. We evaluated them against the primary goals and came up with 21 sites. Then, as a final step, we evaluated those 21 sites again, based on the primary goals, and came up with a final list of 8 potential disposal options.

One alternative is to dredge the waterway. We also are considering no action. We are looking at habitat opportunities, including CAD or caps in these areas. Our thinking is tied closely with risk-reduction issues. We have source control concerns, so we are weighing the value of capping versus CAD versus a confined disposal facility, insofar as the source (i.e., the seep of mercury) will be confined. We hope that some of the material that needs to be dredged can be used beneficially, but we are not there yet. I am encouraged, and I want to keep hearing more about beneficial reuse. When we get down to the bottom line, we hear a lot about the difference in cost associated with the beneficial reuse of contaminated material. We have to sort that out.

Despite the process we have undertaken and the progress made so far, we still have a lot of hurdles to overcome. Depending on the alternatives we select, costs could range anywhere from $24 million to $144 million. We are just beginning to address the issues of whether to use standard regulatory mechanisms or nonregulatory mechanisms to conduct this work, and the pros and cons therein. We are trying to couple as many contaminated cleanups as we can with habitat restoration actions to minimize the transaction costs. We are working with the USACE on the possibility of advance identification for this whole project to help streamline our permitting process. Of course, all the time we are keeping in touch with the public to make sure that we are doing the right thing from their perspective.

We are now on the threshold of going out for a scoping for an environmental impact statement (EIS) under the state Environmental Policy Act. This EIS, which I have not really addressed here, will be both a programmatic evaluation of a bay-wide strategy as well as an evaluation of seven project alternatives. In conclusion, although this project is far from complete, we believe that our process of early, comprehensive, and broad-reaching goal setting by all of the affected parties will not leave us eating crow—or mud—in the end.

CASE STUDY

Evaluation of Remedial Alternatives for Contaminated Sediments

A Coherent Decision-Making Approach

John Connolly, *Quantitative Environmental Analysis, LLC*

As I talk about methods for evaluating contaminated sediments, a bias will come through. I want to acknowledge that this work is not mine alone but the combination of efforts by Dawn Foster, Warren Lyman, and me. The three of us have been involved in the trenches, evaluating sites and trying to come up with appropriate remedial alternatives to address contaminated sediments.

The goal that almost everyone has when looking at contaminated sediments is to try to find some permanent remedy, one that protects human health and the environment. There is a typical approach applied at most sites. Go into a site, look at data, and decide whether an unacceptable risk exists. That is a bit complicated and somewhat controversial because of how we define risk. I will not get into that here, but think about it, because an important issue in determining what we do at a site is how we define the risk. If there is an unacceptable risk, then in most cases, we immediately move to evaluating the feasibility of various remedial options—you have to do something now. We set out remedial action objectives, evaluate options relative to those objectives, choose an option, and then attempt to clean up the site.

At most sites, the preferred option is to remove the contaminated sediment. There is a presumption that removing sediment accelerates recovery. There is a presumption that, by taking the sediment out, we have eliminated a risk that some catastrophic event will occur that will reset the clock, as John Haggard said earlier, and bring to the surface sediments that may have been buried. I would like to challenge this approach by saying that it is not axiomatic that taking out sediments accelerates recovery, at least not in all cases. I will give two examples; I am sure there are others.

In 1994 and 1995, about half of the polychlorinated biphenyl (PCB) mass in New Bedford Harbor, in Massachusetts, was removed. There is a program in which caged mussels are sampled. They were sampled before, during, and after the dredging operation, through 1997. The caged mussels have shown no reduction in contaminant levels as a result of taking out half of the PCB mass. There were other reasons to go after the PCB mass in New Bedford besides accelerating recovery, because of the levels there. The other example is the Grasse River in New York, where 27 percent of the PCB base mass was removed by dredging in 1995. A resident fish sampling program has been going on since the early 1990s. That program has shown no effect associated with the removal of 27 percent of the PCB mass.

Why does mass removal not necessarily accelerate recovery? I will suggest a few reasons. It may be that the sediments taken out were not the dominant contaminant source for the ecosystem to begin with. That could happen if ongoing sources are part of the problem. We talked earlier about ongoing sources and how to address them. It also may be true that the source issue is a surface-area phenomenon as opposed to a "hot spot" phenomenon, and if we went in and removed the hot spots, then we may not have addressed the problem.

It is also possible that we have not substantially reduced surface sediment concentrations by taking the sediment out. That happens in places where dense, non-aqueous phase liquid (DNAPL) is present. When you remove sediment, DNAPL tends to move toward the bottom, because it is heavier than sediment. The removal efficiency for the oil would be less than the removal efficiency for the sediment. If the concentrations are much higher at depth than at the surface, then there is a good chance, or at least a chance, that the residual concentration left behind will be close to—or maybe even higher—than what was there at the start. Similarly, if the contamination extends down to hardpan, which means that the dredge cannot get an overbite with clean sediment, there is the potential of leaving contaminated sediment behind.

I will quickly discuss a few examples of these types of issues. First, an example of an ongoing source problem is Lavaca Bay in Texas, a mercury-contaminated site. Like a number of other sites with which I am familiar or have been involved, the initial focus was on the sediments. The sediments were the problem; the focus was on what we could do about the sediments. It was only after quantitative evaluations of what was going on in Lavaca Bay that it became clear that maybe contaminated sediments were not the real problem.

We made a vertical profile of mercury concentrations in the sediment core. Then, based on the history of mercury releases in the late 1960s, we developed a model predicting what the concentration profile would look like assuming that the only releases in the system were the original ones. That profile does not look anything like the measurements you get close to the surface of that sediment core. The reason is that the concentrations of mercury in the surface sediments of that core are due largely to ongoing sources as opposed to historical releases. At sites where there is not necessarily a point source that you can focus on right away, the issue is complicated and the source is sometimes not obvious.

With regard to the issue of hot spots versus surface area, it becomes important to look at problems in the right units. If we look at organic contaminants, for example, then the right units are normalized organic matter because that is what the organisms are seeing. The benthic organisms are eating so many grams of organic matter per day, so their dose of PCBs is related to the organic matter PCB content. In water, PCBs are controlled by what is on the particles of organic matter, so the fluxes from sediments depend upon what is on the organic matter.

If you look at PCB concentrations in the Hudson River, both in areas designated as hot spots (because they have dry weight concentrations significantly greater than other areas of the river) and in other areas, and you normalize the data to get micrograms of PCBs per gram of organic carbon, there is no difference. The hot spots and non-hot spots are comparable. In 1984, the numbers were essentially the same; in 1991, the number is slightly higher—statistically, it was not higher—in the non-hot-spot areas. In this case, we are looking at a surface-area problem. The hot spots in Thompson Island pool in the Hudson River represent 10 percent of the surface area. If you dredged out the hot spots, then you would have removed just 10 percent of the surface area. You would have left behind 90 percent of the surface area, which had the same concentration on an organic carbon basis as did the hot spots.

With regard to our ability to get stuff out, we have to be careful when there are high concentrations at depth. One example is a sediment core profile we did of PCBs in a river. The PCB concentrations were very low near the surface, although actually not that low from the standpoint of what most people would consider a risk-based evaluation. The surface concentrations were about 20 parts per million (ppm) in this core. About 107 m into the core, there was a peak PCB concentration of almost 1,300 ppm. The bottom of the core was hard material. We did not know if it was truly hardpan or not, but it certainly would be hard to dredge. Down at the bottom of this core, the concentration was almost 300 ppm. If we dredged here because of the high concentrations at the bottom, to the extent that this was hardpan, it would be difficult to reduce the concentration relative to what is already at the surface. Dredging might or might not have the intended effect.

When we evaluate sites, we need to consider all of these issues. It is not enough to say there is an unacceptable risk and therefore the presumptive remedy is dredging. Dredging may work. It works in some places, but it does not work everywhere. In cases where we are looking at significant risks and significant costs, we need to do what I call a prognostic risk assessment. We need to evaluate all of the alternatives in terms of how they reduce risk. We need to compare natural recovery to various other options, and we need to be frank with ourselves. Let us not presume that dredging will be effective; let us look at the things that might affect dredging to determine whether or not it would be effective, and then put it on the same plot as the other alternatives and look at risk reduction.

I will run through a proposed procedure for doing that type of a risk assessment. The first thing that we clearly need to do at all sites is to look at the distribution of contamination spatially and vertically, in three dimensions. We need to have the data appropriately normalized. To look at concentrations on a dry weight basis and conclude that it is high here and low there and, therefore, we have to address that, is missing the issue. If we are looking at organic contaminants, then we should carbon-normalize all the data to decide where the problem areas are. If we are looking at divalent metals, then maybe we want to normalize by acid volatile sulfides. We have to know what the contaminant levels are in the buried sediments, at what depth there are clean sediments, and whether we can get an overbite with a dredge.

In all cases, we have to determine the significance of ongoing sources. At many of these sites, the ongoing source is not obvious; there is no pipe sitting there with a permit that tells us it is putting out 20 pounds of contaminants per day or per year and that this is part of the problem. At many sites, the ongoing sources are nonpoint, groundwater sources that we may not even know about. To determine whether these sources exist, you can do some things with the data, to the extent you have data. The spatial and temporal trends in the data may reveal something about ongoing sources. We also can conduct mass balances. In the absence of knowing whether there is an ongoing source, can we balance all the sources and sinks, or is there a piece missing? Are we missing some particular source that we can use to balance all the sinks? When the sinks are a lot bigger than the sources, are we missing a source?

We need to establish the rate of natural recovery. If ongoing sources are not important, then we can establish this rate based on temporal trends. If we have data over time, and if contamination levels are going down, then we can use those data to establish the natural recovery rate. However, if there are ongoing sources, then the trend we see in time is not reflecting natural recovery; rather, it is reflecting the influence of the ongoing sources. Then we need to do more research. We need to look at things like burial rate—how fast are sediments accumulating, if they are accumulating? We need to look at degradation rates—does this compound degrade, and at what rate?

Because this is a prospective risk assessment, we will try to look at risk reductions in the future. We will use a model. I think we need to constrain ourselves to quantitative models, which by definition have to conform to physical laws. (Sometimes we create models in our heads that violate laws such as conservation of mass, and we never know it.) The nice thing about quantitative models is that they are testable—all the assumptions are defined explicitly; you can see them. (The models in our heads, however, make lots of assumptions but they are not necessarily explicitly defined.)

The other nice thing about quantitative models is that they take advantage of all the science. They use our full scientific understanding. We know a lot about PCBs, for example, and how they behave in the environment. All of that knowledge can be incorporated into a quantitative model. We can use the totality of the field data. We can integrate, for example, water column data, sediment data, and biota data in the context of a quantitative model and evaluate the consistency of all that data. It then becomes an objective tool—it does not know anything about politics—for projecting future concentrations; by using that objective tool, we have a basis on which to make remedial decisions.

This type of approach is not new; it is applied in many places, including rivers, bays, and large lakes. There are a lot of PCBs, but also other contaminants, such as Kepone in the James River and metals in the Patuxent River. The models allow us to test the efficacy of practical alternatives. We can get an estimate of risk reduction because we can predict the concentrations in water sediment in the future and use that as a basis for estimating risk in the future.

A model also allows us to look at the permanence of the remedy. Remember, we are looking for a permanent remedy, and there is always this nasty voice in the back of your head that says, "Well, if I leave the contaminant out there, then there is a risk that this will not be a permanent remedy." The model is an objective tool for evaluating that risk. The models have been used successfully to evaluate the impact of catastrophic events, such as floods and hurricanes, for example.

I will conclude by saying that, whatever we do, we should answer the following questions, and we should do so through a prognostic risk-assessment approach. First, we need to look at the appropriate remedial actions. How do we define the goal for the site? We have to ask ourselves, critically and quantitatively, whether removal will accelerate recovery. We have to address all the issues about ongoing sources, contamination at depth, and whether hot spots really are hot spots. Are other remedial options more effective in accelerating recovery? What is the risk associated with leaving contaminated sediments in place?

Lastly, we need to look at the collateral impacts of the remedial options. All options have collateral impacts—impacts on the ecosystem, on the community in which remedial option is occurring, and on human health. We need to keep all of these questions in our minds as we evaluate contaminated sediments. With my bias, I think that prognostic risk assessment, looking out into the future, is the approach that allows us to have all of these discussions.

Case Study

Establishing Environmentally Acceptable End Points for the Management of Sediments and Soils

Edward R. Neuhauser, *Niagara-Mohawk Power Corporation*

I want to introduce you to an aspect of decision making that is somewhat narrower than some of the things talked about earlier. You might say, why is this guy from an Upstate New York utility attending a dredging symposium? Well, remember the Erie Canal? We still have problems with that. I will introduce you to a national program in which I am involved and talk about how we propose to deal with sediments placed in upland situations from the dredging of the Erie Canal.

I am part of the National Environmentally Acceptable End Points Program. It is headed by the Gas Research Institute (GRI) because a lot of utilities once had manufactured-gas plants, which, from about the 1840s to the 1950s, supplied gas from the coking of coal. This left a whole series of sites contaminated with polyaromatic hydrocarbons (PAHs). The coal, in many cases, was transported by water; consequently, contaminated sites ended up right next to waterways.

We started work on these sites almost 13 years ago, taking sediments from the sites and treating them biologically. (My training is in biology. My coworkers are all engineers, so I am woefully outnumbered.) We took the sediments out, aerated them, and put them in a tank with water and bubbles to expose them to a lot of oxygen. We consistently saw that, in most cases, we got a rapid reduction in contaminant levels and then a plateau. We call this the hockey-stick effect. We saw this in a number of places with a number of agricultural chemicals and other contaminants as well. This was a phenomenon that we neither understood nor knew how to handle at the time.

Are there concentrations of materials—in our case, PAHs—that would be safe? The concentrations are not zero, but are they safe enough to enable reuse of these sites in a beneficial way? The national program is trying to determine if that can take place. The chemicals in soils are not all instantaneously available. If you reduce their bioavailability, then you reduce the exposure and risk. A number of famous scientists are working in this area. We all began to see this common phenomenon, and we decided we needed to understand what was going on.

When we do risk assessments, we make very conservative assumptions (and rightfully so) because we simply do not know what is happening out there. Actual data are relatively scarce. There are very few field data for some of the parameters that I will describe. When I talk to the state and federal regulators about this, they say, "This is great, Ed. Show me the data." Some people want to see money; other people want to see data.

We are going after a couple of key issues. We are not disputing that, in the sediment particle itself, there is some release to both plants and humans. That is always happening. But there is also a release to the groundwater that takes place over time, and during that release, an attenuation takes place. We want to understand those two key issues.

We have property along the Erie Canal near Utica, New York. There is a peninsula, Harbor Point, which in the 1920s was the largest energy center in the Northeast. There was a huge manufactured-gas plant there, and a lot of the contaminants are around that area. There is PAH contamination in the soils and sediments around the site. How do we, as a company, manage those sites today to reduce risk? We know we need some basic information. We need to understand the release and attenuation rates of these chemicals. We need to know how much and how fast, because we do not have a good handle on that.

To start this program, we came up with a series of hypotheses. As I mentioned already, the availability of these contaminants in soil is decreasing over time. We think that release occurs very slowly. We know there is a natural degradation that occurs over time. In the national program, we are adding a different twist by working with sediments. I also happen to work for my company on the development of biomass resources. We have a question: Can we use the plants that we are developing under the Department of Energy (DOE) biomass program to enhance that natural degradation?

In New York State, we decided to concentrate on sediments because we wanted to understand the release and sequestration rates. We were going to take these sediments and put them in upland situations, which is really the only option for us because they want to use the canal system for recreation. We do not have the option of putting the material in some other part of the canal. We want to look at this attenuation concept in the presence and absence of the plants. We believe that the addition of biological materials from the growth of the plants can enhance the degradation rates of these chemicals. We are looking at a series of ecological receptors to try to get a whole-ecosystem picture of this idea.

We divided the project into three basic areas. We have a laboratory phase in which we look for a measurement tool, something we can use to get a quick evaluation of how dangerous a sediment is. Second, we have greenhouse growth chambers, in which we are growing these plants, and also a larger growth chamber to get information that we cannot get readily or inexpensively from the field. Third, we want to go to the field, because we know that, unless you show the regulatory community exactly what you are going to do, they never believe you.

What do we need from the lab? We need something like a toxic characteristics leaching procedure test for sediments to give us an indication of the amounts of available chemicals. We need something that is relatively inexpensive and can be done in a laboratory fairly rapidly. We are looking at two things for this particular site.

First, a series of earthworm tests were developed by the Environmental Protection Agency (EPA) in the early 1980s. This is an effective test; it gives you an indication biologically of what that organism is seeing. It is an integrator. The worm takes in the material and processes it through its gut, and then you measure the concentrations in the tissue. There is also a solid-phase extraction test, which we are working on now. It currently uses a matrix with a carbon-18 (C-18), waxy-like compound on it. We put a series of these disks in a slurry and shake them over time. The test gives us an indication of what is biologically available.

Over time, we saw that about 60 percent of one particular contaminant type latched onto the disks, meaning it was bioavailable. Those data corresponded to what we found with the earthworm test. When we took that same sediment, treated it biologically (aerobically in this case), and then subjected it to both the earthworm test and C-18 disk test, about 90 percent of it was not biologically available. There is evidence here that the total concentration does not always give you a clear indication of the biologically available amount of the chemicals.

We started working on greenhouse tests. We needed to screen some of the willow clones to make sure that they can grow in these sediments. They seem to do quite well. The tests in the greenhouse helped us to define parameters to use in our large-scale pot studies. These are 30- to 50-gal (114-to 189-L) pots. We are mimicking the acid deposition work of the 1970s and 1980s, when they were trying to understand the effect of ozone and acid deposition on individual plants. It was very difficult to measure those parameters in the field.

Our greenhouse tests are going on at the Boyce Thompson Institute for Plant Research at Cornell University. We are looking at different varieties of willows and other crops and controls. In the initial tests, after a four-month period, there was a statistically significant decrease in PAHs in the soils with the plants in them relative to the soils without plants. We saw the greatest decrease in the five- and six-ring PAHs, which is good, because they are of the greatest concern to us.

Why would you want to use these larger growth-chamber pots? Because it is difficult to go out and measure things in the field. We want to put out these pots, run them for three to five years, and then look at changes in the total PAH concentrations and available PAHs in the soils due to the presence of the plants. We think the plants have a real role in enhancing PAH degradation. These data will be very helpful in the full-scale field project, which we know we have to do. When you analyze sediments, you learn that they are very heterogeneous; it is difficult to figure out exactly what is happening if there is a small change over time. It became clear to us that we needed to take a whole series of sediments and mix them up a great deal.

What do we hope the field demonstration will do? It will stabilize the site. The mass of plant roots will stabilize it very well; we hope that it will lower the groundwater at these sites. At most of these sites, the groundwater and surface water, for parts of the year, are equal. When I took my environmental affairs staff out to look at these plants, their first impression was, "This is a great living fence. People cannot get in there; that is what we want. We do not care about your PAHs, Ed, just keep the people out." We also are hoping to look at biodiversity. We have studies under way on micro-arthropod diversity in which we can show, with the presence of the plants, the very rapid recovery of these ecosystems after the sediments are placed there.

I want to give you an idea of what these willows can do. As part of our bioenergy project with DOE, the willows are planted as 10-in (25-cm) pieces of wood. We have commercial planters that do this now. There are about 40,000 acres (16 200 ha) of these plants in Europe now, and we are adopting the system here in the United States. We cut them in the winter to promote rapid growth in the next year. The plants take over the site. They completely cover everything; there is no weed problem at all. After three years, you have an incredible mass of biomass that nobody can get through, and it is extremely stable.

Our goal in the biomass project is 5 to 7 dry tons/acre/year (11 to 15.5 tonne/ha/year). This is the highest rate of biomass production that we can get from any of a number of different crops. We hope to adapt this technology to sediments and get a stable upland sediment situation with enhanced degradation of the PAHs.

When you put together a project like this, you have to go to a number of different organizations to raise seed money. I worked with GRI on that. We have some money from DOE and we are talking to the Department of Defense's Strategic Environmental Research and Development Program, which is interested in certain aspects; the Electric Power Research Institute; EPA; and some New York State agencies. When I put together these projects, I try to identify pieces that appeal to all those people, so they can say, for example, "Yes, I'll fund 10 percent of this for you, and then I can buy into the results of the overall project."

What do we expect out of this? What are we really targeting? A key thing is to go right to state and federal regulators. As I said earlier, they want to see data, but they are willing to work with us. Staff members of our company regularly brief them on these areas. You have to make them stakeholders right from the beginning; that has worked effectively for us. We hope to have tests for the groundwater and ecological receptors so that we can look at a sediment and say, yes, this is really dangerous, or no, this does not look so bad. For the company's sake, we hope to reduce human exposure. This is a very big issue for us; we do not want people to get hurt going to these sites. There is also the idea of making these sites into wildlife refuges. In many cases, because the sites are in the flood plain, they will become wildlife refuges.

We want to make sure we end up with a better use of these materials than our current options offer us. In the end, we hope to equalize the playing field a bit. We want to get a lot of real data out there so that people can compare options, because we do not think these things are as potentially dangerous as the current models make them out to be.

ROUNDTABLE DISCUSSION

Improving Decision Making

Jerry Cura, *Menzie-Cura Associates*
Elizabeth Southerland, *U.S. Environmental Protection Agency*
K.E. (Ted) McConnell, *University of Maryland*

DEVELOPING DECISION-MAKING CRITERIA

Jerry Cura

We are trying to develop decision-making criteria. There are four basic characteristics that decision-making criteria should have. Generally, such criteria should be risk based, which immediately puts us into a paradigm with certain steps to take as we proceed in developing such criteria. What those criteria are, of course, is a discussion in itself. I also think it is important that decision-making criteria be site specific. It was evident from Rachel Friedman-Thomas's talk that the only way to incorporate multistakeholder concerns is to have a specific problem. I do not think there will be universal decision-making criteria for all sites. Rather, there has to be stakeholder involvement, and that means the criteria almost always will be site specific.

The criteria obviously have to incorporate human exposure concerns and ecological concerns. The work that Ed Neuhauser was addressing certainly demonstrates that the basic question of bioavailability of polyaromatic hydrocarbons (PAHs) gets to both of those issues. Any set of decision-making criteria should encompass both of those concerns. Another important thing—all three case studies, particularly John Connolly's, pointed this out—is that, whatever decision-making criteria you use, they have to be carried through the entire risk analysis process, from problem formulation to the end. In the example John gave of New Bedford Harbor, if the criteria had been developed in some other way, then you perhaps would not be saying at the end, "Well, we removed half of this stuff but we are not seeing any effect in caged mussels," or, "Is the caged mussel the right criterion?" You would avoid that type of back-end problem.

In this morning's talks, we heard references to "seven-year fast tracking" and that sort of thing, where there seemed to be no end to the process. I think if we expend the resources and time up front to reach consensus on decision-making criteria, then we can avoid the delays associated with reacting to sporadic environmental concerns that come up along the way. Rachel Friedman-Thomas's group came to the conclusion that we are beating each other up by reacting to what we are saying. It is probably better to sit down and develop some a priori criteria. However long that might take, it is time better spent.

MONITORING THE EFFECTIVENESS OF REMEDIATION PROJECTS

Elizabeth Southerland

What I got out of the case studies presented here is that we definitely need to get some guidance on how to monitor the effectiveness of remediation projects based on the initial objectives. I am sure this is serendipitous, but John Connolly showed a situation in which the objective apparently was to lower the concentrations of polychlorinated biphenyls (PCBs) in fish. I think what he showed were data taken less than three years after the remediation projects.

I have about five case studies here. When we did similar projects in which we looked at a change in fish tissue concentration, we had to go four years before we saw the improvement we sought. Furthermore, we had to measure only those fish that were three years old to really see an improvement. That is an important issue. After you have done a remediation project, it will take some time for the system to come back into equilibrium, particularly if that project is dredging, where you have disturbed and moved the sediment. While equilibrium is being reestablished, all the old fish that were exposed to the concentrations before the dredging are still there. You would not want to pick any of them up, because they already have been exposed to the pre-remediation situation.

For example, we were looking PAHs in the Black River in Ohio. The concern there was lip and liver tumors in bullheads and other fish in that system. At the four-year limit—and not until the four-year limit—when they finally measured fish that were only three years old, they found that all the tumors had disappeared. Thus, the dredging and removal of the PAH-contaminated sediments from the Black River was a successful project. However, if they had stopped monitoring after just two or three years, then they would have missed that effect.

A similar situation occurred in Waukegan Harbor, Illinois. In that case, there was a human health concern, similar to the cases that John Connolly cited in which the remedial objective was to reduce PCB concentrations in fish that are eaten by humans. They monitored every year. It was not until the fourth year that they found, in fish that were three years old and had been exposed only to the cleaned-up situation, that PCB concentrations were down to 5 ppm from an average of 20 ppm before the remediation. Maybe one of our problems is that we have not told people how to monitor for effectiveness. Nor have we told them how to think through their objectives.

In the Comprehensive Environmental Response, Cleanup, and Liability Act (Superfund) program, we are looking at the impact of remediation on the number of allowable meals you could offer the public in some type of fish consumption advisory process. This is very controversial. We often want no restrictions imposed on fish consumption whatsoever—thinking that the remedial alternatives will be so effective that, whenever the four- or five-year period is over, and the system comes back into equilibrium, we could eat unlimited fish. But we are finding some of the problems that John Connolly pointed out: the contamination runs so deep, or the fractures in the bedrock are so deep that they trap highly contaminated (2,000 ppm or 5,000 ppm) sediments, so that even if we could afford to go down to bedrock, there still would be fish contamination.

How do we show a benefit to the public in situations like this? One approach that we are considering now is to move from a ban on all fish consumption in an area to suggest instead that consumption be restricted to 2 meals a month, 10 meals a year, or whatever. At least there would be a fishery open that would benefit the public, as opposed to insisting on zero contamination in the fish and a complete cleanup, which might be both technically and financially infeasible.

The second issue is our concern about the timing of remediation cleanups. The standard approach with the Superfund program is to do the on-land cleanup first, even when they know there are contaminated sediments right below the site. The process of land-based cleanup is so time-consuming that sometimes 10 years or more can go by and it still is not cleaned up. In the meantime, those contaminated sediments are moving downstream and causing the non-hot-spot contamination that John Connolly was pointing out in many of our systems.

We have many situations in which it would have been a lot cheaper and easier if, when designating site, they had worked right away on the contaminated sediments. Maybe they could put up silt screens on the land-based site and get the contaminated sediment out. When they wait so long for the whole cleanup on land before they attack the contaminated sediments, the problem often migrates far downstream, where there is a much lower level of contamination but still enough to cause fish consumption advisories and to be expensive to manage.

I will give two examples. In a Green Bay, Wisconsin, mass balance analysis focusing on low-level contamination that started from a hot spot in a tributary to the Fox River and migrated downstream, it was found that, once every two years, there was a storm big enough to resuspend that contaminated sediment, causing the contamination in fish tissues to elevate to levels of concern for several years. The contamination was migrating downstream and causing frequent problems. The process required a storm, but once every two years is quite frequent, and it was keeping fish tissue contamination at levels of real concern. It is a shame that the hot spot was not cleaned up first instead of waiting for so many studies. They spent $15 million on monitoring in Green Bay.

Another situation was the Housatonic River in Connecticut, where there was sediment contamination in the floodplain, and backyards were highly contaminated with PCBs because of the overflow from the river. They cleaned up everyone's backyard, assuming that was the big concern; they did not want kids digging holes and eating the dirt. They put a lot of money into cleaning up those backyards. Sure enough, once every two years there is an event big enough to cause the river to overflow its banks, and now all of those backyards are contaminated with PCBs again.

We need a discussion of that, but I think we have not told people how to monitor effectively for remediation success. We have not done the monitoring at all in many cases. Secondly, we have to revisit how we time the priorities in a Superfund project or some other remediation cleanup. Contaminated sediment cleanups might be a higher priority than some of the land-based work usually done first. Also, Ed Neuhauser mentioned a toxic characteristics leaching procedure test for PAHs for evaluating dredged material once it is put in an upland site. I would like to have a discussion about that. The Environmental Protection Agency (EPA) is working on a total PAH sediment criterion for in situ sediments. We are looking at the combined effect of PAHs that are still in the river. It would not help with the land-based disposal, but it would help with waste-site allocations.

That gets me to my final point. The NRC report makes the point, which seems like a consensus opinion, that upstream controls are very important in preventing contaminated sediments from burdening ports with all of these problems and high disposal costs. But the report did not point out that the main thing to implement an upstream control is some type of chemical criterion that will set the total maximum daily load calculations to allocate lower waste loads to those upstream dischargers. A chemical criterion also is needed to trace the responsible party for investigation.

Unfortunately, there has been a delay in getting out chemical criteria for sediments. Some of the controversy has been due to concern over using the criteria for dredged material, for which it is not effective. Chemical criteria are not needed for dredged-material evaluations because there is no need to know what chemical is causing the toxicity. All we need to know is that the material is toxic or highly bioaccumulative, and the restrictions on disposal come into play. It is only the point or nonpoint source dischargers upstream and the remediation people who need the chemical criteria to identify the responsible parties and to do the mass balance calculations that are so necessary if we want to end the ongoing input of contaminants. That is an area for discussion.

Valuing the Outcomes

K. E. (Ted) McConnell

I want to make some broad comments and then relate them to the presentations. The comments are broad not because I want them to be, but because, as an economist, there is no research I can talk about other than principles.

I have been involved in the topic of contaminated marine sediments since the formation of the NRC committee about five years ago. Since that time I have heard a great deal about the scientific and engineering issues discussed at this roundtable and earlier today. I have seen that there is a substantial input of resources to manage contaminated marine sediments. The resources are spent not only on cleanup, treatment, and removal or navigational dredging, but also on research. Even though research funds are scarce and maybe getting scarcer, there is a substantial group of people in this room and elsewhere who do research on this topic. We have a lot of resources going into this area.

In terms of what we are gaining from managing contaminated marine sediments, over the past five years I have seen very little evidence. We really do not know what we are getting. I would like to emphasize that one of the conclusions of the report is the need to do something like risk assessment or cost-benefit analysis to know what we are getting. For example, when we undertake dredging or treatment of contaminated sediments for environmental reasons, presumably we are getting some reduction in the exposure of ecological resources or humans to the contaminants. How much do humans care about that? Do we know?

When we dredge for navigational purposes, we sometimes do many benefit-cost analyses to find out what the navigational benefits are, but those are limited. When we devote extra resources to being especially careful of sediments that are dredged for navigational reasons and also are contaminated, presumably we get some sort of improved ecological health or reduced human exposure. What are we really getting?

This is not a parochial plea for economic research. I think it will be very hard to maintain an enterprise like this, with such a large quantity of resources going into it, without some evidence of a public gain. This holds true for specific projects, but it also holds in general for the whole effort to manage contaminated marine sediments.

This broad statement reflects on two of the earlier presentations. Rachel Friedman-Thomas talked about the negotiations among stakeholders. Negotiations among stakeholders are very valuable, but they do not always result in decisions. There are situations in which one group can gain only if another loses. Improved decision making in such cases would require monetary or other types of compensation. I like the idea of bringing stakeholders together, but it will not solve all the problems. There are a number of situations in which stakeholders have interests that cannot be reconciled voluntarily. When they can, it is great, and we are all better off.

Regarding the presentation by John Connolly, I would like to second his motion for the use of quantitative models in predicting what will happen. This is essential; you absolutely must have this sort of prediction. As he so aptly said, the models do not know politics. Predictions with models like these need more components, dealing not only with the ecological effects, but also the human end of things. How humans value the outcomes is essentially what we will have to model at some time or another.

This sort of modeling is essential, but to justify the call for more research, new resources, and better techniques, it will be necessary to show that there are benefits, and in some cases it will be necessary to quantify those benefits in dollars. I am not arguing that this is always the case. But sometimes it is necessary simply to count up what the public gets—and the more you can measure it in dollars, the better.

My last point is connected to policy making and the negotiations among stakeholders. There is a substantial disparity between scientifically measured risks and the risks perceived by humans. If we were to do this scientifically, then we would look at the measurable effects on the ecological system or human health. But frequently the general public places a much higher value on this risk than the objective scientific research does. This is true not only for contaminated sediments but also in any other situation in which humans are exposed to risks. There is always this disparity. There is a role here for risk communication—to try to communicate to the stakeholders the distinctions among these risks. Coming back to Rachel Friedman-Thomas's discussion of stakeholders, I think risk communication can be done effectively in that context.

Decision Making
Summary of Dialogue with Audience

Analyzing Cost

Audience Member: The NRC report speaks broadly about using risk-based analysis to make the management of contaminated material more cost-effective. I have not found anything in the report that will support a numerical analysis of cost with respect to navigation projects. I do not think the committee looked at how we now analyze the cost of managing contaminated sediments for navigation projects nor did it determine whether those costs would go up or down if a risk-based analysis were used. If I missed it, then please tell me where it is. I do not think you can substantiate the conclusion without that analysis.

Ted McConnell: I have to appeal to Spyros Pavlou. The idea of risk analysis is to try to make things systematic, so that, across projects, you can tell what you are getting in one project versus what you are getting in another. Perhaps within a single project it may not help, but I think that, if used systematically, it would. I plead ignorance on the question of whether we have proven it in the text.

Spyros Pavlou: Appendix D to the report gets into the use of decision analysis as a way of evaluating alternatives. It was an effort to demonstrate the potential for using a tool like decision analysis to help the decision process. We did not have a specific example or demonstrated case to provide substantial evidence that, indeed, this approach has worked. With respect to cleanup issues—and not necessarily navigational dredging—we wanted to have a tool to evaluate the trade-offs among risk, costs, and benefits, to come up with a decision that might help take (or not take) remedial action. We proposed an approach. Actually, what we are seeking is a project in which this approach can be tested.

Evaluating Alternatives

Audience Member: I am not sure that the cost-effectiveness issue is to make a decision about whether it is better to dredge based on some nominal criteria or on risk-based criteria. I think the cost-effectiveness issue is to evaluate alternative remedies based on some type of metric, such as a reduction in risk, so that one can determine systematically the marginal benefits of each strategy. I agree that there are few projects in which you can demonstrate this. There was an example of New Bedford; if the model that was developed had been successful in meeting its objectives, I think you would have been able to demonstrate it. I think that is a good, idealistic goal.

Pavlou: If you look at risk reduction, there is a acceptable level that might not be zero. You do not necessarily have to go to zero risk. We wanted to evaluate methodologies that might say, for a given level of risk reduction, how much you have to pay, and whether that level of risk reduction is acceptable and meets society's needs. It is not necessarily just a matter of looking at a number of alternatives and ranking them; it is also a matter of saying what the acceptable risk is. That is an issue that John Connolly brought up. Acceptable risk varies; it is in the eyes of the beholder. If you evaluate the trade-offs among risk, costs, and benefits, then you might come up with a risk reduction that is not the toxicological base criterion that you want to see, because society's values might be different. That is what we tried to say.

Jerry Cura: The gentleman's point is probably well taken. The text did not, in any robust way, demonstrate its recommendation. Perhaps the text expresses the hope or sense that this is the paradigm to use. That hope may be based on the experience of other programs that have gone to risk-based decision making and found it to be, if not cost-effective, at least a way of getting things moving. The program I am thinking of involves the Massachusetts waste law. The state had a backlog of sites early on; it was unable to get those sites through the process easily. State officials rewrote their regulations, and they now have a very strongly risk-based, outcome-based program. As a result, sites are moving quickly through the system, and people are able to buy and develop sites at a much faster rate than before. If time is money, then the risk-based approach has been very cost effective relative to the previous, chemical-based approach. At least in one state, there is evidence that the approach works well. Hopefully, the application of that paradigm to a contaminated sediment or dredged material situation will be equally as effective.

Assessing Risk Assessment

Tom Johnson: Regarding the risk-based approach, Tom Wakeman said he hopes we go in that direction. I think we all see that as a laudable goal, but in my area we are scared, because in California we have an example of a risk-based approach to contaminated sediments—the Palos Verdes shelf dichloro-diphenyl-trichloroethane (DDT) situation. We saw EPA's attempt to formulate a remedial action plan totally shut down by its reliance on a risk-assessment process for which there were no data. They had so few data on the ecological processes and human exposure pathways and mechanisms in that area that the risk assessment was essentially a compilation of assumptions. As soon as this was made public, the other side shot it down, and the whole EPA process has gone back to the drawing board. We have not had a technical advisory committee meeting for the better part of a year now.

From the port's perspective, the thought of basing navigational dredging of contaminated sediments on such an uncertain process is scary. I suggest that we proceed more carefully in jumping on the risk-assessment bandwagon and be careful not to use risk assessment unless it is robust and unless there is nothing better already in place in a local area. In Southern California, we are forming a regional task force to come up with disposal alternatives and strategies for contaminated sediments. They will not incorporate risk assessment, and yet I think we will be able to move ahead. I worry about a risk assessment that is a scientific process based on a lot of assumptions. When we go before the public, the public will go ballistic.

Regarding the criteria used by EPA, I cannot give you the details and model, but there were a great many assumptions (for lack of data) in following fish from the area of the contaminated sediment to people's tables. The risk factors that EPA came up with to support the contention that the sediment needed remediation were viewed as highly suspect because nobody could say, "Yes, these types of fish that feed out there did pick up DDT from the sediments; they are consumed by a number of people; and this how much of those fish these people eat."

Pavlou: We should be very careful not to confuse a conservative assumption being used in a parameter for the risk model with the nontechnical and technical defensibility of the process of risk assessment. Just because your assumptions are wrong and you have a wrong result, that does not mean the process is no good. You say that maybe the reason EPA, or whatever agency was responsible for the risk-based approach, was shot down is because it used conservative assumptions that were not technically defensible. That is one way to look at it, versus the rejection of a model and risk-based approach. I want to be sure we make the distinction so that we do not conclude that risk assessment is no good.

Mike Connor: I think Jerry Cura would agree that any of us who have done risk assessment know that the difference between the alternatives is dwarfed by the uncertainty in the risk assessment. The panel has to think carefully about its recommendations for a risk-based approach and an adaptive-management-based approach. One gentleman is saying that a risk-based approach is so analytically burdensome that the time it would take to satisfy all parties would distract you from what may be a more adaptive approach, which is to quickly identify the biggest problem, go after that, see if that is enough, and keep iterating a solution.

You have a lot of practical people out here who are saying, "Let's just do something to get off the dime in this situation." There are dilemmas involved, because, particularly for private cleanups, the parties want some sort of certainty about how much they will put in and get back. Ted McConnell said we may be spending much more in evaluating contaminated sediment management than we get in terms of benefits. That could well be true. It would not be the first time; one could make that argument about fisheries management, too, I suppose.

We keep talking about how nice it is that these models are free of politics. The amount of money involved in these remediation projects is so high that, by definition, the process has to have politics. That is why, in an approach like Rachel Friedman-Thomas's in which you are trying to negotiate among the parties, you try to make it political so that you can glom onto other sources of benefits and monies to get the project off the ground.

These counterbalancing questions of politics, money, and analytical and scientific approaches are woven into the report. The report tries to balance them, but it comes out with something that, in the end, may not be able to balance all those issues. Thus, you have these counterbalancing good ideas that may not ever balance. I was curious about the philosophy of some of the panelists on risk-based versus adaptive-management versus politically-based solutions.

Pavlou: I think the reaction we are getting is a good one, because the purpose of the report was to start with something. Before the report, nobody had a specific recommendation or process that someone could shoot at. The point is, as we evolve, and as we consider this to be a stepping stone for future considerations of how to manage contaminated sediments, maybe the report has done its duty and we now have to think beyond it.

McConnell: I appreciate those comments. About having politics involved, you are right. This is useful, because politics just means the representation of people who have money at stake. I think the value of having a model without politics is the same as having assumptions in risk assessment that are robust. A model will not give you an answer, but it will help in the decision process. The more objective the model is, the better.

Risk Assessment and Adaptive Management

Rachel Friedman-Thomas: I was interested in Ted McConnell's comment about how negotiation will not always help you reconcile some of those irreconcilable differences in a political setting. I will tell a short story about our project. When we began, all four local parties had a very strong directive for a presumptive remedy. They were convinced that we should take the landfill that had been migrating out into the aquatic environment and turn it into a nearshore confined-disposal facility, which would provide new upland economic benefits for the port. As we moved through the process, we turned around 180 degrees in our thinking. We were driven by negotiations, whether centered on the risk or habitat considerations, coupled with the port district going back and looking very critically at its master plan and saying, "In the long run, we do not think this is where we want to go from a development standpoint." It was very much an adaptive management approach. I think different approaches work in different contexts.

Cura: Obviously there would be some trepidation, even fear, among various sectors concerning the possibility that risk assessment will be overwhelming or will slow things down. We want to view risk assessment not as the decision-making process but as *part* of it, and see that it does allow adaptive management techniques. I think we see that now. For instance, the program that Elizabeth Southerland described referred to the steps in the technical framework; they allow you to make a decision based on increasing layers or an increasing quantity of information. Risk assessment can be integrated with that without supplanting it. In terms of other regulatory frameworks, I will use Massachusetts as an example again. Another example is the American Society for Testing and Materials RBCA (risk-based corrective action) project, which uses risk-based decision analysis.

There are tiers or stages, depending on whether it is the Massachusetts or RBCA process, which allow you to make a decision early on based on some simple decision-making tools. If you like that decision, if it seems cost-effective, and you want to get the project done right away, then you can do it the simple way, but you do not have to. You can be adaptive. You can say, "Let's take a closer look at this. Based on what this first-tier or screening-level analysis has said, I need these five more pieces of data before I can make a decision." Then you go out and collect them.

The process does not have to be "all or nothing," where we have to jump into a whole set of conservative assumptions. I think it does allow you to think the thing through and make a decision along the way. I would hate any group to be left with the impression that risk assessment means that you will spend $2 million to get rid of 100 yd^3 of contaminated material. That is not the case and should not be. Risk assessment should not dominate the decision-making process; it should be integrated with the other elements, such as risk communication, public participation, and the final decision-making process itself.

Other Elements in Decision Making

Jim Wenzel: There is one aspect of this discussion that troubles me. We placed great emphasis in the report on the subject of systems engineering and its application from the beginning in carrying out the management plan. Yet we focused here almost entirely on the subject of risk analysis. Risk analysis is a very important element, but if you look at Figure 5.1 in the report, it is only one element in the decision-making process, and it comes into play in several different places at the beginning in trying to set up some design requirements. We showed in the trade-off studies that performance is important, cost is important, environmental effects are important, and risk analysis also is important. We are focusing on only one element of the process of the application of systems engineering to solve the remediation problem.

Site-Specific Analysis

Connor: I would like to say "amen" to that and then offer a couple of comments. We are talking about two distinct types of contaminated sediment management, navigational dredging and environmental remediation. From my perspective, environmental remediation does not carry with it a presumptive remedy. It does not carry with it the presumption that you will be removing sediment, whereas navigational dredging does. The risk assessment that you undertake for navigational dredging focuses on how you deal with the removed sediment in the most cost-effective and environmentally protective way. In environmental remediation, you need to look at risk assessment as an important tool and one of several tools that you might use to evaluate whether there is an alternative other than dredging that would be equally cost-effective. A concern I have with the "just do it" mentality is that it may drive a remedial action objective founded more on mass removal than on risk reduction or risk management.

Given that there are no presumptive remedies with regard to environmental remediation and dredging, each site is unique. I am not necessarily responding to all of Elizabeth Southerland's comments earlier, but it is important to understand the uniqueness of each site. There may be locations where hot-spot removal is of little real benefit in reducing risk in the long term. There may be other locations where hot-spot removal is important to avoid a catastrophic release. A site-specific analysis needs to be undertaken.

Lowering Expectations

Audience Member: Do you mean to tell me that you have this nasty pollution and you will not let me dredge it? And now these fish are just half-nasty and I could eat one every other day, and I am supposed to be glad about this? Why not cap this site, because it is a site that can be capped, and in four years we will have a seafood feast?

Elizabeth Southerland: Sure, if it is an area that can be capped. The problem is when these things have dispersed down a river or into a lake system. The surface layer is contaminated, and when you get a storm (as frequently as once every two years), the fish get recontaminated. The issue is, how can we afford to take the top layer off an entire river basin? Should we look instead at just trying to get the contamination down to a point where some of the fishery is open, and there is restricted consumption?

Everyone's hope is that we would be able to stabilize it, cap it, treat it in situ, or treat it ex situ—whatever is necessary to get unlimited fish consumption. That was the goal of the Clean Water Act, to get fishable, swimmable waters. I am responding to situations that I keep hearing about, in which this goal just cannot be achieved; there are thousands of parts per million of PCBs or some other contaminant, and it is even in the bedrock fractures. Even if we remove the whole thing down to bedrock, we still would have sediments in the fractures that would recontaminate the fish. We should look at the remedial alternatives and do the best we can, but, in some situations, it seems we must lower our expectations.

Getting a "Buy-In"

Dennis Wolterding: This small exchange inspires me to state the obvious. There is a difference between selling risk assessment—I do not care how you sell it or whether you refer to a system, a site, or a particular result—when risk is perceived as involuntary, versus risk assessment where risk is voluntarily assumed. I can guess how you could sell your fish advisory that says people can eat only two fish per month. Give coupons to the entire drainage basin community, so people can go out and have two or three fish meals, depending on what the average person eats, and bill it to you. There would be not only risk but also a voluntary incentive to assume risk. We have not made enough of that tool.

When you have a modeling process, a very responsible regulatory agency, and principal responsible parties, you still may come out with a risk that is unacceptable simply because you have not gotten the type of buy-in you need. If a buy-in was absolutely essential from the beginning (and this buy-in may not be scientific), then you may do it very responsibly. I apologize for stating the obvious.

No Prescriptive Intent

Audience Member: We do not know the practical effect of applying risk assessment to get a navigation project through. Would it make it harder or easier? It certainly would make it more informed. To apply it, one needs to have more information, more analysis, more understanding of what the practical effect would be on the dredging programs, because it is so difficult to carry out that one would not want to change without having better information.

Donald Hayes: We were trying to combine navigational dredging and environmental dredging. Those are two different things and difficult to combine. This session was about decision analysis, and as a modeler myself—and I think most people would agree—I think the intent of decision analysis is not to be prescriptive. We need to remember that. No one is, or should be, suggesting or implying that we will develop something that will say, "You have to do X." They are tools to help us, not handcuffs.

Perspectives on Project Implementation

Panelist Presentations
Breakout Discussions

PANELIST PRESENTATION

Beneficial Uses of Processed Sediment

Anne Montague, *Montague Associates*

I will discuss the beneficial uses of processed sediment, getting from barriers to benefits, with a marketing perspective. I was disheartened to hear yesterday in our breakout session that people say cleanup is more expensive than litigation. That is not going to be true.

I like to do what I call "back-asking," a concept I got from Scandinavians. When they start an initiative, rather than forecast where they will be in 10 years, they say, "Where do we *want* to be in the future?" Then they back-ask from there. I think our long-term goal is for processed dredged material to be a commodity. In other words, most types of sediment will be commonly used, and the uses will be varied.

The mid-term goal is significant demand for most processed sediments. A new industry to produce and use processed sediment will be established. We can quibble about whether or not it should be called a new industry, because it will be many industries. The initial thrust has to come from research and development (R&D) focusing on sediments. The near-term goal is for site buyers to choose and use processed sediment products because they perform better, cost less, and can be more attractive than conventional materials. We are getting there more quickly than people recognize.

What has happened to allow this confidence? First, there is growing acceptance of fixation and encapsulation, as well as passive processes such as wetlands creation or construction and manufactured soil, which reduce the cost of remediation of contaminated sediment. Second, there are growing indications that decontamination technologies will be less expensive and less in demand. I am sure you see that those trends tie together. Third, most people do not realize this yet, but there is strong evidence that it is cost-effective to process clean sediments as opposed to conventional materials. What I am saying is that we need to look at all sediments, and we need to use them as well as we can. By focusing on the needs of the site and the user, sediment uses will be market driven.

My own research began in 1996 when Dick Lee at the U.S. Army Engineer Waterways Experiment Station asked me to do research on beneficial uses. This would be comprehensive research. At that point, the general focus in the nation was on (a) decontamination and (b) other technologies (i.e., those that bind up toxins so they are not available to the environment). My focus was to get to uses, so I held in-depth discussions with at least 300 people on any issue I could find related to the use of sediment. I talked to scientists about "how clean is clean?" I talked to materials specialists for departments of transportation, people who drive standards, and so on. I still go back to the uses I offered as possibilities very early in my research. I believe that many are still to emerge; some already are emerging.

Standards definition was the most exciting part of this research early on, because I realized that we can establish standards, even if they are process standards or performance standards. I began to look in-depth at this and tried to list the standards that have to be met, like those of the American Society for Testing and Materials and the American Association of State Highway and Transportation Officials, and others for products to be used in given ways. One issue at that time was end-product validity. If a vendor says its process makes an aggregate, what does the vendor really know? How do we establish the validity of that end product? How clean is clean? We still hear that constantly. To me, it is one of the most exciting questions.

Other issues included volume—not only the volume coming in, but also the volume of product that can be used—transport, public perception, and user criteria. Blends were a big thing. I discovered that low-tech processes, in which sediment is blended with materials from ash to manure, often work. Another issue was sediment characteristics, which we heard a lot about yesterday. Last year, the general focus was on watching New York policy emerge. I was nervous, as were a lot of people, about the idea of using sediments on sites such as brownfields or landfills, where there would be no adverse impact. Would the public accept it? Was it really safe?

Stabilization and solidification have been around a long time as a set of processes, but ECDC and its partner ITECH certainly were on the cutting edge in some notable applications. Other low-tech processes include manufactured soils and cement-substitute products, such as bricks and blocks for erosion control. Brookhaven National Laboratory on Long Island emphasized decontamination in choosing technologies to be considered seriously for cleaning up New York/New Jersey Harbor. These included plasma arc technology, a proposed process called "cement lock," and soil washing. Again, I make a distinction between decontamination and making contaminated sediments environmentally safe without completely decontaminating them. As one might suspect, the dividing line is not always clear. The issues are safety, cost, and what can best be done with the end product.

Through that time I was doing more interviews, focusing on New York/New Jersey Harbor and what was happening in planning regulations for specific uses, such as landfills. That is complicated but fascinating. I also was introducing new technologies and processes; I have been excited about that and continue to be. Thus far, I have been objective in my research and have had no contracts with vendors. This has been exciting because I can introduce something, say what seem to be its advantages, and then back off and see whether or not it develops. There is still a lot of R&D and development to be done, but I think the potential is huge.

Public attitude is still an issue. It is very different when you start talking about specific sites. Of course, there is case-by-case site evaluation. The emerging uses include mine land reclamation, which involves taking the material into the mines of Pennsylvania to a site that will be a living laboratory at Bark Camp. Other uses include remediation of sites designated under the Comprehensive Environmental Response, Cleanup, and Liability Act (Superfund); landfill covers; brownfield remediation or redevelopment; road fill; and constructed wetlands.

We are trying to commercialize low-tech, low-cost processes. We now are manufacturing soils from clean Toledo (Ohio) Harbor sediment. The demonstration was at the University of Toledo. We also are trying to provide products. We put a block on the table in a New York Dredged Material Management Plan meeting in January, and that block has great promise. Still, it needs a lot of testing, and there is no money to do it. We are trying to succeed with both clean and contaminated sediments.

There has been growing pressure to get decontamination below $35 per cubic yard. Some people think this is impossible. New Jersey is confident that it can be done, as am I. The emphasis there is on emptying confined disposal facilities (CDFs) and avoiding ocean disposal. This is not to say we should avoid building CDFs. We need to do that in a limited way. But we also need to learn to empty them. That is a complicated issue, but the potential for using sediment will be very great and very quick. I think it will be applied first to material that is already dredged.

We need to find money to test and demonstrate remediation processes and demonstrate clean sediment products on site. My focus was on brownfields; I did a good assessment of brownfields in New England. At one point, I said: "This will be the day when I find a brownfield that is on a clean water source that can really benefit." I found a 240-acre brownfield site that is a slag dump on the Monongahela River in Pennsylvania, and we are moving forward. We have been there twice now. My commitment was to prove that we could engineer sediment to perform better than conventional material, save money, serve as a model, and display an array of products with clean sediment.

What do we need to do? We need to work with clean sediments when possible, focusing on engineering a product for performance without fear of contamination. We also need to work with contaminated sediments simultaneously, focusing on engineering products that are environmentally protective. In other words, we should make the applications that are best for the environment early on. The most pressing need is for visible sites to demonstrate structural and aesthetic superiority. I stress the aesthetic; we can make beautiful things.

The barriers to progress include mindsets, which are very bad. There is a dire need for professional and public education, demonstrating, testing, and market analysis. I have a vested interest and hope that I am able to move on both national and site-by-site levels to make sure we drive this with markets, which include everything from the technologies used to make the products, to the products, to cost-benefit analyses, and so on. Another barrier is that people are unable to see the specific products and big picture. They want to kick the tires.

Common concepts of marketing deter progress. Take the concept of push versus pull. You never push if you can get the buyer to pull, and we have been pushing. The supplier must get rid of the product, and this is a bad image. It has slowed us down. Obviously, pull is when the market says "I want that product and know how." In addition, people who commercialize technology know that the "techies" emphasize how it works. They really talk about the features of the technology because it is the market that essentially creates or fills the need.

When should the government get out of the way? The private sector has to see a market before it will invest. The market, on the other hand, must see savings and demos and testing before it will demand the product. If you tell transportation officials that they must use this fill, they give you the PQRST test. They want to know if the price (P) and quality (Q) are better or the same as before. They also want no risk (R). The S is for standards and many other things, including support from colleagues, and T means they do not want to pay for testing. In essence, the market has to see the savings and those other things I mentioned, and it needs to know that demos and testing have been done.

How do we get to savings and demos and testings? We still need money to prove that we will save money. Of course, the money people—the government and investors—must see the big picture. The big picture is that sediment is a valuable resource. I cannot say that I believed this when I first started the research. I wanted to believe it but did not. It was almost like wanting to know that your President is going to do a good job and not get into trouble; I wanted it to happen, but I did not believe it would happen.

The low-tech processes are lowering the barriers to benefits. I am not diminishing decontamination technologies in any way, but it is because of the low-tech processes that we are able to move forward with a tangible product. The low-tech processes are proving to be sufficiently low cost that we can use clean sediment, and, by using clean sediment, we can lead with what the people want without worrying about contamination.

I want to leave you with two quick quotes. Like Martin Luther King, I have a dream. I have a dream that we can make a facility that will be sizable and have many interesting structures made of sediment that nobody ever thought of making before. It will be an environmentally sound place where people can go safely. There will be statues; I actually know a person who can design a statue for me, and a vendor who says he can make statues of this material. This facility will be what I laughingly call the "sediment wonder of the world." I really mean this; this is no joke. I have been a long time coming to this. If anyone would like to sign a noncompete agreement, then I would be glad to show you my artist's rendering.

My second quote is from Wayne Young, who said, "Hey, folks, how in the world are we going to do something with the bad stuff unless we know what we can do with the good stuff?"

PANELIST PRESENTATION

Mining Industry Issues

William J. Adams, *Kennecott Utah Copper Corporation*

I was asked to discuss some of the sediments issues that are important to the mining industry. I have to qualify that term a bit. The mining industry that I can speak to and represent is the hard-rock mining industry, not the coal industry. The principal mine where we are mining copper is located out in Utah. The operation sits on the north edge of the Oquirrh Mountains, next to the Great Salt Lake. Our sediment issues are associated primarily with a tailings impoundment, which encompasses a significant number of acres along the south end of the lake, where there are large numbers of migratory birds.

In reviewing the NRC report, I was most impressed with the forthrightness and the down-to-earth, "let's get out and find a way to do it" approach. I have been involved in sediments issues since about 1980, when we first started to publish on methods of assessing levels of contaminants in sediments that are either safe or harmful. It has become clear that, in spite of our best techniques for assessing levels of contaminants in sediments, uncertainties will remain, even under the best of conditions, in methods for assessing potential human health effects and ecological effects. There is just no way around that right now. I think the issues for scientists dealing with contaminated sediments are

1. How to reduce the risk; and
2. How to reduce the uncertainty associated with our estimates of risk.

The process for Kennecott begins at the open-pit mine in Bingham Canyon. It opened in 1902, and out of that we produce an extensive amount of tailings, which go to our tailings impoundment. The principal issue for our company is what to do with the remaining rock, which is contaminated with metals. It has 300 parts per million (ppm) of copper in it, for example.

We deal with various issues in making risk assessments, or in assessing the science and applying it to determine what is safe and what is not, and what risk is acceptable and what is not. Some fundamental issues concern the background levels of metals. This is more or less important depending on where you are, but it is certainly important for us in the West, where huge areas have been, and continue to be, mined. We look first at what the background is before we assess the elevated risk associated with mining.

Critical to the whole process of risk assessment is establishing the effects-threshold levels. A lot of effort is going into this issue for metals, questioning whether or not we have it right. The reason is that so much of the work has been done in the laboratory, where we used organisms to determine the threshold levels. The organisms were cultured in pristine conditions and then exposed to elevated metals. The latest research shows that this approach causes an increased sensitivity in these organisms that does not occur when they are back in their native environment.

Metal speciation is very important, and, with some of the new techniques available now, we are beginning to get a handle analytically on the various forms of metals that exist. Measurements of bulk metal do not correlate well with toxic effects. The bioavailability of metals in sediments has been a key issue, and measurements such as acid volatile sulfides and binding to sediment oxides, iron oxides, and manganese oxides are critical in making the assessment.

We should not forget the biology. Some of the focus areas in science now deal with issues such as homeostatic mechanisms of control. Some recent publications address this issue of how organisms deal with metals. Particularly for copper, zinc, selenium, and other essential metals, a great deal of research is going on in elucidating both the toxicity curve and the essentiality curve, and in how we use that in an overall risk assessment or in such things as establishing water quality criteria or standards.

Another thing that you cannot get from laboratory studies is, for example, the importance of spatial distribution. I cannot overemphasize the importance of this when going from laboratory bioassays to the field and making determinations about the potential for impact. Feeding habits are certainly important, because organisms do not feed in exactly the same spot all the time. There is also the issue of evaluating the desired level of protection. This issue needs to be debated, because the idea that we can protect 100 percent of the sites 100 percent of the time for all species is not founded on ecological principles. It is a societal desire.

Back to the mining industry and some of our key issues. For our company at least, it is freshwater and not marine issues; it is metals and not organics. Our biggest issue is our tailings impoundment. From a worldwide perspective, suspended solids may be the biggest issue for hard-rock mining. If you follow any of the mining issues over in New Guinea, where three major hard-rock mines do business in copper, gold, and other metals, the suspended solids in the effluent are the key issue.

Another issue for us is the sediments below our discharge point to the Great Salt Lake. This is one issue that we track quite carefully, the loss of ore. (We call it sediment once it is in the river system.) We monitor the area near the shipping terminals to make sure that the people handling our ore are doing it appropriately. We monitor all of our shipping facilities. In some cases, we have had to do some cleanup. A critical factor that comes out in these assessments is the bioavailability of the material that is in the ore state, as opposed to dissolved metal, which partitions to the sediments. You clearly see differences in bioavailability.

The last issue, and probably the one on which I will spend the most time, is sediments and wetlands. This is a major issue for us, particularly with respect to selenium. This element, when transported up through the food chain, results in deformities in birds and fish. We spent a lot of time in the last three years looking across our wetlands. We have perhaps 4,000 or 5,000 acres of wetlands along the south shore of the Great Salt Lake, and a principal concern to us is the protection of the migratory birds, like American avocets. Several thousand types of birds pass through or across this particular region—1 million birds migrate annually through the Great Salt Lake basin.

We are looking at two questions. First, how do we manage our wetlands in terms of the bird usage, water usage, and the sediments out there with metals in them? Second, how do we protect that habitat without destroying it? We are just completing an environmental risk assessment on this project.

We have made an enormous effort to revegetate our tailings impoundment, where the sediments, as I mentioned, have about 300 ppm of copper in them. The ore has 6,000 ppm and we mine it down to the 300-ppm level. We have been very successful in establishing vegetative growth on our tailings impoundment. As a demonstration project last year, a number of different areas were dedicated to such things as vegetable gardens and grapevines. We have yet to find anything that will not grow on it. In some cases, amendments are required. The idea of using of sediments on mine lands was mentioned earlier; I think that is a great application. There are certain areas, not necessarily our tailings but on waste rock piles, where we clearly have to amend the soils before we can grow things, and sediments would be a great solution for that. We need some topsoil on that rock. On our tailings impoundment we use biosolids from the city's waste treatment plant.

I spend most of my time on risk assessment. The problem-formulation stage is where we have had the most success—involving the community, identifying the resource to be protected, and reaching common-sense agreements that allow us to go forward. Once you start down the path of risk assessment, and I am a strong believer in it, you cannot assess everything. You have to decide what you will protect. At this point, if you can achieve some agreement among all the parties, you have some hope of identifying what the risks are, defining those risk levels, and deciding what would be acceptable.

I am a strong proponent of the risk-based approach. I say that because it provides a way to look quantitatively at the data and find common-sense solutions to the problems. It identifies how much risk is left with the first option, the second option, or the third option. It is virtually impossible, in dealing with sediments, to reduce the risk to zero. The risk-assessment process allows us to make statements that people can understand about the probability of the associated risk.

For example, in our risk assessment for our wetlands, we concluded that there was an 8 percent probability of teratogenic effects on birds in the most highly contaminated area. The decision remaining, then, is whether an 8 percent probability of effects is acceptable or unacceptable. Do we allow the wetland to remain as is, or do we clean it up? It ties the solution to the risk reduction in a cost-benefit approach, and I like that.

As a society—this is my plea—we need to avoid shortsightedness. Natural recovery almost always takes place in sediments given enough time. In some cases, we may be talking about decades, but in the overall evolution of the Earth, a couple of decades is a pretty short time. Of course, there is a need for long-term monitoring. We are involved in that for our own wetlands.

Panelist Presentation

Environmental Dredging

Ancil Taylor, *C.F. Bean Dredging, Incorporated*

What I want to demonstrate here is the willingness of industry to respond to requirements in the market, to the demands that you have. As far down the food chain as a dredging contractor is, we relish the opportunity to get up in a forum like this.

We face a number of challenges in dredging and handling of dredged sediments. One is positioning, or controlling exactly the location of the dredge in the waterway or channel. Another challenge is removal of the material as efficiently as possible, without resuspension or removal of additional material that would have to be treated. Still another challenge is transport, which involves safely transporting the material to the disposal site or treatment facilities, usually on land, with as little exposure as possible to people and the rest of the area.

Our company has had a number of firsts in the dredging industry. There has been quite a revolution in our industry. In the early 1980s, the U.S. Congress decided to allow private industry to compete in the development of our nation's waterways, especially the entrance and navigation channels. Since the early 1980s, close to $500 million has been invested in equipment to satisfy the waterways development needs.

I will discuss a project that came on line in the early 1990s. Private industry was allowed to innovate and develop a solution to the problem of Bayou Bonfouca, from 1892 to 1970 the site of a South Louisiana creosote plant. In 1970, the plant caught fire, and much of the product spilled into the bayou; 169,000 yd^3 of material were contaminated over a 55-acre area. In 1982, the site became available for Superfund cleanup; it was the largest Superfund project ever attempted at that time, and it still may hold that record.

A dredge was built specifically for that project. It is 140 by 45 ft and uses spuds, laser positioning for control, computerized excavation, and real-time telemetry. We actually could see, in real time, exactly what was going on with the dredge from our corporate headquarters. This allowed us to help troubleshoot and monitor the operation.

Positioning challenges, winds, currents, waves, tides, and everything else you can think of on the waterway are parameters that you have to design around. Vessel movements, or generally traffic in a navigation waterway, demand greater precision. In this project, we needed to remove contaminants from varying depths; it was not like a navigation channel, where we would dredge to a certain elevation and our job is accomplished. We needed to identify, through site characterization, the extent of the contamination and its elevation, and then remove only the contamination and not everything else around it.

We did that by developing a three-dimensional (3D) model of the sea floor. We used the laser positioning systems now available, getting tremendous accuracy, down to centimeters. We basically took a computer-aided design drawing and dressed it up a little bit. The drawing depicted both the existing elevation and the elevation to which the sediment had to be removed. That was put into a 3D model in the computer, and the dredge operator was able to see the bottom while moving down the waterway.

The operation involved monitoring seven locations on the dredge bucket and comparing the x and y coordinates for those seven locations to seven x and y locations on the channel. The z dimensions were compared, and the operator could see exactly where he was in relation to where he needed to be on the channel. The spud system jacked up the barge slightly to stabilize it and eliminate many of the problems such as wind, current, and tide.

The equipment monitored itself, which was very helpful because our engineers could remain at headquarters and troubleshoot the equipment. As a result, we were extremely pleased with the accuracy of the equipment. Through measurements done prior to beginning the project, we had to demonstrate the accuracy of the equipment to the owner. We actually got down to .05 ft (15 cm) repeatability. I would not guarantee that type of accuracy; it was purely coincidental that, through the measurements, the repeatability of the system was down to .05 ft.

The other types of equipment considered for this project included the cutterhead dredge. It was not satisfactory, given the turbulence, trash, and debris. The client did not want water added to the system; the treatment of the water would be very expensive. Trash and debris would get caught up in the suction pipe and cause additional problems. We also considered the matchbox type of operation. Again, the sediments were not suited to this equipment. It is really best suited to very soft sediments that can maintain a laminar flow entering the suction head and then cause it to go into turbulent flow as it gets into the suction pipe. Although that unit would have removed the material at 80 to 100 percent solids by volume, it was not appropriate.

The backhoe dredge that we chose removed the sediments almost intact in an in situ situation, with a minimal resuspension ratio. It also tolerated the very large obstacles, such as the pickup truck and Mercedes-Benz we pulled out of the waterway. Very little additional water was introduced at this stage of the excavation. We worked from a very stable platform. We had to make some strange cuts up against sheet piling in various places along the bayou, where we had to be very creative in excavating the material at depths up to 42 ft (13 m). The machine basically was well suited for just about everything that we encountered on the project.

Conventional barge transport also was considered. People did not want the barges on the waterway. It is a somewhat messy operation, which requires manual handling, and there was some risk of accidents and spills from the barges. It involved greater exposure to the surrounding environment. On the other hand, conventional hydraulic transportation would not be very efficient in handling that volume of water for our client, the International Technology Corporation and OHM Corporation (IT-OHM). This project was very successful for IT-OHM. This is another jewel in their history.

The process that we decided to use was a combination of the barge and pumping system. We used and patented a slurry processing unit (SPU). We removed and transported densities as high as 75 percent solids by volume, compared to the 15 to 20 percent solids that we probably would have achieved with a hydraulic system. The material was dropped into a hopper, where the larger materials were separated out and transported by barge to shore. Everything else went into the SPU, which monitored the density through specific-gravity loops.

The SPU added in only the amount of water needed to reach the density specified by the client. Then the slurry went into the filter presses in the incinerator, which eliminated as much as 60 to 80 percent of the water that normally would be added through a hydraulic transportation operation. The SPU was monitored by a computer and was fully automated, in that it would monitor the flow rate and density through the pipeline and then transport this material to the shoreline very effectively.

The trash and debris were transported by barge. We reduced the number of barges needed on the waterway and dealt with some traffic issues. The people all were outfitted in protective clothing. The pipeline itself was double cased; there was a pipeline within the pipeline. Thus, if the integrity of the inner pipeline was lost, we still contained the material in the outer pipeline. The area was surrounded by silt curtains and booms, and the project was limited to an eight-hour day, five days a week, because of the neighborhood in which we were working.

We completed the project in March 1995, having removed 162,000 yd^3 (124 000 m^3). The average amount of overdredging (calculated by dividing the overdredged quantity by the total area dredged) equaled just 0.17 ft^3 (.005 m^3). I think EPA and our client were extremely excited about the performance.

Here are some recommendations, from our perspective, for things to consider. Develop performance specifications and allow innovation to meet the requirements of those specs. Require a scientific demonstration of the technology. Ask the contractor to demonstrate mathematically exactly what is going to happen. Perform a thorough site characterization. Avoid the misapplication of equipment due to an inadequate site assessment. There have been a number of times when, because of inadequate site characterization, a contractor has brought in the wrong equipment.

I strongly recommend retaining an engineering firm that has experience with this type of work. This type of firm has resource awareness, knows the industry standards, and knows the contractors that can work effectively in that business. Although the knowledge base may be insufficient as far as this forum is concerned, and we want to add to it, the knowledge base already is vast and the work is complicated; I strongly recommend retaining someone already working in the field. Select contractors based on their science and their solutions for meeting performance specs. Be sensitive to the proprietary nature of the solutions. To maximize exposure to the solution and the science, be sure that the contractor can feel comfortable that this expertise will not be passed on to someone else.

PANELIST PRESENTATION

Developing Techniques for Source Control

Michael Connor, *Massachusetts Water Resources Authority*

I am speaking on behalf of the Association of Metropolitan Sewage Agencies (AMSA), which represents the major public treatment works and sewage dischargers throughout the country as well as most of the dischargers along the coast with which the National Research Council (NRC) report would be concerned. I will share some examples nationally and focus more specifically on Boston, where I work for the Massachusetts Water Resources Authority (MWRA), which supplies water and wastewater service to the metro area.

I will review what the NRC report says about source control and talk about point source trends, changes and associated effects, and chances for future reductions. The report makes many statements that are difficult to dispute. It talks about the strategies and potential for further source reduction, mentioning two strategies that the EPA is now attempting: watershed management and total maximum daily load (TMDL) assessment, and the EPA contaminated sediment strategy.

Regarding point-source trends, AMSA has surveyed its members over the years, and one survey covered about 75 dischargers from 1987 to 1995. The loads were normalized. For most metals (e.g., cadmium, chromium, copper) there was a significant reduction in the inputs of metals into the treatment plants during this time period. The loads are controlled through various source reduction activities and also reflect the changing nature of the U.S. industrial base; a lot of manufacturing no longer happens here. The EPA has written about various management practices that industries can use to reduce inputs.

The products of sewage treatment are effluent and sludge. Most of the contaminants end up in the sludge. A survey by AMSA of 200 plants, as well as data from EPA covering 30 plants, shows significant reductions in metals in sludges over time. We are getting to the point where we have most of the reductions that we will get. The remaining sources, for the most part, are household sources. For instance, a lot of copper, lead, and zinc is from the corrosion of piping in houses and the leaching of small amounts of metals as they get to the plant. We estimate that, for most of the contaminants coming to the plant, more than 90 percent come from household sources.

In Boston, we have seen the same trends. In 1984, we had about 3,000 lbs (1,362 kg) of metals per day coming to our plants; in 1993, we were down to about 600 lbs (272.4 kg) per day. In the last few years, we have dropped another 50 to 100 lbs (22.7 to 45.4 kg), but we have reached an asymptote of reducing or eliminating most of the sources that we can. The decline in sources can be seen in Boston Harbor, where the water column concentrations of zinc, cadmium, and copper have fallen. A regression of metals concentration in the harbor as a function of metals loadings yields a first-order approximation of the harbor flushing time if the contaminant behaves conservatively. Interestingly, this regression works reasonably well, yielding a harbor residence time of about 3.5 days.

The U.S. Geological Survey compared the concentration of metals in harbor sediments in 1993 to the records for 1977 and reported 30 percent to 50 or 60 percent reductions in concentrations of copper, zinc, chromium, lead, mercury, and silver. Similarly, we see declines in liver tumors in fish and in early blood measures of the health of fish (e.g., centrotubular hydropic vacuolation), which is related to declines in levels of organic contaminants, such as polychlorinated biphenyls (PCBs), chlorinated pesticides, and polyaromatic hydrocarbons (PAHs).

In sum, there has been a big improvement over the last 10 to 15 years in the inputs, the resulting concentrations in the water and sediments, and the health of animals living in the harbor. This trend is seen nationally too, with the mussel-watch data. The vast majority of trends for contaminants in mussels around the country are down rather than up.

The recovery of Boston Harbor actually has occurred much more quickly than anticipated. This is due to a lot of the nonlinear effects that Frank Bohlen talked about. Part of the reason for the improvement is the cessation of sludge discharge in 1991. Before that, a very small portion of the harbor could support benthic amphipods and ampelisca; by 1995, they had covered about 60 percent of the harbor, and this proportion increases each year. There is more mixing of oxygen into the sediments of the harbor, so that the redox discontinuity layer has increased from about 1 to 3 cm in the last couple of years.

The situation now is that, with primary treatment, the MWRA source issue is the relative input of the loads of pesticides, PCBs, and mercury. Our point-source discharge was a relatively large proportion of the total load. With secondary treatment, the input is declining quite a bit, so that we are looking at riverine sources, most of which are nonpoint. For mercury, atmospheric sources are starting to dominate, so the remaining point-source contribution to the load is quite small. As we have taken away the point sources, getting at the nonpoint source problem is not trivial. We have trouble getting at this problem to meet water quality standards, let alone some sort of sediment quality standards. It is hard to imagine how we will be successful with sediments in a way that we have not been for water.

It is important to remember that most of this problem is an historic problem. If you look at the annual loads of pesticides, PCBs, and mercury—not just in Boston Harbor but in the whole Massachusetts Bay system—the loads are small compared to the inventory in the water. In Massachusetts Bay, the residence time of water is about six months. To a large extent, what is driving the water-column concentrations at this point is probably release from the sediment load. For instance, of the total load of mercury of about 300 kg per year, MWRA's sewage discharge is responsible for about 30 kg, of which known industrial discharge is less than 3 kg.

We are going after small sources, such as dentist's offices, where the material in fillings is captured in a little screen as patients rinse. The dentists frequently clear that screen; we think that can capture a significant part of our existing mercury loads, but that is maybe a few hundred grams a year. When you look at how much money we will spend to get that extra few hundred grams, and you look at the inventory in surface sediments (i.e., the top few centimeters) of 40,000–80,000 kg, it is difficult to see how you will make a big dent in those materials.

I want to remind you that sewage treatment plants, in particular, face a number of other high capital costs as they look to the future. In an annual needs assessment by EPA, it has been estimated that wastewater facilities must take on $140 billion in remaining costs to rehabilitate sewers and further upgrade secondary treatment, perhaps to more advanced treatment for nutrient removal. There is already a fairly large set of expensive projects on our plate, without trying to increase the removal of sources of toxics.

That gets me to my conclusions. Point source inputs have declined dramatically. This story is not fully understood, but most of the contaminants of concern historically in contaminated sediment cleanup projects (i.e., metals, chlorinated pesticides, PCBs, PAHs), particularly in navigation projects as opposed to environmental remediation, have declined significantly. You can see the decline reflected in the status of the sediments around those discharge points.

It will be difficult to get further reductions because the sediment reservoir is so large that the remaining changes you can achieve through source control will be small. They also will be small compared to the ongoing sources, including nonpoint and particularly atmospheric sources. At this point, it is probably true that most of the PCBs coming into our system are from the transport of products sold outside the country.

If we are trying for a big benefit in the future, where are we likely to get it? It is clear from the changes in concentrations of chlorinated pesticides and PCBs that, at the national level, banning products is the way to make big changes. By the time we start to deal with that problem at individual treatment plants down the line, it does not make any sense. Are there other products out there that we will be worried about in the next 20 years in sediments? Should we be thinking about them now, and regulate them before they get into the waste stream? By the time it gets to the treatment plants—which exist not to treat toxic contaminants but rather to treat wastewater of human origin—it is too late.

PANELIST PRESENTATION

Long-Term Monitoring

Russell Bellmer, *National Oceanic and Atmospheric Administration Fisheries*

I am a marine ecologist working on dredging and disposal activities within the Fisheries' Office of Habitat Conservation of the National Oceanic and Atmospheric Administration (NOAA). I will talk about who we are, explain some of the things we are doing, and offer suggestions about future goals for the dredging community.

NOAA Fisheries is responsible for the management, conservation, and protection of living marine resources in the U.S. Exclusive Economic Zone. We also play a support and advisory role in the management of living marine resources in coastal areas under state jurisdictions, provide scientific and policy leadership in the international arena, and implement internationally agreed-on conservation management. We carry out our stewardship mission through science-based conservation and management and through promotion of a healthy environment.

NOAA Fisheries defines its mission as stewardship of living marine resources for the benefit of the nation through science-based conservation and management and promotion of the health of the environment. Our aim is to maximize benefits to the nation from living marine resources without compromising the long-term health of coastal and marine ecosystems. NOAA Fisheries manages for the sustainable use of living marine resources, including both consumptive and nonconsumptive uses, while striving to balance competing public needs and interest in the use and enjoyment of our living marine resources and also preserving their biological integrity. These management measures often include monitoring both natural and artificial marine habitats, including those created with dredged material.

Management authorities and legal mandates include the Magnuson-Stevens Fishery Conservation and Management Act, under which fisheries are regulated. Fisheries are regulated by our five regional offices along with eight fisheries management councils. They are responsible for preparing fisheries management plans, which identify fishing and nonfishing threats and contain conservation enhancement measures for fish populations in their habitats.

Under the Endangered Species Act (ESA), we are responsible for the protection of marine species listed as threatened or endangered and for identifying candidate species for such listings. ESA allows us to enter into cooperative agreements with states to implement conservation and recovery actions for listed species. ESA also allows for the establishment of conservation plans to protect, restore, and enhance habitat for listed species. Under the Marine Mammal Protection Act, we are responsible for protecting certain marine mammals, namely whales and seals. This act establishes a moratorium on the taking and importation of marine mammals and related products, with a few exceptions for scientific research and allowable incidental taking.

There are various other statutes that confer on us a mandate to reduce or mitigate the degradation and loss of living marine resource habitats. These include the Clean Water Act; Federal Power Act; Fish and Wildlife Coordination Act; and Marine Protection, Research, and Sanctuary Act, among others. Under these statutes, NOAA Fisheries plays a primarily advisory role in reviewing proposed projects and other actions that may affect living marine resource habitats and in making recommendations for adequate conservation of those habitats.

We are using all these authorities, plus others, to look at ways to enhance and restore fisheries habitats. The implementation of the requirements under these acts cannot be addressed fully without long-term monitoring and sound partnerships among those using the marine environment. Based on long-term monitoring, it is known that many marine species are under stress from overexploitation or habitat degradation, or both. Nearly one-half of the fishing stocks for which we have scientific population information are below optimal population levels. Some populations of marine mammals, turtles, and fish are in danger of extinction, and many more are threatened by various human activities.

Habitat loss and degradation affect mostly inshore and estuarine ecosystems. The primary threats come from alteration of freshwater flows, loss of wetlands and submerged aquatic vegetation beds, reduction in shallow water habitat, and destructive fishing methods. Decreases in freshwater volume and flow rate stem from damming and diversions of major rivers affecting nearshore ecosystems that have adapted to seasonal discharge of fresh water. Agricultural practices such as logging contribute to siltation and can destroy spawning habitats and impede migratory paths. The loss of aquatic plant-based habitat resulting from development adversely affects a variety of food webs that are important to adults and juveniles of many marine and anadromous fish.

To fulfill our stewardship mission, we have identified three broad strategic goals: build sustainable fisheries, recover protected species, and restore healthy living marine resources habitats. All three goals have a habitat element. For example, to attain the sustainable fisheries goal, we are providing for increased recreational fishery opportunities through conservation, restoration, and enhancement of aquatic ecosystems. We are rebuilding commercial stocks through management regimes and regulations, which include reduced levels of exploitation, stock enhancement, habitat improvement, and bycatch reduction. To recover protected species, we are characterizing and assessing habitat need, and identifying and minimizing human actions that are detrimental to these precious species. We also recognize that the wise protection of healthy living marine resources habitats is crucial to the success of management and conservation efforts. To realize this goal, we are protecting, conserving, and restoring living marine habitat and biodiversity.

We also are implementing cooperative approaches at the local level in habitat conservation restoration. For example, it is the policy of the Chesapeake Bay program to measurably advance the beneficial use of dredged material to improve habitats in the bay. We also are involved in the Coastal Wetlands Planning, Protection, and Restoration Act project in Louisiana, which is using approximately 5,000 yd^3 (3,825 m^3) of dredged material for wetland restoration. When that project is done, we will have restored more than 80,000 acres (32,400 ha) of wetlands. We are considered a permit applicant, just like any dredge operator going through the permit processes, so we have some sympathy regarding that issue. We also are developing new methods of evaluating and monitoring the quality and productivity of restored habitats as well as improved restoration technologies to ensure that the created habitats are effective.

This stewardship activity depends on strong, effective partnerships. All federal agencies are experiencing budgetary constraints and increasing demands, and none can meet all the mandates on its own. We must collaborate with other organizations with similar mandates to achieve our mutual aims. These include other federal agencies, state and local governments, universities, environmental and industry groups, Native American tribes, and many others. We also must increase the reliability of our monitoring and science, explore new ideas, invest in new technology, undertake long-term monitoring, and continue to be willing to make difficult resource management decisions.

The NOAA Fisheries Habitat Research Plan seeks to accomplish the following activities, all of which involve long-term monitoring:

- Understand the structure and function of natural resource ecosystems, their linkages, and their role in supporting and sustaining an abundance and distribution of healthy living marine resources;
- Quantify the response of habitats and living marine resources to natural and human disturbances;
- Develop and evaluate new techniques to restore or create productive habitats using dredged material;
- Develop indicators to simplify determinations of habitat impacts or recovery; and
- Synthesize research and communicate findings to managers to ensure that sound science is part of the decision process.

We need to improve the quality and credibility of our science by

- Extending and improving peer review of scientific advice by panels of knowledgeable scientists from both inside and outside government;

- Improving professional standards for monitoring, research, and scientific advice by establishing national guidelines for technical programs;
- Implementing policies to ensure the integrity and independence of the science and assure that our monitoring programs, analysis, and products are sound, credible, and provide an objective basis for management;
- Developing new science-based resource assessment and management techniques; improving monitoring and analysis techniques and systems;
- Developing a new series of reports and presentations to communicate scientific results in simplified language; and
- Requiring the various monitoring and research programs to solicit input from external scientists in topical areas when identifying research initiatives.

We need to continue to build strong research partnerships, and we need to use the research and databases that we have. We are currently trying to improve the coordination of habitat restoration efforts between NOAA and its partners by assembling and maintaining a comprehensive database of restoration activities supported by NOAA. That database will be on the World Wide Web to share with others. Success stories in which NOAA Fisheries have played a significant role include the beneficial use of dredged material in projects such as the Poplar Island habitat restoration in Maryland and Galveston Bay wetland creation in Texas. We contributed to project design and baseline monitoring and will continue to provide ecological oversight.

Examples of long-term monitoring projects currently under way include studies on trophic linkages in created and natural salt marshes and long-term fisheries' utilization of created salt-marsh and eelgrass beds. We must place high priority not only on long-term monitoring, but also on demonstrating that restoration and enhancement can occur with present technology, and by promoting cost-benefit information. We need to publish and otherwise broadly distribute the results and lessons learned.

We need to address dredging and disposal activities by

- Applying the "ecosystem approach" and advanced planning to dredging programs;
- Undertaking appropriate scientific studies and long-term monitoring;
- Developing stricter regional and national criteria for economic analysis of dredging activities to differentiate between real and perceived needs;
- Placing greater emphasis on prevention of sedimentation and contamination at their sources;
- Developing mechanisms to improve coordination in the early stages of a proposed project;
- Undertaking the additional research and monitoring needed to increase knowledge of the functions of undisturbed ecosystems and habitats, the response of living marine resources to dredging and disposal activities, and the development of predictive models and associated risk assessments;
- Ensuring that the analysis of disposal alternatives considers the beneficial uses of living marine resources and the least environmentally damaging methods; and
- Seeing that resources to meet the requirements of regulatory process are commensurate with the expectations of the regulated industries, as well as other parties affected by dredging operations.

Armed with this information, the U.S. Congress and the public will be able to see the potential of beneficial use of dredged material and long-term monitoring, which should translate into support for public policy, programs, further technology development, and restoration of aquatic habitats.

Project Implementation
Summary of Dialogue with Audience

Sediment Applications

Audience Member: Could you give me an example of an application in which a contaminated sediment performs better than a sediment of the same type that is uncontaminated?

Anne Montague: To clarify my point, I am saying that when we decontaminate, treat, or process contaminated sediment, in one way or another we can find applications that essentially are doing no more harm to the environment but are improving the environment. There is a real possibility that we can reduce the cost of decontamination enough to produce what is essentially aggregate. In other words, what went in is what will come out, only it will be clean, and then we can bind it up into bricks, blocks, soil erosion products, and so forth.

That is not an answer to the question, but it is something that I did not get to say earlier. The safety issue is, of course, a very serious one. Obviously, there will be times when we want to bind up those materials in fixation processes such as in stabilization or solidification. How to monitor that is a very serious issue. Those applications, however, will be broader when we get concrete-substitute products. Anything that you can make of concrete, you also can make of sediment. I believe that we will be there within a year and a half.

Then the question to society will be are you going to decontaminate it first? Will you use clean material, or will you use contaminated material and bind it up and find applications where you are doubly sure it will not leach? It is an interesting question, whether there are better applications for contaminated material than for uncontaminated. The answer, in a way, is here. If the sediments that are nearby are contaminated, and if you can find a beneficial use and save that site money and do the remediation, then that is better than going a long distance to get other materials.

"Surgical" Dredging

Audience Member: There has been a great deal of controversy, which I think will continue, about the ability to dredge "surgically," cleanly, and adequately. Based on your experience, not only with the Bayou Bonfouca site but in all your experience and the experience of the industry as of 1998, do you believe that dredging can be accomplished in most contaminated sediment environments in a clean, environmentally safe, and very accurate way?

Ancil Taylor: With today's technology, you probably could not do much better than accuracy to within 3 in (7.6 cm), or thereabouts. What is the definition of "clean"? I doubt that, in my lifetime, we ever will see 100 percent removal. You are dealing with contaminated sediments that are generally in a fluid layer on the bottom. It is similar to hitting a golf ball halfway to the hole. You never get all the way there; you just get closer and closer. But I do not believe that, in my lifetime, with conventional technology or the dynamics involved in marine excavation, you will reach 100 percent clean. I think you can remove 95 to 97 percent of what you are trying to remove, but I never would claim to remove 100 percent.

Weighing Bioavailability

Audience Member: Michael Connor showed the reduction of chemicals going from publicly owned treatment works (POTW) into bays, and compared that with the sediment levels. I think you also have to consider the bioavailability of the chemicals. You show thousands or hundreds of kilograms in sediments versus tens of kilograms coming from the outfalls. But if you look at how much of that chemical actually is in the biota, which can be on the order of tens of kilograms, not thousands, then you have to consider the bioavailability.

In one area where the sediments are loaded with contamination, they found that the POTW was keeping the fish levels stable because the mercury in the sediment was not as bioavailable. You have to weigh in the bioavailability and look at the system through a mechanistic process to determine the source. It may be, in fact, that the tens of kilograms are what is keeping the biota "hot." The other issue is atmospheric deposition. But I think you have to consider the bioavailability, because something will keep the biota levels constant, and it may be the POTW. My final point is, did you do any work looking at storm surges? When a large storm comes through and you get sewer overflow, that could "burp" contaminants into the bay.

Michael Connor: The bioavailability question certainly adds another layer to consider. The point I am trying to make is that, for most of these issues, the water quality standards are so low that if you manage the discharges to meet those standards, then you will solve the sediment problems at the same time.

I have a permit limit for polychlorinated biphenyls (PCBs) of 45 picograms/liter. As long as we do not get a lot of extra sediment deposition, I can figure out some way to get to a level that I want. The same is true for mercury. It probably would be more cost-effective for EPA, instead of developing a whole new sediment strategy, to make the existing strategy work well. A primary reason that existing projects are not working so well is that the states and federal government do not have the resources to manage the individual systems in the way they are supposed to (on paper).

Dick Schwer and I had a conversation about the total maximum daily load (TMDL) process. To do TMDLs for all U.S. waterways to meet water quality standards, you need 10 to 50 years to accomplish all the work. If that is adopted as a nationwide strategy for sediments, it is not clear to me that you will get anywhere. This does not mean that, in certain situations in which you have remediation issues, you should skip looking at the existing source terms.

Regarding how much contamination remains in the piping system within each municipality, the material is resuspended and pushed farther down the pipe as flows increase. In fact, all of the loads of chlorinated pesticides and PCBs in our system now are essentially due to the resuspension of material that was deposited 15 to 20 years ago and slowly is getting down to the treatment plant. There may be cheap technologies to deal with that problem; I am just not sure that a cost-benefit analysis would make them look attractive. There may be more effective ways of spending that next dollar. At a sewage treatment plant, we have so many needs that, in my mind, are much higher priorities and offer much greater environmental benefits. I want to pursue them before I put my money into these issues.

Homeostatic Control Methods

Audience Member: In connection with homeostatic methods of control, could you give a definition and maybe a brief example of controlling contaminants? I also am interested in methods of reducing the water in dredged material, not only contaminated but also normal material. If we can get capacity back, then that translates into dollars for any containment facility.

William Adams: I will describe homeostatic control methods for copper, which is a good example because it is an essential element for most life, including aquatic organisms. It is also interesting because certain benthic invertebrates actually use copper in their blood systems as an oxygen-binding agent. Most organisms that need the element have a mechanism to control it and to ensure that they retain enough of it in their blood system and tissues.

In a risk-based process, it is important to understand that you have incorporated these data into the overall potential for risk. For example, as the concentration of chemicals goes down in the water phase or sediment phase, if you are measuring on the basis of bioaccumulation or bioconcentration, then those factors go up. Of course, as the concentration becomes lower, the number gets bigger, and it looks like you are in trouble. However, what the organism is doing is maintaining an adequate amount of metal in its system to ensure its survival. Those are the consequences of considering homeostatic mechanisms when you try to estimate risk based on the presence of contaminants in the environment.

Taylor: Very briefly, if added water in dredged material is an issue, then the slurry processing unit (SPU) monitors the density and compares it to the optimal density that you need for transportation. There is a certain density-viscosity matrix that will be optimized for slurry transportation with the horsepower that you have or can install. The SPU treats the slurry down to that particular concentration. Keep in mind, I said 75 percent solids by volume. If this material is 35 percent solids by weight lying on the bottom, then we are not going to concentrate it to 75 percent solids by weight. I was referring to 75 percent solids by volume.

In the Hart-Miller Island situation, you have almost everything in place there that you need. If added free water becomes an issue, then you could remove the material from the barges, put it into the SPU, and transport it at a much higher concentration that you require now. It could be done, but right now, as far as I know, that is not an issue. Until it becomes an issue, you will move the material from barges into the Hart-Miller Island facility the way you do it now.

Audience Member: Could your unit process 3 million yd^3 (2.3 million m^3) efficiently right now?

Taylor: The unit that we have installed is a very small system. But it can be expanded, scaled up to 30 or 40 in or whatever you want.

BREAKOUT DISCUSSIONS

Enhancements to Decision Making and Implementation

John George, *Aluminum Company of America*
Dan Reible, *Hazardous Substance Research Center*
Ann Montague, *Montague Associates*
Jim Keating, *U.S. Environmental Protection Agency*
Larry Miller, *Port of Houston Authority*
Roberta Weisbrod, *New York City Economic Development Corporation*

RESPONSIBILITY FOR SOURCE CONTROL AND INTERIM TECHNOLOGIES (GROUP A)

John George

We spent most of our time dealing with the issue of source control. We decided it was important to define source control. For example, to a dredger, source control might be the removal of a contaminated mass of sediment. We decided that source control relates to ongoing sources discharged to the surface water system, potentially with an impact on sediments. We identified both point-source discharges to surface water through industrial or publicly owned treatment works (POTW) sources or outfalls, and nonpoint-source discharges, such as surface-water sheet flow or groundwater discharge. We also identified atmospheric deposition as a possible source. Another was the inflow of natural background constituents; for example, overbank deposits might slough into a stream during erosion.

Given the variety of diffusive inputs categorized as ongoing sources, we agreed it is important to look at a rough mass balance on the front end. This may help to prioritize the sources, so that given an understanding of their relative responsibilities, for example, for maintenance of tissue concentrations above some threshold level, we can get the greatest cost-effectiveness in dealing with ongoing sources versus remediation of massive sediment contamination. If, by eliminating an ongoing source we could reduce substantially the impact on a receptor in the surface water body, then that might be a cost-effective way of approaching a contaminated sediment management situation.

With regard to nonpoint sources, it is often very difficult both to recognize and to manage them, especially from a regulatory perspective. Some individuals in our group suggested that a good way of approaching nonpoint-source discharge in surface water might be through some form of cooperative agreement that might bring together the affected or affecting parties. The measure of success would be the net benefit in terms of improvement in the surface water body. For example, if industries, POTW, and other private concerns, all with some portion or allocation of nonpoint-source discharge to surface water, engaged cooperatively and effectively in tracking down the sources, then the benefit would accrue from eradicating those sources.

The technical issues need to be addressed from the perspective of public policy. One of the difficulties that we encounter, not just in dealing with ongoing sources to surface water but in general with regard to sediment management, is the number of different jurisdictional bodies. At the national level are the Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE). There also may be regional regulatory bodies, states, and local interests. It is sometimes difficult to find an agency or group of agencies that will take the lead responsibility. A cooperative effort bringing a variety of different groups together often helps to overcome these types of obstacles.

Having defined what we mean by ongoing sources, and recognizing that the control of those sources may be an important element in overall strategy for managing contaminated sediment, what criteria are appropriate? We spent a lot of time talking about risk as a foundation for the definition and management of contaminated sediment. We need a better method of defining risk-related criteria from human health and ecological perspectives. We also acknowledge that we are getting better at detecting contamination in surface water and sediment, and that this potentially drives the levels for discharge criteria much lower.

We discussed several examples of large-scale cooperative efforts. The first is a very large project on the Rhine River. It involves the cooperative efforts of five countries to define a cost-effective mechanism to resolve disposal options for contaminated sediment or sediment from navigational dredging. Potentially 90 million yd^3 (68.9 million m^3) of sediment will be housed in a common disposal area. Another project is on the Duamish River in the Seattle area, where an effort is under way to integrate environmental remediation, navigational dredging, and permitting of discharges to control ongoing sources. The final example is the Houston, Texas ship-channel widening and deepening project. Many different stakeholders were brought together over a significant period of time to come to an agreement over an approach that will be environmentally protective and fully representative of the individual stakeholders' interests.

We have four recommendations, somewhat in order of priority. First, we need to focus on a system-wide approach. It is important to undertake a rough cut of the mass balance and to track down ongoing sources. It is important to involve the various stakeholders early in the process, from a risk-communication perspective. It is also important to encourage all the stakeholders to contribute their resources. This cannot be a project funded by one industry or one agency, or one in which the funding rolls down from federal coffers. All of the stakeholders need to contribute to some extent, either financially or through "sweat equity."

Second, early in the program, we need to think about source control and incorporate it into the planning of the ultimate remedial approach. We need to look at the mass balance and prioritize potential sources, looking at whether or not, by cutting off an ongoing source, we may be able to obviate the need for more expensive remediation of sediments.

Third, there needs to be a strong risk-based linkage between the ongoing sources and the ultimate strategy. We talked about the possibility, from a global perspective, of providing general guidelines or standards that would be applicable in a generic sense. But we also need to recognize site-specific needs and provide enough flexibility so that those standards do not become overly bureaucratic or burdensome or fail to fully recognize local situations.

Fourth, it is important to balance the cost of addressing environmental risk with the related socioeconomic impacts. In other words, if we define criteria that are relatively stringent with regard to ongoing source discharges to surface water, then we need to take into consideration the impact that those criteria may have on industry, such as the local POTW. This whole thing has to be approached from a global perspective. It cannot be approached with tunnel vision, focusing on a single industry or discharger.

We did not spend a lot of time talking about interim technologies. Once the sources are identified, the technologies to deal with those sources—whether treatment, interdiction of the discharge, or going to a zero-discharge approach—become self-evident and are probably fairly site-specific.

Local Level Solutions

Audience Member: How much time, if any, was spent discussing the fact that a lot of these problems are being corrected at the local level, and that the public is, to some extent, the major contributor? It seems we are taking a top-down approach, when the issue clearly comes down to public behavior. A simple example is automobiles leaking oil. A lot of these problems are caused by the public. I think something is missing here.

John George: The system-wide concept would involve getting all the stakeholders together. We talked about the importance of risk communication, which must be more of a grassroots effort than a top-down effort. The people who are most affected by a particular issue are the ones who probably are most likely to listen and invest energy to work toward a solution. We also talked about the idea, especially where the source of contamination is nebulous or nonpoint, of trying to get cooperative efforts under way at the local level. You may not be able to allocate specific responsibility to an individual, but you might be able to measure the success achieved as a result of this broad effort to track down and interdict ongoing sources.

Audience Member: In all cases, we need to look at the local situation and the sources in that watershed. Although in some cases nonpoint sources and maybe personal contributions play a large role, there also are cases with ongoing contributions of certain chemicals from point sources. That is why we looked at a range of controls. We talked about behavioral and educational changes that need to happen, as well as regulatory or legislative fixes that might address the range of problems.

Site Characterization Needs and Technologies (Group B)

Dan Reible

We framed our discussions around three questions:

- How effective are existing site characterization processes?
- What are the barriers?
- What are the solutions?

I will summarize the discussion in each of those areas.

As far as the effectiveness of site characterization, we often lack the precision we need for in situ measurements. For example, biological measurements that involve the removal of samples and slurry measurements of kinetics may be of limited usefulness. In addition, the measurements often fail to account for the dynamics and spatial variability of the system. But we did not identify a great number of technological needs. There was a lot of discussion about problems with implementation, not necessarily with the suite of tools available to do the job.

An exception is the assessment of ecological effects. No one is completely comfortable with the techniques for assessing and measuring ecological effects. We are hoping for better tools in that area. In addition, the lack of an end point is a real problem. We cannot specify very well the chemical end point for remediation of contaminated sediments. That makes it very difficult to optimize the site characterization.

The barriers to site characterization include the disparity in the goals of various stakeholders. That is a significant barrier, particularly if we focus on a potentially responsible party. For example, there seems to be a lack of willingness to do a proper site characterization. One reason is the uncertain economics. Perhaps the only incentive for improving site characterization would be if it reduced overall remediation costs. Whether it does or not is certainly unclear. Quite honestly, many of us recognized that collecting more data typically means uncovering a bigger problem. It does not necessarily mean that we want to avoid looking under rocks, but sometimes there is not much incentive.

Several people in the group said there was inadequate guidance from EPA and others on how to approach site characterization systematically, and perhaps standardize it. Perhaps more importantly, process understanding is still inadequate to define end points, minimum acceptable risks, and thresholds of liability, and to prepare that guidance. The group also identified a lack of acceptance of innovative technologies that might make it easier, simpler, and cheaper to do site characterization. In some cases, particularly cities with small marinas, there may be inadequate resources to do a proper site characterization.

What are the solutions? We need to improve our research base to develop the guidance and the systematic, standardized procedures for site characterization. We especially need research on ecological effects and the interpretation of experiments to establish ecological effects. There was a recommendation for case-study research involving a cooperative effort by industry, government, and all the stakeholders, to get them to buy-in while developing an understanding. Perhaps the model developed by the environmentally acceptable end-points group might be useful.

That will build a base for better guidance. We need guidance to encourage the standardization of approaches and to recognize site-specific issues. We are not looking at a standardization of outcomes but rather a standardization of approaches. Of course, we all want a clarification of appropriate end points, and we know how difficult that might be. For places that lack the resources—the example cited was a small marina in a small city faced with contaminated sediment issues—the group suggested expanding outreach efforts to provide financial and technical support.

Promotion of Beneficial Uses (Group C)

Anne Montague

We had an interesting group: users; people from the Marine Board, EPA, and state governments; vendors; a congressional aide; and others. It was a vigorous group. There was some opposition, but a general understanding that beneficial uses are necessary. We are way ahead of where we were three years ago.

In promoting beneficial uses, the biggest need is money for demonstration and marketing, strategic development, collecting and organizing information, and developing classifications that will make the public feel comfortable. I mean not only sediment classification but also standards and other classifications.

We spent some time discussing the barriers to benefits. Public acceptance, of course, was very high on the list. One question was whether to promote sediment as a bad material made good, or to start with clean material as soon as possible, on the assumption that we would have successes with structures and other clean applications without the complications of contamination, and therefore would be subject to less regulation and permitting. We decided to look at both contaminated and clean material simultaneously and move on with each one.

To gain public acceptance, we must find ways to classify sediment to avert problems later on. We should stress marketing; look to the states and ports to sponsor research (a surprising directive); find a variety of sites and be successful with them; stress quality control; develop a strategy to offer users an array of products and processes, with full information on costs and benefits, monitoring, and community impact; and find technologies and processes that do the most in the end—safely.

The second barrier was the lack of collected, organized, and disseminated information on all aspects of commercialization. The decision was to let the states lead while we continue to move forward at the federal level, hoping to encourage the private sector to pick up the ball as quickly as possible. The problem is that collecting, organizing, and disseminating information entirely in the public sector does not get out there. We need to know that we have a common good and try to figure out how to protect that common good. We are not sure how to collect, disseminate, and fund. Eli Weissman from Congressman Frank Pallone's office is thinking about this issue.

The third barrier is the lack of a system. This is a new initiative, so we do not have a system in which to work. How far can—or should—USACE go in terms of commercialization, which is not the Corps' mandate. The actions we came up with were to pressure the U.S. Congress, the states, and friendly groups like TRB to do the following nine things:

First, make sure that Congress is more specific in designating sediment as a nonwaste. Congress has said that sediment is not a waste, but we consistently see the states arguing with that, and some say they will continue to do so. That makes it very complicated. If you are going to commercialize or launch a product in a state that says it is a waste, then it apparently has to be regulated from cradle to grave, at least in some states. The nonwaste status needs to be underlined more strongly by Congress.

Second, we need to make sure that the EPA designates sediment as a recovered material, which will mandate that all federal agencies consider it in procurement. I do not know the details, but when you have a recovered material that meets certain standards and certain processes, the federal government says its procurement people must look at those products very early on. We believe this will mean that the federal government will use more sediment-based products.

Third, we need to pressure Congress not to impose inflexible legislation. When we met a couple of nights ago regarding the Senate bill, we began to realize that there may be a very small number—this has yet to be verified—of Comprehensive Environmental Response, Cleanup, and Liability Act (Superfund) sites that are sediment sites. It is my understanding that only a small number of the 1,100 Superfund sites in the country involve contaminated sediment. If the number is low, then maybe legislation should be crafted to let us look at each site independently; in other words, that bill's $300 million might be designated so that each site is looked at more independently.

Fourth, we should assess ways to make the pathway less arduous. We need to make sure that the agencies involved are not scrapping with one another so that we do not give up figuring out who has the responsibility. Where do jurisdictions overlap? Where are the black holes? We need to avoid bogging down the process with too many agencies arguing over different things.

Fifth, we need to encourage EPA to look closely at the benefits of using sediments on brownfields. This is happening, but not in a very organized way.

Sixth, we should encourage the National Institute of Standards and Technology (NIST) to develop standards for not only the sediment products, but also the process of manufacturing sediment products and applying them. That is somewhat complicated, but I know that ASTM has a procedural standard for the development of brownfields, and that standard goes way back to the beginning of the process (e.g., designating a site and getting the public involved). It is essentially a set of guidelines. For products, we may want to go very early into sediment assessment and then move forward in a similar pattern with NIST. I am not sure whether it would be NIST or ASTM; I think it would be the former.

Seventh, we should identify monies for finding sites and carrying out demonstrations, with systems management focused on diversity and good image projects. I have a list of 5 to 10 sites, but I do not have the resources or organizational ability to bring vendors to these sites. How do we go about identifying the monies so that sites can be presented along with the various alternatives?

Eighth, we should encourage requests for proposals to define the criteria that vendors must meet in bringing products to market. We always stress bringing the product to market, but in my view, the vendors are looking for the particular processes that they must use or the criteria they must meet.

Ninth, we should encourage partners who have materials that would be blended with sediments to be cooperative in the development of applications. We named some high priority uses: mine reclamation, raw materials manufacturing, wetlands, brownfields, beach nourishment, and soils for farmland. Some of those applications, of course, would involve clean material.

Long-Term Monitoring (Group D)

Jim Keating

Maybe we can promote beneficial uses of sediments if we stop calling them contaminated and instead call them "chemically challenged." Then we could establish programs to help them out.

I have eight summary points from our discussion.

First, there is a need for long-term monitoring. This is probably self-evident, but as we start considering risk-based analyses and other systems-engineering types of approaches, we will need the data to support them.

Second, monitoring needs and requirements can be categorized by the particular situation, such as navigational dredging, remediation, or restoration.

Third, we have to know why we are collecting data. We need to design the monitoring plan to have measures that match the questions to be answered. I am talking about a rigorous data-quality objectives analysis. We need to set criteria for success. We need to recognize that this can be the longest part of the process, but it is important to avoid rushing into sampling without knowing what we will do with the data or how they will drive decision making. It is imperative that our long-term monitoring measure the long-term effectiveness of our projects.

Fourth, these plans have to be put in place ahead of time, ideally with stakeholder involvement. We talked a bit about public participation and the importance of public buy-in. We recognized that the risk communication and education processes are inherent—and can be frustrating—but this is the real world and the process has to be recognized and managed.

Fifth, these plans have to include assurances that they will survive such set backs as personnel turnover. Long-term monitoring plans often are put in place for many years—20 years in an example mentioned in the breakout discussion—and there can be a lot of changes over that length of time. That brings us to a related point—the plans have to be adaptive. They need to have triggers in place for stopping or for intensifying as necessary. Someone has to watch the data as they come in. The triggers should be specified in advance in documents such as the record of decision.

Sixth, there needs to be a baseline against which to compare the long-term data in order to measure effectiveness, and the baseline needs to be considered objectively ahead of time. We think multiple objectives can be accommodated in long-term monitoring. We recognize that most monitoring is done for compliance, but there is no reason that additional objectives, such as research, cannot be accommodated in the sampling efforts. But this has to be accomplished through partnerships. For example, in Southern California, a broad-based coalition of regulators, dischargers, and other entities has been able to achieve multiple objectives in its long-term monitoring strategy.

Seventh, we recognized several institutional disincentives for long-term monitoring. Paradoxically enough, some industries and principal responsible parties do not want decisions reopened, and some governments are afraid of the accountability, that they will not be able to demonstrate success. This might be changing, but it certainly needs to be recognized.

Finally, we discussed the possibility of a centralized database for long-term monitoring. This would be beneficial because it would help us learn from our successes and failures. The idea had broad-based support in our group, but we recognized that a substantial investment would be required to create a database, and that there are many barriers, including quality assurance and quality control considerations. On the positive side, existing partnerships could champion such a cause. There might be regional models in the Pacific Northwest and perhaps other places, that have collected centralized databases.

Public Outreach and Participation (Group E)

Larry Miller

Our group dealt with public outreach, communication, and public perception. This is the most difficult area we have to tackle. The science and technology are there; computers do not talk back. But perceptions have to be changed, because they are not always correct. We focused on two questions:

- How effective are the current programs in communicating to the public?

• What tools are effective in communicating to the public?

Communication is a two-way street. Communi-cation is defined as the dissemination of information, but the aspect that gets lost sometimes is being understood by an area or group. You can talk for an hour or a day; but if the public, or your audience, walks out without understanding what you tried to communicate, then you did not do a good job. The consensus was that there was no one solution or formula. We addressed this issue along with teaming and partnerships. The obvious choice of a communicator might not be a politician or a head of an agency; it might be someone at the civic level. There is no one particular formula, but it is important to communicate at the level of the audience.

Civic groups might not be the lowest level you need to reach. You may need to go out to work places; you may need to go to homes. Given that human and financial resources are limited, you have to be creative in targeting your efforts. There was a comment about certain outreach efforts being made and apathy being the result. Maybe the communicators did not choose the best place to target their efforts, because I guarantee that, if you are being affected in some manner, you will not be apathetic. You will attend the meetings; you will voice your opinion. Every group has a spokesperson. Some people are more vocal than others, and usually they speak up more than once. It is a good idea to communicate with those people, get to know them, and build a relationship.

Joan Yim was our moderator, and she echoed several things in our group. One is that you need to have an informed public, and you need to have buy-in, or acceptance, from the beginning. Reaching out in midstream or afterwards is not soon enough. Public outreach should take place at the start of the project or program, not in the middle or at the end. Civic groups are becoming involved through environmental justice organizations, and we heard several comments in that regard. The verdict is still out. We thought the intentions were very good, but that in some cases, the result may be divisiveness among the state, the agency, and the public. We have a situation in Houston somewhat like that.

The contact or spokesperson might not be the obvious choice. That person should be someone who can be trusted, can build on that relationship, and keep informed about the subject matter. There has to be a delicate balance. The person has to be believable and able to build relationships with many different groups. There was talk in our breakout session about blacks and whites, but there are so many different races out there: Hispanic, Japanese, Chinese, Vietnamese, and Europeans. You cannot target any one. People are people. The only difference between you and me may be the color of our skin or our backgrounds, but people are people and you have to approach it that way, with a positive attitude.

Building relationships is paramount in our dealings at work, or in our environment. Usually things do not happen without the building of a relationship, or if something is accomplished, then it takes a lot longer. By meeting face to face, as we are right now, and building relationships, we can achieve our goals more easily. We have to know where to target our efforts.

We also talked about risk management. We have dwindling resources; we need to know where to spend our dollars to get the best bang for the buck. When you talk to the public, what you say and how you say it are very important. Someone who lives in a residential area and hears the terms "risk management" and "disposal sites" may think that risk denotes danger and disposal denotes garbage. I prefer to use terms such as "weighing your options" and "dredged material placement areas." Those are much more positive ways of stating things.

Remember, you are dealing with people who may have lower or higher IQs than you do. Ignorance equals fear; people who know little about a subject usually become skeptical. It is difficult to appreciate things we do not understand. Our intentions may be good, but unless we communicate in a way that our audience can understand, it is difficult to build a relationship and get buy-in and acceptance of our project.

When representatives of corporations try to communicate with the public, they must present themselves in a humane or human way. There is usually an immediate perception that the spokesperson is only after the bottom line, the dollar. But most of us have kids; we have significant others; we go home in the evenings and want to live in a safe environment. That is a common thread that needs to be emphasized—not that you should belabor that point, just make them aware that you are a human being like they are.

Make sure you communicate at the level of your audience. We had someone in our group who had a scientific bent, but she was used to translating technological and scientific terms into language that could be understood by the target audiences. It is very important to do that.

Knowing the Community

Audience Member: Communities often have an impact presented to them. When they find out about the dredging or the seeping and placement in their back yard, they are suddenly outraged, and that is when they start to mobilize. Previous community outreach has no effect.

Larry Miller: It is critical to know the audience. Communities have different backgrounds. Some have a lot of retirees. You also have communities in which both the husbands and wives work, and they are not available during the daytime. You also have "watchdogs" in communities. Everyone reacts a little bit differently. But I think prevention is less costly than corrective action. By communicating what your plans are, at least you can say you did it. Whether you believe it was heard or whether you get feedback is another story. Feedback is good sometimes; apathy is good sometimes.

Using the Media

Audience Member: That raises a good point about the operations in which many of us are involved. The scale of these operations is large, involving 5, 10, or 15 acres of sludge. That scale makes it hard to believe that the impact is not adverse. Therefore, when you draw the stakeholders together, you are well advised to run a video early on to give them a feeling of the scale of the project. If you have had buildings constructed near you, or watched a pipeline run through a section of woodland, then you know that the building process is big and ugly. You come back a year or two later and you hardly know they were there, but the process is large and invasive. Part of the communication process is not just to talk concept; show them what it looks like. It goes a long way toward reducing the surprise.

Miller: A comment was made in the group that you should go out of your way to build relationships with the media. People read the newspaper and listen to the radio more than we realize. But there is no one solution. The Internet is great, but it is not viewed as user-friendly by some people. When a voice-command setup is available on a cost-effective basis, then maybe that will change. In the meantime, there are a lot of different ways to communicate.

I dealt with a civic group in Houston called Pleasantville. The media made it known that the port was about to undertake a widening and deepening project. The USACE did a viewing of the site. The sites in Houston are sandwiched between residential areas. There is no zoning, so I get involved with the community whether I want to or not, and that is good thing. This group saw an article in the paper about the widening and deepening project, which was 10 miles downstream. They also saw people at a site that had not been used in 40 years. They put these facts together and jumped to the wrong conclusion. They thought the port was about to dredge to their site and not tell them about it.

I saw that as an opportunity to meet with the group, which had been hostile in the past. I was prepared to let them vent their concerns of 40 years ago, and they did that several times. I let them talk. I was prepared to diminish that anger and tell them that I could not control what had happened in 1956, but that I was here with them today in 1997. I said, "I am the contact person; call me if you have a concern." It is amazing how, once we got over that hurdle, our relationship improved. But we have to be prepared to go through that at the beginning.

Proper Perspective

Audience Member: I do not think you should try to sugarcoat your operation by calling it a dredged sediment placement operation. It is sediment disposal. If it is contaminated, then there is a risk, and these risks need to be communicated properly and put into perspective. I think it is much more effective, in terms of communication, to call it what it is, rather than trying to make it sound different.

Miller: I do not agree with that. Our thinking and attitude need to change. Anne Montague mentioned beneficial uses. I think we need to change our thinking to understand what beneficial uses can do for us. I do not think of the material as being disposed of, because I see that, down the road, we can use it for something else. It may not be obvious right now, but the sediment came from somewhere. It may have been contaminated with other constituents, but if you really try to find ways to use it—maybe by combining it with something else—there are beneficial uses. Sedimentation is not going away; there always will be a need for dredging. I would rather refer to a site as a temporary placement area, or a warehouse, than as a disposal area.

Improving Decision Making (Group F)

Roberta Weisbrod

Our group was a problem-solving session. Our objective was to use the themes of the symposium—risk reduction, sustainable management, and reuse—as a framework to determine the factors that influence decision making, and, in particular, to identify show-stoppers. We highlighted some newly emerging tools, and we made recommendations on how to proceed. Incidentally, there were some common themes that transcended these three issues.

With regard to risk-based analysis and risk reduction, we agreed that the concept is difficult to put into practice, because the methodologies, assumptions, and underlying toxicology are uncertain. In addition, there needs to be clarity in the definition of acceptable risk, including whether we are referring to human health or ecology.

Because of these uncertainties, the best way to approach risk-based analysis is to look at risk in a comparative way, by looking at the cost of reducing risk and examining the trade-offs in terms of costs and benefits. That should be done during problem formulation. The end point should be defined in terms of the desired risk reduction, and risk reduction versus cost should be plotted on a graph. The optimal solution is one in which there is maximum risk reduction per unit cost, as opposed to maximum risk reduction alone, which has a much higher unit cost. Regulators tend to prefer the latter in the absence of considering the total benefit package.

When pursuing risk-based analysis and risk reduction, it is very difficult to communicate the risk, or a comfort range, to the public. There is always some uncertainty. In terms of available tools, the National Research Council has an outstanding report on risk communication.* One solution is the early involvement of stakeholders. Small-scale farm applications were achieved this way in the USACE's Baltimore District. The Maryland Port Administration (MPA) has a parallel applied research program for clean dredged material, to assess what grows best on the dredged material, with and without amendments.

We also discussed criteria; we compared the use of criteria to the risk-based approach. We all acknowledged that criteria such as the Green Book's 20 percent amphipod mortality and the bioavailibility tests are not indicative of real risks to the ecosystem. On the other hand, they allow regulators and project managers to move forward with a good deal of certainty; the risk-based approach, however, requires a lot of site-specific data. Indeed, in the case of sludge reuse, the criteria that EPA has set for land application have been effective in encouraging widespread acceptance.

In the end, the philosophical question that we posed but did not answer was: Are our flawed but useful criteria (when the public buys in) better than an accurate, but difficult-to-achieve, risk-based approach? Although this philosophical question may contain its own answer, we decided not to come to a conclusion.

Regarding the second major theme of the symposium, sustainable management, we discussed Tom Wakeman's approach in the sense that, although project managers adapt to changes in regulations, the regulators themselves do not. It takes time for regulators to respond to the issues that new regulations engender. The solution to that problem—and also the problem of effective, credible risk communication—is demonstration projects to show how new solutions work positively. To encourage beneficial reuse for wetlands and other containment areas, local demonstration projects with a definable monitoring system are an effective first step.

In a great MPA demonstration project that included early and frequent communication with stakeholders, in-water disposal of dredged material was encouraged by the oystermen at a small site near a bridge that had been used for the disposal of various materials, including burned debris. The dredged material covered the contaminated area and debris that snagged fishing gear; in addition, the state transportation department (which owned the bridge) contributed $18 million toward oyster seeding. The oysters not only were a resource for the oystermen but also benefited the water body by filtration. A lot of negotiation must have been involved, but everyone won.

Another aspect of sustainable management is that regulations are not keeping pace with regulatorily defined solutions. This problem would best be approached by pushing for guidance on monitoring to analyze new technologies and demonstration projects as well as to understand completed projects retrospectively. This information would help the public and regulators to comprehend and, when appropriate, accept new actions. We strongly endorsed the concept of performance-based standards for remedial cleanups as well as other environmental management processes.

Finally, for beneficial reuse, we said some things that have been said before. Standards are needed for dredged material products such as road fill and topsoil. Sometimes they exist; sometimes they do not. On the federal side, there needs to be guidance and rulemaking on how contaminated material can become a clean product. That will allow us to decide whether to use dredged materials for beneficial reuse projects. Incidentally, EPA Region 5 (the Great Lakes) is developing such guidance and rulemaking in preparation for a beneficial reuse workshop in Toledo, Ohio.

A very strong conclusion of our session, which transcended all three symposium themes, was that we definitely see a need for more demonstration projects. This will allow us to build a database, which will allow us to provide credible risk communication to the public based on verifiable experience, which will promote the beneficial reuse projects that we all want.

* *Improving Risk Communication.* National Academy Press, Washington, D.C., 1989. Available via the Internet at http://nap.edu/readingroom, or call the National Academy Press (1-800-624-6242).

Summation and Next Steps

Industry Response Panel

Industry Response Panel

Lillian Borrone, *Port Authority of New York and New Jersey*
Richard Schwer, *E. I. duPont Nemours and Company*
C.L. (Skip) Missimer, *P. H. Glatfelter Company*
Paul Ziemkiewicz, *National Mine Land Reclamation Center*
Stephen Garbaciak, Jr., *Hart Crowser, Incorporated*

Coastal Ocean Ports Perspective

Lillian Borrone

I was heartened not only to see the National Research Council (NRC) report on contaminated sediments, but also to participate in this session, because this is a very important step forward from a port community perspective. It gives us the opportunity to see and understand what is happening nationally and to talk through, with every sector of stakeholders, how we might better work together to accomplish changes that we perceive as necessary.

Tom Wakeman, who works with me, previously discussed how ports are forced to deal with contaminated sediment. This is not our choice, obviously. Our business is to provide the economic foundation and facilities that allow commerce to flow in and out of this country. But to do that, we have to assure that we have safe, navigable waterways, and that our berths can accommodate the vessels that come in and out of our harbors.

Although we generally are not responsible for the contamination, clearly we have ended up being responsible by default or, in some cases, by a lack of aggressive pursuit of the potentially responsible parties or of other funding sources. At least we stimulate the removal of this dredged material, which has contamination in it.

In New York Harbor, widespread areas of sediment have been contaminated by a variety of sources. Some sources are far upstream, and many were shut down years ago. Ports have to dredge to keep their channels open and their berths free, but we do this in a regulatory environment that, in our view, has been plagued by procedural uncertainty and technical complexity. Both factors have led to enormous increases in the cost of managing dredging projects, and both have placed significant constraints on accomplishing harbor improvement programs in the time frame and manner that we require. In many cases, these programs have been under way for quite a few years.

The NRC report is an important step forward, because it gives us the opportunity to reach resolution on strategies that we have talked about for a while in a piecemeal fashion. The first two key areas are regulatory reform and partnerships to achieve reuse. From our point of view, the logical solution—as many of you have said over the last two days—is to treat dredged material as a resource, create the markets that would enable the material to be seen as acceptable for use, and not only lower our costs of disposal but also perhaps create a viable economic product for other users. The NRC study clearly and thoughtfully explains that this can occur only when we address regulatory uncertainties and develop adequate public/private partnerships that allow vital, sustained markets to develop.

My port and others around the country have been working through federal efforts, particularly Environmental Protection Agency (EPA) demonstration activities, as well as using our own resources and sometimes the resources of state programs, to create market opportunities and experiences that we can share. We want to demonstrate to our local constituents—particularly the everyday citizen—that this product approach is reasonable and responsible.

Regulatory reform is a crucial aspect of creating partnerships. We can learn a great deal from two fairly recent regulatory reform initiatives that have sought to create beneficial reuse opportunities for resources that historically were viewed as waste. One resource is sewage sludge and the other is contaminated industrial properties, or brownfields. Both programs have succeeded in increasing beneficial uses by providing clear, risk-based regulatory frameworks tailored specifically to the end use. In addition, both programs have addressed potential legal and financial liabilities that were keeping the private sector from embracing beneficial uses.

It is clear to us in the port community that similar reforms are needed desperately to allow the demonstration of new technologies or applications that will help us overcome barriers to innovation, enable us to reconcile differences between regulatory entities at the federal and state levels (and also regional levels), and to offer incentives to the private sector. These changes are needed to allow dredged material to evolve into a beneficial-use material and to create the markets that we believe are available.

How do we do that? Regulatory reform is only half of the equation. The other half is partnerships with the private sector, allowing it to develop products and markets that use dredged material. The public sector—whether the port authority or local, state, or federal government—cannot raise the capital to establish these markets on its own. It might control the supply, although not fully, because clearly there are private owners who also control some of the dredged material. In those cases, we still might be influencing the supply in terms of how we allow the material to be removed and managed.

We have heard from private entities over and over again that they are willing to step forward, but only if they have some assurance that we can meet the demand for dredged material if markets are found. My point is that we—and in particular the U.S. Army Corps of Engineers (USACE)—need to find a way to create the opportunity for a more reasonable supply process to evolve. We cannot have the process that exists today, which is project-by-project decision making that takes time and moves in fits and starts and stops.

In our harbor, we are talking about a "mud bank," for which we might pool the resources of USACE, the private sector, and public agencies, to create a flow with reasonable predictability. The applications will go through all of the appropriate and rigorous regulatory processes necessary to incorporate those projects into the bank. We take the challenge seriously, so we also need to look further at ways to moderate contracting procedures so that we do not inhibit the creation of new markets.

We also strongly support something that was mentioned previously—tracking down the parties responsible for contaminating the sediment in the first place, so that they can share in the cost of cleanup. Finally, we have to work together to demonstrate that dredged material is marketable by assuring the public that this is a safe proposition. Larry Miller and Roberta Weisbrod talked about some of the tools we might use.

It was appropriate in our decision-making breakout session to focus on how to array the alternatives and help local constituencies to understand that there are choices, depending on the values we bring to the table. We can choose how to proceed, whether to sequester this material, use it to create new land or do other useful things with it, or amend it and make some other product. As raw material, sediment may have the potential to be a very reasonably priced supply, perhaps supplanting something like clean sand from the ocean that we would rather preserve to maintain the ecosystem.

What are our next steps in terms of a reuse market? We think the research so far, supported by demonstration projects, shows that there are beneficial uses of dredged material, even contaminated material; that many of these uses should generate some economic return; that the economic return is crucial to lowering the costs of dredged material disposal at ports; and that we can expect these markets to develop if we can tackle the obstacles presented by the current regulatory process to spur market-driven partnerships.

Using the information already in hand—and, if possible, new demonstration projects to help us develop additional credible evidence—we should be able to help the public accept the idea of these products. As we undertake some of these demonstration projects and continue to build our databases, we will develop the ability to lay out the case that this is not harmful, these are viable products, and this is an approach that can work. Both the report and the breakout sessions mentioned many things that require all of us to join together to build strategies for public understanding of risk-based approaches and tools for working with the public to find a strategy to deal with this material.

Chemical Manufacturers Perspective

Richard Schwer

I represent not only my company but also the Chemical Manufacturers Association, a leading voice for the chemical industry. I will summarize the situation in the chemical industry regarding sediments. I liked Jim Keating's reference to "chemically challenged" sediment, because that is really what we have.

Many of our issues, as most of you know, result from practices of 50 or 75 years ago, or maybe even before that. The main constituents about which we are concerned are metals, such as lead, zinc, copper, and mercury; and a wide array of organics, such as polychlorinated biphenyls (PCBs). Everyone has these types of problems. But there are also fluorinated hydrocarbons, polyaromatic hydrocarbons (PAHs), and so forth that are unique to the chemical industry. The contamination is often on older manufacturing sites located in highly industrialized areas. The companies accept responsibility for both current manufacturing sites and sites that are no longer operating but for which they still have environmental liability and responsibility.

We are very supportive of the approaches taken by the NRC report. We think it points us in the right direction, and that its systematic process for evaluating and addressing sediment problems will lead to sound management decisions, which we all seek. I wanted to emphasize the key points that we pulled out of the report, mostly from Chapter 6, the conclusions and recommendations. These are key in terms of our industry's response to the needs addressed in this report.

First, we feel that three approaches identified in the report are basic to technically sound and effective decision making. Partnership formation is one. We put a lot of emphasis on this too, because we believe that forming partnerships in this day of limited resources is very critical. In this way, we can pool our limited resources and share information that is so important to making sound decisions.

I am disappointed that I have not heard more at this symposium about one partnership that is really exciting and involves the chemical and other industries. The Remediation Technology Development Forum (RTDF) was formed in 1992 by EPA to facilitate public-private partnering to develop cost-effective remediation technology. The participation formats are flexible, ranging from formal consortia to cooperative research and development (R&D) agreements, work groups, and information-sharing groups. The key is to focus on a technology problem that needs to be solved, go about developing a solution, and then publish enough information to give that solution credibility.

The group that we are interested in here is called the Sediments RTDF. It has three basic objectives. One is to develop and evaluate passive, in situ techniques to address contaminants such as PAHs and metals, two constituents that are important to the chemical industry. It also is taking a look at confined disposal facilities. Another objective is to investigate the mechanisms and rates of natural biological degradation and other forms of natural recovery. The third objective is to enhance and develop assessment procedures to evaluate the need for successive remedial activities. This is in line with many of the concerns of the people at this conference. I certainly hope that we can put effort into this, because the RTDF could accomplish a lot.

The two other approaches identified in the NRC report also are key to a lot of what has been said at this symposium. One is early stakeholder involvement. There is no substitute for it. You have to get all of the stakeholders together to gain an understanding of the objectives of the remediation project and get their buy-in. If you do not develop this consensus, you get nowhere in terms of accomplishing the remediation objective. The third approach, also extremely important, is risk analysis, which involves risk assessment, methods to reduce risk to acceptable levels, and communication to improve decision making.

We also focused on remediation technology. The report did an excellent job of describing the pros and cons of the various options; it suggests a reasonable decision-making hierarchy, starting with a review of the possibility for natural recovery to be effective in reducing the risk to reasonable levels within an acceptable time. This is the first place to look, as far as we are concerned. Capping is the next option to consider for situations in which it is appropriate and will hasten and improve opportunities for risk reduction. We believe that the last alternative to look at, if the first two are not appropriate, is dredging. When this is necessary, dredging should be done in a surgical manner to remove only the material that absolutely must be removed to reduce risk. Please note that we are talking about environmental dredging, as opposed to navigational dredging.

Where do we think the R&D emphasis should be placed? These are issues particular to the chemical industry. We understand that we have to go ahead, make decisions, and do the best job we can in terms of resolving real environment problems by making optimal use of the technology. However, we need to keep pushing the envelope to develop new and better approaches, which hopefully will be available in the not-too-distant future.

Dredging can continue to be an important option, but we need to develop sound dredging approaches that are more precise, more cost-effective, and environmentally sound. Dredging often involves large volumes of material, so we need to develop cost-effective treatment technologies. I was encouraged to hear some of the earlier presentations indicating that less costly treatment-combination technologies are on the horizon. That is important. Finally, site assessment is where it all starts, because these are site-specific problems. We need to improve site assessment techniques.

I want to leave you with recommendations on where to focus future efforts. Although we believe that sustainable management and beneficial use are very important, we would keep focusing on risk analysis. Our three recommendations all are geared in that direction. We need to develop risk analysis techniques that have broad acceptance across a broad array of stakeholders and that lead to decisions. A lot of us give lip service to risk analysis, but when it comes down to making a decision, how often does that carry the day? Maybe this approach lacks credibility in terms of whether it will get us where we want to go. Some comments at this symposium certainly indicate concern about the present techniques.

We need to quantify the relationship between contaminant availability and the real risk to people and the environment. I appreciated the presentation by John Connolly about the possibility of developing a prognostic model. I think we need these types of models to look at the cause-and-effect relationship, which is key. Monitoring is also important. If we want to give credibility to the long-term risks, capping technologies, and the effectiveness of natural recovery, we must do the long-term monitoring that can show us what happens.

Forest Products Industry Perspective

C.L. (Skip) Missimer

Before getting to recommendations, I would like to do a little storytelling. Contaminated sediments are not a pervasive concern in the forest products industry, either in the forestry or wood products segments of the industry or in the pulp and paper segments. That is not to say, however, that individual mills and companies have no specific sites where they have issues. Rachel Friedman-Thomas spoke about a site contaminated with mercury from a pulp and paper facility, and several speakers have referred to the sediment capping project that took place outside the Simpson Tacoma mill in Washington State.

However, we are interested in a few issues. Perhaps the single largest contaminated-sediments issue in the forest products industry involves the manufacturing and recycling of carbonless copy paper. Between 1954 and 1971, carbonless copy paper was manufactured using Aroclor 1242 as the primary constituent of the ink-containing capsules on the back of the sheet. Mills that recycled waste paper and converted trimmings containing carbonless copy paper or off-spec carbonless copy paper were not aware until later that these papers contained PCBs. Therefore, PCB contamination from recycling operations is a concern at three or more Comprehensive Environmental Response, Cleanup, and Liability Act (Superfund) sites and one other large site that is not under Superfund.

Given that this recycling activity ended more than 25 years ago, the overwhelming majority of sediments containing PCBs from recycling have been covered with more than 25 years of "uncontaminated" sediments. At these sites, therefore, we see a sediment profile showing low-to-moderate concentrations of PCBs at depths of 1 to 3 ft (.3 to .9 m), with very low concentrations of PCBs near the surface, usually less than 5 parts per million. Furthermore, the tissue monitoring conducted since the mid-1970s reveals an unabated decline in fish tissue concentrations of PCBs. For example, lipid-normalized tissue concentrations in fish from the Fox River near Green Bay, Wisconsin, are decreasing by 50 percent every five to seven years for most species.

Most of the contaminated sediment sites associated with the forest products industry are not in ports and waterways, where navigational dredging is a primary objective. Because these sites are located in nonnavigational waters, the primary objective should be risk reduction. This raises several questions concerning human health and ecological risk. For example: What are the true human health and ecological risks currently at these sites? How are these risks changing over time, and what is the effect of natural recovery on reducing risks? I echo what John Connolly said about modeling, suggesting that we can use models to answer this question.

Other questions include the following: Are there remedial actions (e.g., mass removal, hot-spot removal, capping) that will accelerate significantly the current rate of natural recovery and lower the risk, or does it just make us feel better because we did something about it? What are the risks associated with mass removal? Are those risks greater or less than those associated with other remedial activities, including natural recovery?

Another question: What are the collateral risks associated with mass removal? These risks range from the volatilization of PCBs out of acid-watering facilities to running dump trucks filled with contaminated sediments up and down neighborhood streets and highways. In short, is "mass removal equals risk reduction" a testable hypothesis? To my knowledge, this hypothesis has not been tested. Therefore, I would like to make three recommendations.

It seems appropriate that the work of the NRC committee that produced this report should be extended to address three issues that are particularly relevant to environmental remediation:

- First, we should develop improved site assessment and characterization techniques, including monitoring techniques, to assess the efficacy of remedial alternatives after implementation.
- Second, we should improve the linkage between site assessments and risk assessments. This effort should include the development of models that predict reductions in risks for various remedial options, including natural recovery, as John Connolly suggested. In other words, we need improved decision-making tools before we start spending millions of dollars on remedies that may not have any effect.
- Third, we need to test the hypothesis that mass removal equals risk reduction, and we need to do this at multiple sites to better understand when mass removal might or might not make sense.

Mining Perspective

Paul Ziemkiewicz

I will focus on the interests of the coal industry as a user or recipient of some of these sediments. This material has a lot of potential in the coal industry. We are near many sources of sedimentation along the East Coast, where we have two types of mining settings. There are abandoned mine lands, which are pre-1977 mines and are, in a sense, orphans of the state. There are also active mines. Thus, we have two very different types of regulatory environments.

We also have underground mines and surface mines. To give you some idea of how much volume can be involved, a relatively small underground mine of 10 mi^2 (25.9 km^2) in the Pittsburgh basin, or even in the anthracite country here, normally has 25 million yd^3 (19.1 million m^3) of storage capacity, or something along those lines. Of course, you need to find out several things: Is the roof in good shape? Has it fallen in yet? Have the pillars collapsed? Structural things have a lot to do with the geology of the area and how long it has been since the mining was completed. But the potential volumes are very high.

In a surface mine, if you put a 2-ft (.6 m) layer of sediment on an acre of ground, you probably can get something like 30 to 100 tons per acre of dredged sediments, given the densities I have heard for this material. For example, within 80 mi (128.8 km) of New York City is the anthracite region in northeastern Pennsylvania, where extensive underground workings have existed for a long time. You also have 10,000 acres (4050 ha) of unreclaimed surface mines and tailings in the Luzerne and Lackawanna county areas. We are looking at transportation costs to get materials from New York City to that area.

In the coal industry, we always assume 10 cents to load per ton, and 10 cents/mi (6 cents/km). This means transportation costs—running legally on a 22-ton dump trailer—would be in the range of $8/ton to move it from New York City to Wilkes-Barre, Pennsylvania. What does it cost to get dredged material hauled? We have made slurries and mine grouts out of coal ash and other materials, and we need to bring in the ash and the cementing agent, normally concrete kiln dust or some type of scrap. We normally get them hauled for something less than $5/ton. I know nothing about dredging costs or port handling issues.

What are the applications for this type of material in the mining setting? One is mine grouting. A lot of mines, when we are finished with them, wind up with 50 percent voids, because we must keep about 50 percent of the coal in place to hold up the roof. When we pull out, there are enormous underground reservoirs of 10 to 30 mi^2 (25.9 to 77.7 km^2), which might be tipped at 30 degrees or be relatively flat. They eventually start filling up with water, particularly if they are below the natural water table. We wind up with an anoxic environment, reducing conditions, carbon dioxide gas, saturation in the water, and often very strongly acid water.

There are many occasions when you start pushing water up out of the ground again, and you can actually get "blowouts," in which the side of the hill fails and tens of millions of gallons of pH 2.5 water show up overnight. Blowouts can kill people; these are very serious events. Blowout protection, which involves trying to control the pressures inside these mines, is a major interest of the state abandoned mine land (AML) agencies and the active industry.

There is the potential of replacing these acid-forming voids or reservoirs with an inert grout. To turn sediments into grout, we would need to add a cementing agent. We would need to make sure the material would remain stable in the weathering environment of low-pH reducing conditions in an underground mine. A lot needs to be done to realize this idea, but it has major potential.

The other possibility is surface applications. We are looking at manufactured soils, what type of material you need to add to them, how suitable they are for growing crops versus other types of vegetation (e.g., forest cover), and so forth. I am sure that a lot of work has been done on this, but it certainly has not been documented to the point that the coal industry is either comfortable with it or aware of all of it. Most of the costs will be related to material handling, transportation, slurrying, bringing in cementing agents, and drilling.

What do we need to make this happen? No coal operator or AML agency would want to turn a plain-vanilla coal mine, no matter how bad it looks, into a Superfund site. Therefore, they need to know ahead of time how suitable a material is for their application and what the potential liabilities are. For that reason, it is necessary to have a classification system, not just "good" and "bad" sediment but several classes of it, indicating whether the material will pose a potential problem. If it will, they need to know that up front. They either have to encapsulate the material or take some special precautions.

A neat thing about moving this material underground is that the whole operation can be handled hydraulically. There would be no dust; the PCBs would not be mobile. To a large extent, mine acid is a sedentary agent. It contains a lot of acid and ferric iron, so there may be some dechlorination potential; this issue has not been explored yet.

The recipient states will develop their own guidelines at some point, if this gets to be an application. It would be beneficial if EPA or some other federal agency came out with guidance documents, pooled all the information, tried to develop at least guidelines for a classification system, and then let the states take it from there. In terms of the other issues, we need regulatory coherence. We need to define the relationship between the states and federal agencies. The liability issues also need to be simplified, and then we need research on suitability classification and on quality assurance and quality control (QA/QC) issues.

We need to have a QA/QC program so that a truck could come on site, and within a day or so, an analysis could be performed indicating whether or not the material meets the specifications for that particular classification. We cannot have a six-month test if we want an ongoing delivery system. These tests need to be collapsed into a relatively simple QA/QC procedure. We need to know mix formulations, their suitability, their stability in a chemical environment, and their strength.

We need, for example, materials that can develop unconfined compressive strengths of 200 to 300 lbs/in^2 to ensure roof control in underground mines. We need to know the flowability, which determines how many drill holes you will need and what your ultimate delivery costs will be. Ultimately, we need well-documented demonstrations on site so that state agencies and the public can be comfortable—or at least know how these various procedures will work for them and whether they will create an environmental benefit or another risk.

Inland Waterways and Lakes Perspective

Stephen Garbaciak, Jr.

I want to talk about an item that kept popping up during the presentations and breakout sessions, at least the two in which I participated. That item is uncertainty, and its role in a variety of issues related to dealing with contaminated sediments, for both remediation projects and navigational dredging. I think we heard some uncertainty about who this audience is; we heard a reference to this symposium as a dredging meeting. We heard talk about whether dredging is a presumptive remedy when it comes to reducing risk. The issue of uncertainty—including what it means for the selection and implementation of effective remedial options—is where the contaminated sediments debate is going. That would be a recommendation for the future.

We heard about uncertainty in assessment techniques, in establishing remedial objectives, and in what the beneficial reuse markets might be or how we can develop them. We heard uncertainty about the regulations. Do we have enough regulations? Are they being applied correctly or incorrectly? We heard about the uncertainty regarding dredged material among the potential processors and developers of beneficial reuse products. How can we overcome that uncertainty?

We heard uncertainty—and I was a little disappointed at this—when Tommy Myers and Dennis Timberlake reviewed the technology recommendations of the NRC report and expressed skepticism about natural recovery. They put bounds on it and were careful to say that natural recovery is limited to a select few cases. I understand the caveats that USACE would put on it, because we have to remove material for navigational dredging purposes. But EPA's contaminated sediment management strategy is clear in identifying natural recovery as the first option to be evaluated, indicating that we should only proceed to more invasive (and therefore more expensive and complex) remedial options after we eliminate the possibility that natural recovery will achieve the same risk-reduction goals in a reasonable time frame. That feeds back into the uncertainty.

John Connolly's presentation expressed it well, echoing some of the things that John Haggard had said. We need to work toward developing better quantitative models. I think that is an extreme challenge. We have a hard enough time developing models so that all sides in a negotiation can agree on the relative differences between model runs. Coming up with the more objective modeling techniques that he was talking about will be an even greater challenge.

In conclusion, it is important for both the regulatory side in the remedial-objective negotiation process and the identified responsible parties to realize that uncertainty can be used as either a tool or a weapon, depending on your perspective. It can be a tool to help you or a weapon for avoiding action. It also can be used, when there is uncertainty, as an argument for requiring unnecessary and illogical actions. We should do what we can in all respects, but particularly in developing true remedial actions and in evaluating the effectiveness of remediation projects, to help eliminate that uncertainty in the future.

Industry Response
Summary of Dialogue with Audience

Funding Assessments

Audience Member: I spend a lot of time working with Lillian Borrone and her staff; I agree with the panel on the notion of developing quantitative tools. We are spending some of our own money, some of the Port Authority of New York and New Jersey's money, and some of EPA's and USACE's money, to develop the sorts of tools that John Connolly talked about. I am glad that you endorse this. I also got the impression that you strongly endorse the application of those tools, which really means a system-wide approach, as we discussed in one of the breakout sessions. It also means spending money on other things, such as data collection, which has turned out to be very expensive. We have a $13 million monitoring program just to provide verification data to run the model for which the Port Authority is paying.

Richard Schwer mentioned that his organization and U.S. chemical manufacturers have some responsibility for contaminating the sediments. If that is the case, do you not have some responsibility, within the industry side of things, to provide some of the money for the assessments that you endorse?

Richard Schwer: We have worked in a cooperative fashion to evaluate assessment techniques through the RTDF approach. You have to look at each situation, because there is enough responsibility to spread around in a lot of cases. When it is clearly the responsibility of a particular party, that party certainly needs to do what is necessary to reduce the risk to the point where the contamination is not harming human health and the environment.

Audience Member: If you are recommending, from the industry's perspective, that we need these improved tools, who should pay for them?

Schwer: I think that amount of money is overwhelming for any one party.

Audience Member: I understand that. But many of the companies you represent are Fortune 500 companies that probably had their best year ever on record, and it seems only appropriate that a very small percentage of that money could be spent on this. It seems to me that if people accept certain responsibilities, and if you are sincere about improving assessment techniques, and if your industries are responsible, then there should be some mechanism to fund the types of things that are necessary, because the government does not seem to have the money these days.

Schwer: It has to be a joint effort. We are talking about huge programs. We are talking about situations in which there is often more than one responsible party. There is often a group of parties who have some joint responsibility for a situation, and they need to work together and pool resources. They need to come up with a cost-effective monitoring and assessment approach and then do the best they can to go about solving that particular problem. I would not want to say that one particular party should take on the total responsibility for funding something like this.

Skip Missimer: I know of at least one example on the Fox River, where a group of paper companies (including mine) is working cooperatively with the state and funding more than $1 million worth of modeling just to develop the predictive tools that you are talking about. We think that, in the end, it will be very successful and very important in helping to determine the right remedial options for the Fox River.

Lillian Borrone: I would like to invite any of the chemical, oil, or other industries who do business in our harbor to participate with us—and participation can take a lot of different forms, not just money, although money helps. You certainly are welcome to join us, because we are putting in a very large amount of money, which the public sector really is not able to afford. We are doing it because, if we do not, then we will not advance our dredging programs, and we are desperate for the right solutions. We are willing to put some money up front and work with the states to do that, so I welcome anyone who wants to step forward.

Schwer: I think consortia and partnerships are the ways to go. We need to see if we can expand the resource base and leverage as much as we can among everyone who has an interest in recognizing that there is responsibility that has to be accepted.

Generalizing Site-Specific Lessons

Audience Member: Over the last several years, we have collected a lot of information about remediation technology at the Port Authority of New York and New Jersey. How much of that can be generalized? How do we go about transferring that information, and what are the most important types of things that can be transferred?

Borrone: There is information that can be generalized, depending on where various technologies are in the development process and whether they can be used in certain circumstances. This is information that we could easily share and, to some degree, have shared already. We have tried to transfer knowledge and information through EPA, USACE, and our two states. Both states have participated with us as well as in their own, parallel processes. We shared a lot of this information with the American Association of Port Authorities (AAPA) as well as with the committee that worked on the NRC study. There really is not one central resource, whether the TRB's Transportation Research Information Services system or a federal exchange. We have documented a lot of this material, which was put together by Tom Wakeman's staff with our engineering folks. Anything that is not proprietary we certainly are willing to share.

Evaluating the Public

Audience Member: I see this as a very American exercise. We argue and argue, but over the last several years, people have been working independently of one another much more than I expected. In Massachusetts, we have to educate the public as to what is possible. I honestly do not have any ideas, but I want to try. Do you have a suggestion about how that type of information is transferred?

Borrone: I think the federal highway program is an ideal model, in which the funds allocated to the states come back through the states to the TRB and AASHTO for R&D purposes. They use that foundation to pull information together, disseminate it throughout the 50 states and the territories, and feed it back to developing programs and other activities. Maybe there is a way, whether through Clean Water Act (CWA) or Water Resources Development Act legislation or some other mechanism, to create a clearinghouse for information that would encompass the entire country. In addition to disseminating information, it could provide resources for documentation if a project is done through some sort of federal program, such as a request for approval of a permit. I do not know how to achieve this, because there are so many different jurisdictions—states, local communities, regional agencies, federal government, and private sector. But if there were some sort of clearinghouse resource, then maybe the Volpe National Transportation Systems Center or NRC Marine Board could play that role. I can envision a lot of different possibilities.

Caveats on Modeling

Audience Member: As someone whose background is in water quality modeling, I know we need to recognize one thing when we pursue modeling. Models are no better than their least-precise component, so I make a plea for tiered modeling. I am strongly in favor of the very sophisticated "back of the envelope" approach, which at least lets us evaluate some scenarios rather quickly and maybe eliminate several and then go on to things that are more pertinent. I would like to think that we could develop perfect models. That would be wonderful. But I am also a realist, and I know that is not possible. I am just making a plea for a reasonable level of modeling. Do not get too sophisticated, because the answer never will be better than the least-precise component.

Spyros Pavlou: I was going to make the same comments. There was a lot of discussion about models, and I wanted to caution everyone that a model is only as good as the data it is based on. There is no problem with using prognostic models to assist your thinking process so you can develop a solution or understand a system. However, I have seen models that are just "curb-fitting exercises" constructed to devise the answer that someone wants to see. We should stay away from that mode of operation. We should look at models as useful tools for decision making, but we have to be very careful how we use them.

Natural Recovery (Part I)

Audience Member: I am from the Sierra Club, so you know what is coming. Regarding the Fox River, the mills did contribute $1 million for monitoring and $9 million more for other projects. But that is one of the most studied rivers in the country. Perhaps $10 million or $20 million—I cannot remember the exact figure—of taxpayer dollars was spent on the mass balance study, and EPA and the Fish and Wildlife Service have spent millions more trying to assess the state of the river. We really appreciate the mills' contribution and I am glad to see them at the table, but it did come under pressure from Superfund and the natural resource damage assessment of that river.

I appreciate TRB putting on this symposium to discuss the report. There is one thing I would like to see in the future. We have an industry response panel here; it would be nice to see a citizens' response panel. A common theme throughout this symposium has been the need for early stakeholder involvement. You have industry, ports, and governments, but you usually have to work to get the public involved. It seems to me that this effort could include asking for the public's contribution to something like this as well.

I also want to respond to another common theme at this symposium—the notion of uncertainty and that maybe cleanup is not appropriate at all times. That is definitely true; we have talked a lot about the cost of cleanup and why it may not be worthwhile. But one thing that has *not* been discussed much is the cost of doing nothing, or the benefits of cleanup. We touched a bit on the cost to ports, but there are also costs to commercial fishermen, recreational fishermen, and human health that I think must be accounted for in decision making. This is something we need to study more. We do not have a good handle on it, particularly with respect to natural recovery, which is the status quo. In certain situations, it may be appropriate. But we still have fish advisories throughout the Great Lakes and, in fact, across the nation. If we are willing to live with natural recovery in the case of contaminated sediments in the Great Lakes, then that is one thing, but we have not discussed it.

Missimer: Natural recovery is not the status quo under any circumstances whatsoever. Natural recovery is allowing nature to fix a problem more expeditiously than we can fix the problem. We know that this is occurring in many systems, that the systems are recovering without any intervention (e.g., dredging or capping), and that each situation is unique. Each situation has to be looked at individually. But to say that natural recovery is the status quo is absolutely incorrect.

Imposing Taxes

Audience Member: Given that, according to the report, about a half a trillion dollars' worth of trade is going through ports, I wonder if the Port Authority of New York and New Jersey has had any discussions about, say, imposing a nominal tax on ships that could be earmarked to cover the additional costs of dredging contaminated sediments? Given that you are dealing with a problem that you did not cause, this might provide additional funds to help deal with it.

Borrone: Let me give you some background. There is a tax now, the harbor maintenance tax, a portion of which the U.S. Supreme Court just found unconstitutional on exports. That tax was put in place to fund the USACE dredging program. It is currently paid by shippers on their products. It is a value-added tax. As a result of the court's decision (which was a ruling on a lawsuit by shippers who claimed that a large trust fund balance had been built up that appeared to violate the General Agreement on Tariffs and Trade), there is a debate going on among the federal government, Congress, courts, and shippers about what would be an appropriate and acceptable replacement strategy to generate revenue to fund both maintenance and construction programs.

Using the example of New York Harbor, those maintenance funds already go toward cleanup, because there is a requirement that sediment be disposed of in a way that is environmentally and regulatorily acceptable. So we do have a tax, but it needs to be replaced by something new. The Administration and the director of the Office of Management and Budget sent a letter this week to members of Congress proposing a new approach. Without specifying how they would raise the funds, they are proposing a national sediment fund, which would be off-budget, to raise about $800 million a year for maintenance and construction. The big discussion will be about how to generate that money in the future.

To answer your specific question, we have discussed it in my port, and other ports have talked about it. We are reluctant to impose additional taxes on vessels that could leave our harbors in favor of ports that have no need for maintenance dredging.

Audience Member: You would have to make it a national tax so as not to give some ports an advantage.

Borrone: Right, that is our philosophy. AAPA members have come together as a community and said we want a national program. We do not want ports to be forced into competition with each other. We are already competing, but we do not want it to be because of navigation policy at the federal level. We compete enough already by going to our members of Congress for appropriations. The idea of a national fund such as the Administration is proposing is exactly the type of thing that needs to be discussed. Because there are so few days left in this legislative session, I doubt that you will see it this year. It will have to happen next year.

Acceptable Time Frames

Audience Member: Is 25 years an acceptable time frame for remediation? I got an application several years ago for a groundwater remediation project in which the half-life and degradation work had been done and the sponsoring party indicated that groundwater standards would be achieved within 25 years if natural recovery processes occurred. The question then becomes, is that time frame acceptable? It was certainly acceptable to the responsible party; it might even have been acceptable to the regulatory commission. It would *not* be acceptable to my wife if I told her that I would mow the lawn in 25 years, because she frequently wants me to mow it.

What has not been addressed at this symposium is how we deal with these core disagreements that are based on economics. If I am a corporation and I am the responsible party, then I have very definite feelings about what is acceptable in terms of time to recover based on my cost-benefit curve. But my cost-benefit curve is not the curve of the community. We have not addressed the dynamics of dealing with real disagreement. As the next step, we may want to talk about these dynamics and how we get disagreeing parties to try to work it out.

Missimer: I agree. The time frame issue could be viewed in different ways. It could be viewed as a societal decision based on the particular situation and whether you are dealing with a minimal risk or a risk that is affecting the environment in a definable way. A lot of elements go into a determination as to whether 25 years is acceptable, or whether even 1 year is acceptable. You cannot come up with an answer to that question until you have defined all the elements that you need to consider. This gets back to early stakeholder involvement. If you convene all of the stakeholders in a particular community (depending on how you define the community for a particular contaminated sediment concern), then you at least have a group of people who can talk about these types of issues, weigh the different elements, and hopefully come up with a consensus decision that is best for the community.

Natural Recovery (Part II)

Audience Member: Skip Missimer stated that he does not consider natural recovery to be the status quo, but rather nature cleaning up contamination better than active remediation would. Are you willing to stick with a definition that we would call it natural recovery only if we can show evidence that it really is a faster and better way to go? That is a more difficult standard to meet.

Missimer: I do not think that natural recovery should be the presumptive remedy in every situation, but it needs to be considered in many situations.

Audience Member: I agree. But if you are holding it to the standard that it is better than active remediation, it is difficult to prove that.

Missimer: For many of these—particularly freshwater—sites where you have contaminated sediments and dredging is not being done for transportation purposes, there is a serious question about whether the remediation activity itself creates more risk than leaving the system alone to recover. You have a series of equations on this side that have to do with summing the risks of natural recovery, and you have a series of equations on the other side that have to do with summing all the risks associated with active remediation, whatever that is. I do not think it is impossible to get a handle on those risks. I think you can, and it needs to be looked at on a site-specific basis.

Pavlou: In our report, we considered natural recovery an alternative to be evaluated for risk reduction. We also determined that, to attain acceptable risk levels, we might consider a combination of alternatives, including natural recovery. We might kick-start it with removal, capping, or some containment, then let it go back to an acceptable risk level with natural recovery over a time frame that is mutually agreeable to the stakeholders.

Audience Member: I want a better understanding of how the status quo on the Fox River would be characterized. If it is not natural recovery, then what would be a good summary of the action that is being contemplated or taken?

Missimer: I was not referring to the Fox River when I said it was incorrect to characterize natural recovery as the status quo. That was not a site-specific comment. In the Fox River, we have had continual reductions in fish tissue concentrations. Fish tissue concentrations in the Fox River are dropping by 50 percent every five years in most species.

Audience Member: I would like to comment that the "no action" alternative is not a "no cost" alternative. There is a cost in terms of human health. There is a cost in terms of the impact on natural or living resources and on the people, industries, or businesses that rely on the use of those natural resources.

Audience Member: I feel a need to state the obvious. During natural recovery, the water does not meet CWA "fishable, swimmable" standards. We are talking about time here. For 25 years, that river has not been fishable or swimmable; we are talking about natural recovery doing nothing.

Audience Member: Steve Garbaciak mentioned that the EPA sediment management strategy referred to natural recovery as a preferred option. I have not read the whole document, but the portions I read that relate to natural recovery make no mention of it as a preferred option. What it says is—and I think we agree—that it is an option, but there are a lot of uncertainties and research questions that need to be answered before we can implement a strategy of natural recovery with any confidence.

Audience Member: There is a perception that we should stay away from natural recovery—that it is like no action, an easy way to get out of doing something. That is not the issue. It applies in some cases; it does not apply in others. In other cases, dredging makes sense. In still others, capping makes sense. What we need to do is to find out what proper and effective remediation is. John Connolly said there is a tendency to view dredging as risk reduction. In some cases it is; in some cases it is not. It is the same with no action.

We are spending a lot of money as a society on sediment remediation, maintenance dredging, and other things. Let us quantify what effect that has had on the environment in terms of risk reduction. Right now the data are insufficient to allow us to say one thing works better than another. But we are doing things, and if we could gather information to determine what does or does not work, that would go a long way toward resolving these questions.

Appendix A

Conference Poster Displays and Exhibits

Battelle

Contaminated Sediment Evaluation, Remediation Action Alternatives, and Regulatory Determination

Since the 1800s, waters in the New York Bight Apex and surrounding areas have been used for disposal of dredged material and a variety of other waste products, including municipal garbage, building materials, sewage sludge, and industrial waste. Ocean disposal of garbage was stopped in 1934 and ocean disposal of other waste products ended with the passage of the Ocean Dumping Ban Act. Despite past and current uses of the Bight Apex, the region is rich in fish, shellfish, and mineral resources, contains habitats used by endangered species, and is of significant commercial, recreational, and cultural importance.

In the mid 1990s, field studies of the Bight Apex detected undesirable levels of bioaccumulative contaminants and toxicity in surface sediments in and around much of the Mud Dump Site (MDS), the Environmental Protection Agency's (EPA's) designated ocean disposal site for dredged material from the Port of New York and New Jersey. In July 1996, administrators of EPA, the U.S. Department of Transportation (DOT), and the U.S. Army Corps of Engineers determined that the Mud Dump Site should be closed and a Historic Area Remediation Site (HARS) designated to remediate the degraded sediment areas. Battelle provided multidisciplinary programmatic and technical services to EPA for the closure of MDS and designation of HARS. Over a two-year period, Battelle conducted field surveys, literature reviews, laboratory analyses, and National Environmental Policy Act (NEPA) process support for EPA. Physical conditions were characterized through open literature sources, agency file data, and National Oceanic and Atmospheric Administration (NOAA) and USACE oceanographic surveys. Chemical evaluations were based on new field samples and laboratory analysis. To evaluate contaminant bioavailability, whole-sediment and infauna tissue samples were quantified for trace-metal and organic constituents. Contaminants of concern included dioxin and related congeners. Effort was devoted to characterizing Bight Apex fish, shellfish, and endangered species habitat because of the economically important commercial and recreational industries in coastal New Jersey and Southern Long Island that depend on these natural resources. Cultural features (e.g., shipwrecks) of historical importance within the degraded sediment areas were evaluated in accordance with Section 106 of the National Historic Preservation Act of 1966, and eligibility determinations were made for potential listing in the National Register of Historic Places.

Following full characterization of the Bight Apex study area, four management alternatives were considered:

1. No action;
2. Close MDS/no HARS designation;
3. HARS designation and sediment remediation; and
4. HARS designation and sediment restoration.

Through the NEPA process, EPA determined that HARS remediation with uncontaminated dredged material (alternative 3) was the appropriate action, and issued the necessary federal rulemaking to close MDS and designate HARS. Degraded sediment areas within HARS are currently being remediated by placement of a 1-m layer of uncontaminated sediment, isolating toxic conditions and bioaccumulative contaminants from the Bight Apex ecosystem.

Brookhaven National Laboratory

Integrated Sediment Decontamination for the New York/New Jersey Harbor

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 overall, comprehensive, dredged-material management plan being developed by the USACE-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 m3) levels. Procedures for demonstration testing on scales from 750 m^3 to 75000 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.

Cable Arm Inc.

How Dredging Is Done

Cable Arm offered a continuous VHS display focusing on polychlorinated biphenyl (PCB) remediation, specifically on how the reduction of treatment costs of contaminated sediments begins with how the dredging is done. Two projects were highlighted:

- Sediment clean-up project at the Ford Motor Co. Plant in Monroe, Michigan; and
- Dredging environmentally sensitive materials at the Dow Canada St. Clair River site in Sarnia, Ontario.

California Regional Water Quality Control Board

Obstacles to Beneficial Reuse of Dredged Sediments in the San Francisco Bay Area

This poster display described the current status of eight proposed beneficial reuse projects in the Bay Area and one completed project. The focus will be on the factors that resulted in progress on some projects and obstacles to progress on others. Reuse projects using dredged material include wetland restorations with and without confined aquatic disposal, agricultural enhancements of reclaimed lands, capping of hazardous wastes on port property, creation of subtidal habitat, and repair of levees surrounding reclaimed lands.

Five state and federal agencies have participated in the development of a Long Term Management Strategy for Dredged Materials in the San Francisco Bay Area. Several alternatives for reducing the impacts of dredging on the San Francisco Bay ecosystem were evaluated in a combined environmental impact report-environmental impact statement (EIR/EIS), that is due to be finalized this year. The preferred alternative selected in the EIR/EIS includes a reduction of dredged material disposal in the Bay, with an eventual distribution of 40 percent ocean disposal, 20 percent "in-bay" disposal and 40 percent beneficial reuse.

Although an average of 6 million yd^3 of dredged material is produced in the Bay Area each year, design and completion of beneficial reuse projects have been slow. Beneficial reuse projects have been difficult to complete, due to the cost of transporting dredged material upland, institutional constraints (such as restrictions on cost sharing), engineering constraints (preparation of dredged material for structural fill) and lack of appropriate reuse sites near the San Francisco Bay margin.

Clean Ocean Action

Alternatives for Managing Contaminated Sediments in New York Harbor

Contaminated sediments pose ecological and human health risks in many bodies of water throughout the United States. In the Hudson-Raritan Estuary/New York Harbor, contaminated sediments come from a multitude of sources, including discharges of industrial waste, sewage, and storm water; leakage from waste dumps; runoff from city streets and air pollutants contained in rainwater. The magnitude of the sediment contamination problem in New York Harbor is evidenced by advisories against consuming fish with toxic bioaccumulative sediment contaminants.

Dredging to maintain shipping channels and sustain waterborne commerce in the New York Harbor region results in the need to dispose of millions of tons of sediment each year. In the past, dredged material from the harbor was routinely dumped at an ocean disposal site known as the Mud Dump Site, located 6 mi (9.7 km) off the Monmouth County, New Jersey, coastline. However, much of this dredged material is contaminated with chemical pollutants, and environment impacts resulting from decades of this practice necessitated the closure of the Mud Dump Site on September 1, 1997, and designation of an approximate 9-mi^2 (23.3-km^2) area surrounding the dump site as the Historic Area Remediation Site. Efforts are currently under way to implement environmentally sound, alternative methods for managing dredged materials in the New York Harbor region.

In order to make informed decisions, citizens need to understand the problems associated with contaminated sediments in the marine environment and have information on current and potential future dredged material management initiatives in the New York Harbor region. Clean Ocean Action has produced *Alternatives for Managing Contaminated Sediments in New York Harbor: A New Jersey Citizen's Guide* for this purpose. Information contained in this publication is based on community needs identified at a series of workshops held in August 1997. The guide is intended to provide citizens with background on the various issues surrounding the dredged material management alternatives and with the resources to understand the issues and respond to proposals for dredged material management that might arise in their communities.

EA Engineering, Science and Technology, Inc.

Minimizing Turbidity and Associated Impacts Due to Dredging and Dredged Material Disposal

Increasingly, permits for dredging and aquatic disposal require monitoring to assure that turbidity does not exceed a level that would cause an adverse environmental impact. Drivers for these requirements include the following:

- Concern that turbidity itself would create conditions adverse to aquatic organisms;
- Use of turbidity as a surrogate for sediment-borne contaminants; and
- Real-time feedback on the zone that disposal and construction activities affect.

Technologies and monitoring techniques that EA has applied to specific project needs include the following:

- ADCP for real-time description of the disposal plume in Boston Harbor;
- Acoustic fish-deterrence techniques to minimize the impact on fish;
- TSS sampling and transmissometer readings at the Newark Bay confined disposal facility (CDF);
- Real-time monitoring of construction activity at the Poplar Island Facility; and
- Use of the environmental bucket to reduce impact and also as a monitoring device.

The display presented case studies for each of these techniques.

ECDC East L.C.

ECDC offered a continuous video presentation focusing on two recent applications of dredge sediments recovery and recycling technologies. The projects are the Seaboard site in Kearny, New Jersey, and the OENJ site in Elizabeth, New Jersey.

ENSR

Sediment Recovery Analysis Through the Application of 3-D Models

Sediment remediation is a costly and complex process. Typical alternatives may involve dredging large amounts of material, or capping in place. These solutions may be more environmentally harmful than leaving contaminated material in place to recover naturally.

A methodology for sediment remediation analysis has been developed and implemented and involves a combination of hydrodynamic and toxics kinetic models that provide site-specific data to support natural recovery. The models used were EFDC, a 3-D hydrodynamic model, and WASP/TOX15, a toxics fate and transport model. Defining recovery regions in detail allows greater precision in developing remediation strategies than is provided by a simple, screening-level model. The approach allows evaluation of the effectiveness of alternate remedial approaches and can guide development of focused, long-term monitoring programs.

The methodology was implemented for a pulp mill that discharged an average of 30 to 40 million gal/day (113.5 to 151.4 L/day) of wastewater to an adjacent cove during its operations, contributing to low dissolved oxygen and high organic content in the sediments. Sampling results showed that more than half of the cove had chemicals of concern above sediment quality criteria. The contaminants of concern included total organic carbon (TOC), ammonia, and 4-methylphenol.

The combination of the 3-D hydrodynamic model and the toxics fate and transport model was calibrated to reproduce observed velocity data and sediment concentrations based on a 41-year discharge of pulp mill effluents. Recovery of sediments was simulated by incorporating zero discharge (since effluent would no longer be discharged after the 1997 source control) with natural recovery processes such as

1. Burial by new, clean sediments;
2. Chemical biodegradation; and
3. Diffusion and tidal flushing to predict the reduction in the concentrations of chemicals of concern over a 20-year simulation period.

Model results showed sediment recovery of TOC in the top 10 cm of sediment within 15 years. Results for 4-methylphenol and ammonia also showed recovery; however, there were some hot spots where other remediation strategies could be implemented.

EPA National Risk Management Research Laboratory

Contaminated Sediments Research Program

The EPA display highlighted the various areas of research and projects with which the National Risk Management Research Lab is involved, including

- Enhancement of confined disposal facility performance;
- CDF Treatment-Use of hydrogen to detoxify highly chlorinated organic contaminants in sediments;
- Use of iron filings (zero-valent iron) for the chemical dechlorination of organics in sediments; pilot plant studies of biotreatment for dredged sediments (i.e., land treatment);
- In situ treatment, such as microbiological immobilization of lead from sediments in situ and in situ biorestoration of contaminated sediments and determination of natural recovery rates;
- Fate and transport of contaminants—engineering models for adsorption and desorption on sediments; and
- Determination of bioremediation endpoints by isotopic analysis of pollutants and metabolic products.

The Environmental Research Center–State University of New York

Volatile Losses of Volatile and Semivolatile Compounds During Soil Remediation

Recent research by the Environmental Research Center and the University at Albany School of Public Health indicates semivolatile compounds readily volatilize during drying and remedial processing of contaminated soils and sediments. These findings suggest significant quantities of organic contaminants can be released to the atmosphere during remedial measures involving excavation, dredging, dewatering and drying of contaminated solids.

Laboratory experiments conducted by the Environmental Research Center on PCB-contaminated sediments collected from New York Superfund sites indicate more than 75 percent of the total PCB concentration of air-dried sediments can be lost through volatilization at ambient temperatures and relative humidity. Greatest volatile loss from the contaminated sediments occurred when water overlying the sediments evaporated.

These results have implications on the handling and remediation of semivolatile contaminated sediments with specific emphasis on the evaporative loss of water that can result in the redistribution of contaminants to the atmosphere. Volatile losses from activities involving dredging, dewatering, and remedial technologies (low temperature thermal desorption, aerobic biodegradation, lime solidification, and others) may result in the atmospheric redistribution of organic contaminants.

Federal Energy Technology Center, U.S. Department of Energy

Redox Gel Probe (RGP) Technology for the Evaluation of Heavy Metal Stability in Sediments

The redox gel probe (RGP) was developed to evaluate the stability of metals precipitated within the sediments of constructed wetlands used to remove metals from acid mine drainage.

Over the past five years, it has been repeatedly field tested and has proved to be easy and inexpensive to use and readily adapted to site-specific environmental concerns. Solid redox-sensitive compounds, such as manganese dioxide (MnO_2), are incorporated into gels held in rigid plastic holders, leaving one longitudinal surface of the gel exposed. These probes are pushed vertically into sediments and are left in situ. After an incubation period of hours to weeks, the probes are removed from the sediment, and the depths where compound dissolution, transformation, and redistribution have occurred are determined relative to the location of the sediment-water interface.

Gel probes placed along surveyed transects and grids in wetland sediments have yielded maps of compound stability that reflect the beneficial and detrimental influence of various environmental variables on pollutant retention and diffusive metal flux from sediments. In one example, gel probes containing particulate manganese compounds (MnO_2, $MnCO_3$, and MnS) were placed along a surveyed grid in the sediment of a wetland built to remove Mn from coal mine drainage at a site in western Pennsylvania. The stability of these compounds within the wetland was shown to be highly variable both temporally and spatially, suggesting that long-term manganese retention in sediments was unlikely.

The method has its most likely application to fine-grained metal-contaminated sediments where the stability of metal species in sediments is in question. Data from recent experiments using live bacteria incorporated within the RGP gel matrix and the potential applications of this approach also will be shown.

Foster-Wheeler/Hartman Consulting Corporation & Port of Tacoma

Sitcum, Blair, Milwaukee Project

The Sitcum, Blair, Milwaukee Project is a landmark cleanup and redevelopment achievement. Hartman Consulting Corporation worked with the Port of Tacoma USA to balance environmental protection with economic vitality and to push traditional engineering and construction techniques to new limits.

Multiple objectives were achieved simultaneously by linking the Sitcum and Blair Waterways cleanup actions with the need to expand navigation uses in the Blair Waterway and to create land for terminal use in the Milwaukee Waterway. Activities included placement of 868,000 cubic yards of contaminated sediments in the Milwaukee nearshore fill. This beneficial use of contaminated sediment created 23 acres of new container cargo marshaling land. The project also unlocked over 300 acres of land for future container terminal development and created new economic opportunity for the entire Puget Sound region.

Hazardous Substance Research Center (HSRC)–South and Southwest

Various Projects and Technologies

The HSRC display highlighted a broad range of projects and technologies with which the center has been involved.

International Technology Corporation (ITCorp)

Bayou Bonfouca Project

An ITCorp joint venture with OHM Corporation remediated the Bayou Bonfouca Superfund site in Slidell, Louisiana. The work was completed in two phases:

Phase one was completed in the fall of 1993 and included completion of regulatory documents and plans required for regulatory approval, prepared base line air and soil analytical surveys, preparing the site for the Hybrid Thermal Treatment System™ (HTTS™) incineration system, operating the groundwater treatment system, constructing and erecting the incinerator and support facilities, performing initial work on the on-site landfill, completing the incinerator trial burn, and incinerating stockpiled, contaminated material on-site.

Phase two of the project included mobilizing dredging and filter-press dewatering equipment; dredging, dewatering, and incinerating approximately 169,000 yd^3 (129,285 m^3) of contaminated bayou sediments; backfilling the bayou; completing the on site landfill; providing continued operation of the groundwater treatment system; demobilizing the incinerator and support facilities; and performing site restoration.

Approximately 1 mi of Bayou Bonfouca was dredged using a barge-mounted mechanical excavator. Dredged material was processed through an on-board slurry unit and then pumped to the on-site retention pond through a concentric, double-walled flotation dredge line. Barge position and depth of cut were controlled by a computerized elemetry unit which adjusted for stream flow and tidal effect and controlled the depth of excavation from 15 ft down to 25 ft (4.6 m down to 7.6 m). The critical effort of stabilization of over 5,000 ft of bayou bank was accomplished by sheet piling along the shoreline. Piling depths ranged from 35 to 40 ft (10.7 to 12.2 m) and were positioned to prevent incursion into the underlying clean-water aquifers. Significant bayou-bed soil boring and analysis preceded initiation of this highly critical activity. Inclinometers monitored the sheet piling during dredge operations to ensure that minimal bank movement occurred.

Lawler, Matusky & Skelly Engineers LLP/ECDC

Beneficial Reuses of Contaminated Dredged Material in New York Harbor

This poster display presented several case studies involving beneficial uses of contaminated dredged material in New York Harbor and related them to the overall framework for contaminated sediment management (CSM) recently developed by the authors (Abood

& Metzger, 1997). These cases are either being successfully implemented or are in development. An overview of the dredged material management crisis threatening the New York/New Jersey Port also was presented. In addition, an outline of several dredged material placement alternatives being considered by public and private entities was described. These alternatives include containment islands, nearshore containment, subaqueous pits, upland placement, decontamination, and beneficial uses. Methods to minimize sediment quantity and contaminant levels are also being evaluated.

There is a vast array of potentially beneficial reuses for dredged material incorporated in the CSM framework. However, this poster display focused on utilization of processed dredged material as

- Remediation capping material;
- Structural fill;
- Landfill cover; and
- Mining reclamation material.

The process involved

- Dewatering of low to moderately contaminated dredged material;
- Debris removal for recycling and disposal;
- Addition of proprietary cement-based additive formulae;
- Blending of the sediments and additive using patented mixing units;
- Curing of the mixed product;
- Transfer to a permitted site;
- Off-loading and final placement; and
- Inspection and monitoring.

The poster display illustrated various aspects (zoning, environmental, permitting, product specifications, manufacturing, and operations) of two recent applications of this technology: the Seaboard site in Kearny, New Jersey, and the OENJ site in Elizabeth, New Jersey.

Louisiana State University (LSU)

Dredging: A Two-Edged Sword in Remediating Contaminated Bed Sediment

Depending on site-specific conditions and its implementation at a particular site, environmental dredging either can be the key effective element of the remediation process or it can make matters worse. This proposition was paramount in the minds of the 28 experts from consulting firms, industry, government, and academia who gathered on the LSU campus, February 11, 1998, for a workshop on dredging effectiveness as it relates to remediation of contaminated bed-sediment. The workshop marked the beginning of a new research thrust for HSRC-South and Southwest, and was convened to gather initial information to produce a position paper, the subject of the poster.

The poster display focused on the various aspects of effectiveness and limitations of environmental dredging. Specific topics covered included the state of the art of environmental dredging, dredge types available, contaminant removal efficiencies, spillages, short-term impacts, long-term impacts, mass removal goals and risk reduction goals, post-dredging monitoring data sets, design removal targets vs. leftover residues, innovative dredges, predictive techniques (such as modeling and laboratory elutriate tests), and case studies cataloging successes and failures vis-à-vis risk management for human health and the ecology.

Malcolm Pirnie, Inc.

Newark Bay Confined Disposal Facility

The Port Authority of New York and New Jersey (PANYNJ) has constructed a subaqueous CDF at Port Newark, New Jersey. The Newark Bay Confined Disposal Facility (NBCDF) is a 1.5 million yd^3 (1.15 million m^3) "pit" excavated from the bottom of Newark Bay, and is a much-needed disposal site for dredged material from portions of New York Harbor. Because the NBCDF is a first-of-its-kind solution, it serves as an innovative and cost-effective model for shipping ports across the United States. It is also the object of intense public scrutiny.

At New York Harbor, the dredging and disposal problem is as acute as anywhere; between 4 to 6 million yd^3 (3 to 4.6 million m^3) are dredged each year. As international commerce grows, the port must accommodate larger and larger ships or lose market share to increased competition from rival ports such as Norfolk, Virginia, or Halifax, Nova Scotia. The Port of New York/New Jersey has spent hundreds of millions of dollars dredging to attract bigger container ships, but extra efforts must be made to accomplish and maintain the 45-ft (13.7-m) deep channels required for the latest vessels. Increased demand for dredging is countered by increasingly limited options for disposal: In 1996 an agreement was made to close the Mud Dump, the main disposal site for contaminated sediments located off of the New Jersey coast.

At the onset of operations in November 1997, the NBCDF had a surface area of 26 acres and a depth of 70 ft (21.3 m). It is anticipated that filling of the NBCDF will occur over a period of approximately two years. Dredged materials eligible for disposal in the NBCDF include those from Port Authority and private projects located in Newark Bay, the Arthur Kill, and the Kill Van Kull. The user fee for disposal in the NBCDF is \$29/yd^3, which is very low when compared with other disposal options.

Malcolm Pirnie, Inc., has been retained by PANYNJ to manage operation maintenance of the NBCDF. Each project considered for the NBCDF must be fully permitted and insured. Precautionary measures include a water quality monitoring program, intermittent bathymetric surveys, capping and penetrometer tests, and long-term monitoring.

Malcolm Pirnie, Inc., Environmental Restoration Group

Using GIS to Identify and Characterize Sediments To Be Dredged

Malcolm Pirnie, Inc., under contract with Louis Berger and Associates, Inc., for the New York District Army Corps of Engineers, was tasked with providing technical assistance in plans for deepening the Arthur Kill and Kill Van Kull/Newark Bay federal navigation channels in New York Harbor. To develop project costs, the Corps needed to determine which portion of proposed channel deepening would require bedrock excavation and which portion of the work would require ordinary silt dredging. Further, since the closing of the Mud Dump Disposal Site off Sandy Hook, New Jersey, to contaminated dredged spoils, disposal of the potentially contaminated material is a critical issue. In consideration of this, Malcolm Pirnie used soil types and other geologic information rather than costly and time-consuming analytical testing to estimate quantities of industrial-era "black mud" which likely would require treatment or upland disposal, because it exceeds EPA disposal criteria.

Using existing information in the form of borings, seismic data, and bathymetry, Malcolm Pirnie utilized GIS\Key™, a comprehensive geographic information and data management software. GIS\Key™ was used to manage the abundant data, develop channel cross-sections and other graphics to assist the Corps with presentations to regulators, and interfaced with Quicksurf to perform 3-D volume calculations to provide the basis for costing.

By using geologic and soil-type information in conjunction with sophisticated computer software, Malcolm Pirnie was able to provide working estimates of quantities of potentially contaminated sediments without the need for time-consuming and costly analytical testing. This allowed the Corps to work with other agencies to identify potential disposal sites before confirmation sampling and testing of the dredged spoils.

New Jersey Maritime Resources

Contaminated Sediments in New Jersey Marine Waters: Moving from Crisis to Management

Contaminated marine sediments pose an ecological and economic threat to New Jersey. However, the risks associated with marine sediments in the environment vary depending on the nature of the contamination, the concentrations present, and the ecosystem exposed. The available data for sediments from the Port District have been summarized and used to evaluate appropriate management of these contaminated sediments.

Examination of the data reveals that the current levels of contamination in most harbor sediments make the material unsuitable for open-water disposal. An analysis of the near- and mid-term dredging needs for the Port of New Jersey indicates that over 5 million yd^3 (3.8 million m^3) of contaminated sediment must be dredged over the next 8 years. Combined with the scarcity of open water disposal in nearshore areas, this has prompted a search for suitable upland disposal areas. Upland placement of contaminated sediments often results in significantly lower risk to the overall ecosystem than in-water disposal and also can be used to remediate sites such as landfills, brownfields, abandoned strip mines, and other known contaminated sites. Using currently available amendment technology, most dredged materials in the Port District meet acceptable upland use criteria without decontamination. These efforts have resulted in approximately 13 million yd^3 (10 million m^3) of permitted upland capacity, including three contaminated sediment processing facilities. Permits for an additional 2.3 mi yd^3 (1.76 million m^3) are currently in process.

Long-term management strategies currently being explored and encouraged by the Office of New Jersey Maritime Resources were presented in the poster display. Efforts included a toxics tracking and reduction plan, sediment decontamination of localized hot spots, remedial dredging, mine and quarry reclamation, utilization of GIS to locate additional brownfield and landfill reclamation sites, and the use of clean dredged materials for habitat restoration and wetlands creation.

National Oceanic and Atmospheric Administration—Fisheries, Office of Habitat and Conservation

The National Marine Fisheries' Office of Habitat Conservation is the agency's focal point for coastal and estuarine habitat conservation, protection, and restoration. Part of its mission is to

- Restore fish habitats and other natural resources;
- Advance the science and technology of coastal habitat restoration; and
- Transfer restoration technology to the public, the private sector, and other governmental agencies.

Under the Coastal Wetland Planning, Protection, and Restoration Act, the Office and the State of Louisiana are engaged in a partnership to restore salt marches lost to erosion, subsidence, and hydrological alterations. The office administers grants programs to foster community-based habitat restoration projects and to fund research on habitat restoration. The community-based grants seek to promote stewardship and a conservation ethic among coastal communities; the research grants work to advance the science and technology of coastal habitat restoration. The office administers the implementation of the Essential Fish Habitat provisions under the Magnuson-Stevens Act. All of these programs have some involvement with dredge sediments.

Parsons Brinckerhoff

Lime Stabilization and Disposal of Contaminated Dredged Harbor Sediments

The lime stabilization of contaminated dredged sediments for Boston's Central Artery/Tunnel crossing project was the first of its kind in the United States. Under this plan, 68 000 m^3 of contaminated sediments, dredged from the upper 1.5 meters of Boston Harbor, were mixed with lime and contained in a lined and capped site on Governors Island next to Logan Airport. The dredged sediments were chemically stabilized and solidified by the addition of 10 percent quicklime by volume to meet environmental and engineering requirements. Leach tests indicated the sediments were completely stabilized—there were no detectable levels of contaminants.

The containment site was enclosed by a dike 4.6 m high and lined with a double geomembrane sandwiching a geonet to intercept leachate in case of rupture in the primary geomembrane. A gravel and perforated pipe underdrain system was installed below the double liner to intercept high groundwater and drain it into a sump for long-term monitoring. A leachate collection pump also was provided to collect any leachate that might be intercepted by the geonet. Mixing with lime in the field was initially performed in the open, but because of problems with windblown dust migrating to airport runways, this practice was discontinued and a pugmill was set up at the site. A protective foam was applied for odor control, and the stabilized sediments were leveled, capped, and surcharged in preparation for reclamation by Massport, the airport's operating authority.

Port of Long Beach

Two Birds with One Stone: Habitat Replacement and Dredged Material Disposal in One Solution

The Port of Long Beach's proposal to reuse the former U.S. Naval Station Long Beach included dredging approximately 4 million yd^3 (3 million m^3) of sediments. Some of the dredging would eliminate a 26-acre shallow-water area presumed to be foraging habitat for the federally-listed endangered California least tern, and some would involve the removal of approximately 700,000 yd^3 (535 500 m^3) of contaminated sediment designated as unsuitable for unconfined aquatic disposal. Under current resource agency policy, the loss of the wildlife habitat must be mitigated by the creation of at least as much shallow-water area nearby. The sediments contaminated by 50 years of U.S. Navy activity contained elevated concentrations of heavy metals, petroleum hydrocarbons, and PCBs. The Port had no available vacant land or planned fills that could accept the contaminated sediments, which posed a serious disposal problem.

The port's solution to these problems was to design a replacement shallow-water habitat that would be constructed of contaminated sediments capped with clean material. This solution was possible because, with the exception of a small amount of sediment designated as hazardous waste due to a high heavy-metals concentration, all of the contaminated material was deemed suitable for confined aquatic disposal. The quadrilateral site would have new, multi-lift rock dikes on three sides and be bounded by an existing mole on the fourth. The most seriously contaminated material would be placed in the bottom of the structure with progressively less contaminated material above, finishing with a 5-ft (1.5-m) thick cap of clean material from the existing habitat area. Modeling demonstrated the effectiveness of the design in preventing contaminant release from exceeding water quality criteria at the sediment-water interface.

Port of Oakland

A Sediment Decision Framework for Beneficial Reuse Evaluation of Dredged Material in the Port of Oakland

The Port of Oakland's Vision 2000 Terminal Development and 50-ft (15-m) harbor deepening project will expand and integrate ship, rail, and truck freight handling capacity to serve the San Francisco Bay area and to meet the increasing needs of the nation. The 50-ft harbor deepening project will deepen and widen Oakland Harbor and selected berths, removing approximately 14 to 15 million yd^3 (10.7 to 11.5 million m^3) of marine sediment and 4 to 5 million yd^3 of intertidal bank material. The key to gaining rapid agency approval for the Port's deepening project was the production of an overall screening strategy to characterize existing sediment. In turn, this characterization would support the evaluation of multiple reuse and disposal options, with a majority of the dredged material geared toward beneficial reuse.

In a collaborative effort with DMMO, the Port's consulting team structured a tiered testing protocol to maximize material suitability determinations by combining the guidelines in the following sources:

1. *Evaluation of Dredged Material Proposed for Ocean Disposal—Testing Manual* (USEPA/USACE 1991; also known as the "Green Book");
2. *Testing Guidelines for Dredged Material Disposal at San Francisco Bay Sites* (Public Notice 93-2, USACE, 1993);
3. *Interim Sediment Screening Criteria and Testing Requirements for Wetland Creation and Upland Beneficial Reuse* (Cal EPA, CRWQCB, 1992); and
4. *Environmental Health Standards for the Management of Hazardous Waste* (Title 22, California Code of Regulations).

By synthesizing a framework from these four sets of guidelines, the port developed a stratified sampling and analysis plan to characterize sediments for four broad classes of reuse and disposal options: ocean disposal, wetland creation, upland construction, and landfill disposal. Preliminary suitability determinations have been completed by the port and are currently under review by the agencies. The port's preferred disposal alternative for approximately half of the marine sediments was habitat enhancement in Middle Harbor; however, because of the regional policy discouraging any type of in-bay fill as well as a lack of coherent guidelines for dealing with all the gradations of sediment contamination, the plan for a Middle Harbor habitat creation has met some resistance on both the political and technical fronts.

This poster reviewed the overall screening strategy used to characterize Oakland Harbor sediments as well as the political ramifications and environmental acceptance of both sediment suitability determinations and beneficial reuse options.

T&M Associates

Dredge Material to Beneficial Uses

The display highlighted a proposal to establish a Public/Private Partnership to operate a permanent dredge material (DM) handling facility. The site would grow steadily as the material is processed with beneficial use (bricks, masonry, structural fill, and composted soil).

The concept was: We have been treating DM as a waste; now let us use it for more logical benefits.

U.S. Army Corps of Engineers (USACE), New York District

The Beneficial Use of Contaminated Sediments for Habitat and Water Quality Improvement in New York Harbor

Because ocean disposal of most dredged material from New York Harbor is no longer an option, the New York District of USACE has been encouraged to search for innovative solutions to the contaminated dredged material disposal problem. Some of these potentially innovative solutions are nontraditional and distinctly "urban" in nature, due to the severe lack of upland and in-water areas for disposal and associated contamination problems. These potential options include the following:

- The use of contaminated sediment for filling highly degraded dead-end basins, which may be a potential source of contaminant uptake to estuarine organisms.
- Filling and capping of bathymetric depressions to improve water circulation and eliminate degraded and often hypoxic pit environments.
- Constructing wetlands with contaminated sediments, and capping them with clean sediments, which would act as outfall and runoff "filters" to improve local water quality.
- Constructing wetlands with contaminated dredged material at the base of landfills to retard the leaching of landfill contaminants from entering the estuary.

Efforts to implement these concepts in the New York area were described, including a discussion of inherent technical and regulatory problems. Examples of similar successfully implemented projects from other areas were provided.

USAE Waterways Experiment Station (WES)

Various Projects and Technologies

The USAE WES display highlighted a broad range of projects and technologies with which USACE has been involved.

University of Nebraska

Risk-Cost Trade-Off Analysis Under Uncertainty for Dredged Material

Disposal of contaminated dredged material can pose risks to ecological and human populations. These risks can be reduced by using disposal alternatives that incorporate measures to confine the contaminated dredged material; however, these measures can increase disposal costs significantly. Risk-cost trade-off analysis is used to identify the disposal alternatives that provide the greatest risk reduction at the lowest cost.

Risk and cost assessments for dredged material management alternatives are often associated with large uncertainties. Understanding these uncertainties can be critical in the decision-making process to ensure that appropriate management alternatives are selected. Therefore, a risk-cost trade-off analysis that incorporates uncertainty analysis into the decision-making framework must be developed.

Risks to humans and ecological species were estimated in a case study for each of several disposal alternatives. A multicriteria decision-making method was used to trade off the risks and costs for these disposal alternatives. Uncertainties were encoded into the MCDM method, using fuzzy set theory (probabilistic methods such as Monte Carlo Analysis also can be used). The final risk-cost trade-off value for each disposal alternative was computed as a fuzzy number allowing the management options with their associated uncertainties to be compared and ranked.

University of Washington

Evidence for Anaerobic Degradation of Phenanthrene in Marine Sediments

Recent work in anaerobic marine sediments is reversing the perception that oxygen is required for microbial degradation of polycyclic aromatic hydrocarbons (PAH) in the environment. To better measure the extent and rate of anaerobic PAH degradation in situ, heavily contaminated sediments were collected from Eagle Harbor, an EPA Superfund site in Puget Sound, Washington, and whole subcores (1.6 x 10 cm) were injected at 0.5-cm depth intervals with tracer quantities of 14C-labeled phenanthrene (67-70 mg/ml porewater), a dominant contaminant at the site. Replicate core were sacrificed, after incubation periods of 0 to 26 d at in situ temperature (13 C), and analyzed versus depth in sediment for the evolution of 14C-labeled carbon dioxide.

Results indicated that up to 48 percent of the labeled phenanthrene in the contaminated sediments was converted to carbon dioxide over the full incubation period, while minor-to-negligible conversion occurred in control sediments from Blakely Harbor, a similar but uncontaminated site. These results bear significantly upon sediment treatment decisions, especially those that exclude oxygen from the system (sediment capping) and rely on native bacterial populations to ameliorate contamination levels.

The poster display was part of the Marine Bioremediation Program (MBP) at the University of Washington (www.weber.u.washington.edu~uwmbp/hmmbp.html). Ten faculty and students from four colleges are determining the mechanisms and rates by which PAHs are biodegraded. Scientific approaches include in situ simulation, mixed culture enrichments, isolations and identification of pure culture rates, philogenetic and molecular methods, and mathematical modeling. MBP is a multidisciplinary research and training initiative focusing on bioremediation of contaminated marine sediments. Historically, the focus has been on biodegradation of creosote, a wood preservative composed primarily of polycyclic aromatic hydrocarbons (PAHs) such as naphthalene and phenanthrene; however, it also includes interests and expertise in the degradation of chlorinated organic compounds and detection of mobilized heavy metals. The primary field site has been Eagle Harbor, which was contaminated with creosote from a now-defunct wood treatment plant located on its shore, as well as lesser amounts of chlorinated organics and heavy metals. Creosote and its components are toxic substances that have been shown to have mutagenic properties. EPA arranged for placement of clean sediment (capping) over the harbor's contaminated seabed in an effort to contain the toxic compounds.

Understanding how organic contaminants are degraded naturally in the marine environment is the primary objective of MBP. The program has been supported in the past by the U.S. Office of Naval Research and the University of Washington Office of Research. The program continues with additional support from individual grants from a variety of federal, state, and private sources.

Woodward–Clyde International

Demonstration of Scenario Analysis for Evaluating Risk Reduction Alternatives for Remediation of Contaminated Sediments

There is growing consensus for using risk analysis as a primary tool in making remedial decisions for contaminated sediments (NRC 1997). Computer simulation is presented as a successful interactive format for decision analysis as proposed by NRC (1997). This is accomplished by coupling ecological risk assessment with variable scenarios of remedial actions and alternates, while evaluating risk reduction. Two examples of computer simulators were demonstrated.

The first was a simulator developed for a chemical manufacturing facility to facilitate evaluation for remedial alternatives for mercury-contaminated sediments in a southern Alabama floodplain area. The risk analysis simulated the impact of sediment remedial actions (i.e., dredging, covering, source control, and natural attenuation) over time and provided estimates of "how soon or long" while comparing alternatives. Such stimulation allows for direct comparisons between variable degrees of remedial action, combined or individual remedial alternatives, with or without the impact of natural attenuation, all in the context of remedial efficacy or risk reduction. This provided a format for interactive decision making—that is, decision analysis.

The second simulator estimated site- and receptor-specific risk-based sediment concentrations. This provided a rapid and cost-effective means of risk analysis at a higher level than comparison to sediment quality benchmarks. In essence, it represented an abbreviated Tier II Baseline Ecological Risk Assessment (USACE 1996). Such simulation identified modeled site-specific risk-based concentrations based on food-web transfers of the contaminants of potential concern. This risk analysis can be used to decide whether further site-characterization is necessary, develop potential remedial volumes and costs, and suggest a biological sampling plan. Similar simulators have been used successfully in screening for ecological risks at sites within Homestead Air Force Base (AFB) in Florida, helped design a focused supplemental biological sampling at Tinker AFB in Oklahoma, and is presently being evaluated by an industrial client for modification and possible use at a site.

Appendix B

Committee Member Biographical Information

W. Frank Bohlen is a professor of physical oceanography in the department of marine sciences at the University of Connecticut in Groton, Conn. Dr. Bohlen is an expert on turbulence and sediment transport processes and has authored several papers on sediment dispersal associated with the disposal of dredged material and the ocean dispersal of particulate wastes. He has served on many research and planning committees, including two National Research Council committees addressing marine particulate wastes and dredging. Dr. Bohlen has a BS degree from the University of Notre Dame and a PhD degree from the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution.

Lillian C. Borrone, NAE, is Director of the Port Commerce Department of the Port Authority of New York and New Jersey. She oversees the management of major marine terminal facilities within the Port of New York and New Jersey and is also responsible for the Port Authority's industrial parks and other regional development assets, which include Port Newark/Elizabeth Port Authority Marine Terminal complex; Red Hook Container Terminal in Brooklyn; Howland Hook Marine Terminal in Staten Island; industrial parks in Elizabeth, N.J.; and in Bathgate and Yonkers, N.Y.; and the Teleport, a telecommunications office park in Staten Island; Newark Legal Center; Essex County Resource Recovery Facility in Newark; and Waterfront development projects in Hoboken, N.J., and Queens, N.Y. In addition, Ms. Borrone oversees work to strengthen the role of the New York-New Jersey region as a center for international trade and business. Key programs and projects under her direction include new capital development and construction at the marine terminal facilities, implementation of key policies in such diverse areas as dredged material disposal within the port, new business development and long-range strategic planning. She is also responsible for the management and financial performance of these agency assets. Ms. Borrone is past chairman of the American Association of Port Authorities, and a board member of the International Association of Ports and Harbors, the North Atlantic Ports Association, and the Regional Business Partnership in Newark, N.J. She is also chairman of the U.S. Department of Transportation Advisory Committee to the Bureau of Transportation Statistics, past chairman of the TRB Executive Committee, and a member of the Marine Board Executive Committee. In 1996, Ms. Borrone was honored with membership in the National Academy of Engineering for her work in multimodal transportation planning and operations. Ms. Borrone holds a Masters of Science degree in civil engineering and transportation management from Manhattan College and a Bachelor's degree in political science from The American University.

Billy L. Edge is Professor of Ocean and Civil Engineering at Texas A&M University. An internationally recognized expert in coastal engineering and dredging technology, Dr. Edge has pursued a career encompassing service as a senior research physical scientist with the U.S. Army Corps of Engineers, 20 years of academic experience with Clemson University and Texas A&M University, and 15 years of civil engineering consulting practice with Dames and Moore, Cubit Engineering, and Edge & Associates. He has served as secretary of the Coastal Engineering Research Council of the Waterway, Port, Coastal and Ocean Division of the American Society of Civil Engineers; as editor of ASCE's *Proceedings of the International Conference on Coastal Engineering*; and is current chairman of the biennial International Coastal Zone Conference. A registered professional engineer in South Carolina, Florida, and Virginia, Dr. Edge holds BS and MS degrees in civil engineering from Virginia Polytechnic Institute and a PhD in civil engineering from the Georgia Institute of Technology.

Spyros P. Pavlou, co-chair, has more than 20 years of experience in the application of environmental chemistry and toxicology to the evaluation of contaminant transport fate and to the assessment of ecological risks in the aquatic and terrestrial environment. He has provided technical direction and performed numerous risk evaluations associated with the computation of clean-up goals at hazardous waste sites and the development of sediment quality criteria for marine and freshwater environments. He has performed multipathway exposure analysis for organic and inorganic contaminants using deterministic and probabilistic methods, and has integrated quantitative risk analysis in the selection of cost-effective remediation alternatives for hazardous waste site closures. He has co-authored more than 40 papers combining peer-reviewed publications, conference proceedings, feature articles, and oral presentations. His has served as a member of the editorial board of the *Journal of Environmental Toxicology and Chemistry* and provided peer review in the field of hazard assessment. Dr. Pavlou has served on the National Research Council (NRC), Marine Board Committee on Contaminated Marine Sediment Management to evaluate the applicability of risk-cost-benefit trade-off analysis and decision analysis in the management and remediation of contaminated sediments. He has provided expert assistance to the EPA Office of Science and Technology, serving on technical review panels in the area of sediment quality criteria development and contaminated sediment management. He served as technical advisor to the Maritime Administration (MARAD), assisting the Office of Environmental Activities to develop a decision-making methodology for dredged material management. Dr. Pavlou received a BSc degree in chemistry from the University of California at Los Angeles, an MS degree in physical chemistry from San Diego State University, and a PhD degree in physical chemistry from the University of Washington.

Peter Shelley is the senior attorney and project director for the Marine Resources and Water Resources of the Conservation Law Foundation, Inc., a public interest conservation advocacy organization. His areas of concentration are water pollution and conservation, fisheries management, wetlands protection, pesticides, land-use management and planning, and marine resources. Mr. Shelley is a member of the board of directors and policy committee for Save the Harbor/ Save the Bay, Inc., the board of directors of the Center for Coastal Studies, the advisory committee on Statewide Environmental Impact Report in Pesticide Use Rights-of-Way, and the Massachusetts Coastwide Monitoring Project Steering Committee. He is a frequent lecturer, writer, and panelist on a range of environmental issues. Mr. Shelley received a BA degree from Hobart College and a JD degree from Suffolk University Law School.

Louis J. Thibodeaux, co-chair, is Jesse Coates Professor of Engineering at Louisiana State University in Baton Rouge and director emeritus of the EPA Hazardous Substance Research Center-South and Southwest. He has also been a professor or visiting professor at the University of Arkansas, the Ecole Nationale Superieure des Mines de Paris, the University of Exeter (U.K.), and Oregon State University. He has authored numerous papers and book chapters on the transport of contaminants from sediment beds and across the air-water interface. He has served on the editorial boards of the *Journal of Hazardous Materials, Hazardous Waste and Hazardous Materials, American Environmental Laboratory*, and *Remediation*. In addition to teaching and research he is active as a consultant and expert witness for government and corporations. Dr. Thibodeaux is past chairman of the Environmental Division of the American Institute of Chemical Engineers. He is the author of a textbook, *Environmental Chemodynamics—Movement of Chemicals in the Air, Water, and Soil*, now in its second edition. He served on the NRC Committee on Remedial Action Priorities for Hazardous Waste Sites, Committee on Contaminated Marine Sediments, and Committee on Environmental Management Technologies. Dr. Thibodeaux holds BS, MS, and PhD degrees in chemical engineering from Louisiana State University.

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Appendix D

Contaminated Sediments in Ports and Waterways

*Cleanup Strategies and Technologies**

Executive Summary

There is no simple solution to the problems created by contaminated marine sediments,** which are widespread in U.S. coastal waters and can pose risks to human health, the environment, and the nation's economy. Marine sediments are contaminated by chemicals that tend to sorb to fine-grained particles; contaminants of concern include trace metals and hydrophobic organics, such as dioxins, polychlorinated biphenyls (PCBs), and polyaromatic hydrocarbons. Contamination is sometimes concentrated in "hot spots" but is often diffuse, with low to moderate levels of chemicals extending no more than a meter into the seabed but covering wide areas. Approximately 14 to 28 million cubic yards of contaminated sediments must be managed annually, an estimated 5 to 10 percent of all sediments dredged in the United States.

The many challenges to be overcome in managing contaminated sediments include an inadequate understanding of the natural processes governing sediment dispersion and the bioavailability of contaminants; a complex and sometimes inconsistent legal and regulatory framework; a highly charged political atmosphere surrounding environmental issues; and high costs and technical difficulties involved in sediment characterization, removal, containment, and treatment. The need to meet these challenges is urgent. The presence of contaminated sediments poses a barrier to essential waterway maintenance and construction in many ports, which support approximately 95 percent of U.S. foreign trade. The management of these sediments is also an issue in the remediation† of an estimated 100 marine sites targeted for cleanup under the Comprehensive Environmental Response, Cleanup, and Liability Act (CERCLA) (P.L. 96-510), commonly known as Superfund, as well as in the cleanup of many other near-shore contaminated sites.

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** For purposes of this report, contaminated marine sediment is defined as containing chemical concentrations that pose a known or suspected threat to the environment or human health.

† For purposes of this report, sediment management is a broad term encompassing remediation technologies as well as non-technical strategies. Remediation refers generally to technologies and controls designed to limit or reduce sediment contamination or its effects. Controls are practices, such as health advisories, that limit the exposure of contaminants to specific receptors. Technologies include containment, removal, and treatment approaches. Treatment refers to advanced technologies that remove a large percentage of the contamination from sediment.

The Committee on Contaminated Marine Sediments was established by the National Research Council under the auspices of the Marine Board to assess the nation's capability for remediating contaminated marine sediments and to chart a course for the development of management strategies. In the committee's view, cost-effective management of contaminated marine sediments will require a multifaceted campaign as well as a willingness to innovate. The committee determined that a systematic, risk-based approach incorporating improvements to current practice is essential for the cost-effective management of contaminated marine sediments. The committee identified opportunities for improvement in the areas of decision making, project implementation, and interim and long-term controls and technologies, as outlined in this summary. Although the study focused on evaluating management practices and technologies, the committee also found it essential to address a number of tangentially related topics (e.g., regulations, source control, site assessment) because problems in these areas can impede application of the best management practices and technologies.

As part of the three-year study, the committee compiled six case histories of recent or ongoing contaminated sediments projects, visited one of those sites, analyzed the relevant regulatory framework in depth, held separate workshops on interim controls and long-term technologies, and examined in detail how various decision-making approaches can be applied in the contaminated sediments context. The committee also examined the application of decision analysis in contaminated sediments management.

Improving Decision Making

Decision-Making Tools

Contaminated sediments can best be managed if the problem is viewed as a system composed of interrelated issues and tasks. Systems engineering and analysis are widely used in other fields but have not been applied rigorously to the management of contaminated sediments. The overall goal is to manage the system in such a way that the results are optimized. In particular, a systems approach is advisable with respect to the selection and optimization of interim and long-term controls and technologies. Although unlimited time and money would make remediation of any site feasible, resource limitations demand that trade-offs be made and that solutions be optimized.

A fundamental aspect of the committee's recommended approach is the delineation of the trade-offs among risks, costs, and benefits that must be made in choosing the best course of action among multiple management alternatives. A number of decision-making tools can be used in making these trade-offs. Available tools include risk analysis, cost-benefit analysis, and decision analysis.

Cost-effective contaminated sediments management requires the application of risk analysis—the combination of risk assessment, risk management, and risk communication. Contaminated sediments are considered a problem only if they pose a risk that exceeds a toxicological benchmark. In its most elemental form, risk assessment is intended to determine whether the chemical concentrations likely to be encountered by organisms are higher or lower than the level identified as causing an unacceptable effect. The "acceptable risk" needs to be identified, quantified, and communicated to decision makers, and the risk needs to be managed. First, management strategies need to be identified that can reduce risk to an acceptable level. Second, remediation technologies need to be identified that can reduce the risk associated with contaminants to acceptable levels within the constraints of applicable laws and regulations. Third, promising technologies need to be evaluated within the context of the trade-offs among risks, costs, and benefits, a difficult task given the uncertainties in risk and cost estimates. The next step is risk communication, when the trade-offs are communicated to the public.

At present, risk analysis is not applied comprehensively in contaminated sediments management. Risks are usually assessed only at the beginning of the decision-making process to determine the severity of the in-place contamination; the risks associated with removing and relocating the sediments or the risks remaining after the implementation of solutions are not evaluated. The expanded application of risk analysis would not only inform decision making in specific situations but would also provide data that could be used in the selection and evaluation of sediment management techniques and remediation technologies.

Cost-benefit analysis can also be useful for evaluating proposed sediment management strategies. Although risk assessments may provide information about the exposure, toxicity, and other aspects of the contamination, they may result in a less-than-optimum allocation of resources unless additional information is considered. For example, a given concentration of contaminants at a particular site might be toxic enough to induce mortality in a test species, but this information alone does not indicate the spending level that would be justified for cleanup. Cost-benefit analysis combines risk and cost information to determine the most efficient allocation of resources. The basic principle of cost-benefit analysis is that activities should be pursued as long as the overall benefit to society exceeds the social cost. The difficulty lies in the measurement of the benefits and costs, or, more to the point, the projection of what they will be, before a strategy is implemented.

Cost-benefit analysis is not applied widely in contaminated sediments management. It is generally carried out only for major new navigational dredging projects, and the analyses are usually narrow in scope. Cost-benefit analysis could be used in many cases to help identify the optimum solution in which the benefits outweigh the costs (i.e., to maximize benefits for a given cost or to minimize costs for a given level of benefits). The costs and benefits involved in contaminated sediments management are difficult to calculate and cannot be measured precisely, but cost-benefit analysis may be worth the effort; comprehensive cost-benefit analysis may be warranted in very expensive, or extensive projects. Informal estimates or cost-effectiveness* analyses may suffice in smaller projects.

As the demand for the remediation of contaminated sediments grows, and as costs and controversies multiply, decision makers need to be able to use information about risks, costs, and benefits that may be controversial and difficult to evaluate, compare, or reconcile. One approach that could help meet this need is decision analysis, a computational technique that makes use of both factual and subjective information in the evaluation of the relative merits of alternative courses of action. Decision analysis involves gathering certain types of information about a problem and selecting a set of alternative solutions to be evaluated. The evaluation is used to determine and assess possible outcomes for each alternative. The outcomes are rated, and the results are used to develop a strategy that offers the best odds for successful risk management.

Formal decision analysis is not yet widely used in the management of contaminated sediments. The committee examined this technique using a test case and determined that applications of decision analysis may be particularly timely now, because recent advances in computer hardware and software make it possible to perform such analyses in ways that are user friendly and interactive. Decision analysis could be especially valuable because it can accommodate more variables (including uncertainty) than techniques such as cost-benefit analysis that measure single outcomes. Decision analysis can also serve as a consensus-building tool by enabling stakeholders to explore various elements of the problem and, perhaps, find common ground. However, because decision analysis is technical in design and involves complex computations, it is probably worth the effort only in highly contentious situations in which stakeholders are willing to devote enough time to become confident of the usefulness of the approach.

* Cost-effectiveness is defined here as a measure of tangible benefits for money spent.

Regulatory Framework

Few aspects of sediment handling, treatment, or containment are unregulated at the federal, state, or local level, but the regulatory approach is inconsistent, primarily because the applicable laws were originally written to address issues other than contaminated marine sediments. As a result, the current laws and regulations affecting contaminated sediments can impede efforts to implement the best management practices and achieve efficient, risk-based, and cost-effective solutions. This is a shortcoming of the governing statutes, not a criticism of regulatory agencies charged with implementing them. The timeliness of decision making is also an issue, given that it typically takes years to implement solutions to contaminated sediments problems. In the committee's case histories, the delay between the discovery of a problem and the implementation of a solution ranged from approximately 3 to 15 years.

At least six comprehensive acts of Congress, with implementation responsibilities spread over seven federal agencies, govern sediment remediation or dredging operations in settings that range from the open ocean to the freshwater reaches of estuaries and wetlands. When environmental cleanup is the driving force, the relevant federal laws include Superfund; the Resource Conservation and Recovery Act (RCRA) (P.L. 94-580); and Section 115 of the Clean Water Act (CWA) (formerly the Federal Water Pollution Control Act [P.L. 80-845]). When navigational dredging is the issue, the applicable statutes are likely to be the CWA; the Rivers and Harbors Act of 1899 (P.L. 55-525); the Marine Protection, Research and Sanctuaries Act (MPRSA, commonly known as the Ocean Dumping Act) (P.L. 92-532); and the Coastal Zone Management Act (P.L. 92-583). In addition, states also exercise important authority related to water quality certification and coastal zone management. In some cases, local laws may also apply. To complicate matters further, federal, state, and local authorities often overlap.

The principal federal agencies involved are the U.S. Environmental Protection Agency (EPA), which is responsible for implementing Superfund and has major site designation, regulation development, and veto responsibilities under the CWA and MPRSA; the National Oceanic and Atmospheric Administration, which assesses the potential threat of Superfund sites to coastal marine resources and exercises significant responsibilities for research, under the MPRSA, and review and comment, under CWA and MPRSA; and the U.S. Army Corps of Engineers (USACE), which assists in the design and implementation of remedial actions under Superfund, and has responsibilities for dredged material, under the CWA, MPRSA, and Rivers and Harbors Act. The federal navigational dredging program is the joint responsibility of the EPA and USACE; the EPA regulates disposal, whereas USACE handles the dredging.

The committee identified several areas of the current regulatory framework in which changes might be beneficial. For example, the CWA, the MPRSA, and Superfund use different approaches for evaluating remedial alternatives, but none fully considers either the risks posed by contaminated marine sediments or the costs and benefits of various solutions. The MPRSA requires biological testing of dredged material to determine its inherent toxicity but does not fully consider site-specific factors that may influence the exposure of organisms in the receiving environment, meaning that, at best, risk is considered only indirectly and the actual impact is approximated. Although the CWA procedures, which consider chemical and physical as well as biological characteristics in assessing whether the discharge of dredged material will cause unacceptable adverse impacts, are not risk-based, at least they do not specify rigid pass-fail criteria. They are geared to identification of the least environmentally damaging, implementable alternative. The Superfund remedial action program addresses risks and costs to some degree—an exposure assessment (but not a full risk analysis) is required to assess in-place risks; remedial alternatives are identified based on their capability of reducing exposure risks to an acceptable level; and the final selection involves choosing the most cost-effective solution. However, there are no risk-based cleanup standards for underwater sediments. Insufficient attention to risks, costs, and benefits impedes efforts to reach technically sound decisions and manage sediments cost-effectively.

Similar inattention to risk is evident in the permitting processes for sediment disposal. It is currently necessary to secure different types of permits for the placement of sediments in navigation channels or ocean waters as part of the construction of land or containment facilities (under the Rivers and Harbors Act), the dumping of sediments in the ocean (under the MPRSA), the discharge of sediments in inland waters or wetlands (CWA), and the containment of contaminated sediments on land (RCRA). In addition, different regulations come into play depending on whether sediments are removed during navigational dredging (CWA or MPRSA) or are excavated for environmental remediation (Superfund). The committee can see little technical justification for the differential regulation of contaminated sediments, given that neither the location of the aquatic disposal site (freshwater versus saltwater) nor the reason for dredging (navigational dredging versus environmental remediation) necessarily affects the risk posed by the contamination. The regulatory regime does not adequately address risk; instead it focuses rigidly on the nature of the activities to be carried out. This problem has been eased in some instances by the interpretation of regulations based on the intent of the underlying statute(s).

Systematic, integrated decision making can also be undermined by dredging regulations governing cost allocation and cost-benefit analysis. The federal government pays for most new-work dredging and all maintenance dredging but not for sediment disposal, except in open water. The local sponsors of federal navigation projects bear the burden of identifying, constructing, operating, and maintaining dredged material disposal sites, under the "project cooperation agreement" of the Water Resources Development Act (WRDA) of 1986 (P.L. 99-662). Because project sponsors must pay for disposal on land, whereas open-water disposal is paid for by the federal government as a component of dredging costs, the WRDA provision creates a strong preference for open-water disposal. Furthermore, a local sponsor bearing the full burden of disposal costs has little incentive to seek out opportunities for the beneficial uses of dredged material (discussed in the next section). The cost of making use of dredged material adds to the project cost and may benefit only third parties. This inconsistent approach to cost sharing can lead to the economically irrational allocation of scarce societal resources. Additional inconsistencies are introduced in the area of cost-benefit analysis. As noted earlier, costs and benefits must be weighed for new dredging projects but not for the maintenance dredging of existing channels or for the disposal of dredged material.

Improving Project Implementation

Stakeholder Interests

Contaminated sediments are not managed in a political or social vacuum. Most contaminated sediments sites are located in highly populated areas near the Great Lakes or the oceans. The nature of these sites virtually ensures that complicated ecological situations and difficult technical problems will have to be accommodated along with complex political circumstances involving multiple resource users and interest groups. Stakeholders include port managers and transportation officials who have strong economic reasons for dredging; federal, state, and local regulators responsible for protecting natural resources and enforcing regulations; and environmental groups, local residents, fishermen, and other marine resource users who are concerned about public health and natural resources. The successful management of contaminated sediments must respond to all dimensions of the problem: ecological, technical, social, and political.

The committee determined that remediation and disposal projects need strong proponents and that the identification and timely implementation of effective solutions depend heavily on how project proponents interact with stakeholders, who often have different perspectives on the problem and proposed solutions. Because any participant in the decision-making process can block or delay remedial action, project proponents need to identify all stakeholders and build a consensus among them. The development of a consensus can be fostered by the use of various tools, including mediation, negotiated rule making, collaborative problem solving, and effective communication of risks.

Stakeholder acceptance of contaminated sediments management projects can be fostered by the reuse of dredged material. Dredged material has been used for many purposes, including the creation of thousands of islands for sea-bird nesting, landfills for urban development, and wetlands, as well as for beach nourishment and shoreline stabilization. The policy focus and most of the experience to date have concerned the use of clean materials, but some contaminated sediments can also be used safely for certain beneficial purposes. Reuse can provide alternatives to increasingly scarce disposal sites while also making management plans more attractive, or at least palatable, to stakeholders. Some contaminated sediment sites have been successfully transformed into wetlands, and productive USACE research is under way on the safe use of contaminated sediments for "manufacturing" topsoil and landfill covers. However, funding for this type of research is limited, and technical guidelines have yet to be developed. Other barriers include the USACE policy of selecting lowest-cost disposal options with little regard to the possibilities of beneficial use and the uncertainties about whether the incremental costs of beneficial use should be borne by the project proponent or the beneficiary.

Source Control

Because accumulations of sediments interfere with deep-draft navigation, ports have no alternative but to dredge periodically in order to remain economically viable. If the sediments to be dredged are contaminated, then ports become responsible for both sediment disposal and any necessary remediation, even though they have no control over the source of the contamination. Upstream generators of contaminants often cannot be identified or held accountable, leaving ports to manage a problem that is not of their making. This responsibility could be shared by states (when states do not already operate or oversee port agencies), which benefit economically from dredging and already engage in watershed management. Under the CWA (Section 303), the EPA and the states set total maximum daily loads for waterway segments and develop load allocations for pollution sources in an effort to control water pollution. This approach could be readily expanded to address sources of sediment contamination. In addition, government regulators and ports could use all available legal and enforcement tools for ensuring that polluters bear a fair share of cleanup costs.

Site Characterization

Accurate site characterization is essential to the cost-effective management of contaminated sediments. Site assessments need to be sufficiently comprehensive and accurate to ensure that the contamination is well defined both chemically and geographically. Inaccuracies and incompleteness can leave areas of unidentified contamination that pose continuing unmanaged risks. Another compelling argument for accurate site assessment is the need to control remediation costs; precise site definition is necessary to facilitate removal of only those sediments that are contaminated, thus controlling the volume of material that requires expensive remediation. But the high cost of commonly used site characterization technologies (i.e., physical profiling and chemical testing) has limited the precise definition of either horizontal or vertical contaminant distributions, which may have led to the removal and "remediation" of large quantities of uncontaminated sediments at unnecessarily high costs.

Thus, the development and wide use of new or improved site characterization technologies that are less expensive than current methods would enhance the cost-effective management of contaminated sediment sites. One technology that may prove useful in the future is acoustic profiling,* which helps define the thickness and distribution of disparate sediment types. Because contaminants tend to be associated with fine-grained material, acoustic profiling may provide for cost-effective remote surveying of contaminated sediments, thereby increasing the precision and accuracy of site assessment. Additional research and development is needed, however. Sediment characterization may also be enhanced through the adaptation of chemical sensors now used in the assessment of soil and groundwater sites.

* Acoustic profiling involves high-resolution mapping of the acoustic reflectivity of sediments.

Interim and Long-Term Controls and Technologies

The following is a brief assessment of the controls and technologies that are applicable to contaminated sediments. The section concludes with a comparative analysis reflecting the committee's overall judgments of the feasibility, effectiveness, practicality, and cost of each control and technology.

Interim Controls

Interim controls may prove helpful when sediment contamination poses an imminent hazard. Identification of an imminent hazard is usually a matter of judgment, but in general an imminent hazard exists when contamination levels exceed by a significant amount the sum of a defined threshold level plus the associated uncertainty. Administrative interim controls (e.g., signs, health advisories) have been used a number of times. Only two applications of structural interim approaches (e.g., thin caps) were identified by the committee, but additional structural approaches, such as the use of confined disposal facilities (CDFs) for temporary storage, appear promising. Few data are available concerning the effectiveness of interim controls because to date they have not been used often or evaluated in detail.

Long-Term Controls and Technologies

Technologies for remediating contaminated sediments are at various stages of development. Sediment-handling technologies are the most advanced, although benefits can be realized from improvements in the precision of dredging (and, concurrently, site characterization). The state of practice for in situ controls ranges from immature (e.g., bioremediation) to evolving (e.g., capping). Ex situ containment is commonplace. A number of existing ex situ treatment technologies can probably be applied successfully to treating contaminated sediments, but full-scale demonstrations are needed to determine their effectiveness. But these technologies are expensive, and it is not clear whether unit costs would drop significantly in full-scale implementation.

The cost of cleanup depends on the number of steps involved—the more handling required, the higher the cost—and the type of approach used. The costs of removing and transporting contaminated sediments (generally less than \$15 to \$20/yd^3) tend to be higher than costs of conventional navigational dredging (seldom more than \$5/yd^3) but much lower than the costs of treatment (usually more than \$100/yd^3). Volume reduction (i.e., removing only sediments that require treatment and entraining as little water as possible) will mean greater cost savings than increased production rates; improved site characterization coupled with precision dredging techniques hold particular promise for reducing volume. Treatment costs may also be reduced through pretreatment.

In situ management offers the potential advantage of avoiding the costs and potential material losses associated with the excavation and relocation of sediments. Among the inherent disadvantages of in situ management is that they are seldom feasible in navigation channels that are subject to routine maintenance dredging. In addition, monitoring needs to be an integral part of any in situ approach to ensure effectiveness over the long term.

Natural recovery is a viable alternative under some circumstances and offers the advantages of low cost and, in certain situations, the lowest risk of human and ecosystem exposure to sediment contamination. Natural recovery is most likely to be effective where surficial concentrations of contaminants are low, where surface contamination is covered over rapidly by cleaner sediments, or where natural processes destroy or modify the contaminants, so that contaminant releases to the environment decrease over time. A disadvantage of natural recovery is that the sediment bed is subject to resuspension by storms or anthropogenic processes. For natural recovery to be pursued with confidence, the physical, chemical, and hydrological processes at a site need to be understood adequately; however, no capability currently exists for completely quantifying chemical movements. Extensive site-specific studies may be required.

In situ capping promotes chemical isolation and may protect the underlying contaminated sediments from resuspension until naturally occurring biological degradation of contaminants has occurred. The original bed must be able to support the cap, suitable capping materials must be available to create the cap, and suitable hydraulic conditions (including water depth) must exist to permit placement of the cap and to avoid compromising the integrity of the cap. Changes in the local substrate, the benthic community structure, or the bathymetry at a depositional site may subject the cap to erosion. Improved long-term monitoring methods are needed. A regulatory barrier to the use of capping is the language of Superfund legislation (Section 121[b]), which gives preference to "permanent" controls. Capping is not considered by regulators to be a permanent control, but available evidence suggests that properly managed caps can be effective.

Neither in situ immobilization nor chemical treatment of contaminated sediments has been demonstrated successfully in the marine environment, although both concepts are attractive because they do not require sediment removal. Their application would be complicated by the need to isolate sediments from the water column during treatment, by inaccuracies in reagent placement, and by the need for long-term follow-up monitoring. Other constituents (e.g., natural organic matter, oil and grease, metal sulfide precipitates) could interfere with chemical oxidation. Immobilization techniques may not be applicable to fine-grained sediments with a high water content.

Biodegradation has been observed in soils, in groundwater, and along shorelines contaminated by a variety of organic compounds (e.g., petroleum products, PCBs, polyaromatic hydrocarbons, pesticides). However, the use of biodegradation in subaqueous and especially marine environments presents unresolved microbial, geochemical, and hydrological issues and has yet to be demonstrated.

When sediments must be moved for ex situ remediation or confinement, efficient hydraulic and mechanical methods are available for removal and transportation. Most dredging technologies can be used successfully to remove contaminated sediments; however, they have been designed for large-volume navigational dredging rather than for the precise removal of hot spots. Promising technologies offering precision control include electronically positioned dredge heads and bottom-crawling hydraulic dredges. The latter may also have the capability to dredge in depths beyond the standard maximum operating capacity. The cost effectiveness of dredging innovations can best be judged by side-by-side comparisons to technologies in current use.

Containment technologies, particularly CDFs, have been used successfully in numerous projects. A CDF can be effective for long-term containment if it is well designed to contain sediment particles and contaminants and if a suitable site can be found. A CDF can also be a valuable treatment or interim storage facility, allowing the separation of sediments for varying levels of treatment and, in some cases, beneficial reuse. Costs are reasonable; in some parts of the country it may be cheaper to reuse CDFs than to build new ones. Disadvantages of this technology include the imperfect methods for controlling contaminant release pathways. There is also a need for improved long-term monitoring methods.

Contained aquatic disposal (CAD) is applicable particularly to contaminated sites in shallow waters where in situ capping is not possible and to the disposal and containment of slightly contaminated material from navigation dredging. Although the methodology has been developed, CAD has not been widely used. Among the advantages of CAD are that it can be performed with conventional dredging equipment and that the chemical environment surrounding the cap remains unchanged. Disadvantages include the possible loss of contaminated sediments during placement operations. Improved tools are needed for the design of sediment caps and armor layers and for the evaluation of their long-term stability and effectiveness.

Scores of ex situ treatment technologies have been bench tested and pilot tested, and some warrant larger-scale testing in marine systems, depending on their applicability to particular problems. Chemical separation, thermal desorption, and immobilization technologies have been used successfully but are expensive, complicated, and only effective for treating certain types of sediments. Similarly, because of extraordinarily high unit costs, thermal and chemical destruction techniques do not appear to be near-term, cost-effective approaches for the remediation of large volumes of contaminated dredged sediment.

Ex situ bioremediation, which is not as far along in development as are other ex situ treatment approaches, presents so many technical problems that its application to contaminated sediments would be expensive. If these technical problems can be resolved, however, ex situ bioremediation has the potential, over the long term, for the cost-effective remediation of large volumes of sediments. Ex situ bioremediation is much more promising than in situ bioremediation because conditions can be controlled more effectively in a contained facility. The approach has been demonstrated on a pilot scale with some success, but complex questions remain concerning how to engineer the system.

Comparative Analysis of Controls and Technologies

Table S-1 summarizes the committee's overall assessment of the feasibility, effectiveness, practicality, and costs of controls and technologies. For each control and technology, the four characteristics were rated separately on a scale of 0 to 4, with 4 representing the best available (not necessarily the best theoretically possible) features. The effectiveness rating is an estimate of contaminant reduction or isolation and removal efficiency; scores represent a range of less than 90 percent to nearly 100 percent. The feasibility rating represents the extent of technology development, with 0 for a concept that has not been verified experimentally and 4 for a technology that has been commercialized. The practicality ranking reflects public acceptance; 0 means no tolerance for an activity and 4 represents widespread acceptance. The cost ranking is inversely related to the cost of using the control or technology (not including expenses associated with monitoring, environmental resource damage, or the loss of use of public facilities).

The overall pattern of the ratings underscores the need for trade-offs in the selection of technologies. No single approach emerges with the highest scores across the board, and each control or technology has at least one low or moderate ranking. In general, interim controls and in situ approaches are feasible and low in cost but less effective than the most practical ex situ approaches, which tend to be high in cost and complexity. Decisions about which approach is the most appropriate must be made on a project by project basis.

TABLE S-1 Comparative Analysis of Technology Categories

Approach	*Feasibility*	*Effective*	*Practicality*	*Cost*
INTERIM CONTROL				
Administrative	0	4	2	4
Technological	1	3	1	3
LONG-TERM CONTROL				
In Situ				
Natural recovery	0	4	1	4
Capping	2	3	3	3
Treatment	1	1	2	2
Sediment Removal and Transport	2	4	3	2
Ex Situ Treatment				
Physical	1	4	4	1
Chemical	1	2	4	1
Thermal	4	4	3	0
Biological	0	1	4	1
Ex situ Containment	2	4	2	2
SCORING				
0	< 90%	Concept	Not acceptable, very uncertain	$1,000/yd^3$
1	90%	Bench		$100/yd^3$
2	99%	Pilot		$10/yd^3$
3	99.9%	Field		$1/yd^3$
4	99.99%	Commercial	Acceptable, certain	< $1/yd^3$

NOTE: 1 yd^3 = .914 m^3

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