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CONTAMINATED SEDIMENTS SCIENCE PRIORITIES

U.S. Environmental Protection Agency

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DISCLAIMER

This document has been reviewed in accordance with U.S. Environmental Protection Agency (U.S. EPA) policy and approved for publication and distribution. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

This document identifies scientific information and activities that are needed to assess and manage the risks of contaminated sediments by U.S. EPA programs and regions. U.S. EPA staff have recommended research approaches and other science activities to address gaps and reduce uncertainty for risk management decision-making. This document is intended to improve coordination, avoid duplication, and inform decision-makers within U.S. EPA. While this document does refer to some collaborations with organizations outside U.S. EPA, this document is not intended to describe the science and research activities of those collaborators or other parties outside U.S. EPA.

The science priorities do not necessarily reflect management priorities nor do they represent commitments to fund these science activities. Rather, these science needs will be reconsidered from time to time as resources and collaboration opportunities may arise in the future. U.S. EPA and other decision-makers retain the discretion to address these or any other science needs for contaminated sediments on a case-by-case basis and in a manner that may differ from the approaches discussed in this document.

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EXECUTIVE SUMMARY

In 2000, the United States Environmental Protection Agency's (EPA's) Science Policy Council (SPC) initiated the development of a Contaminated Sediments Science Priorities (CSSP) document (formerly titled " Draft Contaminated Sediments Science Plan" because contamination of sediments is a multi-faceted, cross-Agency issue which can benefit from a more comprehensive and higher level of coordination across EPA program and regional offices. Extensive resources to address contaminated sediment problems are spent by a number of Agency program offices, including the Superfund Program, Office of Water (OW), Office of Solid Waste (OSW), Great Lakes National Program Office (GLNPO), Office of Prevention, Pesticides and Toxic Substances (OPPTS), Office of Research and Development (ORD), and EPA regional offices. As a complement to EPA's Science Inventory, the CSSP Document intended to analyze and summarize the Agency's contaminated sediment science activities and thus serves as both an informational and planning tool to EPA's programs and regions. The CSSP Document provides an analysis of the Agency's contaminated sediment scientific activities, identifies and evaluates science needs, and provides key recommendations for filling those needs

The CSSP Document has four goals to promote the vision of providing a strong scientific basis for addressing contaminated sediments:

1. Identify the science necessary to address the assessment and management of contaminated sediments.

2. Identify the science gaps and tools that are important in reducing uncertainty in contaminated sediment risk management decision-making.

3. Recommend approaches to promote necessary scientific activities and research.

4. Enhance the level of coordination and communication of contaminated sediment science activities across Agency program and regional offices.

The CSSP Document is organized into four chapters. Chapter One discusses the goals, objectives, and how the CSSP Document relates to the Agency's mandate. The process used to develop the CSSP Document is also included. Chapter Two provides an overview of the contaminated sediment problems and issues across the Agency. The brief description of issues in Chapter Two is meant to provide an introduction to the discussion of contaminated sediment issues, as well as the overall context for the more detailed discussion of specific science needs and recommendations given in Chapter Three.

Chapter Three, along with U.S. EPA's Contaminated Sediment Science Activities' Database (Appendix A), is the data collection and analysis section of the CSSP Document. It documents the current contaminated sediment science activities ongoing within the Agency, and places these activities within the context of Agency goals. Significant data gaps and uncertainties in methodology/assessment procedures are identified. Finally, it discusses science needs and provides the key recommendations for future Agency science activities.

Chapter Four provides guidance on how to meet the science needs identified in Chapter Three. Critical U.S. EPA partners and the immediate or long-term nature of the science activity are proposed. The Contaminated Sediments Science Priorities Workgroup (Workgroup) did not constrain the recommendations to fit within available resources. Instead, the recommendations are a comprehensive list that U.S. EPA organizations can consider when balancing resource allocations across competing high-priority needs.

Key scientific questions, which are given below, were developed for each major topic in order to focus discussions on scientific needs and to identify recommended science activities to address these questions.

Key Scientific Questions:

Sediment Site Characterization: What physical, chemical and biological methods best characterize sediments and assess sediment quality?

Exposure Assessment: What are the primary exposure pathways to humans and wildlife from contaminants in sediments and how can we reduce uncertainty in quantifying and modeling the degree of exposure?

Human Health Toxicity and Risk Characterization: What are the risks associated with exposure to contaminants in sediments through direct and indirect pathways?

Ecological Effects and Risk Assessment: What are the risks associated with exposure to contaminants in sediments to wildlife species and aquatic communities?

Sediment Remediation: What sediment remedial technology or combination of technologies is available to effectively remediate sites?

Baseline, Remediation, and Post-Remediation Monitoring: What types of monitoring are needed to ensure that the implemented remedy meets remedial performance goals and does not cause unacceptable short-term effects?

Risk Communication and Community Involvement: How can we provide communities with more meaningful involvement in the contaminated sediments cleanup process?

Information Management and Exchange Activities: How do we improve information management and exchange activities on contaminated sediments across the Agency?

Table E-1 summarizes the key recommendations, the critical U.S. EPA partners, and the immediate or long-term nature of the science needs.

Table E-1. Summary of Key Recommendations, Time Frame for Implementation, and Suggested Critical Partners

Recommendations
A. Sediment Site Characterization *Immediate Time Frame* A.1 Conduct a workshop to develop a consistent approach to collecting sediment physical property data for use in evaluating sediment stability. (OSRTI, ORD, U.S. EPA Regions) *Longer Time Frame* A.2 Develop more sensitive, low-cost laboratory methods for detecting sediment contaminants, and real-time or near real-time chemical sensors for use in the field. (ORD, OSRTI, GLNPO) A.3 Develop U.S. EPA-approved methods with lower detection limits for analysis of bioaccumulative contaminants of concern in fish tissue. (ORD, OSRTI, OW, U.S. EPA Regions) A.4 Develop methods for analyzing emerging endocrine disruptors, including alkylphenol ethoxylates (APEs) and their metabolites. (ORD)
B. Exposure Assessment *Immediate Time Frame* B.1 Develop a tiered framework for assessing food web exposures. (ORD, OW, OSRTI, U.S. EPA Regions) B.2 Develop guidance and identify pilots for improving coordination between TMDL and remedial programs in waterways with contaminated sediments. (OW, OSWER, U.S. EPA Regions) B.3 Develop and advise on the use of a suite of most valid contaminant fate and transport models that allow prediction of exposures in the future. (ORD, OSRTI, OW, U.S. EPA Regions) B.4 Develop a consistent approach to applying sediment stability data in transport modeling. (ORD, OSRTI, OW, U.S. EPA Regions)

C. Human Health Toxicity and Risk Characterization

Immediate Time Frame

C.1 Develop guidance for characterizing human health risks on a PCB congener basis. (ORD, OSRTI, OW, U.S. EPA Regions)

C.2 Develop sediment guidelines for bioaccumulative contaminants that are protective of human health via the fish ingestion pathway. (ORD, OSRTI, OW, U.S. EPA Regions)

Longer Time Frame

C.3 Refine methods for estimating dermal exposures and risk. (ORD, OSRTI, U.S. EPA Regions)

C.4 Evaluate the toxicity and reproductive effects of newly recognized contaminants, such as APEs and other endocrine disruptors and their metabolites on human health. (ORD, OPPT)

D. Ecological Effects and Risk Assessment

Immediate Time Frame

D.1 Develop sediment guidelines to protect wildlife from food chain effects. (ORD, OSRTI, OW, U.S. EPA Regions)

D.3 Develop guidance on how to interpret ecological sediment toxicity studies (lab or *in situ* caged studies) and how to interpret the significance of the results in relation to site populations and communities. (OW, ORD, OSRTI, U.S. EPA Regions)

D.4 Acquire data and develop criteria to use in balancing the long-term benefits from remedial dredging vs. the shorter term adverse effects on ecological receptors and their habitats. (ORD, OSRTI, U.S. EPA Regions)

D.6 Continue developing and refining both chronic and sub-chronic sediment toxicity testing methods. (ORD, OW, U.S. EPA Regions)

D.7 Develop whole sediment toxicity identification evaluation procedures for a wide range of chemicals. (ORD, OW)

Longer Time Frame

D.2 Develop additional tools for characterizing ecological risks. (ORD, U.S. EPA Regions, OPPTS, OW)

D.5 Conduct field and laboratory studies to further validate and improve chemical-specific sediment quality guidelines. (OW, ORD)

E. Sediment Remediation

Immediate Time Frame

E.1 Collect the necessary data and develop guidance for determining the conditions under which natural recovery can be considered a suitable remedial option. Such guidance would include: measurement protocols to assess the relative contribution of the various mechanisms for chemical releases from bed sediments (*e.g.*, advection, bioturbation, diffusion, and resuspension), including mass transport of contaminants by large storm events; approaches to assess the vertical extent of the bioavailable zone in different environmental settings; methodologies to quantify the uncertainties associated with natural recovery; and development of accepted measuring protocols to determine *in situ* chemical fluxes from sediments. (ORD, OSRTI, U.S. EPA Regions, GLNPO)

E.2 Develop performance evaluations of various cap designs and cap placement methods and conduct cap placement and post-cap monitoring to document performance. Continue to monitor ongoing capping projects to monitor performance (*e.g.*, Boston Harbor, Eagle Harbor, Grasse River). (ORD, U.S. EPA Regions, GLNPO)

E.4 Using the data provided in recommendation E.1, develop a white paper evaluating the short-term and long-term impacts from dredging relative to natural processes and human activities (*e.g.*, resuspension from storm events, boat scour, wave action, and anchor drag). (OSRTI, U.S. EPA Regions)

Longer Time Frame

E.3 Encourage and promote the development and demonstration of *in situ* technologies. (ORD, GLNPO)

E.5 Support the demonstration of cost-effective *ex situ* treatment technologies and identification of potential beneficial uses of treatment products. (ORD, GLNPO, U.S. EPA Regions)

F. Baseline, Remediation, and Post-remediation Monitoring

Immediate Time Frame

F.1 Develop monitoring guidance fact sheets for baseline, remediation, and post-remediation monitoring, and monitoring during remedy implementation. (ORD, OSRTI, U.S. EPA Regions, OW)

F.2 Conduct training and hold workshops for project managers regarding monitoring of contaminated sediment sites. (OSRTI, ORD, U.S. EPA Regions)

G. Risk Communication and Community Involvement

Immediate Time Frame

G.1 Establish a research program on risk communication and community involvement focusing on developing better methods, models, and tools. (ORD, OSRTI, U.S. EPA Regions)

H. Information Management and Exchange Activities

Immediate Time Frame

H.1 Establish regional sediment data management systems which can link the regions and program offices with each other and with the National Sediment Inventory. (U.S. EPA Regions, OW, OSWER, GLNPO)

H.3 Develop national and regional contaminated sediment sites web sites for sharing information. (U.S. EPA Regions, OW, OSWER, GLNPO)

H.4 Re-establish and expand the Office of Water-sponsored Sediment Network by including more regional representation. (OSRTI, OW, U.S. EPA Regions)

H.5 Promote communication and coordination of science and research among Federal agencies. (ORD, OSWER, OW, U.S. EPA Regions, NOAA, U.S. Navy, U.S. ACE, USGS, U.S. FWS)

H.6 Promote the exchange of scientific information via scientific fora (*i.e.*, workshops, journals, and meetings). (CSMC, OW, OSWER, U.S. EPA Regions, GLNPO)

Longer Time Frame

H.2 Standardize the sediment site data collection/reporting format. Establish minimum protocols for quality assurance/quality control (QA/QC) using the Agency's Quality System for Environmental Data and Technology. (OEI, OW, OSWER, U.S. EPA Regions)

Table E-2 is a list of the Acronyms used in the Executive Summary.

Table E-2. List of Acronyms in Executive Summary

APE	Alkylphenol Ethoxylate
CSMC	Contaminated Sediment Management Committee
CSSP	Contaminated Sediments Science Priorities
GLNPO	Great Lakes National Program Office
NOAA	National Oceanic and Atmospheric Administration
OEI	Office of Environmental Information
OSRTI	Office of Superfund Remediation and Technology Innovation
OPPT	Office of Pollution Prevention and Toxics
OPPTS	Office of Prevention, Pesticides and Toxic Substances
ORD	Office of Research and Development
OSW	Office of Solid Waste
OSWER	Office of Solid Waste and Emergency Response
OW	Office of Water
PCB	Polychlorinated biphenyl
QA/QC	Quality Assurance/Quality Control
SPC	Science Policy Council
TMDL	Total Maximum Daily Load
U.S. ACE	United States Army Corps of Engineers
U.S. EPA	United States Environmental Protection Agency
U.S. FWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

Suggested Uses of This Contaminated Sediments Science Priorities Document

This CSSP Document is designed to satisfy a number of different perspectives and needs. Here are three suggested approaches for its use:

1. For those within or outside the Agency seeking a *general understanding* of the purposes and goals of the Contaminated Sediments Science Priorities Document (what is it and why is it needed?) and some understanding of its history and Agency activities and products, the reader is referred to Chapters One and Two, Goals and Objectives and Overview of Contaminated Sediment Science Issues Across the Agency's Regulatory Programs, respectively.

2. Those who understand the contaminated sediments issues in general, but *desire to analyze and assess the validity of the scientific basis* for the science recommendations, should refer to Chapter Three, Assessing the Science on Contaminated Sediments and the Key Recommendations therein.

3. *Knowledgeable risk assessors, risk managers, and program managers* who desire to see how the science priorities directly impact their programs will find a quick overview, the key recommendations, and the recommended approach for implementation of the science priorities in Chapter Four, Meeting Science Needs.

1. GOALS AND OBJECTIVES

1.1 Introduction

U.S. Environmental Protection Agency's (EPA's) mission is to protect human health and to safeguard the natural environment – air, water, and land – upon which life depends. Sediments are an integral component of aquatic ecosystems providing habitats for many aquatic organisms. Many sediment-dwelling organisms at the base of the food chain are eaten by organisms at higher trophic levels. Contaminants in sediments[1] pose a threat to human health, aquatic life, and the environment. Chemicals released to surface waters from industrial and municipal discharges, atmospheric deposition, and polluted runoff from urban and agricultural areas can accumulate to environmentally harmful levels in sediment. Humans, aquatic organisms, and other wildlife are at risk through direct exposure to pollutants or through consumption of contaminated fish and wildlife. Exposure to these contaminants is linked to cancer, birth defects, neurological defects, immune dysfunction, and liver and kidney ailments. Contaminated sediments may also cause economic impacts, at both the local and regional level, on the transportation, fishing, tourism, and development industries.

Sediment contamination is an issue that cuts across offices and jurisdictions throughout the Agency, other Federal agencies (*e.g.*, National Oceanic and Atmospheric Administration (NOAA), U.S. Fish and Wildlife Service (U.S. FWS), U.S. Army Corps of Engineers (U.S. ACE)), state agencies, and tribes. U.S. EPA programs with the authority to address sediment contamination operate under the mandate of many statutory provisions including the Comprehensive Emergency Response, Compensation, and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA), the Clean Water Act (CWA), the Oil Pollution Act (OPA), the Toxic Substances Control Act (TSCA), and the Marine Protection, Research, and Sanctuaries Act (MPRSA). Other Federal agencies having authorities that may be used to address contaminated sediments include: U.S. ACE, through the statutory provisions of the Water Resources Development Act (WRDA), CWA, and MPRSA; and U.S. FWS and NOAA, through Natural Resources Damages (NRD) authority.

In 2000, U.S. EPA's Science Policy Council (SPC) initiated the development of a Contaminated Sediments Science Priorities (CSSP) Document (formerly titled "Draft Contaminated Sediments Science Plan") because effective management of contaminated sediments is a multi-faceted, high profile issue that requires comprehensive and a heightened level of coordination across the Agency. Extensive resources are spent by a number of Agency program offices to address contaminated sediment problems. Program offices addressing this problem include: the Superfund Program, Office of Water (OW), Office of Solid Waste (OSW), Great Lakes National Program Office (GLNPO), Office of Prevention, Pesticides and Toxic Substances (OPPTS), Office of Research and Development (ORD), and U.S. EPA regional Offices.

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[1]Contaminated sediments are defined as soils, sand, and organic matter, or minerals that accumulate on the bottom of a water body and contain toxic or hazardous materials that may adversely affect human health or the environment (U.S. EPA's *Contaminated Sediment Management Strategy*, EPA-823-R-98-001).

The CSSP Document is a mechanism for the U.S. EPA to develop and coordinate Agency office- and region-wide science activities that affect contaminated sediments. Along with U.S. EPA's Contaminated Sediment Science Activities' Database (Appendix A), the CSSP Document analyzes current Agency science activities that concern contaminated sediments, identifies and evaluates the science gaps, and makes recommendations to fill those gaps.

The CSSP Document follows in the footsteps of previous U.S. EPA initiatives, such as the *Mercury Action Plan* (U.S. EPA, 2001c), the *Action Plan for Beaches and Recreational Waters* (*Beach Action Plan*) (U.S. EPA, 1999a), and *A Multimedia Strategy for Priority Persistent, Bioaccumulative, and Toxic (PBT) Pollutants* (U.S. EPA, 1998a). These plans and strategies contain elements of both science plans and management action plans.

Figure 1-1. Goals and Expected Results of CSSP Document

CSSP Document: Goals

- Identify the science necessary to address the assessment and management of contaminated sediments.
- Identify the science gaps and tools that are important in reducing uncertainty in contaminated sediment risk management decision-making.
- Recommend approaches to promote necessary scientific activities and research.
- Enhance the level of coordination and communication of contaminated sediment science activities across Agency program and regional offices.

CSSP Document: Expected Results for EPA

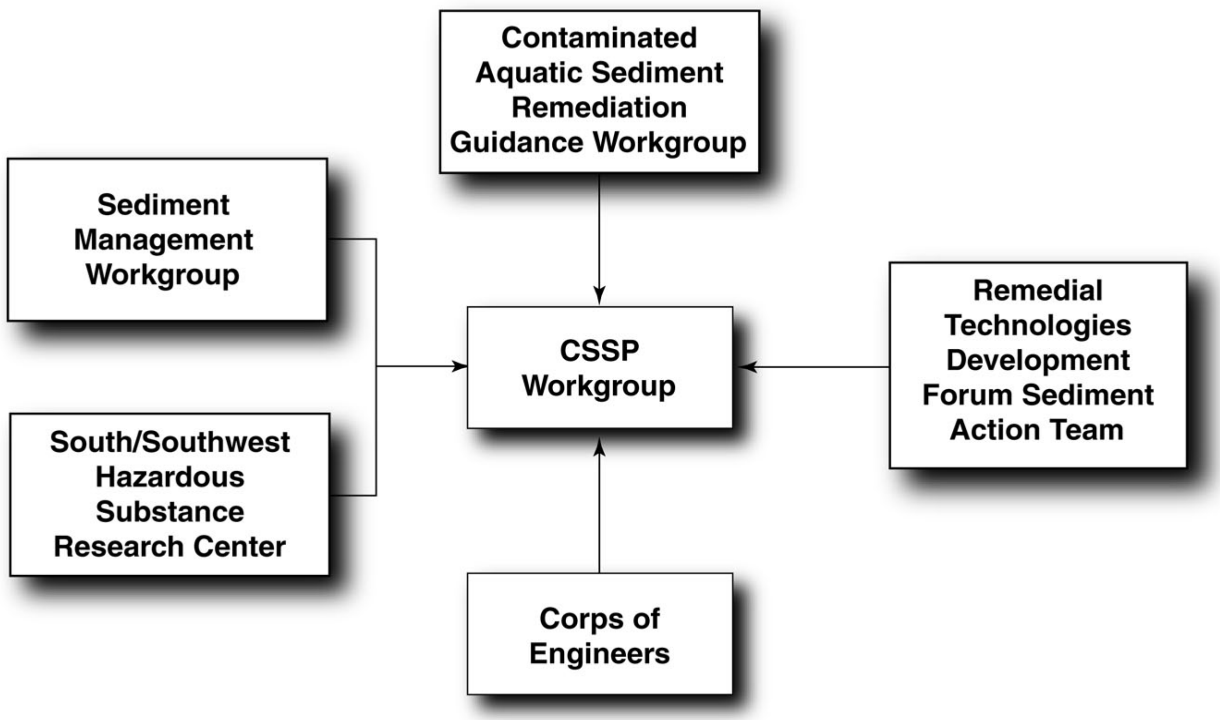
- More focused, better directed contaminated sediment research.
- Improved coordination of contaminated sediment activities within EPA.
- Better informed contaminated sediment decision-making based on sound science.
- Efficient and appropriate expenditure of resources.

1.2 Goals of the Contaminated Sediments Science Priorities Document

The CSSP Document has four goals which are highlighted in Figure 1-1. The first goal is the identification of the science necessary to address the assessment and management of contaminated sediments. The second goal is to identify the science gaps and tools that are important in reducing uncertainty in contaminated sediment risk management decision-making. The third goal is to recommend approaches to promote necessary scientific activities and research to fill the gaps, including development and dissemination of contaminated sediment management tools. The last goal is to enhance the level of coordination and communication of science activities dealing with contaminated sediments across Agency program and regional offices. Taken together, these goals promote the vision of providing a strong and scientifically sound basis for addressing contaminated sediments. The result will be a better informed decision-making process which conserves both human and financial resources.

The goals of the CSSP Document are based upon the strategic guidance proposed in the *Strategic Framework for U.S. EPA Science* (U.S. EPA, 2000e) to unify science activities across the Agency. First, the CSSP Document uses the Science Inventory to assemble and evaluate the current contaminated sediment science activities and research across the Agency. Second, it uses effective planning ("doing the right science") to insure that the most appropriate science activities are being conducted. Third, it uses sound scientific practices and approaches ("doing the science right"), such as Agency and public consultation and external peer review, in its development (see Figure 1-2).

Figure 1-2. Peer Consultation in Development of the CSSP Document



1.3 Development of the Contaminated Sediments Science Priorities Document

The Contaminated Sediments Science Priorities Workgroup (Workgroup) has been responsible for the development of the CSSP Document, although it has also received wide input from staff from U.S. EPA's regional and program offices. The development process is described below.

A cross-Agency workgroup of key staff working in the contaminated sediments area, the Contaminated Sediments Science Priorities Workgroup, was charged by the U.S. EPA Science Policy Council with developing a Contaminated Sediments Science Plan (now renamed the Contaminated Sediments Science Priorities Document). The Workgroup went through the following action steps to develop the Contaminated Sediments Science Priorities Document:

- Collected information on contaminated sediments research and science activities across the Agency.
- Incorporated the identified science activities into U.S. EPA Science Inventory.
- Identified key contaminated sediments issues and data gaps.
- Identified areas for better coordination of contaminated sediments research and science activities.
- Developed a strategy for future contaminated sediments research and science activities.
- Provided for a broad consultative review of the CSSP Document both internal and external to the Agency, and a Science Advisory Board (SAB) peer review.
- Developed a strategy to implement the CSSP Document and evaluate its performance (see Section 4.2 for details).

To manage this process, the Workgroup held weekly conference calls and a two-day meeting in June 2001. These efforts resulted in the Workgroup preparing a draft of the Contaminated Sediments Science Priorities Document which was first circulated for internal review, to ensure both accuracy and completeness of the document. The CSSP Document was subsequently reviewed externally by the Agency's Science Advisory Board, relevant Federal agencies, states, tribes, and others.[2]

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[2]An expert panel (Panel) under the Executive Committee of EPA's Science Advisory Board, met on October 30-31, 2002, to review the June 13, 2002, draft document, *Contaminated Sediments Science Plan* (Science Plan). The review was conducted at the request of the Office of Solid Waste and Emergency Response in Washington, D.C. at a public meeting. The Panel was charged with reviewing the adequacy of the Science Plan in addressing a range of contaminated sediments issues, as well as considering the methods exemplified by the Science Plan for cross-Agency science planning.

Other important inputs to the development of the CSSP Document were recommendations contained in the *Contaminated Sediment Management Strategy* (U.S. EPA, 1998b), *A Risk Management Strategy for PCB-Contaminated Sediments* (NRC, 2001a), and *Contaminated Sediments in Ports and Waterways* (NRC, 1997).

1.4 Linkage of the CSSP Document to Agency Planning Processes

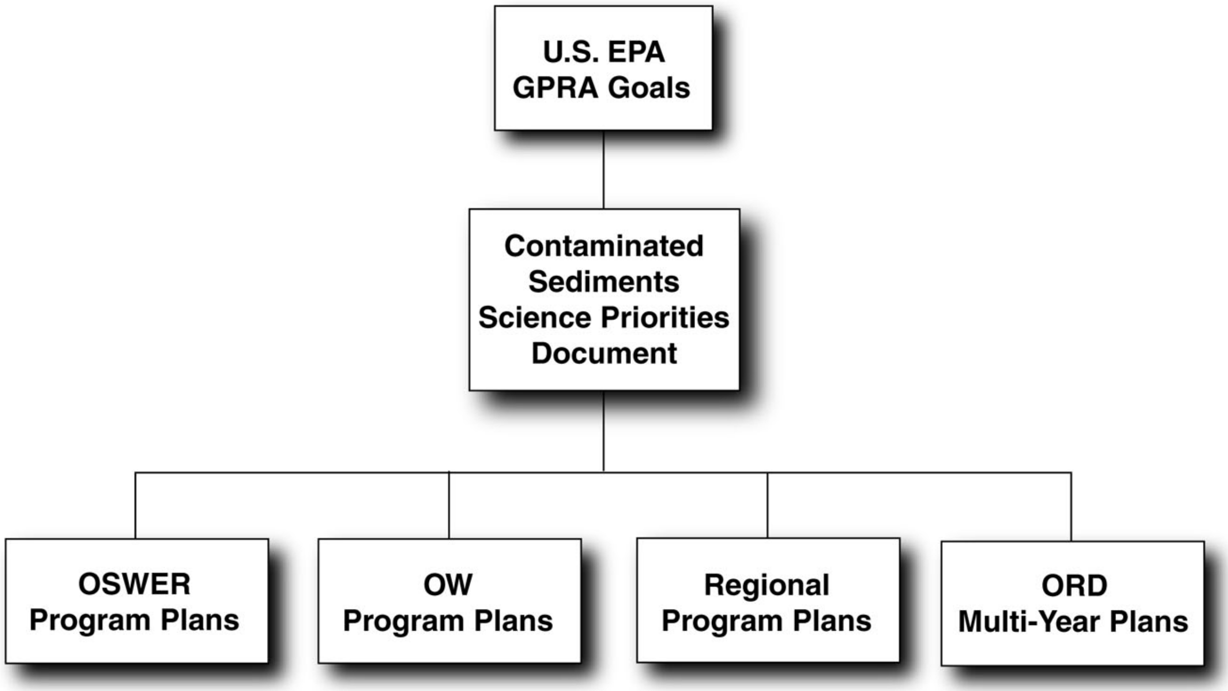
Organizations within U.S. EPA use various planning processes to ensure that they meet the Agency*'s National Strategic Plan* goals. For planning cross-program work, three tools are available. Two of these tools are management strategies and action plans, which describe commitments by all of the relevant organizations within U.S. EPA to meet specified goals. Examples of these documents are the *Mercury Management Strategy* (U.S. EPA, 2001c) and the *Beaches Action Plan* (U.S. EPA, 1999a). These types of documents usually focus on statutory authorities and implementation by the program offices and regions; research needs are usually considered. The third and newest tool is the CSSP Document, which promotes the vision of providing a strong and scientifically sound basis for addressing contaminated sediments.

The CSSP Document is an important tool that will be used by U.S. EPA regional and program offices in annual budget formulation and work planning processes. Implementation of CSSP Document recommendations will help identify the highest priority contaminated sediment needs, coordinate ongoing work across the Agency, avoid duplication of effort, and promote complementary endeavors. Workload requirements to implement CSSP Document recommendations need to be evaluated to determine if new budget initiatives will be needed. The CSSP Document will receive the same analysis and accountability reviews as any other Agency science/technical assessment priority. Agency annual planning cycles and annual performance measures may be examined by lead offices and regions to see how U.S. EPA is addressing CSSP Document recommendations (please refer to Section 4.2 on recommended approaches for strategy implementation).

The CSSP Document encompasses more than research, but where research needs are identified, it will inform ORD of the most important contaminated sediment needs to consider during the ORD annual planning cycle. ORD plans its research through Multi-Year Plans (MYPs) to provide a long-term view of the research direction. Research Coordination Teams (RCTs), comprising of representatives from ORD and U.S. EPA regions and program offices, participate in developing MYPs and determining research priorities. The National Regional Science Council (NRSC), formed in 1997, helps the regions to focus their research needs for ORD's consideration. The multi-year plans and annual resource planning describe how ORD will address recommendations in the CSSP Document.

Figure 1-3 is a schematic illustration of the relationship of the CSSP Document to U.S. EPA Government Performance and Results Act (GPRA) Goals and program and regional office plans and ORD's multi-year plans. The CSSP Document reflects the Agency's integrated efforts to achieve the GPRA goals and objectives, *e.g.*, Goal 2 - Clean and Safe Water, Objective 2.1 - Protect Human Health, for contaminated sediments. This effort is accomplished through cooperation among the critical partners, Office of Solid Waste and Emergency Response (OSWER), OW, ORD and the regional offices, within U.S. EPA.

Figure 1-3. Relationship of the CSSP Document to GPRA Goals and Other Plans



1.5 Relationship of the Contaminated Sediments Science Priorities Document to EPA's National Strategic Plan Goals

The relevance of addressing the problem of contaminated sediments to the Agency's mission is reflected in the linkages with U.S. EPA's *National Strategic Plan* goals, as discussed below. The GPRA requires all Federal agencies to develop a five-year strategic plan that establishes clear goals, objectives, and annual performance measures. The strategic plan is updated every three years, and agencies must report back to Congress annually on the results achieved. U.S. EPA's 2003 Strategic Plan (U.S. EPA, 2003c) establishes five goals that identify the environmental results that U.S. EPA is working to attain. Contaminated sediments is a significant multi-media issue related to the desired results for many of the goals (Table 1-1). Addressing contaminated sediment problems significantly helps the Agency achieve identified environmental outcomes.

The CSSP Document includes the first few steps in developing a science plan. It does not include management endorsement of the priorities or the implementation steps and schedules that are part of a complete science priority setting and implementation plan.

Table 1-1. Relationship of *National Strategic Plan* Goals and the Contaminated Sediments Science Priorities Document

Goal 2: Clean and Safe Water	
Objective 2.1 – Protect Human Health	Contaminated sediments affect human health by both direct and indirect exposure pathways (*e.g.*, direct contact, ingestion, uptake into the aquatic food chain). Contaminants in sediments can enter the aquatic food chain, thus contaminating aquatic organisms and ultimately placing humans at risk of adverse health effects from consumption of these organisms. U.S. EPA is addressing contaminants in sediments in order to prevent contaminant movement through the food chain.
Objective 2.2 – Protect Water Quality	Contaminated sediments affect water quality and threaten healthy aquatic communities.
Objective 2.3 – Enhance Science and Research	A sound scientific understanding of contaminated sediments is necessary for EPA to meets its goal of clean and safe water.
Goal 3: Land Preservation and Restoration	
Objective 3.3 – Enhance Science and Research	The protecting and restoration of land (including contaminated sediments) requires the best available science and research.
Goal 4: Healthy Communities and Ecosystems	
Objective 4.1 – Chemical, Organism, and Pesticide Risks	Toxic substances in sediments, such as polychlorinated biphenyls (PCBs) and mercury, can enter the aquatic food chain, contaminate fish, and place wildlife and humans at risk through their consumption. U.S. EPA is working to clean up contaminated sediment sites to prevent harm to human health and the environment.
Objective 4.4 – Enhance Science and Research	Contaminated sediments may cause unwanted, adverse consequences to human life, health, and the environment, and U.S. EPA is committed to using the best available science to reduce these risks.

1.6 Document Organization

The CSSP Document is organized into four chapters. Chapter One discusses the goals, objectives, and how the CSSP Document relates to the Agency's mandate. Chapter Two provides an overview of the contaminated sediment issues across the Agency. The brief description of issues in Chapter Two is intended to provide an introduction to the discussion of contaminated sediment issues, as well as providing the overall context for the more detailed discussion of specific research and science needs given in Chapter Three.

Chapter Three, along with U.S. EPA's contaminated sediment science activities database (Appendix A), is the data collection and analysis section of the CSSP Document. It documents the current contaminated sediment science activities ongoing within the Agency, and places these activities within the context of Agency goals. Significant data gaps and uncertainties in methodology/assessment procedures are identified. It proposes research and science activities to fill those data gaps and resolve related issues. Finally, it provides the key recommendations for future Agency science activities, including research.

Chapter Four discusses approaches to implement the contaminated sediments science priorities. For each recommendation, critical U.S. EPA partners and the immediate or long-term nature of the science activity are proposed (see Table 4-1).

2. OVERVIEW OF CONTAMINATED SEDIMENT SCIENCE ISSUES ACROSS THE AGENCY'S REGULATORY PROGRAMS

2.1 Introduction

Chapter Two provides an overview of the contaminated sediment problems and issues across U.S. EPA. The brief description of issues in this chapter is meant to provide an introduction to the discussion of contaminated sediment issues, as well as providing the overall context for the more detailed discussion of specific research and science needs given in Chapter Three of this document.

2.2 Scope, Magnitude, and Impacts of Contaminated Sediments

U.S. EPA defines contaminated sediments as soils, sand, and organic matter or minerals that accumulate on the bottom of a water body and contain toxic or hazardous materials that may adversely affect human health or the environment (U.S. EPA, 1998d). In 1997, U.S. EPA published its first National Sediment Quality Survey Report to Congress, *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States* (U.S. EPA, 1997a). This report describes areas where sediment may be contaminated at levels that may adversely affect aquatic life, wildlife, and human health. To evaluate sediment quality nationwide, U.S. EPA developed the National Sediment Inventory (NSI) database, which is a compilation of existing sediment quality data and protocols used to evaluate the data. The NSI was used to produce the first biennial Report to Congress on sediment quality in the United States as required under the Water Resources Development Act of 1992 (U.S. EPA, 1997a). Data in the NSI were generated from studies conducted between 1980 and 1993, and represent information collected in 1,363 of the 2,111 watersheds in the United States. U.S. EPA's evaluation of the data shows that sediment contamination exists in every region and state of the country and that various waters throughout the United States contain sediment sufficiently contaminated with toxic pollutants to pose potential risks to sediment-dwelling organisms, fish, and humans and wildlife that eat fish.

U.S. EPA published the first update to *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States, National Sediment Quality Survey: Second Edition* ("Update";U.S. EPA, 2004b) in 2004. The initial report presented a national baseline screening-level assessment of contaminated sediments from sediment quality data collected from 1980 through 1993. The Update identifies locations where data collected from 1990 to 1999 indicate that direct or indirect exposure to the sediment could be associated with adverse effects to aquatic life and/or human health. Of the 19,398 sampling stations evaluated in the Update, 8,348 stations (43 percent) were classified as Tier 1 (associated adverse effects on aquatic life or human health are probable), 5,846 (30 percent) were classified as Tier 2 (associated adverse effects on aquatic life or human health are possible), and 5,209 (27 percent) were classified as Tier 3 (no indication of associated adverse effects).[3] The Update

[3] It is important to note that the percentage of all NSI sampling stations where associated effects are "probable" or "possible" (*i.e.*, 43 percent in Tier 1 and 30 percent in Tier 2) does not represent the overall condition of sediment

does not provide an assessment of the "national condition" of sediments. However, it does provide an assessment of changes in the extent and severity of sediment contamination over time for specific areas in the United States where sufficient data exist.[4]

The NSI sampling stations were located in 5,695 individual river reaches (or water body segments) across the contiguous United States, or approximately 8.8 percent of all river reaches in the country (based on EPA's River Reach File 1).[5] Approximately 3.6 percent of all river reaches in the contiguous United States contained at least one station categorized as Tier 1, approximately 2.9 percent of reaches contained at least one station categorized as Tier 2 (but none as Tier 1), and in about 2.3 percent of river reaches all of the sampling stations were classified as Tier 3.

Watersheds containing areas of probable concern for sediment contamination (APCs) are those with at least 10 Tier 1 sampling stations and in where at least 75 percent of all sampling stations were classified as either Tier 1 or Tier 2. The NSI data evaluation found that 96 watersheds throughout the United States contained APCs (Figure 2-1). These watersheds represent about 4.2 percent of all watersheds in the United States (96 of 2,264) and APC designation could result from extensive sampling throughout a watershed, or from intensive sampling at a single contaminated location or a few contaminated locations.

Sediments act as both a repository and a source of pollutants. Many of these pollutants adsorb onto sediment particles which eventually settle to the bottom of water bodies. Over time these pollutants may be buried under layers of cleaner sediments. But sediments are subject to erosion and resuspension, which may result in the pollutants being released and dispersed through the water column for transport downstream, uptake through the food chain, or release to the atmosphere via volatilization, for transport through the air and re-deposition into lakes and other waterways.

across the country; most of the NSI data were obtained from monitoring programs targeted toward areas of known or suspected contamination (*i.e.,* sampling stations were not randomly selected).

[4] Two general types of limitations are associated with the Update: limitations of the compiled data, and; limitations of the evaluation approach. Limitations of the compiled data include the mixture of data sets derived from different sampling strategies, incomplete sampling coverage, the age and quality of data, and the lack of measurements of important assessment parameters. Limitations of the evaluation approach include uncertainties in the interpretive tools to assess sediment quality, use of assumed exposure potential in screening-level quantitative risk assessment (*e.g.,* fish consumption rates for human health risk), and the subsequent difficulties in interpreting assessment results.

[5] A river reach can be part of a coastal shoreline, a lake, or a length of stream between two major tributaries ranging from approximately 1 to 10 miles long.

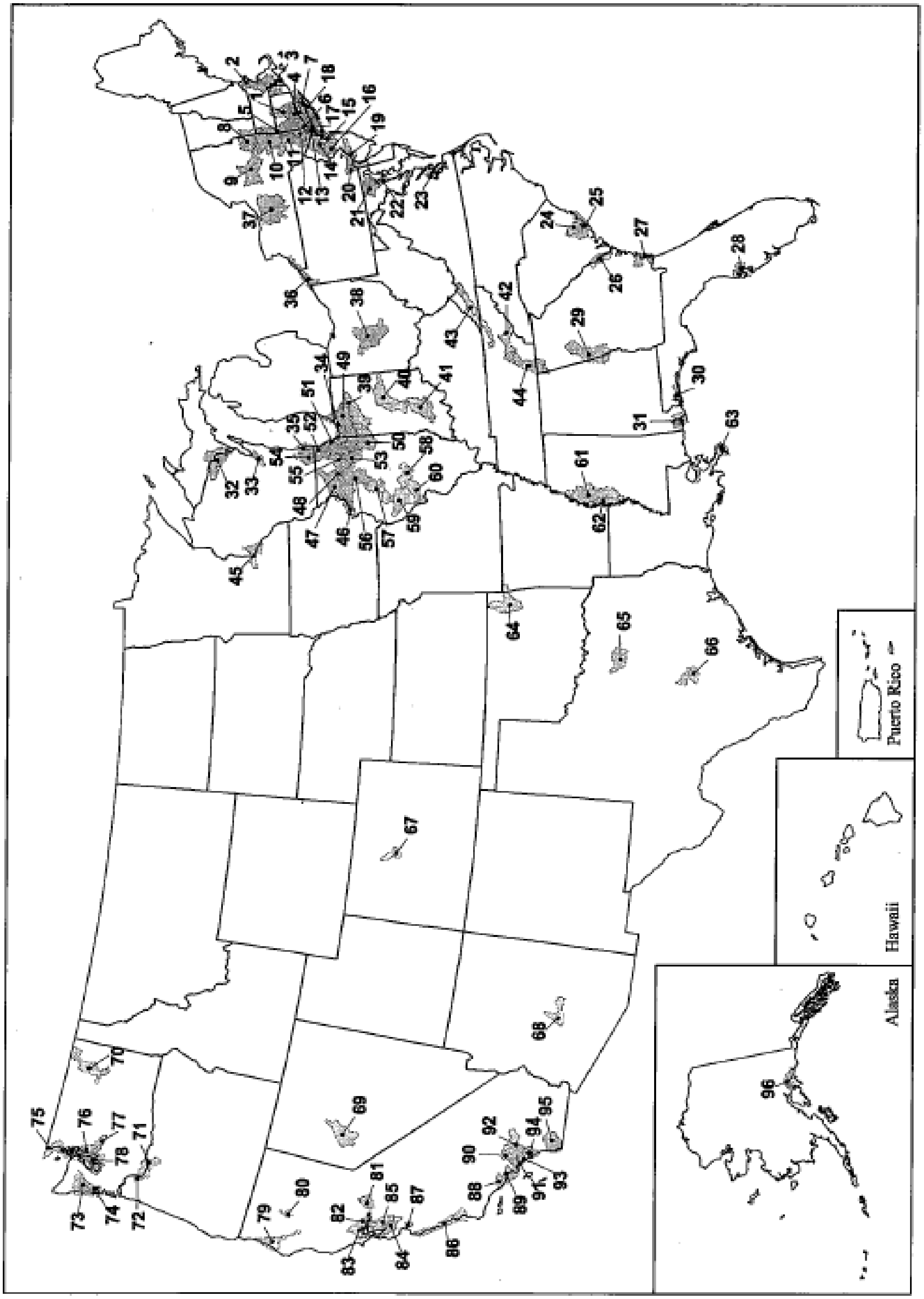


Figure 2-1. Watersheds Identified as Containing Areas of Probable Concern
Source: U.S. EPA. 2004b

The bioaccumulative, persistent, and toxic forms of contaminants in sediment affect aquatic life and wildlife through direct contact, ingestion, food chain effects, and habitat modification. These impacts include reproductive effects, developmental effects, birth defects, cancer, tumors, other deformities, and even death. Humans are also at risk through direct exposure to pollutants or through consumption of contaminated fish and wildlife. Exposure to these contaminants is linked to cancer, birth defects, neurological defects (*e.g.*, in infants and children), immune dysfunction, and liver and kidney ailments. Research is currently underway studying the potential for endocrine disruption effects due to contaminants in sediments.

In addition, contaminated sediments can impose costs on society through lost recreational opportunities and revenues. For example, fish consumption advisories can have a significant impact on the use of our natural resources. Approximately twenty-three percent of the nation's lake acreage and nine percent of the nation's river miles are under advisory for fish consumption, in many cases due to contaminated sediments. Contaminated sediments may also cause severe economic impacts on local and regional transportation, fishing, tourism, and development industries. In one Great Lakes harbor, the Indiana Harbor Ship Canal, contaminated sediments are imposing an annual cost of eleven to seventeen million dollars (Peck et al., 1994).

2.3 Overview of Major Sediment Issues and Needs Across the Agency

The management of contaminated sediments is a multi-faceted challenge for the Agency. As a multi-media issue, aspects of contaminated sediment management fall under different parts of U.S. EPA. This section provides an overview of the major contaminated sediment issues across the Agency. This discussion is meant to provide the overall context for the discussion of the specific research and science needs that follow in Chapter Three.

Water Quality Standards

The Clean Water Act was established to restore and maintain the quality of waters in the United States. Sediment underlying surface water is recognized as a significant source of, and sink for, toxic pollutants in the aquatic environment. Therefore, addressing sediment quality is an integral component of water quality standards programs. It is necessary to incorporate appropriate sediment quality protection policies and procedures to protect and maintain designated water uses. The Clean Water Act establishes as a national goal "...that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and provides for recreation in and on the water," be achieved by July 1983 (CWA Section 101(a)). Sediment quality can affect the attainment of designated uses. It is appropriate to assess and protect sediment quality as an essential component of the total aquatic environment in order to achieve and maintain designated uses. The relationship between sediment quality, biological effects, and attainment of designated uses is uncertain.

Development of Total Maximum Daily Loads

Section 303(d) of the CWA and its implementing regulations (40 CFR 130.7) require states and authorized tribes to establish Total Maximum Daily Loads (TMDLs) of pollutant discharge at levels necessary to achieve applicable water quality standards. TMDLs identify the loading capacity of the water body, wasteload allocations for point sources, and load allocations for nonpoint sources and natural background. About 40,000 TMDLs are required for about 20,000 impaired water bodies in U.S., based on U.S. EPA's 1998 list of impaired waters. The 2000 305(b) report has been published and is available at http://www.epa.gov/305b/. About twenty-four percent of the TMDLs (based on 1998 data from the TMDL tracking system) are for pollutants that are also found in contaminated sediments. These TMDLs require analysis of the contribution of pollutants from contaminated sediments.

Fish Advisories

The states, U.S. territories, and Native American tribes have primary responsibility for protecting their residents from the health risks of consuming contaminated, non-commercially caught fish and wildlife. They do this by issuing consumption advisories for chemicals such as mercury or PCBs for the general population as well as for sensitive subpopulations (*e.g.*, pregnant women, nursing mothers, and children). These advisories inform the public when high concentrations of chemical contaminants have been found in local fish and wildlife and include recommendations to limit or avoid consumption of certain fish and wildlife species from specific water bodies or water body types. Approximately twenty-three percent of the nation's lake acreage and over nine percent (9.3%) of the nation's river miles are under advisory for fish consumption. Many of these advisories can be linked to contaminated sediments. One hundred percent of the Great Lakes and their connecting waters and seventy-one percent of coastal waters of the contiguous forty-eight states were under advisories in 2000. It is expected that improving sediment quality will reduce the need for many consumption advisories. Bioavailability, accumulation, tissue distribution, and depuration are major issues for fish advisories.

Management of Dredged Material from Navigational Dredging

Several hundred million cubic yards of sediment are dredged from United States ports, harbors, and waterways each year to maintain and improve the nation's navigation system for commercial, national defense, and recreational purposes. Of the total sediment volume dredged, approximately one-fifth is disposed of in the ocean (*i.e.*, waters outside the baseline) at designated sites in accordance with Section 103 of MPRSA. Most of the remaining dredged material is discharged into inland waters of the United States (*i.e.*, waters inside the baseline), placed in confined disposal facilities with a return flow to waters of the U.S. (*i.e.*, inland waters and waters out to three miles from the baseline), or used for beneficial purposes (including as fill) in waters of the U.S., all of which are regulated under Section 404 of the CWA.

U.S. Army Corps of Engineers, the Federal agency designated to maintain navigable waters, conducts a majority of this dredging and disposal under its Congressionally authorized civil works program.

The balance of the dredging and disposal is conducted by a number of local public and private entities. In either case, the disposal is subject to a regulatory program administered by U.S. ACE and U.S. EPA under the above statutes. U.S. EPA shares the responsibility of managing dredged material, principally in the development of the environmental criteria by which proposed discharges are evaluated and disposal sites are selected, and in the exercise of its environmental oversight authority. Estimates by U.S. ACE indicate that only a small percentage of the total annual volume of dredged material disposed (approximately three million to twelve million cubic yards) is contaminated such that special handling and/or treatment is required. The major issues here are uncertainties about the biological effects of risk management options and environmental effects of disposal practices.

Superfund Sites

Superfund is the Federal government's program to clean up the nation's uncontrolled hazardous waste sites under CERCLA. The National Priorities List (NPL) is a published list of priority hazardous waste sites in the country that are being addressed by the Superfund program. The regions have identified about four hundred NPL sites potentially having contaminated sediments. These include a number of very large contaminated sediment sites where remedies may cost up to several hundreds of millions of dollars. The major issues associated with contaminated sediments include risks to human health and the environment, limited disposal space, high costs, and the uncertainties related to risk management options.

Resource Conservation and Recovery Act Sites

Like the Superfund program, RCRA sites/facilities are remediated to support current and reasonably anticipated uses. RCRA authority for Corrective Action is to clean up releases from a specific facility; therefore it is less amenable to an area-wide approach than Superfund. The number of RCRA sites with contaminated sediment issues is smaller than the number of CERCLA contaminated sediment sites. In March 1999, the regions and states identified seventeen RCRA Corrective Action sites with sediment contamination problems. The major issues associated with contaminated sediments related to RCRA sites include uncertainties regarding risks to human health and the environment and uncertainties related to risk management options.

Deposition of Contaminants via Short- and Long-Range Air Transport

Over the past thirty years, scientists have collected a large amount of data indicating that air pollutants can be redeposited on land and water, sometimes at great distances from their original sources. These data demonstrate that air transport of contaminants (both near- and far-field) can be an important contributor to declining water quality. These air pollutants can have undesirable health and environmental impacts: contributing to fish body burdens of toxic chemicals, causing harmful algal blooms through deposition of nutrients, and impacting water quality, resulting in unsafe drinking water.

In response to mounting evidence indicating that air pollution contributes significantly to water pollution, Congress added the Great Waters Program (Section 112(m)) when it amended the Clean Air Act in 1990. The Great Waters Program, a joint program including U.S. EPA and NOAA, is designed to study and address the effects of air pollution on the water quality and ecosystems of the Great Lakes, Lake Champlain, the Chesapeake Bay, and estuaries that are part of the National Estuary Program or the National Estuarine Research Reserve System.

Persistent, Bioaccumulative, and Toxic Pollutants

Persistent, bioaccumulative, toxic chemicals (PBTs) often accumulate in sediments. The Agency has three major efforts related to PBTs: a PBT Initiative; the Great Lakes Binational Toxics Strategy; and Testing Requirements for Pesticides and Toxic Substances Use under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and TSCA.

PBT Initiative

U.S. EPA has developed and is implementing a national multi-media strategy for the reduction of persistent, bioaccumulative, toxic chemicals (PBTs), entitled the PBT Initiative.[6] The goal of this strategy is to reduce risks to human health and the environment from existing and future exposure to priority pollutants. The four main elements of the PBT Initiative are:

1. Develop and implement national action plans to reduce priority PBT pollutants, utilizing the full range of U.S. EPA tools.

2. Continue to screen and select more priority pollutants for action.

3. Prevent new PBTs from entering the marketplace.

4. Measure progress of these actions against U.S. EPA's Government Performance Results Act (GPRA) goals and national commitments.

U.S. EPA's challenge in reducing risks from PBTs stems from the pollutants' ability to travel long distances, to transfer rather easily among air, water, and land, and to linger for generations in people and the environment. Although much work has been done over the years to reduce the risk associated with these chemicals, they frequently occur at levels of concern in fish tissue. All of the substances that are causing the fish consumption advisories are PBTs and metals.

[6] Priority PBTs currently being addressed under the PBT initiative include: aldrin/dieldrin; benzo(a)pyrene; chlordane; DDT/DDD/DDE; hexachlorobenzene; alkyl-lead compounds; mercury and its compounds; mirex; octachlorostyrene; PCBs; dioxins and furans; toxaphene.

Great Lakes Binational Toxics Strategy

The Great Lakes Binational Toxics Strategy provides a framework for actions to reduce or eliminate persistent, toxic substances from the Great Lakes Basin, especially those that bioaccumulate. The Strategy was developed jointly by Canada and the United States in 1996 and 1997 and was signed April 7, 1997. The Strategy establishes reduction challenges for an initial list of persistent, toxic substances targeted for virtual elimination (‘Level One’ substances) which are synonymous with the first twelve priority pollutants identified through the PBT Initiative. These substances have been associated with widespread long-term adverse effects on wildlife in the Great Lakes, and, through their bioaccumulation, are of concern for human health. The Strategy provides a framework for action to achieve specific quantifiable reduction “challenges” in the 1997 to 2006 time frame for specific toxic substances.

Testing Pesticides and Toxic Substances for Registration and Use

FIFRA and TSCA provide U.S. EPA the authority to ban or restrict the use of pesticides and toxic chemicals that have the potential to contaminate sediment. These actions can be taken if environmental or human health risks are determined to be unacceptable. Sediment toxicity testing can be required to assess the risks of sediment contamination posed by pesticides and other chemicals. These tests must be applied under the authority of FIFRA and TSCA in a strategy to systematically evaluate the risks of sediment contamination.

2.4 Recent U.S. EPA Contaminated Sediment Science Activities and Products

To address the contaminated sediment issues discussed above, U.S. EPA produces scientific products such as guidance documents and risk assessments. Various scientific activities, internal and external to U.S. EPA, support the development of these scientific products. Figures 2-2 through 2-4 summarize the major recent science products and activities in contaminated sediments by OW, OSRTI, ORD, and U.S. EPA regions. The information has been separated into effects and assessment, sediment characterization and fate and transport, and remediation monitoring and managing contaminated sediments. Cross-Agency relationships have resulted in focused scientific activities to more directly support science products and program office or regional decisions. A detailed listing of U.S. EPA’s Contaminated Sediment Science Activities Database, including program and regional office activities, is contained in Appendix A. It presents recent projects that include scientific areas on program implementation, human health and ecological effects and assessment, exposure and modeling, and remediation and risk management. Collaboration among U.S. EPA scientists and engineers enhances the use of quality scientific information in risk management decision-making.

Figure 2-2. Current Agency Science Activities And Products Regarding Contaminated Sediment Effects And Risk Assessment

SCIENCE PRODUCTS

- Draft Equilibrium Partitioning Sediment Guideline Documents.
- Integrated Water Quality Criteria for Ambient Waters.
- Use of Sediment Benchmarks to Predict Toxicity in Great Lakes Sediments.
- Site Human Health and Ecological Risk Assessment.
- Site Assessment Framework Document.
- Improved Site Assessment.

ORD SCIENCE ACTIVITIES

- Toxicity Identification Evaluation Sediments.
- Sediment Toxicity Test Methods (acute, chronic, toxicity correlation with field data, criteria development issues).
- Sediment Toxicity Assessment Methods with OW and USGS.
- STAR Grants Basic Research (ecological system assessment effects of contaminated sediments on biota).

OW SCIENCE ACTIVITIES

- Field Valuation Sediment Toxicity Tests (ORD and USGS).
- Development of Methods to Test Chronic Toxicity of Marine Sediments.
- Sediment Toxicity Test Methods.

REGIONAL SCIENCE ACTIVITIES

- Miniaturized Sediment Toxicity Tests on Marine and Freshwater Amphipods and Fish (U.S. EPA Region 2 and U.S. EPA Region 6).
- Sediment Quality Assessment.
- *In situ* Real-time System to Assess PAH Contaminated Sediments (GLNPO and OSRTI).
- Human Health and Ecological Risk Assessment.

Figure 2-3. Current Agency Science Activities And Products Regarding Contaminated Sediment Characterization And Environmental Fate And Transport

SCIENCE PRODUCTS

- Equilibrium Partitioning Sediment Benchmarks Documents.
- Integrated Water Quality Criteria for Ambient Waters.
- Use of Sediment Quality Guidelines to Predict Toxicity in Great Lakes Sediments.
- Site Human Health and Ecological Risk Assessment.
- Site Assessment Framework Document.
- National Sediment Inventory.
- Summary of Available Fate and Transport Models.

ORD SCIENCE ACTIVITIES

- STAR Grants Basic Research (fate, transport, and bioaccumulation of contaminated sediments; physical and chemical sediment parameter impacts; watershed and ecological system studies and trophic transfer; bioavailability of contaminants; mechanisms of contaminated release from re-suspended sediments during dredging).
- Fate and Transport Methods (*e.g.*, bioaccumulation, distribution of contaminants, uptake into biota).
- Indicators of Ecosystem Sustainability.

OW SCIENCE ACTIVITIES

- Sediment Bioavailability.
- Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment: Status and Needs.
- Sediment Fate Transport Model.
- Tiering Classification for the National Sediment Inventory.
- Methods for Collection, Storage, and Manipulation.

OSWER SCIENCE ACTIVITIES

- Site Characterization.
- Risk Assessment Guidance Development.
- Co-sponsoring a conference on Using Chemical Fate and Transport Models at Contaminated Sediment Sites.

REGIONAL SCIENCE ACTIVITIES

- Site Characterization.
- Risk Assessment.
- R/V Mudpuppy Sediment Assessments in the Great Lakes Basin (GLNPO).
- Fully Integrated Environmental Location Decision Support (FIELDS) Software Package.

Figure 2-4. Current Agency Science Activities And Products Regarding Remediation, Monitoring, And Managing Contaminated Sediments

SCIENCE PRODUCTS

- Sediment Cleanups.
- Development of Contaminated Sediment Remediation Guidance for Hazardous Waste Sites.
- Development of Biological, Physical, and Chemical Monitoring Fact Sheets.

ORD SCIENCE ACTIVITIES

- Remediation Technology Performance (dredging and capping).
- Site Specific Technical Support.
- Monitored Natural Recovery
- Research.
- *Ex situ* Management and Treatment Technologies.
- Site Demonstrations of Innovative Technologies.
- Innovative *In situ* Treatment Technologies.

OW SCIENCE ACTIVITIES

- Ocean-Dredged Material Disposal.

OSWER SCIENCE ACTIVITIES

- Rule-making Applicable to Contaminated Sediments (OSW).
- Contaminated Sediment Technical Advisory Group review of large and complex Superfund Sites (OSRTI and Regions).
- Evaluation of Remedial Effectiveness at Superfund Sites (OSRTI).

REGIONAL SCIENCE ACTIVITIES

- Remedial Action Plan (RAP) Program (U.S. EPA Regions 2, 3, 5, and GLNPO).
- Demonstration of Sediment Decontamination Technology Development with Beneficial Use Applications (U.S. EPA Region 2 and GLNPO).
- Sediment Capping and Natural Recovery Project (U.S. EPA Region 3).
- Multi-Media Initiative for Calcasieu Estuary (U.S. EPA Region 6).
- Sediment Environmental Priority Initiatives (U.S. EPA Region 5).
- Great Lakes Contaminated Sediments Initiative (U.S. EPA Region 5).

2.5 Overview of Communication and Collaboration Activities

Management of contaminated sediments requires a coordinated effort which surpasses any single legislative authority or media. Comprehensive, multi-media responses that combine multiple programs, agencies, and resources with public and private support can result in resolution of the contaminated sediments problem. This section provides an overview of how such coordinated multi-media efforts occur within and outside of U.S. EPA.

2.5.1 Collaborative Efforts Within U.S. EPA

Several key collaborative efforts within the Agency are relevant to the CSSP Document and include the Contaminated Sediment Management Committee (CSMC), publication of the *Contaminated Sediment Management Strategy* (CSMS) (U.S. EPA, 1998b), development of the National Sediment Inventory, the Agency-wide Science Inventory, and cross-media teams such as the U.S. EPA Region 5 Sediment Team that focus their efforts on the contaminated sediments issue. In addition, there has been enhanced Headquarters collaboration with the regions and coordination across media programs in the regions. These efforts are briefly discussed below.

Figure 2-5. The Goals of the Contaminated Sediment Management Strategy

- Prevent the volume of contaminated sediment from increasing.
- Reduce the volume of existing contaminated sediment.
- Ensure that sediment dredging and dredged material disposal are managed in an environmentally sound manner.
- Develop scientifically sound sediment management tools for use in pollution prevention, source control, remediation, and dredged material management.

- U.S. EPA published the Contaminated Sediment Management Strategy in April 1998. The CSMS summarizes U.S. EPA's understanding of the extent and severity of sediment contamination; describes the cross-program policy framework in which U.S. EPA intends to promote consideration and reduction of ecological and human health risks posed by sediment contamination; and identifies actions U.S. EPA believes are needed to bring about consideration and reduction of risks posed by contaminated sediments (see Figure 2-5 for goals).

- The CSMC was established to coordinate all the appropriate programs and their associated regulatory authorities involved in the management of contaminated sediments. CSMC includes representation from OSWER, OW, ORD, Office of Enforcement and Compliance (OECA), and many of the regions.

- The National Sediment Inventory is a national database and repository of data regarding sediment quality in the United States. In accordance with the requirements of Title V of the Water Resources Development Act, U.S. EPA's Office of Water developed the first comprehensive national survey of data regarding sediment quality and compiled all available information in a national database. The database includes information regarding quantity, chemical and physical composition, and geographic location of pollutants in sediments. This information was summarized in a report to Congress entitled, *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States* (U.S. EPA, 1997a). The National Sediment Inventory is being updated on a regular basis and will be used to assess trends in sediment quality.

- U.S. EPA's Science Inventory is a database of Agency research and science activities for a number of different topics, one of which is contaminated sediments. The Office of Science Policy coordinated development of the Science Inventory for the Agency. The portion on contaminated sediments identifies the current scientific activities and research efforts in the contaminated sediments area from across the Agency.

- Contaminated sediments were designated as an U.S. EPA Region 5 Environmental Priority in 1995 due to both the extent and severity of the problem across the region. Because a coordinated, multi-media effort would be required to address the problem, a Regional Team was formed with members representing regional programs and the Great Lakes National Program Office. The Team helped develop a strategy to implement a coordinated approach to program and office efforts to address contaminated sediments sites and provide technical expertise to the region, state agencies, and others.

- In 2000, the Agency established five Estuarine Indicator Research Programs. These Programs were designed to identify, evaluate, recommend and potentially develop a suite of new, integrative indicators of ecological condition, integrity, and/or sustainability that can be incorporated into long-term monitoring programs and which will complement the Agency's intramural coastal monitoring program. Moreover, the Agency, the U.S. Department of Agriculture (USDA), and seven other Federal agencies have developed a Clean Water Action Plan to protect public health and restore the nation's waterways through 111 key actions.

- The Agency's Environmental Monitoring and Assessment Program (EMAP) is a long-term research effort to enable status and trend assessments of aquatic and other ecological resources across the U.S. with a known statistical confidence. Initiated in the late 1980's within ORD, EMAP addresses monitoring the conditions of estuaries, streams and lakes in selected geographic regions, as well as examining the surrounding landscapes in which these resources occur. EMAP is now progressing towards national demonstrations of monitoring science in these and other aquatic resources. This strategy forms the basis for the research needed to establish the condition of the nation's aquatic and other resources. Future plans for EMAP involve research and technology transfer to enable periodic national assessments of all aquatic ecosystems. Regional Environmental Monitoring and Assessment Program (REMAP) was initiated to test the applicability of the EMAP approach to answer questions about ecological conditions at regional and local scales. Using EMAP's statistical design and indicator concepts, REMAP conducts projects at smaller geographic scales and in shorter time frames than the national EMAP program.

- A framework and guidance for assessing the hazards and risks associated with metals and metalloids is being developed through the Risk Assessment Forum. The work was initiated in 2001 to identify the special properties of metals in soils, sediments, water, and air. The final products will provide tools and advice for sampling, analysis, and assessment of the hazards and risks from metals, including environmental chemistry and fate, bioavailability, and health and ecological effects.

2.5.2 External Collaborative Efforts

The Agency recognizes the importance of an open dialogue and active collaboration with Federal and state agencies and other stakeholders who are concerned with the contaminated sediment issue. U.S. EPA is participating in, is sponsoring, or has sponsored a number of multi-stakeholder collaborations concerned with the various aspects of this issue. These efforts have been diverse. For example, the National and Regional Dredging Teams, co-chaired by U.S. EPA and U.S. ACE, were formed in response to the final report of the Interagency Working Group on the Dredging Process in order to provide a mechanism for timely resolution of conflicts over navigational dredging by involving all agencies and maximizing interagency coordination.

OSWER's Technology Innovation Office (TIO) and ORD's National Risk Management Research Laboratory (NRMRL) are co-sponsors of the Remedial Technologies Development Forum (RTDF) Sediment Action Team, a public- and private-sector partnership created to undertake the research, development, demonstration, and evaluation efforts needed to achieve common cleanup goals (see Figure 2-6). It is anticipated that these collaborations will continue and expand through the implementation of the CSSP Document.

Figure 2-6. Examples of External Collaborative Efforts

- Contaminated Aquatic Sediment Remedial Guidance Workgroup: developing Superfund Contaminated Sediments Remediation Guidance; involves ORD, OW, and the regions, as well as inter-agency participation from NOAA, USGS, U.S. FWS, and U.S. ACE.
- National Dredging Team (NDT): includes members from U.S. EPA, U.S. ACE, NOAA (Ocean and Coastal Resource Management (OCRM) and National Marine Fisheries Service (NMFS)), U.S. Coast Guard (USCG), USGS, and U.S. Maritime Administration (MARAD).
- RaDiUS database of Federally-funded research.
- Great Lakes Dredging Team: Comprised of Great Lakes states, Great Lakes Commission and six Federal agencies, including U.S. EPA.
- Inter-state Technology and Regulatory Cooperation (ITRC) Sediment Remediation Team.
- U.S. EPA Region 5/State Superfund Conference Calls.
- Ashtabula River Partnership.
- Remedial Technologies Development Forum (RTDF). Sediment Action Team.
- Superfund Forum on Managing Contaminated Sediments at Hazardous Waste Sites (May 30 -

In addition to these direct collaborative efforts with other agencies, the RAND Corporation, in cooperation with the National Science Foundation (NSF), was funded by the Federal government to develop a database called RaDiUS (Research and Development in the United States). This database tracks government resources and research and development activities. RaDiUS helps the research community understand the research being conducted by the Federal government in order to eliminate duplication of effort and promote collaboration. The database was searched using the term "sediment" and identified more than 650 projects in eight agencies: USDA, Department of Commerce (DOC), Department of Defense (DoD), Department of Energy (DOE), Department of Interior (DOI), U.S. EPA, National Aeronautics and Space Administration (NASA), and NSF. The results of this search were considered in the development of this document and will be revisited as the document develops and is implemented.

2.6 National Research Council Report on PCB-Contaminated Sediments

In an effort to address the controversial issues related to the management of PCB-contaminated sediments, the U.S. Congress directed U.S. EPA to "enter into an arrangement with the National Academy of Sciences (NAS) to conduct a review which evaluates the availability, effectiveness, costs, and effects of technologies for the remediation of sediments contaminated with polychlorinated biphenyls, including dredging and disposal." In response to this Congressional request, the National Research Council (NRC) published *A Risk-Management Strategy for PCB-Contaminated Sediments*, which was released in March 2001 (NRC, 2001a). Among the eleven major conclusions and recommendations made by the committee, one was directed at the research areas shown in Figure 2-7.

Figure 2-7. Recommendations for Further Research on PCB-Contaminated Sediments (NRC, 2001a)

- A better assessment of human health and ecological risks associated with mixtures of individual chlorobiphenyls present in specific environmental compartments.
- The impact of co-contaminants on PCB risk assessments and risk management strategies.
- Processes governing the fate of PCBs in sediments, including erosion, suspension, transport of fine cohesive sediments, pore water diffusion, biodegradation, and bioavailability.
- Improvement of *ex situ* and *in situ* technologies associated with removal or containment of PCB-contaminated sediments, treatment of PCB-contaminated material, and disposal of such sediments.
- Pilot scale testing of innovative technologies, such as biodegradation and *in situ* active treatment caps, to assess their effectiveness and applicability to various sites.
- The impact of continuing PCBs releases and global environmental cycling on site-specific risk assessments.

2.7 National Research Council Report on Contaminated Marine Sediments

The National Research Council established the Committee on Contaminated Marine Sediments to "assess the nation's ability for remediating contaminated sediments and to chart a course for the development of management strategies." The Committee published the results of their findings in *Contaminated Sediments in Ports and Waterways* (NRC, 1997). In general, the report concluded that there is no need to delay sediment remediation projects in anticipation of a ground-breaking remediation technology, since no such technology is on the horizon. The recommendations are organized into three areas: decision-making, remediation technologies, and project implementation. A summary of the recommendations is given in Figure 2-8.

Figure 2-8. National Research Council Recommendations on Contaminated Marine Sediments (NRC, 1997)

DECISION-MAKING

- U.S. EPA and U.S. ACE should continue to develop uniform/parallel procedures for environmental/human health risks associated with freshwater, marine, and land-based disposal, containment, or beneficial reuse of contaminated sediments.
- Because consensus building is essential for project success, Federal, state, and local agencies should work together with appropriate private-sector stakeholders to interpret statutes, policies, and regulations in a constructive manner so that negotiations can move forward and sound solutions are not blocked or obstructed.
- To facilitate the application of decision-making tools, U.S. EPA and U.S. ACE should: (1) develop and disseminate information to stakeholders concerning the available tools; (2) use appropriate risk analysis techniques throughout the management process, including the selection and evaluation of remediation strategies; and (3) demonstrate the appropriate use of decision analysis in an actual contaminated sediments case.
- U.S. ACE should modify the cost-benefit analysis guidelines and practices it uses to ensure the comprehensive, uniform treatment of issues involved in the management of contaminated sediments.
- U.S. ACE should revise its policies to allow for the implementation of placement strategies that involve the beneficial use of contaminated sediments even if they are not lowest cost alternatives. In addition, regulatory agencies involved in contaminated sediments disposal should develop incentives for and encourage implementation of beneficial use alternatives.
- Federal and state regulators, as well as ports, should investigate the use of appropriate legal and enforcement tools to require upstream contributors to sediment contamination to bear a fair share of cleanup costs.

TECHNOLOGIES

- U.S. EPA and U.S. ACE should develop a program to support research and development and to 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 comparisons. 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 research and development, from the concept stage to field implementation.
- U.S. ACE and U.S. 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.
- U.S. EPA and U.S. ACE should support research and development to reduce contaminant losses from confined disposal facilities and confined aquatic disposal, to promote the reuse of existing confined disposal facilities, and to improve tools for the design of confined disposal facilities and confined aquatic disposal systems and for the evaluation of long-term stability and effectiveness.

2.8 Long-term Trends Affecting Contaminated Sediments

The purpose of this CSSP Document is to capture not only immediate and intermediate scientific needs for contaminated sediment management, but also longer term trends or impacts which may be "outside the box of regulatory focus," yet are of critical environmental concern. In many cases, these scientific concerns encompass more than the area of contaminated sediments. A listing of some of these concerns is given in Figure 2-9.

The sources and activities that lead to sediment contamination are likely to increase with the growth in world population and economic development. Atmospheric loadings are likely to increase as well. Under most current projections of future conditions here and abroad, societal and governmental pressure will increase to maintain navigation channels, protect food and water supplies, and develop housing, business, and recreation along waterways and coastlines. While it is extremely important to develop the capability to detect and manage contaminated sediments, that strategy alone is unlikely to achieve the desired levels of environmental protection.

Figure 2-9. Environmental Trends Relevant to Contaminated Sediments

- Expanding urban centers in coastal areas and increased waterfront development.
- Increase of impervious roof and pavement surfaces.
- Long-range transport of contaminants.
- Total Maximum Daily Load challenge.
- Nonpoint source controls.
- Large/complex sites ("mega" sites), including sites that span multiple communities.
- Limited disposal capacity.
- High costs of remediation vs.

An important area for future research is the collection and analysis of contaminated sediment data to understand environmental loadings, develop measures and management strategies to prevent additional loadings to sediments and develop alternative uses, promote recycling, and minimize the generation of waste to reduce future loadings. Such approaches (*e.g.*, conceptual models of the sources and pathways that lead to contaminated sediments and global budgets of metals and persistent and bioaccumulative organics) could be integrated with other U.S. EPA programs, Federal agencies and states, industrial trade groups, stakeholders, and foreign countries. Consideration of these broader scientific/societal issues in this kind of strategy will require national and international collaboration.

3. ASSESSING THE SCIENCE ON CONTAMINATED SEDIMENTS

Chapter Three presents the state of the science for assessing and managing contaminated sediments and specific science needs. Science needs were developed to provide guidance on the scientific tasks required to address the key scientific questions within each topic. Science needs were evaluated for their ability to address high priority, critical data gaps, to reduce uncertainty in risk assessment/risk management decision-making, and to provide state-of-the-science guidance or tools. Key recommendations for each major topic were agreed to by the Workgroup members using a group consensus process that included the evaluation criteria, professional judgment, and comment or input from both internal and external review. The Workgroup however, purposely did not constrain the recommendations to fit within available resources. Instead, the recommendations are a comprehensive list that U.S. EPA organizations can consider when balancing resource allocations across competing high priority needs.

The thirty-three (33) key recommendations described in this section address the contaminated sediment issues and data gaps, as well as areas for better coordination of contaminated sediment science activities, including research, across the Agency that are identified as highest priority by the Workgroup and have undergone both internal and external Agency review. The recommendations follow each science topic: sediment site characterization; exposure assessment research; health effects research; ecological effects research; sediment remediation; baseline, remediation, and post-remediation monitoring; risk communication and community involvement; and information management and exchange activities.

It is important to understand that the recommendations presented in this document are closely interrelated, reflecting the relationships among the underlying science areas. Therefore, each recommendation may be viewed as a single aspect of the larger universe of science needs in the area of contaminated sediments, generating insights for use in other areas and relying on insights gathered from the implementation of other recommendations. For example, the information gathered from Recommendation A.1 (a workshop on sediment stability) is intended to provide information to be used in Recommendations B.3 (fate and transport modeling), B.4 (use of sediment stability data), D.4 (ecological benefits and adverse effects of dredging), E.1-E.4 (remediation alternatives), and F.1-F.2 (monitoring). Similarly, Recommendations E.1 (collecting the data necessary and developing the guidance for determining the conditions under which natural recovery is a viable option) and E.4 (evaluating the short- and long-term impacts of dredging relative to natural processes and human activities) are strongly linked to Recommendation D.4 (acquiring data and developing criteria to use in balancing long-term benefits from dredging versus shorter term effects on ecological receptors and their habitats). Users of this document are encouraged to identify and explore these links.

3.1 Introduction

Contaminated sediments threaten ecosystems, aquatic resources, and human health. Sediment contamination primarily occurs because many pollutants adsorb to organic and inorganic particles that eventually settle to the bottom of streams, rivers, reservoirs, lakes, estuaries, or marine waters. Sediments also serve as a habitat for the benthic community. However, when contamination of the sediments occurs, the entire system becomes a contaminant reservoir for bioaccumulation and trophic transfer. Substantial and complicated impacts on the ecosystem are well documented, ranging from direct effects on benthic communities to substantial contributions to contaminant loads and effects on upper trophic levels (*e.g.*, humans and other fish eaters) through food web contamination.

The assessment and management of contaminated sediments in ports and harbors, rivers, lakes, and at hazardous waste sites do not easily lend themselves to simple solutions. Contaminated sediments in aquatic environments are best characterized as systems problems, with multiple causes and effects. Aquatic environments are a complex assemblage of interacting physical, chemical, and biological processes, many of which are inherently nonlinear, with considerable uncertainty about both their nature and their interconnections, and that are strongly linked to terrestrial ecosystems. Further difficulties arise from the great variability in the physical and biogeochemical characteristics of aquatic environments; human and ecological receptors; and the cultural, social, and economic values associated with different freshwater, estuarine, and marine environments. Fundamental to the assessment and effective management of contaminated sediments is a sound understanding of the science affecting contaminated sediment systems. This chapter weighs science needs against the backdrop of current contaminated sediment science activities within the Agency.

To illustrate how complex sediment processes can be, Figure 3-1 presents one example of a conceptual model for a generalized contaminated sediment site. The model depicts the pathways from the source of contamination through the various environmental media to exposure of ecosystems and human populations. Table 3-1 lists key processes that underlie contaminated sediment systems.

Broadly defined, science needs for contaminated sediments may be separated into several areas:

- Characterizing water body/sediment systems (including physical and biogeochemical characteristics, human and ecological receptors).

- Understanding the physical/chemical processes that operate in water body/sediment systems.

- Understanding the biological effects of contaminants found in sediments, particularly with regard to the complex mixtures of contaminants typically found at contaminated sediment sites.

- Modeling water body/sediment systems— including accounting for the spatially variable and dynamic nature (*i.e.*, seasonal flow variations and episodic storm events) of real systems.

- Clarifying the processes that are the basis of technological systems designed to mitigate/remediate environmental degradation.

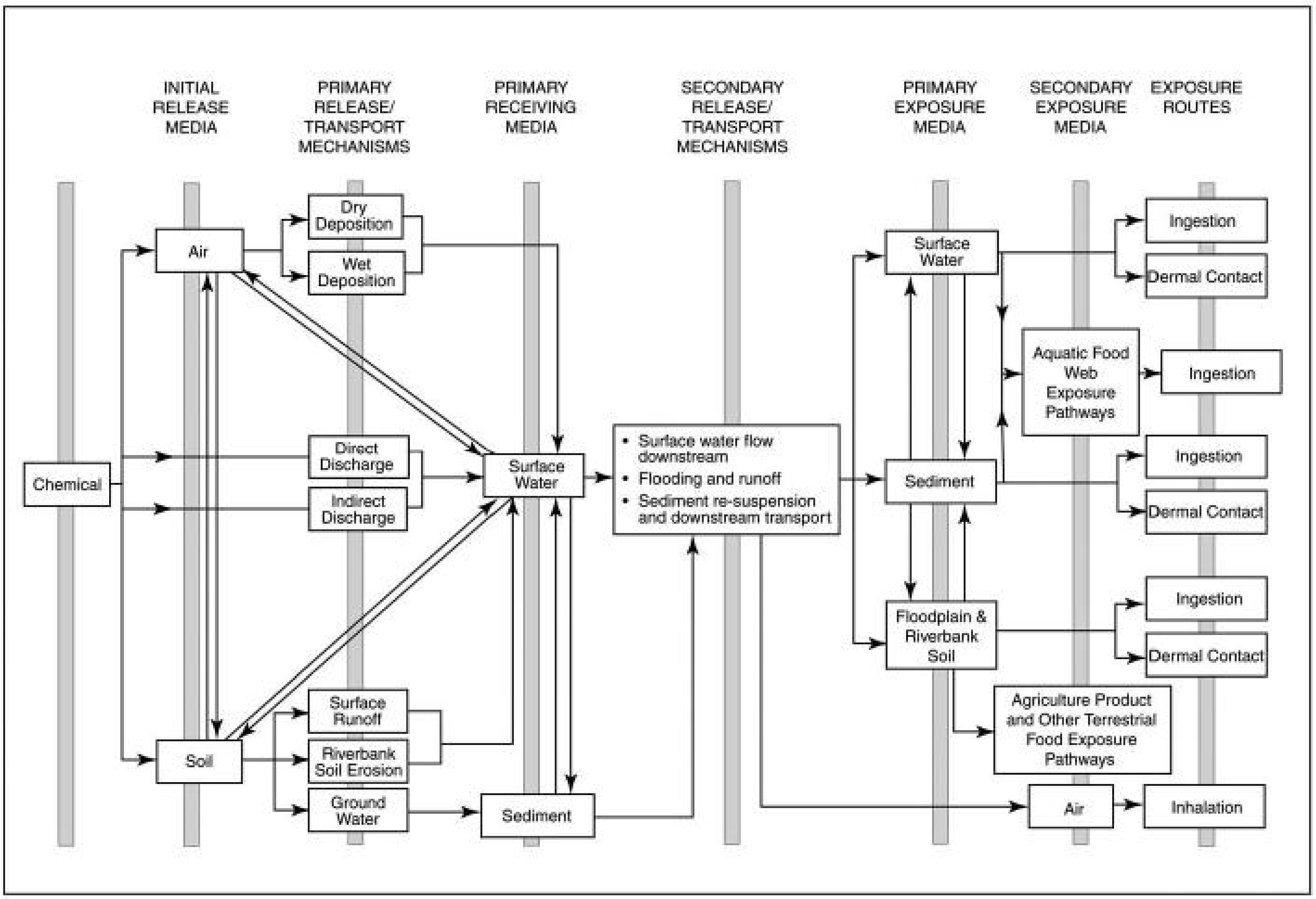
- Understanding the interactions and feedback among physical and biological processes.

Table 3-1. Key Processes Underlying Contaminated Sediment Systems

Physical/Chemical Systems
Transport and cycling of contaminants in sediments, water column, and atmosphere
Chemical and phase transformations
Energy flow and transformation
Biological Systems
Biological production
Origins, functions, and maintenance of biological diversity
Reproduction and development
Metabolism, growth, and death
Cellular differentiation and proliferation
Immune function
Neurobiological function
Incidence and mechanisms of pathology
Growth and regulation of populations
Interactions of biological processes with physical/chemical and social processes

Source: Adapted from *Building a Foundation for Sound Environmental Decisions*, National Research Council, National Academy Press, Washington, D.C., p19

Figure 3-1. Conceptual Model of a Generalized Contaminated Sediment Site



This chapter discusses current contaminated sediment science activities and identifies science needs within eight major topic areas. The major topics are:

- sediment site characterization
- exposure assessment
- human health toxicity and risk characterization
- ecological effects and risk assessment
- sediment remediation
- baseline, remediation, and post-remediation monitoring
- risk communication and community involvement
- information management and exchange activities.

Key scientific questions were developed for each major topic in order to focus discussions on scientific needs and to identify recommended science activities to address these questions (see Figure 3-2). Future updates to the Contaminated Sediments Science Priorities Document will re-evaluate the current state of the science and identify any new and emerging science issues and needs.

Appendix A, the Contaminated Sediment Science Activities Database, provides a summary of recent and current projects (as of June 2000) on various scientific topics of concern in the assessment and management of contaminated sediments. The database is divided into major science areas. Program implementation projects include remediation, monitoring, pilot studies, and initiatives. Human health and ecological effects and assessment projects include productive cross-Agency efforts on equilibrium partitioning of contaminants, ecotoxicological method development, risk assessments, and characterization studies. Exposure and

Figure 3-2. Key Scientific Questions

Sediment Site Characterization:

- What physical, chemical and biological methods best characterize sediments and assess sediment quality?

Exposure Assessment:

- What are the primary exposure pathways to humans and wildlife from contaminants in sediments and how can we reduce uncertainty in quantifying and modeling the degree of exposure?

Human Health Toxicity and Risk Characterization:

- What are the risks associated with exposure to contaminants in sediments through direct and indirect pathways?

Ecological Effects and Risk Assessment:

- What are the risks associated with exposure to contaminants in sediments to wildlife species and aquatic communities?

Sediment Remediation:

- What sediment remedial technology or combination of technologies is available to effectively remediate sites?

Baseline, Remediation, and Post-remediation Monitoring:

- What types of monitoring are needed to ensure that the implemented remedy meets remedial performance goals and does not cause unacceptable short-term effects?

Risk Communication and Community Involvement:

- How can we provide communities with more meaningful involvement in the contaminated sediments cleanup process?

Information Management and Exchange Activities:

- How do we improve information management and modeling tasks include work on topics such as TMDLs, bioavailability, and environmental fate. Remediation and risk management projects include guidance development, technology development and evaluation, site specific efforts, field demonstration of technologies, and information management systems.

More recently, the Agency has prepared an online Science Inventory, a searchable, Agency-wide catalog of more than 4,000 science activities such as research, technical assistance and assessments, along with more than 750 peer-reviewed products (http://cfpub.epa.gov/si/). The database contains more than 19,000 records in the archives including project descriptions, products produced, types of peer review, links to related work and contacts for additional information. Users can conduct keyword searches or search within nine cross-cutting science topics, one of which is 'Contaminated Sediments'.

3.2 Sediment Site Characterization

U.S. EPA has evaluated sediment quality data collected from more than 21,000 sampling stations nationwide (U.S. EPA, 1997a). This evaluation has indicated that contaminated sediment sites occur in different types of water bodies in every state. The water bodies affected include streams, lakes, harbors, near shore areas, and oceans. U.S. EPA has recognized that in different water body types, many factors can affect the kinds and magnitude of impacts that contaminated sediments have on the environment (U.S. EPA, 1992b). These factors include hydrology, physical and chemical characteristics of the sediment, types of contaminants present and their associated human health or ecological effects, and synergistic or antagonistic effects of contaminants. Sediment characterization and assessment tools vary in their suitability and sensitivity for detecting different endpoints and effects. For example, the most appropriate method for conducting screening level assessments may not provide adequate information for definitive risk assessments. Similarly, methods providing information about food chain exposure may not answer questions about direct toxicity. It is, therefore, necessary to match the assessment method used with the site or program-specific objectives of a study being conducted. For this reason, multiple complementary characterization or assessment methods are used to assess sediment quality. Assessments of sediment quality have commonly involved: use of various spatial and temporal sampling strategies, analyses of physical parameters, analyses of chemical parameters, biological testing (both laboratory and *in situ* testing for toxicity and bioaccumulation of contaminants), and evaluation of ecological indicators such as benthic community structure.

3.2.1 Sampling Strategies (Temporal and Spatial)

Selection of an appropriate sampling design is one of the most critical steps in assessment and characterization studies. The sampling design chosen will depend upon the study objectives. U.S. EPA (U.S. EPA, 2001b) describes the factors to consider in designing a sampling study. It is important that the study design control extraneous sources of variability and error so that data are representative for the objectives being addressed. Sampling designs for spatially distributed variables fall into two major categories: 1) random or probabilistic, and 2) targeted designs. Probability-based designs avoid bias in the results of sampling by randomly assigning and selecting sampling locations. In targeted, judgmental, or model-based designs, sampling locations are selected on the basis of prior knowledge or variables such as estimated loading, depth, salinity, and substrate type. Because targeted sampling designs can often be quickly implemented at a relatively low cost, this type of sampling is often used to meet schedule and budgetary restraints that cannot be met by implementing a statistical design. A comprehensive review of site-specific factors that may influence the location of sampling stations, particularly for large-scale monitoring studies, is provided by Mudroch and MacKnight (1994).

U.S. EPA has also developed a computerized sampling design program called the Field Environmental Decision Support (FIELDS) system. This system is a set of software modules designed to simplify sophisticated site and contamination analysis. Each module is a self contained unit that can be applied to a variety of scenarios. When used together, either working through the FIELDS process, or being applied according to a different schedule, the modules offer power and efficiency in the characterization, analysis, and discrete sampling data points to be interpolated into a surface. Important uses of these interpolated surfaces include delineating hot spots, calculating average concentrations, estimating contamination mass and volumes, and developing post-remediation scenarios. An updated 2003 version of the FIELDS software can be downloaded from the site http://www.epa.gov/region5fields/.

Regardless of the appropriateness of a sampling plan, its ultimate effectiveness will be dependent upon the ability to retrieve the samples. Recovering a complete sediment core representing the desired vertical interval can prove to be infeasible. Representativeness of a sample may be affected by such problems as: core shortening or compression, sample loss during retrieval, sample washout, and inability to determine the sediment surface. The Superfund Innovative Technology Evaluation (SITE) Program has conducted studies to evaluate the capability of samplers to collect representative sediment samples (U.S. EPA, 2000d).

Science Needs

The National Research Council (1997) discusses the complex factors necessary to develop a sediment sampling plan. The distribution of sediment contaminants is determined by complex interactions among meteorological, hydrodynamic, biological, geological, and geochemical factors. Interactions among these factors result in a transport system with wide variations, both spatial and temporal. For example, it is particularly important to consider sediment transport time scales, which typically range from hours to months but are sometimes disturbed by high-energy storms which can displace large amounts of sediment and significantly alter the distribution and availability of contaminants. Understanding these interactions is critical to specifying comprehensive sampling designs. As NRC (1997) notes, designs of sediment sampling strategies increasingly rely on computer-based numerical models. These models fall into four categories: hydrodynamic, sediment and chemical transport, biological toxicity, and ecosystem response. Improved numerical models will facilitate the design of optimal sediment sampling strategies. However, accurate simulations of sediment and chemical transport will also require the development of site-specific formulations.

3.2.2 Physical Parameters

Analysis of physical characteristics of sediment provides information that can be used to assess the effects of contaminants on the benthic environment and the water column. Physical analysis of the sediment is generally the first step in the characterization and assessment process. Information describing physical parameters of the sediment is required to understand bioavailability, fate, and transport of sediment contaminants at any site. Physical analysis often includes measurement of parameters such as particle size distribution, total solids, and specific gravity. Methods for measuring sediment physical characteristics have been published and widely used for a number of years. Many of these methods are based on analytical techniques originally developed for soils.

Particle size distribution analysis defines the frequency distribution of size ranges of the mineral particles that make up the sediment (Plumb, 1981; Folk, 1980). Sediment particle size influences both chemical and biological characteristics of the sediment. It is used to normalize chemical concentrations and account for some of the variability found in biological assemblages (U.S. EPA, 1998c) or in laboratory toxicity testing (U.S. EPA, 2000d; Hoss et al., 1999). Particle size is frequently described in percentages of gravel, sand, silt, and clay. Each of these size fractions, however, can be subdivided further so that a more complete characterization of particle sizes can be determined (Puget Sound Estuary Program, 1986). Commonly used sediment particle size methods include: wet sieving (U.S. EPA, 1979; Plumb, 1981; Puget Sound Estuary Program, 1986; Singer et al., 1988), hydrometer method (Day, 1965; Patrick, 1958), pipette method (Guy, 1969; Rukavina and Duncan, 1970), settling techniques (Sandford and Swift, 1971), and X-ray absorption (Duncan and Lattaie, 1979; Rukavina and Dunkan, 1970).

Total solids is a gravimetric determination of the organic and inorganic material remaining in a sample after it has been dried at a specific temperature. The total solids values are used to convert concentrations of contaminants from a wet weight to a dry weight basis. Water content of sediment provides useful information for assessments of sediment quality. Methods for determining water content of a sediment are described by Plumb (1981) and Vecchi (1999).

Specific gravity of a sediment sample is the ratio of the mass of a given volume of material to an equal volume of distilled water at the same temperature (Plumb, 1981). The specific gravity of a sediment sample can be used to predict the behavior (*i.e.*, dispersal and settling characteristics) of sediments. Methods for determining specific gravity are described by Plumb (1981) and Blake and Hartge (1986).

Science Needs

As noted above, reliable methods are available for measuring the physical parameters of a sediment. It is necessary, however, to collect sediment samples to measure these parameters. The National Research Council (1997) describes a variety of mechanical methods available to collect vertical sediment column samples for evaluation of physical parameters. Depending on the objectives of a study, sediment samples can be mixed to provide composite samples. This provides an indication of average physical parameter measurements at a site. However, high-resolution spatial data are often needed to fully characterize physical sediment parameters at heterogeneous sites. Obtaining such data requires conducting detailed site surveys with dense sampling. This is a very slow and expensive process that, even with dense sampling, can provide limited spatial resolution.

Sampling is currently conducted using two main types of devices: grab samplers and core samplers. Various grab and core samplers have limitations that can affect cost and time required for sampling. Grab sampler limitations can include: boats, winches, and lines required for operation; limited sampling depth and volume; loss of sample due to incomplete device closure; and sample contamination from metal frame. Core sampler limitations can include: equipment required for operation and lifting, difficulty of deployment and handling, repetitive and time consuming operation and removal of liners, and risk of metal contamination. Improved sampling and data collection techniques could reduce cost and provide improved spatial resolution.

The National Research Council (1997) notes that sediment physical parameters and contaminant concentrations are often interpolated horizontally, resulting in an overestimation of the mass or volume of a contaminated sediment. However, interpolation could also result in an underestimation of the mass or volume of a sediment. Thus, it is important to develop and implement more cost effective assessment technologies to replace coring. The National Research Council further notes that a promising technique for measurement of physical sediment parameters is acoustic sub-bottom profiling. Development of acoustic sub-bottom profiling technology could permit high resolution mapping of acoustic reflectivity, and determination of physical sediment parameters such as porosity, bulk density, and grain size. This technology has the potential to reduce overall sediment assessment costs and increase the spatial resolution of field surveys. In addition to improved field methods for measuring physical sediment parameters, research is needed in two other important areas. An important area for future research is the effect of geomorphological and physical sediment parameters, such as sediment texture, on the response of benthic organisms exposed to contaminants. Work is also needed to better understand the relationships between bioturbation and physical sediment parameters (such as surface roughness, internal porosity, and physical strength), and the resultant modification of sediment erodability and contaminant transport pathways.

It is recommended that U.S. EPA hold a workshop to identify work necessary to develop methods that could reduce the cost and increase the efficiency and accuracy with which physical parameters can be evaluated at contaminated sediment sites.

3.2.3 Chemical Parameters

Chemical analysis of sediment provides information about chemicals that, if bioavailable, can cause toxicity or bioaccumulate to levels of concern. In addition, chemical parameters such as pH, total organic carbon, and redox potential furnish information to assess bioavailability and contaminant exposure.

U.S. EPA and other agencies have developed analytical methods capable of identifying and quantifying these chemical parameters. However, techniques for analysis of chemical constituents in sediment have some inherent limitations. Interferences encountered as part of the sediment matrix, particularly in samples from heavily contaminated areas, may limit the ability of a method to detect or quantify some analytes. The most selective methods using gas chromatography/mass spectrometry (GC/MS) techniques are often used for nonchlorinated organic compounds because such analysis can avoid problems due to matrix interferences. Gas chromatography/electron capture detection (GC/ECD) methods are frequently used as the analytical tool for PCB and pesticide analyses because these methods result in lower detection limits. GC/ECD is effective at detecting and measuring all PCB congeners in media including sediments. Methods for collection of sediment and interstitial water samples and for analysis of chemical parameters are described in a number of publications (U.S. EPA, 1998c, 1995b, and 2001b).

Many chemical contaminants can persist for relatively long periods of time in sediments where bottom-dwelling animals can accumulate and pass them up the food chain to fish. Therefore, methods are needed for analysis of chemical contaminants in fish tissue. U.S. EPA has published interim procedures for sampling and analysis of priority pollutants in fish tissue (U.S. EPA, 1981); however, official U.S. EPA-approved methods are available only for the analysis of low parts-per-billion concentrations of some metals in fish and shellfish tissues (U.S. EPA, 1991b). Although the U.S. EPA-approved methods for many analyses have not been published, states and regions have developed specific analytical methods for various target analytes (U.S. EPA, 2000d).

In addition to conventional laboratory methods of analyses, rapid sediment characterization technologies are starting to be used at some sites. These are field transportable analytical tools which provide measurements of chemical, physical, or biological parameters on a real-time or near real-time basis. Some such typical screening level *ex situ* analytical tools recommended by the Assessment and Remediation of Contaminated Sediment (ARCS) Program for freshwater sediments include X-ray fluorescence spectrometry (XRF) for metals, ultraviolet fluorescence spectroscopy (UVF) for PAHs, and immunoassays for pesticides, PCBs, and polycyclic aromatic hydrocarbons (PAHs). The XRF technique for metals measures the fluorescence spectrum of x-rays emitted when atoms are excited by an x-ray source. The energy of emitted x-rays reveal the identity of the metals in the sample and their intensity is related to their concentrations. An XRF spectrometer can analyze a wide range of elements from ppm to percent levels, encompassing typical element levels found in soils and sediments. Field portable XRF units provide near real-time measurements with minimal sample handling, allowing for extensive, semi-quantitative analysis on site. UVF is based on the measurement of fluorescence observed following UV excitation of organic solvent extracts of sediments. Typically used for PAHs in sediments, this technique gives near real-time measurements as solvent extraction adds to the analysis time. Immunoassays are used for field screening of target contaminants through the use of an antibody than binds only to that substance. Quantitation is generally performed by monitoring solution color changes with a spectrophotometer. This technique has a sample turnaround of the order of minutes, providing near real-time measurements (US Navy, 2002).

The Federal Remediation Technologies Roundtable (FRTR), a collaboration of multiple Federal agencies including EPA, DOD, DOE, DOI, and NASA, has developed a matrix that provides a general understanding of state-of-the-art technologies for site characterization and the applicability of various technologies to specific problems. The matrix can be accessed through the internet at http://www.frtr.gov/site. In addition, EPA's Technology Innovation Office provides a source of innovative remediation and characterization technologies that can be accessed at http://www.epareachit.org. Not all of these technologies are EPA-verified; verification of the performance of site characterization and field analytical technologies is conducted through EPA's Environmental Technology Verification Program (ETV) and the Consortium for Site Characterization and Technology (CSCT), along with certification statements from California EPA's (CalEPA) California Environmental Technology Certification Program.

Science Needs

Although published methods for sampling sediment and quantifying chemical parameters are available, the National Research Council (NRC, 1997) notes that there is growing interest in the use of real-time or near real-time chemical sensors for use in the field. NRC (1997) remarks that these sensors can provide both point measurements and long-term, time-series observations. Development of these technologies is needed for more cost-effective site assessment. Although sensors that measure pH, Eh, oxygen, carbon dioxide, and ammonia are currently available, these sensors are not capable of measuring contaminants of concern in sediments. NRC (1997) identifies fiber-optic sensors as a technology that holds promise for assessment of sediment chemistry. These sensors make use of optical measurements down a fiber, or immobilized membranes or reagents at the fiber tip that reversibly or irreversibly bind with specific analytes, producing a response that can be sensed optically. NRC identifies development of these kinds of technologies as a scientific advancement that would contribute significantly to the development of improved management protocols for contaminated sediment sites.

In addition to the development of field methods for real-time detection of sediment chemical parameters, work is needed to develop more sensitive, low-cost laboratory methods to detect sediment contaminants and chemical parameters that control bioavailability of contaminants. Interferences encountered as part of the sediment matrix, particularly in samples from heavily contaminated areas, may limit the ability of available methods to detect or quantify some analytes. In other instances, the impetus to develop still more sensitive methods are often risk-based criteria that arise to meet specific project or site needs. An important area for future research is the development and validation of methods that minimize the use of hazardous solvents and reagents thereby reducing the exposure of laboratory workers to these chemicals and minimizing the waste which must be disposed of in accordance with RCRA regulations. Work is also needed to develop faster and less expensive methods for analysis of interstitial water. Interstitial water analysis is particularly useful for assessing sediment contaminant levels and associated toxicity. Isolated interstitial water can provide a matrix for both toxicity testing and an indication of partitioning of contaminants within the sediment matrix. In addition to improved laboratory methods for detection of sediment contaminants, improved methods for analysis of chemical contaminants, especially bioaccumulative compounds, in fish tissue are also needed.

An important area for future research is the development and validation of methods to assess sediment contaminants of emerging concern, such as endocrine disruptors, including alkylphenol ethoxylates (APEs) and their metabolites. Many of the suspect endocrine disruptor compounds (EDCs) identified to-date are low-solubility, neutral organic compounds that are highly sorbed to organic carbon phases of sediments, suspended particles in the water column, airborne particulate matter, and soil. Sediment-associated contaminants not only serve as a source of toxicity to benthic organisms living in contact with these sediments, but also can reintroduce contaminants into the water column or aquatic food chain. Alkylphenol ethoxylates can biodegrade to alkylphenols, such as nonylphenols, which can persist in the environment and be highly toxic to aquatic organisms. Exposure to alkylphenol ethoxylates, specially their metabolites, may affect endocrine and other important human and animal system functions (U.S. EPA, 2001).

In order to address these science needs, it is recommended that U.S. EPA: 1) develop more sensitive, low-cost laboratory methods for detecting sediment contaminants and real-time or near real-time chemical sensors for use in the field, 2) develop U.S. EPA-approved methods with lower detection limits for analysis of bioaccumulative contaminants of concern in fish tissue, and 3) develop methods for analyzing emerging endocrine disruptors, including APEs and their metabolites.

3.2.4 Emerging Potential Sediment Contaminants

In response to requirements set forth in the Water Resources Development Act of 1992, the Agency developed the *National Sediment Quality Survey* (NSQS) report and initiated the NSI (designed to compile sediment quality information from available electronic databases into one centralized, easily accessible location). U.S. EPA published the first update to the NSQS in 2004. The objective of the initial NSQS, and subsequent updates, is to depict and characterize the incidence and severity of sediment contamination based on the *probability* of adverse effects to human health and the environment. Severity of contamination was evaluated using multiple lines of evidence, using sediment chemistry data, chemical residue levels in edible tissue of aquatic organisms, and sediment toxicity data. Of the sampling stations evaluated in the 2004 update, 8,348 stations (43 percent) were classified as Tier 1 (adverse effects are probable), 5,846 (30 percent) were classified as Tier 2 (adverse effects are possible), and 5,204 (27 percent) were classified as Tier 3 (no indication of adverse effects). It is important to realize that these percentages do not represent the overall condition of sediment across the country as NSI data were obtained from monitoring programs that generally target areas of known or suspected contamination.

Science Needs

Although the NSI includes approximately 4.6 million records of sediment chemistry, tissue residue, and toxicity data, for more than 50,000 monitoring stations across the country, for approximately 150 compounds (including isomers), there is no single, comprehensive list of *potential* sediment contaminants that could be used to guide monitoring efforts. Such contaminants include commercial compounds – for example, alkylphenol ethoxylates, and pharmaceuticals – produced in high volume that are both likely to be found in sediments and have adverse biological effects.

3.2.5 Key Recommendations for Sediment Site Characterization

Accurate sediment site characterization is of great importance to scientists, risk managers, and others involved in the decision-making process. Because of the complexity of chemical fate and transport processes in sediment, water, and biota, many factors can affect the kinds and magnitude of impacts that contaminated sediment has on the environment. These factors include hydrology, the physical and chemical characteristics of the sediment, the types of contaminants present and their associated human health or ecological effects, and synergistic or antagonistic effects of contaminants. Better tools and methods for analysis of physical and chemical parameters, biological testing, evaluation of ecological effects, and sediment sampling will result in sound science to support decision-making.

Physical Parameters

A.1 Conduct a workshop to develop a consistent approach to collecting sediment physical property data for use in evaluating sediment stability.

A workshop is needed to identify research necessary to develop better, faster, and more cost-effective methods for high resolution determination of physical sediment parameters. Such methods are needed for evaluating remedial options (*e.g.*, natural attenuation, capping, or dredging). When evaluating remedial options, it is important that risk managers obtain information on key physical sediment parameters including the erosional and depositional properties of sites to be remediated. High resolution spatial data are needed to characterize freshwater sites where sediment is often heterogeneous. Improved spatial resolution of field survey data will enable more accurate determination of the volume or mass of contaminated sediment. It is recommended that U.S. EPA consult with USGS, U.S. ACE, and U.S. Navy on their progress in developing these techniques. An improved understanding of the relationships between geomorphological and physical sediment parameters and contaminant transport, fate, and effects will enable decision-makers to more effectively evaluate site management alternatives.

Chemical Parameters

A.2 Develop more sensitive, low-cost laboratory methods for detecting sediment contaminants, and real-time or near real-time chemical sensors for use in the field.

Interferences encountered as part of the sediment matrix, particularly in samples from heavily contaminated areas, may limit the ability of available methods to detect or quantify some analytes. More sensitive, low-cost methods are needed to detect sediment contaminants and the chemical parameters that control bioavailability of contaminants such as PCBs, dioxin, PAHs, metals, and pesticides. Real-time or near real-time sensors are also needed to provide both point measurements and long-term, time-series observations of sediment contaminants of concern. Real-time chemical sensors will enable better, faster, and more cost-effective site assessment and the immediate targeting of hot spots for potential remediation.

A.3 Develop U.S. EPA approved methods with lower detection limits for analysis of bioaccumulative contaminants of concern in fish tissue.

Many chemical contaminants can persist for relatively long periods of time in sediments where bottom-dwelling animals can accumulate and pass them up the food chain to fish and wildlife. Therefore, improved methods are needed for analysis of chemical contaminants such as dioxin, metals and pesticides in fish tissue. U.S. EPA has published interim procedures for sampling and analysis of priority pollutants in fish tissue (U.S. EPA, 1981). However, official U.S. EPA-approved methods are available only for the analysis of low parts-per-billion concentrations of some metals in fish and shellfish tissues (U.S. EPA, 1991b). Although U.S. EPA-approved methods for many analytes have not been published, states and regions have developed specific analytical methods for various target analytes (U.S. EPA, 2000d).

A.4 Develop methods for analyzing emerging endocrine disruptors, including alkylphenol ethoxylates (APEs) and their metabolites.

Present methods for analyzing emerging endocrine disrupting chemicals are inadequate. An important area for future research is the development and validation of methods to analyze endocrine disruptors, including APEs and their metabolites, to support regulatory decision-making.

3.3 Exposure Assessment

The major human health exposure pathways for contaminated sediments are through the food chain. Body burdens in humans can be measured directly for past exposures from all sources. However, it is more common to measure contaminant concentrations in food fish and shellfish to estimate the human exposure from the dietary pathway. Areas of uncertainty in exposure estimates from this pathway include:

- Fish and shellfish consumption by sub-populations, such as subsistence, recreational fishers, women of child-bearing age, pregnant women, Native American tribes, immigrants from fishing cultures and young children (U.S. EPA 1997c, U.S. EPA 2002b, U.S. EPA 2000c).

- Fish and shellfish preparation, such as whole fish versus fillet, and cooking methods (*e.g.* pan frying, grilling, etc.).

- Effects of contaminant mixtures, such as weathered Aroclor mixtures rather than mixtures of commercial Aroclors (U.S. EPA, 2000f).

- Predictions of the rate and extent of reductions in contaminant concentrations in fish in response to metabolism and depuration and natural processes or remedial actions affecting contaminant release and environmental loadings.

- Contamination transformations in a biological system encompassing such issues such as consuming different types of fish and the metabolic effects of different types of organs and tissues on transformation, storage, and depuration in the consumer.

- Degree and duration of exposure to evaluate short- and long-term human health impacts (U.S. EPA, 1989).

Other potential pathways of human exposure include dermal contact, incidental ingestion, and inhalation exposures from in-place sediments, historical dredge spoils, floodplains, and contact with sediments during removal and *ex situ* management. These pathways have not received as much attention as the food ingestion pathway.

OSWER has issued the *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (U.S. EPA, 2004a) http://www.epa.gov/oerrpage/superfund/programs/risk/ragse/ to address human health dermal assessments. However, scientific information needs to include the development of better estimates of dermal exposures to types of soils (*e.g.*, beach, river, intermittent stream, etc.), biologically available fractions of sediment contaminants (e.g, contaminant may be slow to desorb due to strong adsorption by the sediment matrix), and contaminant interactions in sediments.

OSWER's *Supplemental Guidance for Developing Soil Screening Levels at Superfund Sites* (U.S. EPA, 2002c) and the *Soil Screening Guidance* (U.S. EPA, 1996d) describe a process by which to evaluate exposure to contaminated soils via volatilization and dermal pathways. There is a need to include better guidance during the formulation of the sediment exposure assessment of when contaminant volatilization and fugitive dust emissions need to be considered as a direct contact threat to human health.

3.3.1 Bioavailability

The bioavailability of a contaminant relates total concentration in the sediment, overlying water column, or ambient air to the concentration that affects the ecological or human receptor. Bioavailability depends on the exact chemical speciation of the toxic constituent; the contaminant binding phases in the sediment (*e.g.*, organic carbon for nonionic organic contaminants and acid volatile sulfides for metals); the degree to which the receptor is in contact with the sediment; and the degree to which the contaminant is absorbed by the receptor.

Several tools are available to assess bioavailability. Acute and chronic toxicity testing are direct measures of whether or not a contaminated sediment contains enough of the toxicant in an available form to exert a toxic effect. Research by ORD, in cooperation with OW, has led to development of a range of toxicity tests. Such tests are used in assessing contaminated sediments and in managing dredged material disposal under MPRSA and CWA. Bioassays have become an effective assessment tool providing direct, quantifiable evidence of biological consequences of sediment contamination and are used to determine the relationship between toxic effects and bioavailability. These tests can be used to determine whether sediment is toxic, but they do not provide an indication of the chemicals causing the effect.

When unacceptable exposures to toxicants are determined from sediment concentrations, the simplest assumption used is that 100% of the contaminant is available to receptors. This is a conservative assumption appropriate for screening levels.

More realistic and site-specific estimates of bioavailability can be developed using field-measured biota sediment accumulation factors, which relate contaminant concentrations to tissue concentrations to determine what residual sediment concentrations will not pose a threat of acute or chronic toxicity (Burkhard, 2003; Burkhard et al, 2003).

An alternative, indirect approach is the use of Equilibrium Partitioning Sediment Guidelines (ESGs) (DiToro et al, 1991; Ankley et al, 1996). This approach uses contaminant concentrations in sediment and other sediment properties to estimate the pore water concentration of contaminants at chemical equilibrium. The pore water concentration is then correlated with the concentration available to the aquatic organism and can be compared to various reference values for acute or chronic toxicity. ESGs can be used to determine which contaminants in sediment might be exerting a toxic effect demonstrated in whole sediment toxicity tests. They can also be used to help establish unacceptable levels of toxic contaminants in sediment.

3.3.2 Bioaccumulation Potential

Some sediment contaminants exert toxic effects by being accumulated to greater degrees in successively higher trophic levels. Thus, a sediment contaminant concentration that poses no direct acute or chronic toxicity to aquatic biota or humans via direct exposure may be magnified through the food chain so that species eating fish, birds, or wildlife are exposed to an unacceptable toxicant dose. If the contaminant is metabolized and stored by the predator, it may exert toxic effects to the predator under stress, such as during migratory journeys or during reproduction (*e.g.*, during embryonic development or lactation).

Figure 3-3. Methods for Estimating Bioaccumulation

- *Field-measured bioaccumulation factor* - direct measurement of the relationship between water concentrations and tissue concentrations of the toxicant.
- *Field-measured biota-sediment accumulation factor* - direct measurement of the relationship between sediment concentrations and tissue concentrations of the toxicant.

The most direct measure of bioaccumulation is measurement of the toxicant in the tissues of the receptor (see Figure 3-3). Direct measurement is ideal because it includes all sources of exposure and accounts for elimination and metabolism. Bioaccumulation test method protocols have been developed for freshwater oligochaetes and marine polychaetes and bivalves (U.S. EPA, 2000d; Lee et al., 1989). The National Research Council (2001a) recommends this method for PCBs: *An assessment of present exposure to PCBs is best addressed through direct measurement in specific organisms or in their diet.*

The direct measurement method is referred to as a field-measured bioaccumulation factor (BAF) for water/organism interactions and a field-measured biota-sediment accumulation factor (BSAF) for sediment/organism interactions. The BAF is appropriate for all chemical stressors, while the BSAF is appropriate for nonionic organic compounds and ionic organics that partition to lipids and organic carbon in similar ways. Although direct measurement can be expensive and difficult, it is commonly used in assessments of contaminated sediment sites. There are uncertainties if bioaccumulation is measured in food sources because consumption rates by higher trophic levels are not always well-known for ecological predators and humans, particularly human sub-populations from fishing cultures. In addition, the mobility of predator populations means food/prey may have been ingested in areas beyond the contaminated sediment site of concern. Therefore, OW and ORD have collaborated on extensive research to provide alternative estimates that relate contaminant concentrations in sediments and water to the concentrations that would consequently occur in various species.

Laboratory tests can be used to assess bioaccumulation by freshwater and marine benthic invertebrates. Methods are available for freshwater *Diporeia* spp., *Lumbriculus variegatus*, and mollusks and marine species. OW has published a compendium of methods for measuring bioaccumulation of sediment-borne toxicants in freshwater (U.S. EPA, 2000d).

Deployed organisms also can be used to measure current exposures to sediment-borne toxicants. These measures are very useful in determining baseline exposures and responses to remedial actions and to estimate variabilities. However, the linkage between caged organism uptake and dietary exposure of higher trophic levels is uncertain. A further confounding factor exists for persistent and bioaccumulative toxicants such as PCBs and PAHs. These complex mixtures change over time through weathering and are found in different mixtures in source sediments and receptor tissues.

The current state-of-the-practice is to use direct testing and models to estimate the direct dose delivered to the lowest trophic level in a food web and the food-delivered dose to successively higher tropic levels. Models range from simple to complex. Empirical models use partitioning coefficients (BAFs or BSAFs) to link sediment concentrations with tissue levels in organisms. More complex models use mechanistic models of uptake, metabolism, and excretion, along with feeding patterns to estimate the tissue burdens for fish, birds, and mammals.

The approaches described above provide several different ways to assess exposure of ecological and human receptors to sediment-borne contaminants. Each of the estimation approaches can cause disagreements among affected parties, ranging from the theoretical soundness of alternative approaches to the values selected for exposure duration and dietary composition. Even with the direct measurement of contaminants in receptor tissues, arguments can be made about the relative importance of sediment contamination relative to other sources. Validation of models is hindered by a paucity of data sets that overcome the natural variability of ecological receptors. Research on monitoring may provide additional tools to measure bioaccumulation in receptors.

3.3.3 Fate and Transport Modeling

Aquatic sediments are a sink for contaminants from a wide range of point and nonpoint sources. But the “sink” is connected to ecological and human receptors through a variety of mechanisms: partitioning to the overlying water column and air; uptake by organisms and accumulation or magnification in the food chain; chemical and biological alteration; dilution and dispersion; bulk sediment transport; and burial by fresh sediments. For non-degradative processes, it may be necessary to evaluate the transport and fate of the contaminant in the short- term and the long-term. Over the short-term for a persistent and bioaccumulative toxicant, the focus may be on dilution and dispersal in a river; over the longer-term, the biogeochemical cycle may be evaluated and monitored over a much larger region.

The National Research Council (NRC, 2001a) made two recommendations for research specifically related to PCB-contaminated sediments:

- *A better understanding of the contribution of PCB-contaminated sediments to the total global burden is needed.*

- *The role of global cycling of PCBs in assessing the PCB problem at a specific site should be considered.*

Although the NRC report specifically addressed PCBs, these recommendations are also applicable to other persistent and bioaccumulative toxicants such as mercury and some pesticides.

The current state-of-the-practice is to apply one or more of a suite of mathematical models to simulate the important processes. Fate and transport modeling can be highly controversial because various models, assumptions used in the models, and selection of input parameters can lead to very different conclusions about present risk and how protective various remedial alternatives will be.

The fate of organic contaminants in sediments may include degradation via chemical and biologically-mediated pathways. The mechanisms, rates, and endpoints of degradation processes need to be better understood to assess both natural recovery and active remedies that are intended to enhance contaminant degradation. NRC (2001a) noted that anaerobic dechlorination may have a threshold value. This implies that degradation may proceed from higher concentrations toward the threshold value and then become negligible; models need to account for such non-linear behavior. Such models are chemical and sediment-matrix specific.

Contaminant transport in sediments and overlying waters is critical to assessing both present risk and the performance of all remedies. Contaminants can be transported by diffusion and dispersion within bed sediments, advection from upward groundwater movement, bulk sediment movement, movement of suspended sediments, and dissolution into the overlying water. Contaminants can enter and leave the system through landscape erosion, atmospheric deposition, and volatilization. Many of these processes are active in different contaminated sediment systems and determine how biotic exposure changes over time. The wide range of transport mechanisms contributes to uncertainty in the characterization of sediment sites as well as estimates of present risk. Active capping and the natural process of burial by cleaner sediments can only be effective over the long-term if contaminant transport by diffusion, advection, and bioturbation are slow enough that sediments and the overlying water column remain at safe levels. These remedies also depend on the long-term stability of the system with respect to bulk sediment movement by natural hydrodynamics, catastrophic events, and human intervention, such as dam removal, navigation dredging, and boat traffic.

The role of uncertainty in fate and transport modeling needs to be addressed so that stakeholders understand how sure we are of existing risks and the risk reduction achievable by remediation. It is critical that the contaminant transport models link smoothly with biological uptake and trophic transfer models to obtain an accurate assessment of present risks and risk reductions achievable by management alternatives.

Science Needs

The science needs associated with exposure assessment relate to refining our understanding of the important pathways of exposure, including the exposure of aquatic organisms to contaminants of concern, and improving the tools used to measure and model how contaminants cycle within the system. It is important that the complexity of the tools applied to specific sites be commensurate with the risks and costs of proposed decision-making and consistent with the National Research Council recommendation (NRC, 2001a). It is important that the use of different tools at different sites or under different authorities be integrated so that consistent decisions can be made to protect the environment and potential ecological or human receptors. Because contaminated sediment is a mobile medium and contaminants within sediment can migrate into other media, understanding all the important fate and transport processes is a key step in assessing the risk and estimating the potential effectiveness of various remedial actions.

3.3.4 Key Recommendations for Exposure Assessment

B.1 Develop a tiered framework for assessing food web exposures.

The National Research Council (2001a) recommended a tiered approach to risk assessment for PCB-contaminated sediment sites that would work well for any sediment contaminated by bioaccumulative compounds. The screening tier would apply conservative assumptions and rely on existing data in the literature to easily distinguish sediments that do not pose an unacceptable risk from those that may. The middle tier would use a combination of some site-specific data and interpretive tools to produce a more refined assessment of the level of risk. At many sites, this approach would be sufficient to determine whether or not remediation was warranted and would provide some insight into the potential benefits of alternative remedies. The highest tier of exposure assessment would rely heavily on site-specific data and would include model tailoring and model calibration to site conditions. This most sophisticated assessment would be applied only at selected sites where the combination of site complexity, resource values, affected party interests, and potential costs warrant a detailed investigation of existing and potential future exposures.

ORD's research and program applications are presently focused at the middle tier; funding is being sought to expand the research to the lower and higher tiers. This recommendation is to provide program guidance for implementing the screening tier and to conduct research and model validation for the highest tier.

B.2 Develop guidance and identify pilots for improving coordination between TMDL and remedial programs in waterways with contaminated sediments.

In many of the country's water bodies, there are multiple legal authorities to address both existing contaminated sediments and continued contaminant loading. Different legal authorities vest power in various Agency programs and guidance is needed concerning coordination of scientific activities (*e.g.*, improvements in fate and transport models) between programs. Integrated management models need to be improved and communicated within U.S. EPA and to partners in state programs. Pilot projects need to be developed to identify the most effective ways to integrate and coordinate environmental management to control sources and achieve water quality goals. Results of the TMDL pilot projects in waterways with contaminated sediments could be made available to the states as potential models for the development of complex TMDLs involving multiple toxic pollutants and media (*i.e.*, water, sediment, and fish tissue).

B.3 Develop and advise on the use of a suite of most valid contaminant fate and transport models that allow prediction of exposures in the future.

Numerous models exist for contaminant fate and transport, including both public domain and proprietary codes. Some models have not been peer-reviewed in the open literature and there are very few long-term data sets that can be used to judge predictive capability. The existing public domain and commercial models need to be evaluated to determine their mechanistic and mathematical foundations and robustness, and to determine the extent to which they are accepted by the scientific community. One or more models need to be further developed to improve any weaknesses determined from the evaluation; the ORD has begun this work. The models need to be validated with high quality data sets, which will be developed via other recommendations in this document. Refer to the Council on Regulatory Environmental Models (CREM) and its models knowledge database (http://cfpub.epa.gov/crem/knowledge_base/knowbase.cfm) for information on models validation.

The fate and transport models also need to be compatible (*i.e.* able to be easily linked) with models that predict direct and food web exposures for the purpose of assessing risks and comparing remediation alternatives. The bioavailability of the contaminants within portions of the system has to be considered to provide input from the transport models to the exposure/effects models.

B.4 Develop a consistent approach to applying sediment stability data in transport modeling.

Current approaches to evaluating sediment stability in transport modeling vary across the Agency and the larger stakeholder community. While a single model is probably not appropriate for all sites, a consistent approach is needed to ensure that important factors are being considered. Data sets developed by the regions and other organizations can help identify the key factors that the transport models need to include for realistic predictions. In addition, a workshop was held in January 2002 to conduct a comparative evaluation of the models for hydrogeological conditions in terms of the reliability of predictions.

3.4 Human Health Toxicity and Risk Characterization

Contaminants in sediments can present risks to humans through direct contact (inhalation of particulates or gases, ingestion, dermal contact) or indirect exposure pathways (ingestion of fish, wildlife, or plants that have accumulated contaminants). Health effects may occur at the point of contact, *e.g.*, skin or lung, but will most often occur in response to contaminants or their metabolites circulating internally (the internal dose). The scientific base for human health toxicity and risk characterization crosses environmental media and is shared among EPA program offices. ORD's research on this issue (*e.g.*, exposure factors handbook; Integrated Risk Information System (IRIS), *Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures* (U.S. EPA, 2000f), etc.) is so central to multiple programs that the relevant work is being assembled into a new human health risk assessment plan to provide a complete, coherent view of the program, informed by the needs across EPA programs. Detailed information on these human health toxicity issues can be found in many other Agency documents. Similarly, research on newly-identified compounds that potentially interfere with human endocrine systems, relevant to multiple media and multiple programs, is assembled in the multi-year plan for endocrine disruptor research. It would be redundant to do a complete assessment of high priority needs solely for contaminated sediments in this document. Therefore, this section focuses on human health toxicity issues that occur at contaminated sediment sites, but are not addressed in other Agency documents.

EPA has published guidance for conducting risk assessments at Superfund sites (Risk Assessment Guidance for Superfund, http://www.epa.gov/superfund/programs/risk/tooltrad.htm). Although exposure parameters are not explicitly given for all sediment exposure pathways, the guidance can be used to select parameters suitable for a particular site. In addition, EPA's FIELDS software tools contain a human health module for analyzing the human health impact of contaminated sediments via dermal, ingestion, and inhalation pathways. Further, improvements underway on this module include refinements of existing exposure pathway models.

There are several risk assessment issues that are particularly common or problematic for contaminated sediment sites. Using the existing science base, the programs and regions will need to develop or update guidance on possible ways to address these issues.

Sediments contaminated with PCBs are common at many Superfund sites as well as navigational dredging sites. The National Academy of Sciences made a point that baseline and post-remedy risk assessments should not rely on toxicity of technical grade Aroclor mixtures, because the aged and weathered residues found in the environment have significantly different compositions. Their recommended alternative approach is to use congener-specific analysis and toxicity assessment, including multiple toxicity endpoints (*e.g.*, cancer and Ah receptor activation). Currently, there is a lack of guidance and policy on the quantification of risks from the co-planar PCB congeners in a human health risk assessment and whether the weathering and biological uptake of the congeners lead to significant increases in toxicological potency.

Dermal exposure to contaminated sediments also presents a risk to human health as many contaminated sediment sites are considered attractive for recreational purposes such as wading or participating in sports on contaminated floodplains. Intermittent streams, staged dredge spoils, and floodplains are examples of areas where direct contact may occur. These exposure scenarios provide unique but direct dermal contact with contaminated sediment and surface water. The *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (U.S. EPA, 2004a) proposes a methodology for assessing the exposures from the dermal pathway for contaminated soils, sediments, and water.

Many of the contaminants commonly located in sediments are environmentally and biologically persistent and exert their effects by disrupting sensitive physiological systems such as the endocrine system (*i.e.*, endocrine disruptors). Some of the noted health effects are trans-generational and thus do not exhibit their toxicity until later generations. Further guidance on the methodology and policy for quantifying human health risks from endocrine disruptors is necessary.

3.4.1 Science Needs

Advances in almost any aspect of human health toxicity and exposure would result in an improved understanding of the health effects of exposure to contaminated sediments. Several of these areas are extremely important for assessing other environmental problems as well. Needs particularly important to sediments include:

- Characterizing individual contaminants in sediment or biological samples to evaluate mode of action and individual chemical contributions to risk. Examples include dioxins, furans, and dioxin-like PCBs; PAHs; and mercury species.

- Determining interactions among multiple contaminants found in sediments and the resulting impacts on site-specific risk assessment (NRC, 2001a).

- Studying of mode- and mechanism-of-action for species and mixtures most often found in sediments, particularly focusing on chronic or sub-chronic systemic effects.

- Developing biomarkers of effect (toxicity) and relating these to measurable toxic endpoints.

- Evaluating the reproductive toxicity of endocrine disruptors and other newly emerging contaminants of concern such as APEs.

- Revising methods for estimating dermal exposures and risk from sediments.

3.4.2 Key Recommendations for Human Health Toxicity and Risk Characterization

C.1 Develop guidance for characterizing human health risks on a PCB congener basis.

Improved methods are needed to assess the risks associated with exposure to aged PCBs in sediment. For example, although it is recognized that measurement of PCB Aroclors in sediment can underestimate exposure to PCBs, this method of chemical analysis continues to be used in risk assessments because a toxicity equivalence approach for evaluating PCB congeners has not been fully developed.

C.2 Develop sediment guidelines for bioaccumulative contaminants that are protective of human health via the fish ingestion pathway.

Contaminant-specific sediment guidelines to protect recreational and subsistence anglers should be developed. This will conserve resources by efficiently eliminating sites or parts of sites and chemicals from further study, and will help focus site investigations on the most important areas. Fish tissue contaminant guidelines have been developed for a range of chemicals (U.S. EPA, 2000a), but corresponding levels of contaminants in sediments are still needed. Guidelines for bioaccumulative contaminants such as DDT and metabolites, PCBs, methyl mercury, dieldrin, and high molecular weight PAHs should be developed.

C.3 Refine methods for estimating dermal exposures and risk.

Although the greatest human health risk is generally from ingestion of contaminated fish, there is a need to develop better methods, models, and exposure factors that will enable risk assessors to estimate the exposure from direct skin contact with contaminated sediments. Research is needed to determine the amount of sediment that might come into contact with the skin from various activities. Research is also needed to develop a model that accurately predicts how much of the sediment-borne contaminants actually crosses the dermal barrier and is available to cause a toxicological effect. Current dermal absorption models are either water or soil-based and it is not clear which might be more applicable for sediments.

C.4 Evaluate the toxicity and reproductive effects of newly recognized contaminants, such as APEs and other endocrine disruptors and their metabolites on human health.

Additional long-term toxicity data are needed on APEs and other similar chemicals to further understand their long-term effects on reproductive and other systems. EPA programs will need to monitor advances in toxicity data and incorporate new information into guidance and policy on managing contaminated sediment sites.

3.5 Ecological Effects and Risk Assessment

Aquatic ecosystems are a complex assemblage of interacting physical, chemical, and biological processes. Many of these processes are inherently nonlinear and there is considerable uncertainty about both their nature and their interconnections. The ability to predict site specific ecological effects or risks is maximized with knowledge of these processes and interactions present at the particular site. Since contaminant availability and ecological food webs differ from site to site, it is critical to understand exposure-effect dynamics.[7]

The primary focus of sediment assessments is determining the potential for (*i.e.*, the risk of) adverse impacts to biota. The simplest of all assessments might include the use of single lines-of-evidence such as a set of toxicity tests, a benthic community survey, or the use of Sediment Quality Guidelines (SQGs) to make a decision regarding adverse effects. However, the initial screening of contaminated sediments may be insufficient for making decisions due to uncertainty. In such cases, it is useful to gather additional lines of evidence that improve certainty. This may involve utilizing a weight-of-evidence approach or conducting an ecological risk assessment. Elements of these approaches include developing a conceptual site model, understanding organism linkages, selecting measurement and assessment endpoints, characterizing exposure, and performing a risk characterization. Section 3.5 focuses on the narrower issue of understanding the science needs for assessing contaminated sediment systems. These include ecological screening levels, ecological indicators, direct toxicity to aquatic biota, ecological significance and population models, and the selection of remedial alternatives that are protective of ecological receptors.

3.5.1 Ecological Screening Levels

Numerical screening levels or SQGs based upon concentrations of contaminants in sediment that are associated with potential adverse effects have been proposed by a number of investigators and jurisdictions around the world using both mechanistic and empirical approaches (Chapman, 1989; Long and Morgan, 1991; Long, 1992; MacDonald et al., 1996; U.S. EPA 1992b, 1996b, and 1997a; MacDonald et al., 2000; Field et al., 1999, 2002).[8] Screening values are needed by U.S. EPA, states

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[7] Fundamental research regarding the assessment and management of aquatic environments (including contaminated sediments) is defined in the Agency's Ecological Research Multi-Year Plan and Water Quality Research Program Multi-Year Plan (U.S. EPA 2003d; U.S. EPA 2003e).

[8] More generally these approaches include the equilibrium partioning (EqP) approach (Di Toro et al. 1991a; Di Toro et al. 1991b; Ankley et al. 1996; NYSDEC 1998; Di Toro and McGrath 2000), screening-level concentration approach (Persaud et al. 1993; Von Stackelberg and Menzie 2002), effects range–low (ERL) and effects range–median (ERM) approaches (Long et al. 1995; USEPA 1996e), threshold-effects level (TEL) and probable-effects level (PEL) approaches (MacDonald et al. 1996; Smith et al. 1996; USEPA 1996e), the apparent-effects threshold (AET) approach (Barrick et al. 1988; Ginn and Pastorok 1992; Cubbage et al.. 1997), and, most recently, the "consensus-based" evaluation approach (Swartz 1999; MacDonald et al. 2000b; MacDonald et al. 2000a) and

and tribes, and other Federal agencies to: 1) help prioritize sites for further investigation, and 2) help identify causative contaminants when toxicity is indicated by bioassays or other tools.

The empirical or correlative approach to the derivation of SQG values has focused on evaluation of the available toxicity data to establish associations between individual chemical concentrations in sediments and adverse biological effects. This approach was originally developed by NOAA using sediment chemistry data collected under the National Status and Trends Program (Long and Morgan, 1991; Long, 1992). The empirical guidelines approach was adopted, with some modifications, by the Florida Department of Environmental Protection (MacDonald, 1994; MacDonald et al., 1996) and the Canadian Council of Ministers of the Environment (CCME) (1995; Smith et al., 1996) to support the development of guidelines in the State of Florida and in Canada. Additional data available in the published literature and collected through U.S. EPA's ARCS program have been used to further refine the empirically derived guidelines (Ingersoll et al., 1996). Although empirically derived SQGs have in many cases accurately predicted sediment toxicity, a number of limitations have been associated with this approach (MacDonald et al., 1996; NRC, 2001a). The correlative approach does not require the quantitative evaluation of cause and effects relationships between contaminant concentrations and biological responses. Because the approach is based on empirical associations between contaminant concentrations and biological responses, various factors other than the concentrations of the contaminant under consideration could have influenced the actual response observed in any investigation.

In addition, the guidelines developed using this approach do not address either the potential for bioaccumulation or the associated adverse effects of bioaccumulation on higher trophic levels.

Another method developed by U.S. EPA (and others) is the equilibrium partitioning (EqP) approach to develop Equilibrium Partitioning Sediment Benchmarks (ESBs). This approach focuses on predicting the chemical interaction among sediments, interstitial water, and the contaminants. Numerous studies have supported an assumption that interstitial water concentrations of contaminants appear to be better predictors of biological effects than bulk sediment concentrations. U.S. EPA based the ESBs on EqP theory, which is a conceptual approach for predicting the bioavailability of sediment-associated chemicals and their toxicity. The theory assumes that sediment-associated contaminants achieve a steady-state between chemical activity in three phases: the interstitial (pore) water, the binding phases in sediment which limit bioavailability (*i.e.*, organic carbon for nonionic organic chemicals and acid volatile sulfides for divalent metals), and the biota. Under this assumption, the pathway of chemical exposure (*i.e.*, respiration of interstitial water or ingestion of sediment) is not important as activities are equal in equilibrated phases; that is, if the chemical concentration in any one phase is known, then the concentration in the others can be predicted. Thus, EqP theory, enabling prediction of interstitial water concentration from the total sediment concentration, chemical properties (*e.g.*, partition coefficients) and the relevant sediment properties (*e.g.*, organic carbon in its various forms), can be used to estimate the exposure concentration for an organism. U.S. EPA also notes that

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the logistic regression modeling (LRM) approach (Field et al. 1999, 2002).

equilibrium partitioning theory does not address potential food chain effects of bioaccumulative sediment pollutants[9] and EqP does not apply to most inorganic and metal contaminants in sediments.

It is important to note that the above discussion of ESBs and the other screening tools does not address nor is it meant to imply any EPA policy concerning the use of screening levels in EPA programs. The information is provided only as a review of some work that has been undertaken to derive screening levels. This review was used to assist in the identification of science needs for further development of these approaches.

Many additional issues regarding ecological screening levels and risk assessment are addressed by the FIELDS Team.[10] The FIELDS software tools contain an ecological risk module, peer reviewed by U.S. EPA Ecological Risk Assessors Forum, which includes screening values and can be used for analyzing the impact of contaminated sediments on ecological receptors. Further refinements on this module include the addition of wildlife exposure models and the ability to evaluate risks based on tissue concentrations.

Science Needs

U.S. EPA's Science Advisory Board (SAB) and others have identified a number of science needs to further support regulatory use of the Agency's ESBs and other chemical-specific screening values and sediment quality guidelines (SAB, 1992 and 1996). These science needs include:

- Field and laboratory studies to evaluate the accuracy of chemical-specific sediment quality guidelines. These could include new studies and the use of existing data from contaminated sites where both contaminants and benthic community data are available. Sublethal sediment toxicity tests (*in situ* studies, laboratory studies of field-collected sediment, and spiked-sediment laboratory studies) using a range of species including benthic fish and algae, long-term studies of population dynamics, and colonization studies are examples of sensitive tests that could be used to further validate sediment quality guidelines. An important area for future research is the evaluation of the range of sediment types to which sediment guidelines can be applied. Field validation of these guidelines in different sediment types would help define the appropriate conditions for applying the guidelines.

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9 Details on the ESG methodologies and chemical-specific ESGs can be found in the following documents: *Eco Update. Intermittent Bulletin Volume 3, Number 2 – Ecotox Thresholds. U.S. EPA 540/F-95/038* (U.S. EPA, 1996b); *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Endrin*. (U.S. EPA, 2003f); *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Dieldrin*. (U.S. EPA, 2003g); *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: PAH Mixtures*. (U.S. EPA, 2003h)

10 The mission of the U.S. EPA Region 5 FIELDS Team is to combine field expertise with technical innovation to provide rapid, cost-effective, and high-quality decision support to contaminated site characterization and remediation.

- Studies of chemical concentrations in interstitial water from natural sediment samples are needed. These values can be compared to predicted ESG values for the same sediments.

- Another area for future research is evaluation of bioaccumulation from food and kinetic limitations on contaminant bioaccumulation to determine their relevance for both equilibrium and non-equilibrium conditions. It is important to conduct additional work to determine whether metals guidelines can be used to define conditions where sediment sorbed metals can be bioaccumulated by benthic organisms. These investigations can provide additional insight into the contributions of adsorbed or digested material to total exposure.

- In addition to diet, habitat requirements of benthic infaunal and other sediment-dwelling organisms may cause them to be exposed to higher concentrations of contaminants than those measured in bulk sediments. Yet another area for future research is the investigation of the importance of contaminant exposure routes that are not now explicitly considered. For example, preferential sorting of particulates during tube building may be a route of exposure to contaminants that could be considered in applying sediment quality guidelines.

- There has been considerable discussion regarding whether sediment quality guidelines are most usefully expressed as a range of values reflecting uncertainty, or the current point estimates (current practice). Recent modeling work has attempted to address this by using the probability of effects to define sediment quality guidelines. The use of a range of values, *e.g.*, using one specific value for a particular organic carbon content, or the development of improved estimates of uncertainty could be considered.

- Although U.S. EPA has conducted research to develop mixtures guidelines for PAHs and metals, understanding how mixtures of contaminants in sediments are best evaluated is an important area for future research.

3.5.2 Ecological Indicators

Ecological indicators may be defined as measurable characteristics related to the structure, composition, or functioning of ecological systems. The inherent complexity of ecological systems, however, makes both the assessment of ecological integrity and the creation of a coherent system of ecological indicators challenging tasks (U.S. EPA, 2002d). Biological indicators measure condition more directly, integrate the effects of periodic exposures to multiple pollutants, and provide a more accessible and understandable tool. The Agency's research in this area focuses on measures of community structure and genetic markers to determine and diagnose the cause of poor condition in aquatic systems. Table 3-2 lists essential ecological attributes (EEA) and reporting categories as they relate to contaminated sediments. It is important to note that multiple indicators may be associated with each subcategory in the EEA hierarchy.

Table 3-2. Essential Ecological Attributes and Reporting Categories as They Relate to Contaminated Sediments

Biotic Condition	
Ecosystems and Communities	• Community Extent • Community Composition • Trophic Structure • Community Dynamics • Physical Structure
Species and Populations	• Population Size • Genetic Diversity • Population Structure • Population Dynamics • Habitat Suitability
Organism Condition	• Physiological Status • Symptoms of Disease or Trauma • Signs of Disease
Chemical and Physical Characteristics (Water, Air, Soil, and Sediment)	
Nutrient Concentrations	• Nitrogen • Phosphorus • Other Nutrients
Trace Inorganic and Organic Chemicals	• Metals • Other Trace Elements • Organic Compounds
Other Chemical Parameters	• pH • Dissolved Oxygen • Salinity • Organic Matter • Other
Physical Parameters	• Sediment Particle Size • Depth of Black Layer • Redox Potential

Ecological Processes	
Energy Flow	• Primary Production • Net Ecosystem Production • Growth Efficiency
Material Flow	• Organic Carbon Cycling • Nitrogen and Phosphorus Cycling • Other Nutrient Cycling
Hydrology and Geomorphology	
Surface and Groundwater Flows	• Pattern of Surface Flows • Hydrodynamics • Pattern of Groundwater Flows • Salinity Patterns • Water Storage
Dynamic Structural Characteristics	• Channel/Shoreline Morphology, Complexity • Extent/Distribution of Connected Floodplain • Aquatic Physical Habitat Complexity
Sediment and Material Transport	• Sediment Supply/Movement • Particle Size Distribution Patterns • Other Material Flux

Adapted from: A Framework for Assessing and Reporting on Ecological Condition: An SAB Report United States Environmental Protection Agency-EPA Science Advisory Board, Washington, D.C., EPA-SAV-EPEC-02-009.

Historically, sediment monitoring programs have used benthic community studies as indicators of the effects of sediment contaminants on aquatic ecosystems. An assessment of benthic community structure typically involves field measurements that include the sorting and identification of organisms, and analysis of the numbers of taxa, individuals, and biomass in each sample. At many sites, the objective of the benthic community survey is to determine if there are unacceptable risks to the communities of organisms that inhabit those sediments. Many different benthic community measures have been used as ecological indicators such as: species diversity indices; biotic indices; indicator organisms; species richness measures; enumeration of specific abundances of taxa present; indices measuring similarity between benthic communities at reference and study sites; community function measurements based on habitat; trophic structure and other ecological measures; and statistical approaches applied to determine whether the benthic community at a study site varies from reference or other sites. The major limitation associated with the use of these indicators is difficulty relating them to the presence of individual chemicals or other stressors.

Thus, in order to gain better insight into the ecological state of sediments, integrated approaches are required. First proposed by Chapman et al. (1986), a common integrated methodology is the Sediment Quality Triad (SQT), a weight-of-evidence approach for assessing sediment quality using measures of: (1) sediment chemistry, (2) sediment toxicity, and (3) benthic community composition. One advantage of the triad approach is the use of both chemical and biological data in evaluating the ecological relevance of the results of bioassays and chemical analyses for sites. Although the SQT cannot provide a causal link between a specific contaminant and adverse effects on the benthic community (*i.e.*, it is the ecological relevance of the mixture of contaminants that is being evaluated), the approach provides an indication of the degree of pollution-induced degradation in aquatic communities. Thus, the ecological relevance of the mixture of contaminants in a system may be addressed using the SQT.

Science Needs

The development of new indicator methods for measuring risks from sediment contaminants will improve our ability to assess and characterize contaminated sites, and lead to more effective decisions for managing sites. An important area for future research is to develop new, cost-effective indicator methods at all levels of biological organization (molecular, cellular, organismal, population, and community). It is important that these biological responses can be linked to known chemical stressors. Cellular and biochemical measurements can be used to indicate the bioavailability of sediment contaminants to establish levels of exposure, and to facilitate fate and transport modeling of the contaminants. A number of specific science needs have been identified to link sediment contaminants and other stressors with biological impairment. These include:

- Develop and assess statistical techniques to associate sediment contaminants with community-level responses.

- Develop methods to characterize exposure to individual stressors and predict exposure to contaminant mixtures.

- Develop whole sediment toxicity identification methods.

- Develop tools to determine genetic impairment caused by contaminants in sediment.

- Develop diagnostic indicators for emerging chemicals such as endocrine disruptors.

- Develop mechanistic ecosystem models and a better understanding of benthic community structure and function.

- Develop methods to measure spatial and temporal variation in structural and functional properties of benthic communities, and an understanding of how this variation affects prediction and detection of impacts.

- Determine the cause-effect connection between sediment contamination, behavioral responses, and the relevance of behavioral responses.

3.5.3 Direct Toxicity to Aquatic Biota

Studies at contaminated sediment sites have demonstrated that high concentrations of contaminants have resulted in direct toxicity to benthic invertebrates and to reductions in fish and wildlife populations. At some sites that are heavily contaminated from past mining operations, heavy rain events have resulted in acute lethality of salmonids due to short-term pH-induced increases in metal solubility in the water column.

Biological sediment testing has become an effective assessment tool that provides direct, quantifiable evidence of the impacts of sediment contamination. Sediment tests, with other site information can be used to: 1) determine the relationship between toxic effects and bioavailability, 2) investigate interactions among chemicals, 3) compare the sensitivities of different organisms, 4) determine spatial and temporal distribution of contamination, 5) evaluate dredged material, 6) rank areas for cleanup, and 7) set cleanup goals.

A variety of standard biological test methods have been developed for assessing the short- and long-term toxicity of contaminants associated with freshwater and marine sediments using amphipods, midges, polychaetes, oligochaetes, mayflies, and cladocerans. These toxicity tests provide measures of several different acute and chronic endpoints including survival, growth, behavior, and reproduction. Sediment toxicity identification evaluation (TIE) procedures have also been used to identify toxic compounds in sediment samples containing mixtures of chemicals.

Science Needs

Although a number of sediment toxicity test methods have been standardized, protocols using new test species to provide tests of greater sensitivity are an important area for future research. It will also be necessary to standardize test methods using species that inhabit different geographic ranges and habitat types. Additional work will be necessary to:

- Develop a better understanding of how sediment can be manipulated before, during, and after tests without inappropriately affecting test results.

- Establish appropriate physical test conditions, feeding regimes, test duration, and test initiation or termination procedures.

? Develop a better understanding of how geophysical properties of sediment affect test results.

- Complete additional work to understand the sensitivity of test species to major classes of contaminants. This information can aid in species selection and test interpretation.

- Conduct additional verification and validation studies of toxicity test methods. Validation studies could be conducted by evaluating bioassay response to sediments collected along a natural pollution gradient and comparing results to benthic community studies and *in situ* test results.

- Identify and standardize formulated sediment and sediment spiking techniques.

- Develop tests with amphibians, reptiles, algae, and rooted aquatic plants.

- Develop and standardize higher level tests (*e.g.*, microcosms and mesocosms).

- Develop better understanding of exposure-time relationships in chronic whole sediment toxicity tests.

- Develop field-based methods to assess biological effects of contaminated sediments.

3.5.4 Ecological Significance and Population Models

In an ecological risk assessment, it is important to clearly define and describe ecological significance and to determine what levels of population and community effects are generally acceptable; *e.g.*, will a twenty percent reduction in a specific endpoint still sustain a functioning, healthy ecosystem? U.S. EPA needs to further develop techniques that will improve our ability to determine if: 1) the observed or predicted adverse effects on a structural or functional component of the site's ecosystem is of sufficient type, magnitude, areal extent, and duration that irreversible effects have occurred or are likely to occur, and 2) these effects appear to exceed the normal changes in the structural or functional components typical of similar unaffected ecosystems.

Science Needs

- Develop predictive models for determining the potential population level effects; *e.g.*, how much sediment toxicity is needed before one can predict that there will be significant effects on the population of concern. How many bass or mink or kingfishers can be affected before there will be an impact on the ability of the population of biota to sustain itself at a healthy level in the area impacted by the site?

- Develop a method for estimating depth of bioturbation for benthic macro-invertebrates. Certain benthic macro-invertebrates that colonize on caps build or live in burrows or tunnels in the sand/sediment cap environment. In order to evaluate the potential impact on these aquatic food chain organisms, the depth and extent of benthic bioturbation impacts in a cap need to be identified.

- Potential benthic macro-invertebrate cap attraction. Caps often are of a non-indigenous fill material or sand or are anchored with stone. Will use of different materials reduce colonization times? Will it attract other, less desirable organisms and non-native communities?

3.5.5 Selection of Ecologically Protective Remedial Options

Dredging and capping remedies can result in short-term increases in the water column levels of suspended or dissolved contaminants and can cause severe disruption to benthic habitats. However, criteria are not readily available to help evaluate those situations in which the short-term impacts of intrusive remedial technologies are likely to outweigh the benefits of contaminant removal or sequestration.

Science Needs

- Develop better tools to help evaluate and compare the short-term and long-term impacts and long-term benefits of dredging, capping, monitored natural recovery, and other remedial alternatives, in terms of direct toxicity, habitat loss and recovery, and other ecological effects.

3.5.6 Key Recommendations for Selection of Ecologically Protective Remedial Options

D.1 Develop sediment guidelines to protect wildlife from food chain effects.

Sediment quality guidelines are needed to protect piscivorous birds and wildlife from food chain effects. A critical aspect of developing such SQGs is the need to develop appropriate conceptual ecological site models. Food chains differ from site to site and food chain effects (*e.g.*, bioaccumulation) are not only a function of the chemical concentration in sediment, but reflect how the chemical is transferred from sediment to biota, and how it travels from smaller to larger organisms. This effort would include a consistent method for estimating the site-specific bioavailability of contaminants (see also recommendation B.1). Contaminants of primary concern are bioaccumulative chemicals such as PCBs, DDT, and methyl mercury.

D.2 Develop additional tools for characterizing ecological risks.

Benthic community studies and single-species sediment toxicity tests are often used to evaluate the baseline risks to ecological receptors and the risks after remediation. An important area for future research is the development and validation of additional methods to assess long-term risks, especially for persistent bioaccumulating compounds. This includes the use of smaller, short-lived fish to predict the long-term food chain effects on game fish, and the use of molecular or genetic indicators to predict endocrine disruptor impacts. In addition, SQGs used in conjunction with other tools such as sediment toxicity tests, bioaccumulation, and benthic community surveys, provide additional lines of evidences – and ultimately a weight of evidence approach – that can be used to assess the risks associated with contaminated sediments.

Improvement of uncertainty analysis is also a critical need in ecological risk assessments. Uncertainties result principally from lack of knowledge and from uncertainties in data. Knowledge-based uncertainties hamper each step of a risk assessment or management alternatives evaluation. These arise from incomplete or inadequate characterization of physical, chemical, and biological processes, of the processes that generate stressors, of fate and transport processes (air, water, soil, biota), of exposure pathways to human and ecological receptors, and of their resulting effects and health implications. Uncertainties associated with data arise from inadequate measurement or data summary techniques, from an inappropriate characterization of heterogeneity at the site or ecosystem scale, and from the variability of geological, hydrological, and climatological conditions. The Agency in its *Ecological Research Multi-Year Plan* recommends additional research to improve risk assessment models and better characterize uncertainties (U.S. EPA, 2003d).

D.3 Develop guidance on how to interpret ecological sediment toxicity studies (lab or *in situ* caged studies) and how to interpret the significance of the results in relation to site populations and communities.

A more consistent process is needed to allow risk managers to determine: 1) if the observed or predicted adverse effects on a structural or functional component of the site's ecosystem is of sufficient type, magnitude, areal extent, and duration that irreversible effects have occurred or are likely to occur; and 2) if these effects appear to exceed the normal changes in the structural or functional components typical of unimpacted ecosystems. Interpretive guidance for ecological sediment toxicity studies, and the significance of the results to site populations and communities needs to be developed to better evaluate the need to protect an ecological resource. An important area for future research is the development and validation of population models that include typical bioassay endpoints such as survival, growth, and reproduction, to provide further insight into interpretation of test results.

D.4 Acquire data and develop criteria to use in balancing the long-term benefits from remedial dredging vs. the shorter term adverse effects on ecological receptors and their habitats.

The Workgroup recommends that U.S. EPA collaborate with appropriate Federal agencies to study the short- and long-term impacts/benefits from environmental dredging. It is important that such evaluations include the impacts on habitat and aquatic plants and animals potentially caused by capping, dredging, and/or other remedial methods that alter the physical environmental conditions. It is desirable to monitor thoroughly at least two locations in order to quantitatively determine all contaminant losses (in particular the effectiveness of sediment resuspension controls) during remedial dredging. At these projects, it will be important to employ all currently accepted management practices (*e.g.,* silt curtains, covered clamshell buckets, state-of-the-art cutter heads for hydraulic dredging) to ensure minimal resuspension. All losses quantified as part of the remedial dredging operation would then have to be measured against overall benefits to the site by evaluating ecological benefits for at least a ten-year horizon. Such a study could go far towards resolving the argument that short-term negative impacts from remedial dredging outweigh long-term ecological benefits. Similar studies could usefully be conducted as part of performance evaluations of capping and *in situ* treatment remedial alternatives.

D.5 Conduct field and laboratory studies to further validate and improve chemical-specific sediment quality guidelines.

Chemical-specific sediment quality guidelines have been developed by U.S. EPA for use in contaminated sediment assessment, prevention, and remediation programs. Field validation studies have been conducted on some of these guidelines for these uses. However, an important area of future work is to conduct additional field validation studies and laboratory tests using a range of species to further validate the guidelines and understand contaminant exposure routes. Work is also needed to develop mixtures guidelines for sediment contaminants.

D.6 Continue developing and refining both chronic and sub-chronic sediment toxicity testing methods.

Although a number of sediment toxicity test methods have been standardized, an important area for future research is the development and validation of protocols using new freshwater, marine, and estuarine test species to provide sensitive tests representing a greater range of species and habitat types. The currently available *Leptocheirus plumulosus* chronic test protocol uses an Atlantic Coast species, which may not adequately represent the sensitivity of species from Pacific Ocean systems. Chronic, sublethal test protocols are needed for marine species present in the Pacific, such as the amphipod *Grandidierella japonica*. Additional freshwater test protocols are needed for burrowing species. Field-based test methods (*e.g.*, *in situ* test methods) are needed to assess the biological effects of contaminated sediments. Some of the currently available test protocols are expensive and difficult to run. It is important to develop both simplified test protocols to reduce costs, and interpretive guidance for sublethal test methods. A number of marine and estuarine test protocols for amphipod species have been developed. It is important to give consideration to developing additional methods for species other than amphipods.

D.7 Develop whole sediment toxicity identification evaluation procedures for a wide range of chemicals.

Sediment contaminants often occur in mixtures. Whole sediment toxicity identification evaluation methods are needed in order to determine which contaminants cause observed toxicity. Currently available toxicity identification evaluation methods are capable of characterizing the toxicity of a sediment only by identifying classes of toxic contaminants (*e.g.*, metals or organic toxicants). Additional work is needed to improve the method so that individual chemical contaminants can be identified. In addition, work is needed to conduct field validation studies supporting the method.

3.6 Sediment Remediation

A sediment remedial alternative is a technology or combination of technologies used to reduce the impact of contaminated sediments on human health and the environment. Alternatives can span a wide range of complexity and technological ingenuity. The simplest alternatives might employ only a single component (*i.e.*, *in situ* capping). However, more complex alternatives may involve several different technologies and various project components (U.S. EPA, 1994). For the more complex alternatives, it is important to match complementary components in order to obtain an efficient remedial design (*e.g.*, hydraulic dredging may not be the best choice for sediments that will be disposed of in a landfill due to the "no water in landfills" rule).

Due to all the confounding factors involved in sediment remediation, it is difficult to capture all the complexities of the state of the science in sediment remediation in only a few short pages. However, the subsections below provide a summary of the current state of sediment remediation technology, identification of problems, and a discussion of key research gaps.

3.6.1 Natural Recovery/Bioremediation

Natural recovery involves leaving contaminated sediments in place and allowing ongoing chemical, physical, and biological aquatic processes to contain, destroy, or otherwise reduce the bioavailability of contaminants. No actions are required to initiate or continue the natural recovery process (NRC, 1997). Although natural recovery has been the strategy of choice at only a few contaminated sediments sites, the absence of timely remedial activities at many sites has made natural recovery the *de facto* remediation of choice at these sites. Case studies are identified in the National Research Council (1997) document.

There are a plethora of resources available that provide more information on the natural recovery and bioremediation of contaminated sediments. However, there is still an ongoing debate regarding the viability of using natural processes or engineered biological processes to remediate contaminated sediments, especially those contaminated with heavy metals and chlorinated organics: "Using bioremediation to treat in-place [contaminated] sediments, although theoretically possible, requires further research and development because it raises a number of significant microbial, geochemical, and hydrological issues [including transport by large-scale storm events] that have yet to be resolved" (NRC, 1997).

Additionally, while the "natural capping" and resulting sequestration of sediment contaminants from natural deposition may occur at a faster "average" rate than the ongoing biological breakdown, large scale storm events may result in hot-spot contamination being dispersed over a large area where it would be difficult to remove or remediate.

The NRC (1997) document offers the following science needs for further research.

Science Needs

- Develop scientific principles to describe the process of natural recovery.

- Perform a literature survey to determine the level of effectiveness at natural recovery sites.

- Develop accepted measuring protocols to determine *in situ* chemical fluxes from bed sediments into the overlying water column.

- Develop protocols for assessing the relative contribution of the five or more mechanisms for chemical releases from bed sediments (including mass transport of sediments and contaminants by large-scale storm events).

- Determine the mechanisms for measuring the bioavailability of sorbed contaminants and the effect of sediment aging.

- Determine the rate and/or presence of anaerobic degradation processes in near-shore, mostly anoxic sediments.

- Conduct additional laboratory, pilot-scale, and field-scale demonstrations of the effectiveness of biological treatments.

- Explore the possibility of combining *in situ* bioremediation with *in situ* capping.

3.6.2 *In situ* Capping

"*In situ* capping is the controlled, accurate placement of a clean, isolating material cover, or cap, over contaminated sediments without relocating the sediments or causing a major disruption of the original bed" (NRC, 1997). U.S. EPA's GLNPO and U.S. EPA Region 5 have coordinated with U.S. ACE and USGS in the production of two guidance documents on *in situ* capping (U.S. EPA, 1998d, and in preparation). Capping attempts to limit the adverse impacts of sediment contamination by providing a barrier to prevent contact between aquatic organisms and the contaminated sediments. Capping may also prevent downstream transport of sediments and their associated contaminants.

The design and installation of conventional sediment caps is fairly straight-forward and well understood, including the numerous cap placement technologies (tremie tube, submerged diffuses, and others) described by U.S. EPA (1998d). However, the long-term effectiveness of this alternative has not been well researched, although the National Research Council (NRC, 2001a) documents *in situ* capping case studies that have been completed in Hamilton Harbor, Canada and the St. Paul Waterway in Tacoma, Washington. Reports documenting results of these operations can be found in Zeman and Patterson (1997) and Parametrix (1999), respectively. Additionally, many entities are now beginning to discuss more complex sediment cap designs, including the use of zero-valent iron or biological treatment mechanisms in the cap
design.

Science Needs

- Analyze data from historical and ongoing field applications to determine capping effectiveness (NRC, 1997).

- Research and/or develop technologies to control contaminant releases during cap placement (NRC, 1997).

- Testing to simulate and evaluate the consequences of episodic mixing (*e.g.*, anchor penetration and major flood/storm events) (NRC, 1997).

- Determine the impacts of advective transport (*i.e.*, groundwater flow) on the transport of contaminants through the cap.

- Develop and evaluate the use of innovative cap designs that incorporate chemical and/or biological treatment technologies.

- Assess the uncertainties associated with cap performance predictions.

3.6.3 *In situ* Treatment

In situ treatment involves the active manipulation of in-place sediments to enhance the breakdown or prevent the transport (*e.g.*, immobilization) of contaminants. Potential technologies include: *in situ* immobilization, *in situ* chemical treatment, *in situ* freezing, *in situ* geo-oxidation, and *in situ* vitrification (NRC, 1997).

Immobilization technologies are likely to be based on the concepts of solidification and immobilization. The applicability of these processes to fine-grained sediments with high water content has yet to be demonstrated. Potential problems include: inaccuracies of *in situ* placement, erosion, temperature increases during curing, and increases in sediment volume (NRC, 1997).

Researchers at the Canadian National Water Research Institute have developed and demonstrated equipment capable of injecting chemical solutions into sediments at a controlled rate (U.S. EPA, 1994). However, the applicability of *in situ* chemical treatment appears to be limited because of interference between various classes of contaminants and the possibility of mobilizing metals in the process of oxidizing organics (NRC, 1997). The National Research Council (NRC, 2001a) states that "no effective *in situ* delivery system has yet been developed for [delivering required nutrients, substrates, or reagents to] contaminated sediments."

The use of *in situ* freezing and *in situ* vitrification can be quickly dismissed based on high cost and limited effectiveness. Freezing by injection of molten sulfur has the same limitation as *in situ* solidification. *In situ* vitrification has been demonstrated on soils, but the high water content of sediments would require local site dewatering and the construction of a vapor recovery system (NRC, 1997). The NRC (2001a) documents the difficulties encountered on an *in situ* treatment project in Manitowoc Harbor, Wisconsin. There are many difficulties associated with the application of *in situ* technologies to contaminated sediment deposits. Many of these problems are based upon the application of known processes to the high volumes of low-concentration sediment generally found in the field. In addition, many sediment deposits are both heterogeneous and fine-grained, making the uniform application of treatment amendments difficult.

Science Needs

- Additional extensive research of most *in situ* treatment would be required and is probably not justified based on the limited applicability and effectiveness of current technologies (NRC, 1997).

- It is important that U.S. EPA critically evaluate the three *in situ* and *ex situ* ElectroChemical GeoOxidation (ECGOx) pilot-scale demonstrations that occurred in 2001 and 2002 to determine if additional studies are justified (GLNPO, U.S. ACE, several private companies, U.S. EPA's SITE Program, U.S. EPA Region 2, and U.S. EPA Region 10 are involved in the evaluation and demonstrations currently being discussed).

- Continue an open dialogue with international agencies and technology vendors and perform literature reviews to keep abreast of any advances in *in situ* treatment technologies.

3.6.4 Dredging/Removal

"Efficient hydraulic and mechanical methods are [readily] available for the removal and transport of sediments for *ex situ* remediation or confinement" (NRC, 1997). Additionally, promising technologies for precision control include electronically positioned dredge-heads and bottom-crawling hydraulic dredges. The latter may offer the capability of dredging in depths beyond the standard maximum operating capacity of conventional dredges (NRC, 1997). Finally, many innovative mechanical (*e.g.*, environmental clamshell) and hydraulic pumps (*e.g.*, Eddy pump, PNEUMA pump) are available that advertise reduced sediment resuspension, increased solids content of dredged material, and/or other performance enhancements. Adequate research and data are not available to evaluate all of these claims. Hayes (1989) noted that the operation of the dredge and the experience of the dredge operator have a profound effect on the rate of sediment re-suspension. Furthermore, recent monitoring at dredging sites has focused on the short-term impacts and contaminant losses associated with dredging operations. U.S. EPA (1996a) presents a good general framework for estimating contaminant losses from all components of the dredging and disposal process. Additionally, the USGS (Steuer, 2000) presents a case study for monitoring short-term impacts for a dredging project on the Fox River in Wisconsin.

Science Needs

- Performance evaluation for innovative dredging equipment.

- Performance evaluation of low resuspension dredges capable of removing sediments at near *in situ* densities (NRC, 1997).

- Enhanced capabilities for precision removal of sediments (NRC, 1997).
- Increased monitoring before, during, and after dredging to determine short-term impacts, long-term impacts, and long-term improvements due to dredging projects.

3.6.5 *Ex situ* Treatment Technologies

Numerous *ex situ* treatment technologies have undergone bench- and pilot-scale demonstrations. The results of these studies are documented in numerous reports including U.S. EPA's ARCS program reports (http://www.epa.gov/glnpo/arcs/), International Navigation Association (PIANC) proceedings, SITE programs (http://www.epa.gov/ORD/SITE/), and other documents. *Ex situ* treatment is generally more promising than using the same technology *in situ*, because conditions can be more tightly controlled in contained facilities. Chemical separation, thermal desorption, and immobilization technologies have been employed successfully but are expensive, complicated, and limited to treating certain types of sediments and/or contaminants. Because of the high unit costs, thermal and chemical destruction techniques do not appear to be cost-effective, near-term approaches for remediating large volumes of contaminated dredged material (NRC, 1997).

Following up on the work conducted under the ARCS Program, U.S. EPA Region 2 coordinated a five-year study on sediment treatment technologies, the goal of which was to examine alternative methods to address and manage contaminated sediments in New York/New Jersey Harbor. A particular focus of U.S. EPA Region 2 work was to evaluate treatment technologies that both decontaminate sediments and produce a marketable final product. This study has resulted in a completed pilot-scale demonstration: a sediment washing process whereby a manufactured topsoil and bricks are produced as marketable end-products. An additional thermal treatment demonstration is planned for 2004: a process that produces a blended cement product (Stern et al., 1998; Jones et al., 2001).

Utilizing the information generated by U.S. EPA Region 2 in its New York/New Jersey Harbor decontamination program and in an effort to identify treatment technologies with a unit cost (dollars per cubic yard) of less than one hundred dollars ($100), GLNPO has teamed with the Michigan Department of Environmental Quality (MDEQ) for bench-scale testing and evaluation of sediment treatment technologies with beneficial end products (SEG, 1999). Additionally, GLNPO, U.S. EPA-SITE, the Wisconsin Department of Natural Resources, and Minergy Corporation are coordinating the pilot-scale demonstration and evaluation of Minergy's technology which destroys organic contaminants and encapsulates inorganic contaminants while producing a glass aggregate by-product that can be used for construction fill. Additional demonstrations are planned.

Science Needs

- Research and development of *ex situ* treatment technologies to search for reasonable possibilities for cost effective treatment of large volumes of sediments (NRC, 1997).

- Additional full-scale demonstrations of promising treatment options to determine the effectiveness of technologies on a larger scale; to identify the pathways for contaminant losses; and, to determine the risks associated with contaminant losses during treatment.

- Significant coordination between U.S. EPA, U.S. ACE, and technology vendors to identify cost-effective treatment options and potential end uses of treatment products to offset the cost of treatment.

3.6.6 Beneficial Use Technologies

"Dredged sediments traditionally have been viewed as waste [material]. However, dredged material is often used for beneficial purposes [such as], fill for urban development (such as the construction of National Airport in Washington, DC), beach nourishment, the creation of wetlands and wildlife habitat, for improving farmland [as a soil amendment], as fill for general construction, and for establishing coastal islands where many species of birds nest" (NRC, 1997). The statutory underpinning for the beneficial use of dredged material is provided by the WRDA, which contains provisions for using dredged material for such things as the protection, restoration, and creation of aquatic habitat (NRC, 1997). In addition, both the MPRSA and CWA dredged material disposal regulatory programs help foster beneficial uses by requiring consideration of alternatives (such as beneficial use) to dredged material disposal.

Most beneficial use projects completed to date have used "clean" dredged material, but the National Research Council (1997) contains an extensive list of completed beneficial use projects that used both "clean" and "contaminated" dredged materials. The NRC document also contains references to numerous scientific studies to assess the effectiveness of these beneficial use projects and to determine if there were any environmental impacts from the contaminants associated with the dredged sediments. U.S. ACE, GLNPO, and associated state and local organizations have coordinated on several beneficial use pilot projects within the Great Lakes watershed (mined land reclamation and construction fill projects in Duluth, Minnesota, top soil creation at Toledo, Ohio; Milwaukee, Wisconsin; and Green Bay, Wisconsin).

Additionally, MDEQ realized significant cost savings on a sediment remediation project for Newburgh Lake when the dredged sediments were used as daily cover at a nearby landfill (GLNPO, 2000).

Although there is significant information on research studies and pilot- and full-scale demonstrations of beneficial use, most of the reuse projects are isolated, one-time studies and are not consistently incorporated into long-term management strategies on dredge material management. This is unfortunate since increases in beneficial use could conserve valuable disposal space at Confined Disposal Facilities (CDFs) and landfills.

Science Needs

- Development of technical guidelines for the beneficial use of dredged material, similar to the guidelines for the use of biosolids.

- Literature review and analysis of beneficial use projects and studies to determine the associated environmental impacts.

3.6.7 Disposal Options

The National Research Council (1997) contains an excellent discussion of disposal options for contaminated sediments and a figure for visualizing each alternative. The three major options for contaminated sediment disposal include:

? Landfilling - the placement of sediments into a licensed solid waste facility.

? Confined disposal facilities - placement of sediments into a diked in-water, near-shore, or land-based facility specifically designed for containing sediments.

? Contained aquatic disposal (CAD) - controlled, open-water placement of contaminated material followed by covering (capping) with clean material. (NRC, 1997).

Both CDFs and landfills have a long history of use, and the state of research and study of these facilities is fairly well advanced. In contrast, fewer actual case studies exist for CAD projects, and therefore, there exists only a limited amount of research on this disposal option. Sumeri (1984) and Truitt (1986) document the results of a CAD project in the Duwamish Waterway in Seattle, Washington (NRC, 1997). In 1992, U.S. EPA and U.S. ACE published a document describing techniques for evaluating releases resulting from various disposal options (U.S. EPA/U.S. ACE, 1992).

Science Needs

- Improved methods for evaluation of potential release pathways for each disposal option.

- Literature review and evaluation of releases for current disposal facilities, particularly CDFs.

- Improved design criteria for designing and building CADs.

- Investigation of long-term effectiveness and releases for each disposal alternative.

- Better models to predict loss of contaminants via volatilization.

3.6.8 Key Recommendations for Sediment Remediation

E.1 Collect the necessary data and develop guidance for determining the conditions under which natural recovery can be considered a suitable remedial option. Such guidance would include: measurement protocols to assess the relative contribution of the various mechanisms for chemical releases from bed sediments (*e.g.*, advection, bioturbation, diffusion, and resuspension), including mass transport of contaminants by large storm events; approaches to assess the vertical extent of the bioavailable zone in different environmental settings; methodologies to quantify the uncertainties associated with natural recovery; and development of accepted measuring protocols to determine *in situ* chemical fluxes from sediments.

The Workgroup recommends that research be continued and increased for examining the relative contributions of the various mechanisms for contaminant release from sediments.

When selecting a remedial option for a particular site, it is critical to determine the methods by which contaminants are lost or transported, and which mechanisms play significant roles. In many situations large storm events will be the largest mechanism to move contaminants from a particular hot spot. In other more quiescent settings, such processes as advection, diffusion and bioturbation may predominate. The method of contaminant loss varies seasonally in many systems, with resuspension by storm events typically predominating in spring; other mechanisms are more important over the rest of the year. The flux of contaminants via processes such as advection, diffusion, and bioturbation can also show seasonal variation. Knowing the relative contributions of these mechanisms is critical in determining whether natural recovery or capping are the most appropriate remedial options for a site. Also, being able to better quantify the uncertainties inherent in evaluation of natural recovery and other remedial options will enable more effective remedy selection.

Under certain circumstances, natural recovery through burial of contaminated sediments may be a viable remedial option. In such cases, the depositional history of sediments can be understood through the analysis of sediment physical data in conjunction with age dating techniques using ^{137}Cs, ^{210}Pb, lignin, and other compounds in sediments. Even where physical data are seemingly sufficient to allow construction of a mathematical model of deposition, empirical data are critical for calibration and validation of such models.

E.2 Develop performance evaluations of various cap designs and cap placement methods and conduct cap placement and post-cap monitoring to document performance. Continue to monitor ongoing capping projects to monitor performance (*e.g.*, Boston Harbor, Eagle Harbor, Grasse River).

The design and installation of conventional sediment caps is well understood; however, the long-term effectiveness of this remedial alternative has not been well researched. In addition, many entities are now beginning to discuss more complex cap designs, including the use of biological treatment.

With capping becoming a management option being recommended at more sites, it is critical that evaluations be conducted to document its effectiveness. It is important that U.S. EPA promote capping demonstration projects that include both short- and long-term monitoring to document cap placement methods and cap performance. All mechanisms of loss must be quantified during such a study including sediment resuspension (during placement), diffusion, advection, bioturbation, and storm events.

E.3 Encourage and promote the development and demonstration of *in-situ* technologies.

In situ technologies, if proven effective, would be the most efficient means for remediating contaminated sediment sites. Such a technology would avoid the problems and make moot arguments of whether or not removing sediments via dredging does more harm than good. It would also obviate the difficulties associated with finding a disposal site.

It is important that U.S. EPA actively identify and work with vendors who have a viable technology for treating contaminants *in situ*, conduct demonstration projects examining *in situ* technologies, and evaluate such projects to determine their efficacy.

E.4 Using the data provided in recommendation E.1, develop a white paper evaluating the short-term and long-term impacts from dredging relative to natural processes and human activities (*e.g.*, resuspension from storm events, boat scour, wave action and anchor drag).

Large storm events are known to move large volumes of sediment and their associated contaminants. It is critical that any study examining the impacts from dredging also be examined in relation to all mechanisms of contaminant loss ongoing at a particular site. It is essential that all contaminant losses that would naturally occur at a site including resuspension from storm events, advection, diffusion, and bioturbation, be taken into account when evaluating dredging impacts. Only when the net losses from these processes are known can the impacts associated with dredging be adequately evaluated.

E.5 Support the demonstration of cost-effective *ex situ* treatment technologies and identification of potential beneficial uses of treatment products.

Much work on *ex situ* treatment has been conducted by both U.S. EPA Region 2 and GLNPO. A number of demonstrations have been successfully completed to date, and others are planned. The Workgroup is now confident that tools do exist to decontaminate sediments. It is apparent, however, that to make treatment viable, it is necessary that a marketable end use product (*i.e.*, a cost effective option) either be extant or be developed, particularly at sites that have large volumes of contaminated sediments.

Partnerships need to be developed with industry to conduct joint demonstrations and examine all options for making treatment cost effective and a viable alternative to landfilling.

3.7 Baseline, Remediation, and Post-Remediation Monitoring

To ensure that all sediment risk and exposure pathways at a site are being (or have been) adequately managed by the remedy, it is necessary to implement a sediment monitoring program for all types of sediment remedies, both during remedy implementation and over the long-term. Long-term monitoring should continue until all remedial action objectives have been met. In some instances, this may take many decades. A sediment monitoring program encompasses baseline monitoring, monitoring during remedial action implementation, and post-remediation, or long-term monitoring.

Baseline monitoring encompasses the monitoring of those indicators of environmental change (*i.e.*, fish or other biota, sediment chemistry, pore water chemistry, toxicity testing, and benthic community structure) and is conducted prior to the initiation of the remedial action. It is typically conducted during the remedial investigation or site characterization stage. It is important that baseline monitoring be consistent with the planned long-term or post-remediation monitoring, and to provide a valid basis for comparison with the post-remediation monitoring data in order to detect and evaluate environmental trends and to evaluate the effectiveness of the remedial action.

In contrast, post-remediation, or long-term, monitoring is initiated once the remedial action is completed. It involves multiple measurements made over time to assess the success of the remedy in meeting remedial performance goals. The data are used to evaluate the long-term effectiveness of the selected remedial action in protecting human health and the environment, engineering/construction performance and structural integrity of any containment or stabilization structures, the recovery of areas impacted by the remedial action, and the success of mitigation projects built to offset environmental impacts caused by the remedial action; the data can also be used to evaluate restoration of the ecosystem. Post-remediation monitoring typically consists of monitoring fish or other biota populations and residues, toxicity testing, and benthic community structure evaluations. Monitoring may continue after the remedial performance goals are achieved to assure that the remedy is sound and continues to be effective.

Monitoring during implementation of the remedial action is used to evaluate the short-term effects of the remedial action, whether the remedial action project meets design requirements, whether clean-up levels are met, and whether other remedial action objectives are met. In some cases where the implementation of the remedial action spans a significant length of time, the length of time of monitoring during implementation may span several years, if not decades. Natural recovery sites and large dredging projects encompassing millions of cubic yards of sediment are examples of sites where such monitoring may run for decades. Monitoring during dredging is conducted to measure dredging effectiveness and identify short-term upsets whereas monitoring after dredging is completed (i.e, post-remedial monitoring) is conducted to determine whether the pre-dredging baseline conditions have been negatively affected. Monitoring during remedial action implementation may contain some of the same indicators, but will likely include monitoring of others such as turbidity, dissolved oxygen, sediment chemistry, water chemistry, and air monitoring. Further, the monitoring of environmental effects could include tracking other parameters such as the concentration of contaminants (either dissolved or suspended) in the water column, the amount of contaminants lost downstream, and the concentration of residual contaminants left behind in the bottom sediments.

Monitoring is a standard component at a contaminated sediment project, beginning prior to the site investigation when project managers are trying to determine whether there is a problem, and running through post-remediation monitoring. These various types of monitoring programs are being implemented at a number of contaminated sediment sites, and plans are in place to initiate monitoring at others.

A few examples of sites where post-remediation monitoring is underway or planned to be initiated are:

- Cannelton Industries Superfund site on the St. Mary's River, Michigan.
- Black River, Ohio.
- River Raisin (Ford Outfalls Superfund removal action site), Michigan.
- Manistique River and Harbor, Michigan (Superfund removal action site).
- LCP Superfund site in Brunswick, Georgia.
- Tennessee River Site in Decatur, Alabama. (Consent Decree with stream diversion, capping, and in-place stabilization).

Monitoring during remedy implementation is underway on the Pine River, Michigan (Velsicol Superfund site). The Sediment Inventory may be referred to for additional information. See Figure 3-4 for examples of other science activities related to monitoring.

Figure 3-4. Examples of Other Science Activities Related to Monitoring

- FIELDS software tools have been developed to support the monitoring of remedy implementation and remediation effectiveness (U.S. EPA Region 5 Superfund).
- Development of monitoring guidance and fact sheets (OSWER and Regions).
- Development of tools to be used in monitoring (ORD/OW).

Questions arise regarding the short-term impacts and long-term effectiveness of dredging, capping and other *in situ* remedies. A look at sediment sites across the nation shows inconsistencies in the kinds of monitoring performed. Impediments to the implementation of monitoring may be due to limited knowledge on how to develop and implement monitoring plans.

There is an ongoing debate regarding the short-term impacts and long-term effectiveness of dredging and capping remedies, with some claiming that dredging (and possibly capping) cause greater harm through destruction of habitat and release of contaminants. Others argue that while there are short-term impacts, they can be minimized through technology and operational and other controls, and that these remedies will prove to be more protective over the long-term because of the permanent removal of the contaminants or through limitations on bioavailability. Other questions include: Will dredging or capping result in newly created or increased direct toxicity to biota from increases in dissolved or suspended contaminant concentrations in the water column? Will they result in an increase in the bioavailability of contaminants and increased tissue concentrations in fish and other biota? How long does it take for the habitat of a dredged or capped area to become suitable for aquatic life and for re-colonization to take place? Will caps provide attractive habitat for desirable biota, or will they attract less desirable organisms and non-native communities? Information from the monitoring of both remedy implementation and post-remediation is necessary in order to address and resolve these issues.

In addition, monitoring information can be used to inform decision-making at contaminated sediment sites.

Science Needs

The NRC Report (2001a) recommends that "[l]ong-term monitoring and evaluation of [...] contaminated sediment sites should be conducted to evaluate the effectiveness of the management approach and to ensure adequate, continuous protection of humans and the environment." This is consistent with the issues discussed above - more and better monitoring data are needed. To ensure that such data are collected, guidance and information with regard to available protocols and tests are needed for the remediation project manager's reference. In addition, to ensure that such monitoring is implemented, a cross-program policy may also be needed. For Superfund sites, such a policy may direct the agency to ensure that monitoring is included as a component of remedial alternatives in the Feasibility Study and Record of Decision, and included in settlements with potentially responsible parties (PRPs). For cleanups funded with Federal dollars, sufficient funds would need to be included to cover the cost of the monitoring, or agreements made with state or Federal partners to conduct such monitoring.

Some specific areas that need to be addressed include: an evaluation of the existing protocols and tests performed to identify those which are appropriate for monitoring and any additional needs. For example, U.S. EPA's Office of Water has published protocols for sampling and analysis of fish and shellfish in order to determine human health risks associated with tissue contaminants (U.S. EPA, 2000c). U.S. EPA has also published guidance on collection, storage, and manipulation of sediments (U.S. EPA, 2001b), and existing Agency protocols are available for dredged material testing and assessment (U.S. EPA, 1998c and 1991a). These protocols are available for use in monitoring contaminated sediment sites. However, monitoring guidance needs to be developed to provide remediation project managers with a consistent approach to developing monitoring plans and implementing such monitoring. It is important that monitoring guidance also address how monitoring plans are developed, what protocols and tests are available for use (with recommendations for the use for each), how to develop indicators and measures, how to evaluate monitoring data, minimum quality assurance/quality control (QA/QC) protocols, and specifics regarding which biota and which media should be used for specific situations (*i.e.*, number of, species, and age of fish for bioaccumulative chemicals of concern).

It is important to make monitoring data available to provide information for decision-making at other sediment sites. Please refer to Section 3.9 for additional details with regard to monitoring data management and exchange.

3.7.1 Key Recommendations for Baseline, Remediation, and Post-Remediation Monitoring

A review of sediment sites across the nation show a lack of or limited monitoring data with which to answer these questions and resolve the debate. In addition, monitoring data needs to be made available to inform decision-making at contaminated sediment sites.

The impediments to monitoring include: limited knowledge on how to develop monitoring plans, including the type, frequency, and temporal extent of measurements and limited knowledge on their implementation. Additional issues include the cost of conducting monitoring, providing oversight when conducted by the PRP, and implications of the monitoring results and final compliance of remedial action.

The following key recommendations are made to address these issues.

F.1 Develop monitoring guidance fact sheets for baseline, remediation, and post-remediation monitoring, and monitoring during remedy implementation.

An important area for future study is evaluation of existing protocols and tests in order to identify those which are appropriate for monitoring and what additional needs there may be. Monitoring guidance needs to be developed to provide project managers with a consistent approach to developing monitoring plans and implementing such monitoring (*e.g.*, monitoring of sediment resuspension during remedy implementation). Such guidance would also address how monitoring plans are developed, what protocols and tests are available for use (with recommendations for the use of each), how to develop indicators and measures, how to evaluate monitoring data, minimum QA/QC protocols, and specifics regarding which biota and which media should be used for specific situations (*i.e.*, number of, species, and age of fish for bioaccumulative chemicals of concern). This information would be compiled into a compendium and be available as a reference document for the guidance and fact sheets.

To meet this need, the Workgroup recommends that the OSRTI, with support from the other program offices and regions, initiate the development of monitoring guidance fact sheets. It is suggested that a workgroup be established with representation across program offices and regions to take on this task. It is recommended that this workgroup coordinate with natural resource trustees to ensure that monitoring guidance addresses their values and priorities.

F.2 Conduct training and hold workshops for project managers regarding monitoring of contaminated sediment sites.

Training is needed to teach project managers how to develop and implement monitoring plans, and evaluate the resulting data with regard to remedy implementation and performance. Workshops or other fora are needed to share monitoring information and remedy performance.

To begin to meet these needs, it is recommended that a two-day Monitoring Workshop be held under the suggested lead of ORD and OSRTI. The target audience would be U.S. EPA scientists and project managers of contaminated sediment sites. It is further recommended that an advisory group be formed with participation from the various program and regional offices to plan the workshop.

The CSSP Document also recommends that additional sessions be held periodically (whether they be training workshops or brown bags for the purpose of teaching how to conduct monitoring or prepare monitoring plans, or fora for the purpose of sharing experiences and results), and at various levels (*i.e.*, regional, national, U.S. EPA only, or U.S. EPA plus external parties). The leads for planning such sessions may be at the national or regional level. Use of existing fora is encouraged, such as the annual National Association of Remedial Project Managers meeting, or the National Superfund Site Assessment Conference. At the regional level, a program office may take the lead to sponsor a brown bag on monitoring. The timing of such regional sessions will be left to the discretion of the regions. It is also recommended that a national workshop be held in conjunction with the completion of the draft monitoring guidance, under the sponsorship of OSRTI, ORD, and OW.

3.8 Risk Communication and Community Involvement

The National Research Council's report, *A Risk-Management Strategy for PCB-Contaminated Sediments* (NRC, 2001a) highlighted the many benefits of involving communities in the cleanup process. "Participation makes the process more democratic, lends legitimacy to the process, educates and empowers the affected communities, and generally leads to decisions that are more accepted by the community (Fiorino, 1990; Folk, 1991; NRC, 1997). The affected community members can contribute essential community-based knowledge, information, and insight that is often lacking in expert-driven risk processes (Ashford and Rest, 1999). Community involvement can also assist in dealing with perceptions of risk and helping community members to understand the differences between types and degrees of risk." Although the benefits of early, active, and continuous community involvement have been widely recognized by U.S. EPA and others, the NRC found that there still remains much progress that needs to be made to more effectively involve communities.

U.S. EPA's two major programs/offices with responsibilities for protecting and cleaning-up contaminated sediments, Superfund and the Office of Water, have both expanded efforts to more greatly involve communities in their programs. For example, the Superfund program published a report identifying useful lessons that were learned on how to provide communities greater involvement (U.S. EPA, 1999b). Superfund has developed a number of general guidance documents and tools for use at Superfund sites. *Risk Assessment Guidance for Superfund (RAGS): Volume 1 - Human Health*

Evaluation Manual. Supplement to Part A: Community Involvement in Superfund Risk Assessments (U.S. EPA, 1999c) explains how Superfund staff and community members can work together especially during the risk assessment. A video, *Superfund Risk Assessment - What It's All About and How You Can Help*, describes (in lay terms) the Superfund risk assessment process and how communities can help (U.S. EPA, 1999d). Other fact sheets and Community Advisory Group Toolkits have been developed (U.S. EPA, 1998a, 1995b, 1999b, and 1996b). Additionally, the Office of Water's National Fish and Wildlife Contamination Program is developing an updated (second) edition of its *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume IV: Risk Communication* (U.S. EPA, 1995a). This new edition will provide greater emphasis on ensuring that risk communication is culturally appropriate for diverse communities and that all communities be involved early and throughout the program.

Risk communication provides the means for communities to have a greater role in the evaluation and decision-making process. Risk communication research develops the methods, models, and tools for U.S. EPA to more effectively reach out to communities, earn their trust, and build an effective working partnership. This partnership will allow communities to become more fully engaged in the entire cleanup process – not just as passive listeners, but as important decision-makers. The NRC (2001b) report recognized that U.S. EPA's community involvement program has been advocating greater involvement of affected communities into the cleanup process.

An important component of risk communication and community involvement is ensuring that all the technical information provided to the communities is understandable. Too often communities are either inundated with too much extraneous information that cannot be understood, or they are presented with summaries that contain too little data. Research is needed on both how to effectively extract the appropriate amount of information and determine the best vehicles (*e.g.*, formal presentations, newsletters, informal meetings, videos, infomercials, web sites) for presenting the data to communities. In addition to developing more effective tools for the sender of messages, research is needed to develop better listening skills for all the receivers of messages.

Communities have first-hand knowledge of the site and their own activities (such as catching and consuming fish) that would be very helpful to U.S. EPA's evaluation of the site and its possible impacts on nearby communities. The development of site-specific exposure factors based on the measurements of the habits of the local community could reduce reliance on the use of national default assumptions that may not reflect local habits or conditions.

Communities at contaminated sediment sites are diverse and often have conflicting interests that are hard to articulate and quantify. Measurement methods that might be suitable include public opinion survey instruments, randomly selected focus groups, and computer-based methods such as "virtual" town meetings. This is particularly important for sediment sites because they can cover large geographic areas.

Because the effectiveness of risk communication and community involvement are rarely measured in application, there is considerable disagreement about the effectiveness of current public participation activities. Measuring the performance of existing tools and newly developed tools would focus improvements in necessary areas.

Science Needs

- Develop better methods and tools to measure the preferences of individuals, sub-populations, and communities throughout the entire sediment cleanup process.

- Develop more effective methods and tools to describe, summarize, and present complex technical data to communities.

- Develop better methods and tools to extract and utilize community-based knowledge.

- Develop ways to determine how various societal and cultural values and practices are impacted by contaminated sediments or cleanup activities. For example, the inability of native tribes to harvest fish and then barter them for other valuables is a cultural impact that is not often considered.

- Develop community outreach methods and tools that can be applied to large geographic sites with multiple diverse communities. Because some contaminated sediment sites, especially river sites, can span tens or even hundreds of miles, they present difficult challenges to community involvement staff.

- Develop and apply methods and tools that measure the effectiveness of environmental public participation programs.

3.8.1 Key Recommendations for Risk Communication and Community Involvement

Advances in the science of risk communication would result in much more meaningful community involvement in the contaminated sediments cleanup process. The methods, models, and tools produced by this research would allow U.S. EPA to more effectively reach out to communities, earn their trust, and build effective working partnerships– partnerships that empower communities to become more fully engaged in the entire cleanup decision-making process. To accomplish this, the following recommendation is made:

G.1 Establish a research program on risk communication and community involvement focusing on developing better methods, models, and tools.

There are many potential benefits to be gained by conducting research in this area. ORD could take the lead in developing a solicitation package to conduct research in one or more of these project areas.

3.9 Information Management and Exchange Activities

Figure 3-5. Types of Information/Data Management Activities Currently Underway

- GLNPO's sediment database.
- OW's Sediment Inventory.
- OSRTI's Superfund sediment sites

Information, or data, management is a key component of the characterization, assessment, and monitoring activities conducted at contaminated sediment sites. A data management system provides one point of access for all data and simplifies assessment, QA/QC evaluation, modeling, mapping, querying, trends analysis and other activities that may be conducted using the data. Information communication and exchange are critical components of a contaminated sediment project and would be simplified by the establishment of a quality data management system. Outreach and information-sharing with the public is key to not only their understanding of the ecological and health risks associated with a site, but also of the possible solutions to address those risks. An informed public would be better able to contribute to the decision-making process in a knowledgeable manner. To manage the quality of its environmental data collection, generation, and use, EPA uses a Quality System that ensures that its environmental data are of sufficient quantity and quality to support the data's intended use. Some examples of the types of information/data management activities that are underway are shown in Figure 3-5. Other information communication and exchange activities are identified in Figure 3-6.

Figure 3-6. Information Communication and Exchange Activities

- Sediment Network (OW).
- Superfund Sediment Forum (OSRTI).
- Participation on external fora such as the National Sediment Dialogue and Great Lakes and other regional Dredging Teams.
- Great Lakes sediment web page (GLNPO).
- Public Outreach Tools: Sediment pamphlet and poster (OW) and a dredging video (OSRTI).
- U.S. EPA Region 5 Superfund's FIELDS system.
- Contaminated Sediment Technical Advisory Committee (CSTAG).
- U.S. EPA Region 5/States Sediment Forum.

Science Needs

Environmental data need to be appropriately housed in data management systems. It is important that such data management systems be consistent and able to link across the regions and offices. Environmental information regarding contaminated sediment sites needs to be placed onto regional contaminated sediment web sites which are updated on a regular basis, and be linked across the regions so that information on sites in other regions is available to the viewer. It is also important that networks be formed so that information about contaminated sediment sites and issues can be exchanged and discussed. Workshops and other fora that are held periodically for a range of audiences are an important additional means of communicating and exchanging information, and increasing the science knowledge of stakeholders and others.

There is a need for more timely information exchange, improved access to environmental information and data, both internally across the Agency and with external stakeholders and other interested parties. One of the recommendations in the National Research Council Report (2001b) is that there be "early, active, and continuous involvement of all affected parties and communities as partners." One of the many keys to the success of such involvement is the availability of, and access to, environmental information and data about the site(s) of concern. In addition, stakeholders may also need some basic science knowledge (or someone to explain it) so as to be able to comprehend what the data and information means and be better able to contribute to the decision-making process in an informative manner.

3.9.1 Key Recommendations for Information Management and Exchange Activities

To meet these needs, the following recommendations are made.

H.1 Establish regional sediment data management systems which can link the regions and program offices with each other and with the National Sediment Inventory.

There is a need for more timely information exchange regarding contaminated sediment sites, and improved access to environmental information and data. This will allow for improved decision-making in addition to being able to learn from the experiences of others. The two key impediments or issues, in addition to the lack of sediment data management systems in general, are the lack of consistent formats among such systems, and a lack of accessibility between regional systems and the national program offices.

To address these issues, it is recommended that the regional information management programs take the lead for ensuring regional sediment data management systems are established, and to provide the technical support that may be needed. The regional program offices will need to work together to establish roles and responsibilities on how the data management systems will be set up and maintained. The Office of Environmental Information (OEI) would also have a key role in this activity. It is important to evaluate the existing data management systems such as U.S. EPA's STORage and RETrieval database (STORET) to see if any are able to meet the needs identified here. It is suggested that a workshop be held for the regions and program offices to share information on existing data management systems and how this recommendation might best be implemented.

H.2 Standardize the sediment site data collection/reporting format. Establish minimum protocols for QA/QC using the Agency's Quality System for Environmental Data and Technology.

Because data are collected both by various U.S. EPA programs and offices and by other agencies, collection and reporting formats and QA/QC protocols vary. This leads to difficulties in sharing information across programs/offices and between U.S. EPA and other agencies.

To address these issues, it is recommended that U.S. EPA's Environmental Information Office, with OW and OSWER, take the lead in developing standardized formats and identifying minimum QA/QC protocols under its Quality System for Environmental Data and Technology.[11] It is recommended that the regions, state environmental agencies, and other Federal agencies be involved, as appropriate. It is recommended that a workshop be held in the near future to address these issues, with the protocols being developed from the workshop.

H.3 Develop national and regional contaminated sediment sites web sites for sharing information.

To also meet the need for more timely information exchange regarding contaminated sediment sites, the CSSP Document recommends that a national sediment web site be established. It is recommended that the proposed sediment web site under consideration in OW be considered for use as a centralized web site to meet this need. OW is suggested to take the lead, with support from OEI, OSRTI, and other offices and regions as appropriate. It is recommended that web sites developed by the regions and programs link with the national sediment web site. GLNPO, OW, OSRTI, and some of the regions are developing or have developed contaminated sediment web sites containing information on sediment sites, and also provide links to guidance and other information regarding the contaminated sediment problem. Where they do not exist, and are found to be needed, it is recommended that regional remedial and water programs, working with their regional information management programs, jointly develop contaminated sediment sites web sites. It is recommended that these web sites be in place as soon as practicable.

H.4 Re-establish and expand the Office of Water-sponsored Sediment Network by including more regional representation.

The CSSP Document recommends that the Sediment Network be re-established under the co-lead of OW and OSRTI. Key representatives from appropriate national and regional program offices are

[11] EPA uses its Quality System to manage the quality of its environmental data collection, generation, and use. The primary goal of the EPA Quality System is to ensure that its environmental data are of sufficient quantity and quality to support the data's intended use. The EPA Quality System requires that each EPA Office, Region, and Research and Development Laboratory or Center develop and implement supporting Quality Systems. EPA's Quality System specifications may also apply to extramural agreement holders (*i.e.*, contractors, grantees, and other recipients of financial assistance from EPA).

presumptive participants. The suggested purpose of the Network would be to resolve issues and to share information (each representative would then share the information through their own organizations). It is also recommended that regular teleconferences be scheduled. It is also suggested that an OW/OSWER memorandum be prepared and sent to the program offices and regional offices announcing the Sediment Network and inviting their participation.

A sediment list server is also recommended as an additional means of sharing information and resolving issues for a larger audience. Responsibility for maintenance of such a list server should be jointly shared between OW and OSWER.

H.5 Promote communication and coordination of science and research among Federal agencies.

Many other Federal agencies and departments sponsor research on the same sediment research topics. The Workgroup recommends that coordination and communication of science and research among Federal agencies be promoted in order to avoid duplication of efforts, encourage partnering between researchers working on similar projects, and facilitate the timely sharing of interim and final results. Agencies that might participate include U.S. EPA, NOAA, U.S. Navy, U.S. Army Corps of Engineers, U.S. Geological Survey, and U.S. Fish and Wildlife Service.

H.6 Promote the exchange of scientific information via scientific fora (*i.e.*, workshops, journals, and meetings).

The Workgroup recommends that national and regional program offices encourage their managers and staff to share scientific information via workshops, conferences, publication in journals, and presentations. In addition, great benefit would be achieved by incorporating information of new technologies and approaches applicable to contaminated sediment management within existing regional training programs. It is recommended that other options for sharing scientific information be explored at the regional level.

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4. MEETING SCIENCE NEEDS

4.1 Introduction

There are many scientific uncertainties associated with assessing and managing contaminated sediments. Multiple offices and regions have overlapping science needs; some have individual, program-specific requirements. Realistically, it will take a long-term program to develop, implement, and verify the science. Planning across all U.S. EPA organizations, with recognition and coordination of important work being conducted by other organizations, such as Federal and State Agencies and academic institutions, is essential to advancing the science and managing risks from contaminated sediments in the most cost-effective ways.

4.2 Recommended Approaches to Implement Strategy

It is the Agency's intent that the Contaminated Sediments Science Priorities Document serve as a single, formal assessment of contaminated sediment science activities which can be used to foster collaboration and dialogue between EPA offices and regions. The CSSP Document may be used as a framework for future science inventories or as the starting point for developing a more specific science and implementation plan. It is recommended that each organization consult the key recommendations when planning contaminated sediment science activities.

The Workgroup recommends that a broad Agency oversight committee such as the Contaminated Sediment Management Committee be used to review the key recommendation of the CSSP Document in the future to ensure that science presented herein reflects the Agency’s evolving science needs. If such a group is used or formed, the bullets below identify some tasks that may be useful for review and collaboration.

- **Reviewing science activities:**

  It is recommended that the lead U.S. EPA offices and regions present to the oversight committee the current science activities they are conducting pertaining to research topics and key recommendations identified in the CSSP Document, as well as identifying those additional science activities, based on the key recommendations in the CSSP Document, that they would implement should sufficient resources become available. This information sharing will serve to initiate closer coordination of science activities related to contaminated sediments across U.S. EPA.

- **Implementing science activities:**

  It is recommended that lead U.S. EPA offices and regions who agree to carry out the recommended science activities ensure that these activities are considered within their annual planning, budgeting, and accountability process, and are implemented when resources are committed. It is recommended that for each recommendation, a brief one-page description be developed (or updated) which includes the following information: title, key partners, actions underway, actions planned over next two years, products expected by (date), and primary contact(s). Please refer to Appendix B for an example. The one-page recommendation descriptions and a report out on the status of the implementation of the science activities would be provided at the annual meetings. The oversight committee would then determine whether progress toward the goals is being made and, if necessary, recommend adjustments to science activities to meet the key recommendations.

- **Identifying areas where science partnerships are needed:**

It is recommended that the oversight committee advise U.S. EPA offices and regions where scientific collaboration within the Agency, as well as with other Federal agencies, would be beneficial. These partnerships will hopefully speed the accomplishment of key recommendations. It is important that coordination also occur with the Science Policy Council on the use of science priorities for science planning; with the Council on Regulatory Environmental Modeling on the characteristics and appropriate applications for existing models; and with the Forum on Environmental Measurements on the development and validation of new analytical methods.

- **Coordinating with U.S. EPA offices and regions:**

It is recommended that the oversight committee contact the lead U.S. EPA office or region identified as a suggested critical partner from Table 4-1 for each key recommendation to understand how they intend to implement science activities for the recommendations.

- **Identifying unfunded activities:**

It is important to identify resource needs for unfunded or underfunded tasks. It is recommended that the oversight committee discuss unfunded science areas and communicate these to the appropriate science planning staff within U.S. EPA offices and regions in order to identify the appropriate resources to address them.

- **Updating the Contaminated Sediments Science Priorities Document:**

Periodic reviews of the state of the science on contaminated sediments, a gaps analysis, and updating of the CSSP Document are recommended as needed.

Table 4-1 lists the key recommendations by topic area, the time frame for implementation, and suggested critical partners. Although recommendations are roughly divided into two time frames, immediate and longer term, some of the recommendations could be viewed as continuing needs.

Table 4-1. Summary of Key Recommendations, Time Frame for Implementation, and Suggested Critical Partners

Recommendations
A. Sediment Site Characterization *Immediate Time Frame* A.1 Conduct a workshop to develop a consistent approach to collecting sediment physical property data for use in evaluating sediment stability. (OSRTI, ORD, U.S. EPA Regions) *Longer Time Frame* A.2 Develop more sensitive, low-cost laboratory methods for detecting sediment contaminants, and real-time or near real-time chemical sensors for use in the field. (ORD, OSRTI, GLNPO) A.3 Develop U.S. EPA-approved methods with lower detection limits for analysis of bioaccumulative contaminants of concern in fish tissue. (ORD, OSRTI, OW, U.S. EPA Regions) A.4 Develop methods for analyzing emerging endocrine disruptors, including alkylphenol ethoxylates (APEs) and their metabolites. (ORD)
B. Exposure Assessment *Immediate Time Frame* B.1 Develop a tiered framework for assessing food web exposures. (ORD, OW, OSRTI, U.S. EPA Regions) B.2 Develop guidance and identify pilots for improving coordination between TMDL and remedial programs in waterways with contaminated sediments. (OW, OSWER, U.S. EPA Regions) B.3 Develop and advise on the use of a suite of most valid contaminant fate and transport models that allow prediction of exposures in the future. (ORD, OSRTI, OW, U.S. EPA Regions) B.4 Develop a consistent approach to applying sediment stability data in transport modeling. (ORD, OSRTI, OW, U.S. EPA Regions)

C. Human Health Toxicity and Risk Characterization

Immediate Time Frame

C.1 Develop guidance for characterizing human health risks on a PCB congener basis. (ORD, OSRTI, OW, U.S. EPA Regions)

C.2 Develop sediment guidelines for bioaccumulative contaminants that are protective of human health via the fish ingestion pathway. (ORD, OSRTI, OW, U.S. EPA Regions)

Longer Time Frame

C.3 Refine methods for estimating dermal exposures and risk. (ORD, OSRTI, U.S. EPA Regions)

C.4 Evaluate the toxicity and reproductive effects of newly recognized contaminants, such as alkylphenol ethoxylates (APEs) and other endocrine disruptors and their metabolites on human health. (ORD, OPPT)

D. Ecological Effects and Risk Assessment

Immediate Time Frame

D.1 Develop sediment guidelines to protect wildlife from food chain effects. (ORD, OSRTI, OW, U.S. EPA Regions)

D.3 Develop guidance on how to interpret ecological sediment toxicity studies (lab or *in situ* caged studies) and how to interpret the significance of the results in relation to site populations and communities. (OW, ORD, OSRTI, U.S. EPA Regions)

D.4 Acquire data and develop criteria to use in balancing the long-term benefits from remedial dredging vs. the shorter term adverse effects on ecological receptors and their habitats. (ORD, OSRTI, U.S. EPA Regions)

D.6 Continue developing and refining both chronic and sub-chronic sediment toxicity testing methods. (ORD, OW, U.S. EPA Regions)

D.7 Develop whole sediment toxicity identification evaluation procedures for a wide range of chemicals. (ORD, OW)

Longer Time Frame

D.2 Develop additional tools for characterizing ecological risks. (ORD, U.S. EPA Regions, OPPTS, OW)

D.5 Conduct field and laboratory studies to further validate and improve chemical-specific sediment quality guidelines. (OW, ORD)

E. Sediment Remediation

Immediate Time Frame

E.1 Collect the necessary data and develop guidance for determining the conditions under which natural recovery can be considered a suitable remedial option. Such guidance would include: measurement protocols to assess the relative contribution of the various mechanisms for chemical releases from bed sediments (*e.g.*, advection, bioturbation, diffusion, and resuspension), including mass transport of contaminants by large storm events; approaches to assess the vertical extent of the bioavailable zone in different environmental settings; methodologies to quantify the uncertainties associated with natural recovery; and development of accepted measuring protocols to determine *in situ* chemical fluxes from sediments. (ORD, OSRTI, U.S. EPA Regions, GLNPO)

E.2 Develop performance evaluations of various cap designs and cap placement methods and conduct cap placement and post-cap monitoring to document performance. Continue to monitor ongoing capping projects to monitor performance (*e.g.*, Boston Harbor, Eagle Harbor, Grasse River). (ORD, U.S. EPA Regions, GLNPO)

E.4 Using the data provided in recommendation E.1, develop a white paper evaluating the short-term and long-term impacts from dredging relative to natural processes and human activities (*e.g.*, resuspension from storm events, boat scour, wave action, and anchor drag). (OSRTI, U.S. EPA Regions)

Longer Time Frame

E.3 Encourage and promote the development and demonstration of *in-situ* technologies. (ORD, GLNPO)

E.5 Support the demonstration of cost-effective *ex-situ* treatment technologies and identification of potential beneficial uses of treatment products. (ORD, GLNPO, U.S. EPA Regions)

F. Baseline, Remediation, and Post-remediation Monitoring

Immediate Time Frame

F.1 Develop monitoring guidance fact sheets for baseline, remediation, and post-remediation monitoring, and monitoring during remedy implementation. (ORD, OSRTI, U.S. EPA Regions, OW)

F.2 Conduct training and hold workshops for project managers regarding monitoring of contaminated sediment sites. (OSRTI, ORD, U.S. EPA Regions)

G. Risk Communication and Community Involvement

Immediate Time Frame

G.1 Establish a research program on risk communication and community involvement focusing on developing better methods, models, and tools. (ORD, OSRTI, U.S. EPA Regions)

H. Information Management and Exchange Activities

Immediate Time Frame

H.1 Establish regional sediment data management systems which can link the regions and program offices with each other and with the National Sediment Inventory. (U.S. EPA Regions, OW, OSWER, GLNPO)

H.3 Develop national and regional contaminated sediment sites web sites for sharing information. (U.S. EPA Regions, OW, OSWER, GLNPO)

H.4 Re-establish and expand the Office of Water-sponsored Sediment Network by including more regional representation. (OSRTI, OW, U.S. EPA Regions)

H.5 Promote communication and coordination of science and research among Federal agencies. (ORD, OSWER, OW, U.S. EPA Regions, NOAA, U.S. Navy, U.S. ACE, USGS, U.S. FWS)

H.6 Promote the exchange of scientific information via scientific fora (*i.e.*, workshops, journals, and meetings). (CSMC, OW, OSWER, U.S. EPA Regions, GLNPO)

Longer Time Frame

H.2 Standardize the sediment site data collection/reporting format. Establish minimum protocols for quality assurance/quality control (QA/QC) using the Agency's Quality System for Environmental Data and Technology. (OEI, OW OSWER, U.S. EPA Regions)

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APPENDIX A

CONTAMINATED SEDIMENTS
SCIENCE ACTIVITIES DATABASE

This Appendix provides a summary of recent and current projects (as of June 2000) on various scientific topics of concern in the assessment and management of contaminated sediments. The database is divided into major science areas. Program implementation projects include remediation, monitoring, pilot studies, and initiatives. Human health and ecological effects and assessment projects include productive cross-Agency efforts on equilibrium partitioning of contaminants, ecotoxicological method development, risk assessments, and characterization studies. Exposure and modeling tasks include work on topics such as Total Maximum Daily Loads (TMDLs), bioavailability, and modeling. Remediation and risk management projects include guidance development, technology development and evaluation, site specific efforts, field demonstration of technologies, and information management systems.

More recently, the Agency has prepared an online Science Inventory, a searchable, Agency-wide catalog of more than 4,000 science activities such as research, technical assistance and assessments, along with more than 750 peer-reviewed products (http://cfpub.epa.gov/si/). The database contains more than 19,000 records in the archives including project descriptions, products produced, types of peer review, links to related work and contacts for additional information. Users can conduct keyword searches or search within nine cross-cutting science topics, one of which is ‘Contaminated Sediments’.

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Program Implementation *Activities related to implementing regulatory and remediation programs. These activities are applications of existing methods and technologies*.	OW/OWOW/OCPD	**Dredged Material Bioaccumulation Evaluation Guidance. The Army Corps of Engineers and U.S. EPA are working jointly to develop guidance for evaluating dredged material bioaccumulation potential.**	Dredged Material Programmatic Guidance *GPRA 2.2*	David Redford 202-566-1288
	OW/OWOW/OCPD	**Ocean Dredged Material Disposal Monitoring Program.** Program calls for the continued monitoring of the nation's 85 dredged material disposal sites (Regional responsibility).	Ongoing monitoring *GPRA 2.2*	Sharon Lin 202-260-5129
	OW/OST/SASD	**Implementation Framework for the Use of Equilibrium Partitioning Sediment Guidelines.** Document provides guidance for using ESGs appropriately and describes U.S. EPA's recommendations in using ESGs in conjunction with other assessment tools (bioassays and benthic community assessments).	Draft document *GPRA 2.2*	Richard Healy 202-260-7812
	OW/OWOW/OCPD	**Coastal monitoring by U.S. EPA OSV Peter W. Anderson.** East and Gulf coastal monitoring of dredged material disposal sites, ocean discharges and sensitive areas focusing on water quality, sediment contamination and impacts on living resources such as coral reef ecosystems.	Ongoing monitoring *GPRA 2.2*	Craig Vogt 202-260-5455

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Program Implementation (continued)	Region 5/Water/ GLNPO	**Remedial Action Plan (RAP) Program.** RAP Liaisons develop/implement Remedial Action Plans (RAPs) for all Areas of Concern (AOCs) in the Great Lakes basin. RAPs address impairments to any one of 14 beneficial uses (e.g., restrictions on fish and wildlife consumption, dredging activities).	RAP Liaisons for each AOC Ongoing *GPRA 2.2*	Bonnie Eleder 312-886-4885 Judy Beck 312-353-3849 Francine Norling 312-886-0271 Liz LaPlante 312-886-0399
	Region 5: TSCA	**TSCA pilot.** To provide WDNR the authority to approve disposal of TSCA regulated PCB-contaminated sediment from in-state clean up projects at state-permitted solid waste landfills.	Ongoing	John Connell 312-886-6832
	Region 5	**Shorelands Initiative.** Proposed FY02 Cross-Program, Cross-Media Initiative: a cross-program multi-media approach to address the impacts of contaminated sediments in rivers, waterways, lakes, streams and harbors by providing economic incentives and providing opportunities for liability and regulatory relief.	Ongoing	Bonnie Eleder 312-886-4885
	Region 6	**Alcoa/Lavaca Bay Remediation.** This site covers approximately 60 square miles, and has sediments contaminated with mercury. This site is currently in the RI/FS phase.	Ongoing *GPRA 5.1*	Gary Baumgarten 214-665-6749
	Region 9	Regional Data Evaluation/Validation Approaches for Superfund Data Guidance (R9QA/006.1).		Dawn Richmond
	Region 10	Alaska Cruise Ship Initiative.		Michael Watson
	Region 10	Tribal Leaders Environmental Summit.		Scott Sufficool

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Program Implementation (continued)	NHEERL/AED NHEERL/MED	**Development of toxicity identification evaluation methods for porewaters and whole sediments**. Methods will help further develop toxicity identification evaluation methods for porewaters and whole sediments in fresh and salt water.	*U.S. EPA report on whole sediment TIE methodology, expected FY 02, APM A77, FY01* *GPRA 2.2*	Kay Ho 401-782-3196 Dave Mount 218-529-5169
	OW/OST/SASD	**Field Validation Studies of long-term Sediment Toxicity Tests with *Hyalella azteca* and *Chironomus tentans*.** This analysis is designed to evaluate the response of *H. azteca* and *C. tentans* in laboratory studies with the natural population of benthic organisms.	*Ongoing. Project is scheduled to be completed by the end of FY 01. GPRA #2* *GPRA 2.2*	Scott Ireland 202-260-6091
	OW/OST/SASD	**Equilibrium Partitioning Sediment Guideline (ESG) evaluation**. This project will evaluate the *Leptocheirus plumulosus* chronic test responses to ESGs.	Work is ongoing. Project is scheduled to be completed by the end of FY 01. *GPRA 2.2*	Scott Ireland 202-260-6091
	OW/HECD ORD/NHEERL	**Completion of Equilibrium Partitioning Sediment Guideline Documents for Nonionic Organics: Technical Basis, Site-Specific, Dieldrin, Endrin, and Nonionics Compendium.** Provide U.S. EPA's recommended concentration of nonionic organic chemicals that can be present in sediments with out causing acute or chronic toxicity to benthic organisms, the technical basis for the guidelines, and a site-specific methodology.	Draft documents completed *GPRA 2.2*	Heidi Bell: 202-260-5464 Mary Reiley: 202-260-9456 Dave Mount: 218-529-5169

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Program Implementation (continued)	OW/HECD ORD/NHEERL	**Completion of Equilibrium Partitioning Sediment Guideline Document for Metals Mixtures.** Provides U.S. EPA's recommended concentration of metal mixtures (Cu, Cd, Pb, Ni, Ag, Zn) that can be present in sediments without causing acute or chronic toxicity to benthic organisms.	Draft document completed *GPRA 2.2*	Heidi Bell: 202-260-5464 Mary Reiley: 202-260-9456 Walter Berry: 401-782-3101
	OW/HECD ORD/NHEERL	**Draft Equilibrium Partitioning Sediment Guidelines Document for PAH Mixtures.** Provides U.S. EPA's recommended concentration of PAH mixtures that can be present in sediments without causing acute or chronic toxicity to benthic organisms.	Draft document has been prepared for peer review. *GPRA 2.2*	Heidi Bell: 202-260-5464 Mary Reiley: 202-260-9456 Dave Mount: 218-529-5169 Bob Ozretich: 541-867-4036
	OW/HECD ORD/NHEERL	**Integrated Water Quality Criteria for Ambient Waters.** Establish criteria that evaluate multiple routes of exposure and types of organisms.	Criteria documents and models. No anticipated date of delivery at this time. Project is in scoping stage. *GPRA 2.2*	Mary Reiley: 202-260-9456 Walter Berry: 401-782-3101 Bob Spehar: 218-529-5123 Dave Mount: 218-529-5169
	NHEERL/MED	**Development of methods for testing short-term and chronic toxicity of freshwater sediments.** Methods have been developed and tested, and a round-robin was conducted.	Final document published *GPRA 2.2*	David Mount 218-529-5169 Theresa Norberg-King 218-529-5163 Scott Ireland 202-260-6091

Area	Organization	Description	Product/Estimated Date ***GPRA APGs/APMs***	Contact
Program Implementation (continued)	NHEERL/AED	**Development of alternate measures of benthic infaunal condition.** The usefulness of new approaches for assessing benthic condition is being examined, including CatScan and methods for examining the effects of porewater ammonia.	Comparative estuarine method to discern and quantify the ecological effects of cumulative, multiple anthropogenic point sources on benthic communities, FY00. Sensitivity of NH3 porewater and tube/tunnel structures in soft bottom sediments and macrofaunal community composition to detect changes in season, habitat and estuarine system, FY01. *GPRA 2.2*	Ken Perez 401-782-3052 Kay Ho 401-782-3196

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Effects Activities related to determining the effects of sediment contaminants on human and ecological receptors. These activities advance the state-of-the-art by development and verification of methods, models, protocols, and technologies.	NHEERL/MED	**Horizontal and vertical heavy metal contamination in Lake Michigan**. Lake-wide sampling and analysis of mercury in surface sediments and sediment cores is being done in coordination with the Lake Michigan Mass Balance Project and the Great Lakes National Program Office. Models are being developed to assess the effects of mercury to fish.	Data report of mercury in Lake Michigan and mathematical modeling relating sources to effects on fish, FY03. *GPRA 2.2*	Ron Rossman 734-692-7612
	NHEERL/MED	**Modeling of bioaccumulation of organic chemicals.** Models are being developed to predict bioaccumulation of PBTs, such as dioxins, PCBs and PAHs, in fish and wildlife, in ecosystems with varying bioavailability of contaminants from sediment and water as well as differences in food web structures.	Improved models and tools, including integrated sediment/water quality criteria, for assessing risks associated with contaminated sediments on the basis of predicted residues in fish and wildlife, FY05. *GPRA 2.2*	Lawrence Burkhard 218-529-5164 Philip Cook 218-529-5202
	NHEERL/MED	**Importance of dietary metals uptake in effects of metals-contaminated sediments.** Experiments are underway to assess the effects of dietary metals originating from contaminated sediment on fish.	Published manuscripts, FY02. *GPRA 2.2*	David Mount 218-529-5169
	NHEERL/AED	**Field demographic study of amphipods.** This project is exploring the usefulness of a field indicator of benthic condition using amphipod field demographics, and looks at geographic differences in sensitivity to contaminants.	Published manuscripts, FY00-04. *GPRA 2.2*	Anne Kuhn 401-782-3199

Area	**Organization**	**Description**	**Product/Estimated Date** ***GPRA APGs/APMs***	**Contact**
Human Health and Ecological Effects (continued)	NHEERL/AED	**Examine correlations between measured chemistry, acute toxicity, and benthic community data in field databases**. The usefulness of measured chemistry data to predict biological effects from large field databases (e.g., EMAP) will be examined using three approaches (equilibrium partitioning-derived sediment guidelines to predict acute toxicity to amphipods from measured chemistry data; measured chemistry data will be compared to benthic community data; a population model will be used to predict effects on the benthic community using acute toxicity data).	Manuscripts, FY02-04. *GPRA 2.2*	Anne Kuhn 401-782-3199 Walter Berry 401-782-3101 Marguarite Pelletier 401-782-3131
	NHEERL/GED	**Toxicity of contaminated sediments to aquatic plants and periphyton** . Methods are being developed and applied for toxicity assessment using estuarine aquatic plants (primarily SAV) and periphyton.	Report on the use of periphyton as indicators of metal contaminants in estuaries, APM 551, FY00. Predictive laboratory phytotoxicity test methods on contaminated sediments using seagrasses, FY01. Report on effects of xenobiotics and nutrients on aquatic vegetation, FY03. GPRA 2.2	Michael Lewis 850-934-9382
	NCER/ STAR grants and HSRCs	Environmentally-Mediated Endocrine Disruption in Estuarine Crustaceans: A 3-Taxon Multi-Generational Study of Sediment-Associated EDC Effects from the Genetic to Population Levels		G. Thomas Chandler, Ph.D.

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Effects (continued)	NCER/ STAR grants and HSRCs	Site-specific Validation of a Chronic Toxicity Test with the Amphipod *Hyalella azteca* : An Integrated Study of Heavy Metal Contaminated Sediments in Peak Creek, Virginia.		John Cairns, Jr., B. R. Niederlehner, Reese Voshell, and Eric P. Smith
	NCER/ STAR grants and HSRCs	Phylogenetic Analysis of Microbial Communities in Contaminated Nearshore Marine Sediments.		Russell P. Herwig
	NCER/ STAR grants and HSRCs	Foraminifera as Ecosystem Indicators: Phase 1. A Marine Benthic Perturbation Index; Phase 2. Bioassay Protocols.		Pamela Hallock Muller
	NCER/ STAR grants and HSRCs	Sediment Contaminant Effects on Genetic Diversity New Approach using DNA Analyses of Meiobenthos.		Bruce C. Coull, G. Thomas Chandler and Joseph M. Quattro
	NCER/ STAR grants and HSRCs	Digestive Solubilization of Sediment-Sorbed Contaminants A Comparison of In Vitro and In Vivo Processes.		Donald P. Weston, Larry M. Mayer, and Deborah L. Penry
	NCER/ STAR grants and HSRCs	Transport of Polychlorinated Biphenyls from Adult Oyster *Crassostrea virginica* to Embryos and Larvae and Potential for Reproductive and Developmental Impairments.		Fu-Lin E. Chu, Aswani K. Volety, and Robert C. Hale
	NCER/ STAR grants and HSRCs	Uptake of Sediment-Associated Contaminants by the Deposit-Feeding Amphipod *Leptocheirus Plumulosus* (Shoemaker): Effects of Natural Sediment Qualities.		Christian Schlekat

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Effects (continued)	NCER/ STAR grants and HSRCs	Biochemical Indicator Patterns and their Linkages to Adverse Effects on Benthic Invertebrate Patterns.		Teresa Fan, Richard Higashi
	NERL/EERD	**Development of Indicators as Measures of Ecosystem Sustainability.** Indicator methods can be used to measure PAH exposure, to determine exposure exceeding natural background, and to evaluate changes in exposure to petroleum and combustion by-product (PAH) waste in dredged streams.	Draft report on national background and exposure criteria for indicators of exposure to PAHs - FY02. *GPRA 2.2*	Susan Cormier 513-569-7995
	OAQPS OW OAR Regions	**Total Maximum Daily Load (TMDL) Pilot Projects in Florida and Wisconsin.** The pilot projects are evaluating techniques for (1) determining the amount of mercury reductions needed to meet water quality standards; (2) determining the relative contributions of mercury from various sources; (3) the geographic extent of sources contributing mercury; and (4) analyzing Federal and State programs for reducing mercury emissions.	Both projects should be completed in early 2001. *GPRA 2.2*	
	OW/HECD ORD/NHEERL	**Improvements in sediment bioavailability theory.** Investigate issues such as: non-equilibrium conditions, aerobic sediments, seasonal fluxes, sediment ingestion.	Research reports that can be incorporated into existing ESGs to improve accuracy and precision. No date. *GPRA 2.2*	Heidi Bell: 202-260-5464 Mary Reiley: 202-260-9456 Walter Berry: 401-782-3101 Dave Mount: 218-529-5169

Area	Organization	Description	Product/Estimated Date ***GPRA APGs/APMs***	Contact
Human Health and Ecological Effects (continued)	NHEERL/MED NHEERL/AED	**Bioavailability of polycyclic aromatic hydrocarbons (PAHs) in sediments.** A series of studies are underway to quantify the acute and sublethal toxic effects of PAHs to benthic freshwater and marine species. Specific studies include (1) evaluation of the effects of ultraviolet radiation on the toxicity of PAHs, (2) determination of the contribution of highly insoluble PAHs to toxicity, and (3) assessment of the effects of pyrogenic PAH geochemistry on PAH bioavailability	*Report on predicting metal toxicity in sediments, APM152, FY99* Peer-reviewed publications and technical guidance to support derivation of Agency sediment guidelines. *GPRA 2.2*	Dave Mount 218-529-5169 (freshwater) Rob Burgess 401-782-3106 (marine)
	NHEERL/MED NHEERL/AED	**Bioavailability of metals in sediments.** A series of studies are underway to quantify the acute and sublethal toxic effects of metals to benthic freshwater and marine species. Specific studies include (1) analysis of the toxicity of chromium when associated with anoxic sediments, (2) evaluation of the effects of resuspension on the fate and bioavailability of anoxic metal-contaminated sediments, and (3) performance assessment of *in situ* interstitial water sampling methods.	*Report on predictively metal toxicity in sediments, APM 152, FY99.* Peer-reviewed publications and technical guidance to support derivation of Agency sediment guidelines. *GPRA 2.2*	Dave Mount 218-529-5169 (freshwater) Walter Berry 401-782-3101 Rob Burgess 401-782-3106 (marine)

Area	Organization	Description	Product/Estimated Date ***GPRA APGs/APMs***	Contact
Human Health and Ecological Effects (continued)	NERL/ERD	**Develop Computer Models for Science Integration and Parameterization of Multimedia Models for Watershed Scale Analysis and General Multimedia Exposure Assessments.** Elucidate and model the underlying processes (physical, chemical, enzymatic, biological) that describe the transport and fate of organic pollutants and other stressors in environmental systems.	Configure SPARC (SPARC Performs Automated Reasoning in Chemistry) as a prototype processes constants generator of pollutant fate for organic pollutants; and incorporate planned products on mathematical techniques to quantify coupled chemical speciation processes, and kinetic models describing reductive transformations processes (APM, 9/01). Configure SPARC as a prototype processes constants generator of pollutant fate for organic pollutants; and implement completed speciation models for ionization and tautomerization, and prototype models for hydrate formation, solution phase hydrolysis, and abiotic reduction in sediment suspensions (APM, 9/02). *GPRA 2.2*	Samuel W. Karickhoff 706-355-8321

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Effects (continued)	NERL	**Characterize the Sorption of Organic Pollutants in Soils and Sediments for SPARC.** Measure the magnitude and kinetics of organic contaminant sorption and transport in soils and sediments; apply and compare the utility of bicontinuum and distributed parameter models for describing contaminant release from soils and sediments, and use the measured and estimated sorption/desorption kinetic descriptors developed for assessing long-term contaminant release from soils and sediments.	Report on solute release kinetics from contaminated soils and sediments (APM, 9/02). *GPRA 2.2*	Dermont Bouchard 706-355-8333
	NERL/EERD	**Develop Stressor Signatures of Habitat Degradation Among Metrics from Fish, Benthic Macroinvertebrate, and Periphyton Assemblages.** Develop and evaluate biological indicators and prepare OW-ORD Stressor Identification Evaluation Guidelines that help to identify stressors and sources, including sediments.	Method for developing diagnostic signatures; compendium of Regional case-studies that describe how causes of biological impairment were determined, FY01-FY02. *Compendium of case studies illustrating the application of SIE guidelines, A75, FY01.* *GPRA 2.2*	Susan Cormier 513-569-7995
	NERL/EERD	**Real-Time Aquatic Biomonitoring Using Bivalves in Two Watersheds.** The water quality of two watersheds was monitored (Ohio and Texas). Both biological and physical/chemical metrics were recorded. The gape behavior of the bivalve *Corbicula fluminea* was used as a monitor of overall water quality.	*GPRA 2.2*	Jim Lazorchak 513-569-7076

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Effects (continued)	NERL/ERD	**Hazardous Waste Identification Rule (HWIR).** This multimedia, multi-receptor, multi-stressor, open architectural modeling system is designed for establishing safe exit levels for some waste streams that may now require disposal in Subtitle C facilities. Specific to sediments in the HWIR application, ExamsIO presently simulates suspended solids as a conservative substance. Plans are to add simple routines to ExamsIO to handle net deposition, bed load in streams, and burial in ponds/lakes/wetlands/bays for more realistic estimates of TSS which would be passed to Exams.	HWIR Human Health and Ecosystems Site (Generic) Exposure - Risk Assessment Screening Model Peer Reviewed and Applied to HWIR Listed Chemical Exit Levels - APM 187, 1999. Update the HWIR99 Modeling Methodology for Delisting Hazardous Wastes, in response to public comments on 1999 Federal Register Notice, and incorporating enhanced uncertainty analysis techniques into the revised methodology - APM BB8, FY01. Critical Review of Documented Aquatic and Terrestrial Plant Phyto Processes and Data Complete with Formulation of Kinetic Algorithms for Organic and Inorganic Pollutants of Concern - FY01. GPRA 5.2	Dave Brown 706-355-8300 Gerry Laniak 706-355-8316 Steve McCutcheon 706-355-8235

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Effects (continued)	NERL/ESD	**SITE Demonstration of Sediment Sampling Technologies.** Tested a split core sampler for submerged sediments and a Russian peat borer.	Demonstration Plan for Sediment Sampling - 1999 Verification Reports for Sediment Sampling - 2000. *GPRA 5.1*	Steve Billets 702-798-2232 Brian Schumacher 702-798-2242
	NERL/ESD NERL/HEASD Region I	**Mercury Cycling in the New England Estuaries: A Collaborative Study in Great Bay, NH** (RARE Project). Research will examine cycling, bioavailability, and potential enhanced methylation of mercury in salt marshes in the Great Bay Estuary, NH. Mercury inputs from air and precipitation will be collected to calculate annual and seasonal deposition rates of Hg.	Speciation of Hg Uptake by *Spartina Alterniflora* - 2000. Methylation and Hg Production in a *Spartina Alterniflora* Salt Marsh - 2000. Influx of Hg to the Great Bay Estuary via Fog - 2000. Volatile Hg Fluctuation in the Great Bay Estuary - 2000. Mercury Cycling in the Great Bay Estuary ; U.S. EPA Report – 2001. *GPRA 2.2* *GPRA 2.3*	Brian Schumacher 702-798-2242 Jeanette van Emon 702-798-2154

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Effects (continued)	NERL/ESD	**Environmental Analytical Chemistry.** This work is to provide state-of-the-science sampling, analysis, separation, and detection methods to allow rapid, accurate field and laboratory analyses of various media (e.g., surface or ground water, fish, sediments, soil).	Vacuum Distillation - hardware evaluation, operations manual, method development and testing, tech transfer to Regions - ongoing. Mercury in Fish from National Parks, PRIMENet data base - 2001. Reagent-free Determination of Mercury in Whole-Fish Homogenates Using a Combustion Furnace-Atomic Absorption Analyzer - 2001. Anthropogenic Chemical Loading in Fish from National Park Index Sites, journal article and data base - 2001. Fractionation of Toxic PCB Isomers Using Porous Graphitic Carbon HPLC and Determination by GC/HRMS - 2001.	Christian Daughton 702-798-2207

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Effects (continued)	NERL/HEASD	**Biosensors.** Addressing real-time and in situ monitoring devices which can be used cost-effectively at Superfund sites and RCRA facilities, as well as for ground-water monitoring. Biosensors are being evaluated for detection of contaminants such as phenols and pesticides.	Biosensors for Field Analytical Monitoring, Field Anal. Chem. Technol. 2, 317-331 - 1999. Determination of Phenols in Environmentally Relevant Matrices Using a Liquid Chromatographic System with an Enzyme-Based Biosensor. Field Anal. Chem. Technol. 3, 161-169 - 1999. Organophosphorus Hydrolase-Based Assay for Organophosphate Pesticides. Biotechnol Progress 15, 517-521 - 1999. Biosensors for Environmental Monitoring: An Update. Environ. Sci. Technol. Dec. 1, 500-506, 1999. Field Method/Biosensor for Detection of Phenols in Soil Leachate from Contaminated Superfund Sites - 2001. Microchip-Based CE System with Biosensor Detector for Measurement of Phenols - 2002.	Kim Rogers 702-798-2299 Jerry Blancato 702-798-2456

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Effects (continued)	NERL/HEASD	**Immunochemistry.** Methods and applications are being developed for analytes such as PCBs, pesticides and heavy metals that are found at Superfund and RCRA sites.	Immunoassay Test Kits in Environmental Monitoring - to be published in Current Issues in Regulatory Chemistry, Publisher: Assoc. of Official Analytical Chemists (AOAC) - 1999. Comparison of Quantitative PCB ELISA with Gas Chromatography Determinative Versus Whole Method Effects - 2000. Monoclonal Antibodies for the Toxic Co-Planar PCBs and their Application to ELISA - 2001. PCB Detection Using a Doped Sol-Gel Modified Electrochemical Immunosensor - 2001. Antibody Coated Sampling/Introduction Probe for Ion Trap Determination of Coplanar PCBs - APM 561, FY01.	Jeanette van Emon 702-798-2154 Jerry Blancato 702-798-2456

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Effects (continued)	NERL-EERD Region 2 Region 6	**Miniaturized sediment procedures for assessing toxicity using marine and freshwater amphipods and embryo/larval fish.** Existing U.S. EPA methods were modified and two alternative methods developed. Freshwater methods include a 7-day amphipod, *Hyalella azteca* method and 7-day fathead minnow *(Pimephales promelas)* embryo/larval hatching method and two marine methods, a 10-day amphipod, *Ampelisca abdita*, and a 7-day sheepshead minnow (*Cyprinodon variegatus)* embryo/larval method.	*GPRA 2.2*	Jim Lazorchak 513-569-7076 Jim Ferretti 732 321 6728 Terry Hollister 281 983 2163
	NERL-EERD	**A sediment toxicity method using *Lemna minor* (duckweed).** Developed a *Lemna minor* sediment toxicity test method to assess sediment contaminants which may affect plants. Sediments were also tested using a miniaturized freshwater amphipod method and a fathead minnow embryo/larval (FHM) survival test. A sediment reference toxicant method has been developed for KCl and Atrazine.	*GPRA 2.2*	Jim Lazorchak 513-569-7076
	NCEA	Dermal Exposure Research Program.		Michael Dellarco
	NCEA	Development of a wildlife contaminants exposure model (WCEM) as a tool for completing wildlife risk assessments.		Susan Norton
	Region 1	Charles River Fish Contaminant Survey.		Peter Nolan
	Region 1	Model Calibration Report for the Housatonic River.		Susan Svirsky
	Region 1	Model Validation Report for the Housatonic River.		Susan Svirsky
	Region 1	Model Frame Work Report for the Housatonic River.		Susan Svirsky

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Effects (continued)	Region 1	Monitoring the Success of Sediment Remediation at a Site Contaminated with Chlorinated Pesticides, Polynuclear Aromatic Hydrocarbons and Arsenic.		Cornell Rosiu
	Region 4	Everglades Pilot Study on Linking Air and Water Models.		John Ackerman
	Region 9	Analysis of San Francisco Bay Fish for Dioxin.		Joel Pedersen
	Region 9	Analysis of San Francisco Bay Sediments for Dioxin.		Joel Pedersen
	Region 9	Evaluation of Dioxin-Like Emissions from Residential Wood Combustion.		Barbara Gross
	Region 10	Arsenic Determination in Saline Waters by Hydride Generation – Inductively Coupled Plasma Mass Spectrometry.		Katie Adama
	Region 10	Compilation of report and data supporting the U.S. EPA study, “Asian and Pacific Islander Seafood Consumption Study in King County, Washington”.		Roseanne Lorenzana
	Region 10	Database of chemical analytical results for fish, shellfish, and plant tissues collected during June-July 1997 in areas of Cook Inlet.		Roseanne Lorenzana
	Region 10	Development of a low-level analytical method for co-planar PCB congeners in soil/sediment matrices using GC/ECD.		Bob Rieck
	Region 10	Native American Arsenic Exposure Study in Washington State.		Rebecca Calderon

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Effects (continued)	NCER/ STAR grants and HSRCs	Developing Effective Ecological Indicators for Watershed Analysis.		DT. Duncan Patten, Dr. Robert Crabtree, Dr. Wayne Minshall, Dr. Rick Lawrence
	NCER/ STAR grants and HSRCs	The Particle Size Distribution of Toxicity in Metal-Contaminated Sediments.		James Ranville, Donald Macalady, Phillipe Ross1, William Clements
	NCER/ STAR grants and HSRCs	A Modeling and Experimental Investigation of Metal Release from Contaminated Sediments The Effects of Metal Sulfide Oxidation and Resuspension.		G. Thomas Chandler Thimothy J. Shaw
	NCER/ STAR grants and HSRCs	Processes Influencing the Mobility of Arsenic and Chromium in Reduced Soils and Sediments.		Scott Fendorf
	NCER/ STAR grants and HSRCs	Trace Metal Dynamics in Reducing Aquatic Sediments Determination of Adsorption and Coprecipitation on Undisturbed Sediment Core Sections Using a Plug-Through Reactor.		Philippe Van Cappell
	NCER/ STAR grants and HSRCs	Formation and Propagation of Large-scale Sediment Waves in Periodically Disturbed Mountain Watersheds.		Gary Parker

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Effects (continued)	NCER/ STAR grants and HSRCs	Trophic Transfer of Atmospheric and Sedimentary Contaminants Into the Great Lakes Fisheries Controls on the Ecosystem Scale Response Times.		Joel E. Baker; Nathaniel E. Ostrom
	NCER/ STAR grants and HSRCs	Biogeochemical Control of Heavy Metal Speciation and Bioavailability in Contaminated Marine Sediments.		James Shine
	NCER/ STAR grants and HSRCs	Distribution of Cs-137 in the Lena River Estuary-Laptev Sea System As Evidenced by Marine, Estuarine and Lacustrine Sediments.		Ashanti Johnson Pyrtle
	NCER/ STAR grants and HSRCs	Effects of Interactions Between Sediment Components on Copper Sorption in Estuaries.		Kea Duckenfield
	NCER/ STAR grants and HSRCs	The Effect of Sulfate and Sulfide on Mercury Methylation in Florida Everglades.		Janina Benoit
	NCER/ STAR grants and HSRCs	Metal Speciation and Sequestering in Wetland Systems.		Edward Peltier
	NCER/ STAR grants and HSRCs	Determination of Sediment Contribution from Unpaved Roads Within a Tropical Watershed.		Alan Ziegler
	NCER/ STAR grants and HSRCs	Effect of Natural Dynamic Changes on Pollutant-Sediment Interaction.		Tomson, Kan
Human Health and Ecological Effects (continued)	NCER/ STAR grants and HSRCs	Controls on Metal Partitioning in Contaminated Sediments.		F. M. Saunders; H. L. Windom, R. A. Jahnke

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
	NCER/ STAR grants and HSRCs	Source Identification, Transformation, and Transport Processes of N-, O-, and S- Containing Organic Chemicals in Wetland and Upland Sediments.		W. James Catallo
	NCER/ STAR grants and HSRCs	Sediment Resuspension and Contaminant Transport in an Estuary.		C. E. Adams, Jr., R. E. Ferrell, Jr.
	NCER/ STAR grants and HSRCs	Pollutant Fluxes to Aquatic Systems via Coupled Biological and Physicochemical Bed-Sediment Processes.		Reible, Thibodeaux, Valsaraj, Fleeger
	NCER/ STAR grants and HSRCs	The Role of Competitive Adsorption on Suspended Sediments in Determining Partitioning and Colloidal Stability.		H. G. McWhinney
	NCER/ STAR grants and HSRCs	Particle Transport and Deposit Morphology at the Sediment/Water Interface.		Mark R. Wiesner
	NCER/ STAR grants and HSRCs	Mobilization and Fate of Inorganic Contaminants Due to Resuspension of Cohesive Sediment.		T. W. Sturm, A. Amirtharajah, and C. L. Tiller
	NCER/ STAR grants and HSRCs	Desorption of Nonpolar Organic Pollutants from Historically Contaminated Sediments and Dredged Materials.		Mason B. Tomson, Amy T. Kan, Gongmin Fu, Wei Chen, and Margaret A. Hunter
Human Health and Ecological Effects (continued)	NCER/ STAR grants and HSRCs	Freshwater Bioturbators in Riverine Sediments as Enhancers of Contaminant Release.		A. D. W. Acholonu

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
	NCER/ STAR grants and HSRCs	Modelling Air Emissions of Organic Compounds from Contaminated Sediments and Dredged Materials.		K. T. Valsaraj, L. J. Thibodeaux, D. D. Reible; J. M. Brannon, T. E. Myers, C. B. Price; J. S. Gulliver
	NCER/ STAR grants and HSRCs	Characterization of Laguna Madre Contaminated Sediments.		A. N. S. Ernest
	NCER/ STAR grants and HSRCs	Mobility and Transport of Radium in Sediment and Waste Pits.		DeLaune, Pardue, Patrick, Lindau
	NCER/ STAR grants and HSRCs	Pollutant Fluxes to Aquatic Systems via Coupled Biological and Physicochemical Bed-Sediment Processes.		Reible, Thibodeaux, Valsaraj, Fleeger
	NHEERL/GED	**Improved protocols to determine hazards of contaminated sediments in the Gulf of Mexico.** Development of existing field and laboratory data collected over the past 10 years in Gulf of Mexico estuaries to assess improvements in protocols for hazard assessments	Improved protocols to determine hazards of contaminated sediments in the Gulf of Mexico - FY03. *GPRA 2.2*	Michael Lewis 850-934-9382

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Exposure Activities related to determining exposure of human and biological receptors to contaminated sediments. These activities advance the state-of-the-art by development and verification of methods, models, protocols, and technologies.	OW/OST/SASD NHEERL/ORD	**Development of methods for testing chronic toxicity of marine sediments.** This will be a joint U.S. EPA/U.S. ACE document that will describe methods for measuring sublethal effects of marine sediments with *Leptocheirus plumulosus*.	Document has been published. *GPRA 2.2*	Scott Ireland 202-260-6091 Ted Dewitt 541-867-4029
	OW/OST/SASD	**Revised methodology for tiering classification for the National Sediment Inventory - Report to Congress**. A technical advisory group has been established to modify/update the methodology for classifying sampling stations according to the probability of adverse effects on aquatic life and human health from sediment contamination.	Methodology completed. National Sediment Inventory - Report to Congress - FY01. *GPRA 2.2*	Scott Ireland 202-260-6091
	OW/OST/SASD	**National Sediment Nonpoint Source Inventory and Assessment.** This report is a supplement to the National Sediment Inventory. It characterizes nonpoint sources of sediment contamination and provides a national estimate of annual source loads of selected contaminants from identified categories of nonpoint sources.	Currently undergoing Peer Review. National Sediment Nonpoint Source Inventory and Assessment - Report to Congress - FY01 *GPRA 2.2*	Scott Ireland 202-260-6091
	OW/OST/SASD	**Bioaccumulation Testing And Interpretation For The Purpose of Sediment Quality Assessment: Status and Needs.** This document was prepared to serve as a status and needs summary of the use of bioaccumulation data.	Published February 2000 (U.S. EPA-823-R-00-001). *GPRA 2.2*	Rich Healy 202-260-7812

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Exposure (continued)	OW/OST/SASD	**Methods for Collection, Storage, and Manipulation of Sediments for Chemical and Toxicological Analysis.** This guidance manual covers collecting, handling, and transporting field sediments; manipulating sediments in the laboratory for chemical analysis and toxicological testing; and preparing formulated sediments for toxicological testing.	Draft document. Methods document to be completed FY01. *GPRA 2.2*	Rich Healy 202-260-7812
	Region 5: Water and Superfund	**FIELDS (Fully Integrated Environmental Location Decision Support) Team**. The FIELDS System combines GIS, GPS, environmental database, web site, and graphics technologies with fieldwork experience. Joint tech transfer pilots with ORD and Regions 5, 6, and 9. Also used in risk management/remediation.		Tim Drexler 312-353-4367
	GLNPO	**Use of Sediment Quality Guidelines to Predict Toxicity in Great Lakes Sediments.** Joint project with USGS to evaluate the predictive ability of freshwater Sediment Quality Guidelines (SQGs).	Final Report - FY2001	
	GLNPO	**In-situ LIF System for the Assessment of PAH Contaminated Sediments.** Field demonstration of a rapid, vertically discrete, in-situ technique for measuring PAH contamination in sediments.	Project Report - FY2002. *GPRA 2.2*	
	GLNPO	**Sediment Assessment Framework Document**. Joint effort with the Sustainable Fisheries Foundation to develop a sediment assessment framework to provide guidance on the use and evaluation of chemical, toxicity, benthic community, and bioaccumulation data from sediment assessments.	Framework Document FY2001. *GPRA 2.2*	

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Exposure (continued)	OAR-OAQPS OW Regions	**Total Maximum Daily Load (TMDL) Pilot Projects in Florida and Wisconsin.** The pilot projects are evaluating techniques for (1) determining the amount of mercury reductions needed to meet water quality standards; (2) determining the relative contributions of mercury from various sources; (3) the geographic extent of sources contributing mercury; and (4) analyzing Federal and State programs for reducing mercury emissions.	Both projects should be completed by early 2001. *GPRA 2.2*	Ruth Chemerys (OW) 202-260-9038 Randy Waite (OAQPS) 919-541-5447
	OAR-OAQPS OW Regions	**Air/Water Interface Action Plan.** Coordination effort between OAR and OW to address the problem of air deposition.	Plan to be completed by end of summer 2000. *GPRA 2.3*	Barbara Driscoll (OAQPS) 919-541-0164 Deb Martin (OW) 202-260-2729
	GLNPO	**GLNPO Grants Program.** Annual program to provide financial and technical support to state and local agencies for the assessment and remediation of contaminated sediments in Great Lakes Areas of Concern (AOCs).	Ongoing Project reports posted on the web at www.epa.gov/glnpo. *GPRA 2.2*	Marc Tuchman 312-353-9184
Human Health and Ecological Exposure (continued)	NCEA-W	**Sediment Toxicity Assessment Methods**. The method in development combines bulk sediment toxicity testing with chemical concentrations measured in the same samples. A large database of paired sediment toxicity and chemistry data has been compiled.	Final report describing the assessment method, APM A80, FY01. The method is being applied in the Office of Water's 2000 Report to Congress on Sediment Contamination Status and Trends. GPRA 2.2	Susan Norton 202-564-3246

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
	NCEA-W	Assessment of Toxicity of Dioxins and Related Compounds in Aquatic Wildlife.		Christopher Cubbison
Human Health and Ecological Exposure (continued)	NHEERL/GED	**Assessment of the relationship of contaminated sediments to estuarine biotic effects**. Statistical analyses are used to determine the types and strengths of relationships among contaminated sediment variables and biotic response variables.	Report on the relationship of toxicity of contaminated sediments to aquatic animals and vascular plants, FY00. Report on fish and contaminant indicators of estuarine condition, FY01. *GPRA 2.2* Correlations among water and sediment chemistry, pollutant loadings, and ecological condition of coastal estuaries, FY04. Report on the relationship between sediment quality and benthic community distribution and condition, FY04. *GPRA 5.1*	Michael Lewis 850-934-9382 Kevin Summers 850-934-9244 Virginia Engle 850-934-9354
	NERL/EERD	**Development of Indicators as Measures of Ecosystem Sustainability.** Indicator methods can be used to measure PAH exposure, to determine exposure exceeding natural background, and to evaluate changes in exposure to petroleum and combustion by-product (PAH) waste in dredged streams.	Draft report on national background and exposure criteria for indicators of exposure to PAHs (9/02).	Brian Hill 513-569-7077 Susan Cormier 513-569-7995

Area	Organization	Description	Product/Estimated Date ***GPRA APGs/APMs***	Contact
Human Health and Ecological Exposure (continued)	NHEERL/GED	**Improved protocols to determine hazards of contaminated sediments in the Gulf of Mexico.** Development of existing field and laboratory data collected over the past 10 years in Gulf of Mexico estuaries to assess improvements in protocols for hazard assessments.	Improved protocols to determine hazards of contaminated sediments in the Gulf of Mexico, FY03. *GPRA 2.2*	Michael Lewis 850-934-9382
	NHEERL/GED	**Assessment of reference conditions in estuaries of the Gulf of Mexico**. Field study. Includes assessment of references conditions for sediment contaminants and their seasonal and spatial variabilities.	*Identification of sensitive benthic species, FY99.* Reference conditions for sediments in Gulf of Mexico, FY01. *GPRA 2.2*	Michael Lewis 850-934-9382
	NERL/EERD	**Develop Indicators for Stressors in Environmental Media and Mixtures.** Develop tests that can be used to determine toxicity of site samples of sediment, water, or discharge. Includes: Regional-scale toxicity assessment of sediment in the Mid-Atlantic and Southern Rockies**;** and warm water fish embryo larval test to assess potential exposure/effects from sediments.	Methods manual for sediment toxicity sample collection (9/00). *GPRA 2.2*	Jim Lazorchak 513-569-7076 Susan Cormier 513-569-7995
	NERL/EERD	**Indicator Development and Assessment of Large Rivers and Watersheds.** New methods can be used to detect impairment in large rivers needing sampling by boat. Includes microbial metabolism of sediment.	Bioassessment protocol for large non-wadable rivers in the mid-Atlantic (9/01). *GPRA 2.2 and 8.1*	Florence Fulk 513-569-7379 Susan Cormier 513-569-7995
	Region 1	Assessment of Mercury in Hypolimnetic Lake Sediments of Vermont and New Hampshire.		Hilary Snook

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Exposure (continued)	Region 1	Ecological Risk Assessment for the Housatonic River.		Susan Svirsky
	Region 1	Human Health Risk Assessment for the Housatonic River.		Susan Svirsky
	Region 1	Regional Applied Research Effort – Mercury Flux from Coastal Marsh.		Alan VanArsdale
	Region 1	Sediment Sampling Guidelines.		Andy Beliveau
	Region 3	A Benthic Macroinvertebrate Survey of Non-Tidal Tributaries of the Anacostia River Test Titles.		Jim Green
	Region 3	A Survey of Streams in the Primary Region of Mountain Top Mining/Valley Fill Coal Mining Draft 1.		Jim Green
	Region 4	Ecological Risk Assessment for LCP Superfund Site (NPL).		Lynn Wellman
	Region 4	Field and Laboratory Standard Operating Procedures and Quality Assurance Plan for Conducting Sediment and Nutrient Total Maximum Daily Loads.		Bruce Pruitt
	Region 7	Nebraska REMAP Report '98.		Lyle Cowles
	Region 9	Coastal EMAP Project.		Terrence Fleming
	Region 9	San Francisco Bay Wetlands Regional Monitoring Program.		Paul Jones
	NCER/ STAR grants and HSRCs	Response of Methylmercury Production and Accumulation to Changes in Hg Loading: A Whole-ecosystem Mercury Loading Study.		Cynthia C. Gilmour, Andrew Heyes, Robert P. Mason, and John M. Rudd

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Exposure (continued)	NCER/ STAR grants and HSRCs	Validation of Sediment Quality Criteria in Southeastern Estuaries.		Amy Huffman Ringwood
	NCER/ STAR grants and HSRCs	Application of Sediment Quality Criteria for Metals to a Montane Lotic Ecosystem: Field Validation During Reclamation of a Copper Mine Causing Acid Mine Drainage.		Joseph S. Meyer, Jeffrey A. Lockwood, Richard W. Rockwell
	NCER/ STAR grants and HSRCs	Sediment Contamination Assessment Methods: Validation of Standardized and Novel Approaches.		G. Allen Burton, Jr., Daniel Krane, Thomas Tiernan, Peter Landrum, William Stubblefield and William Clements
	NCER/ STAR grants and HSRCs	Meiofaunal Validation of EqP-Based Sediment Quality Criteria for Metal Mixtures in Estuarine Sediments Population to Community-Level Culturing Studies of Biogeochemical Controls on Bioavailability and Toxicity.		G. Thomas Chandler and Thimothy J. Shaw
	NCER/ STAR grants and HSRCs	Developing a New Monitoring Tool for Benthic Organisms in the Gulf of Mexico Loss of Genetic Variability in Meiofaunal Populations.		Paul A. Montagna
	NCER/ STAR grants and HSRCs	Bioavailability of Organic Contaminants in Estuarine Sediments to Microbes and Benthic Animals.		Gary L. Taghon, David S. Kosson and Lily Y. Young

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Exposure (continued)	NCER/ STAR grants and HSRCs	Environmental Monitoring and assessment of Wetlands Using Sedimentary Diatoms from Present and Past.		R. Jan Stevenson
	NCER/ STAR grants and HSRCs	Sediment Entrainment and Stream Benthic Communities: Implications for Freshwater Bioassessment.		Stephen Kenworthy
	NCER/ STAR grants and HSRCs	Studies of the environmental fate of sediment-associated organic contaminants in marine systems.		P. Lee Ferguson
	NCER/ STAR grants and HSRCs	Investigation on the Fate and Biotransformation of Hexachlorobutadiene and Chlorobenzenes in a Sediment-Water Estuarine System.		Pavlostathis
	OSWER/OSRTI OSWER/OSW OSWER/TIO OW/OWOW OW/OST ORD/NRMRL ORD/Narraganset Regions	**Development of Contaminated Aquatic Sediment Remediation Guidance.** OSRTI has lead for cross-Agency workgroup (Contaminated Aquatic Sediments Remedial Guidance Workgroup – CASRGW) to develop guidance to select remedies for sediment sites under CERCLA.	Draft guidance on remediation - FY00/01. *GPRA 5.1*	Bruce Means 703-603-8815 Ernie Watkins 703-603-9011
	Region 1	Risk-Based Procedures Used to Support Remediation of a Ground Water-Surface Water Transition Zone Contaminated with Chlorobenzenes.		Cornell Rosiu

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Exposure (continued)	Region 2	**Full/Commercial-Scale Sediment Decontamination Technology Development with Beneficial Use Applications.** Bench- through full-scale tests are being conducted to implement environmentally responsible and cost-effective technologies to decontaminate dredged material from the Port of NY/NJ.	Anticipate 1-2 systems processing >250,000 cu yd/yr by FY02.	Eric Stern 212-637-3806
	OW/OST/SASD	**Sediment Modeling Toolkit.** The toolkit consists of three components: Graphical User Interface (GUI) to the Environmental Fluid Dynamics Code (EFDC) grid generator to set up physical domain; GUI interface to EFDC model; and post-processor to view model output. Design is flexible to allow support of other water quality models.	Beta test of toolkit beginning July 1, 2000 Version 1.0 distributed by end of FY 02. *GPRA 2.2*	Russell Kinerson 260-1330
	Region 5: WPTD and GLNPO	**Sediment Capping and Natural Recovery Project**. A joint project between U.S. EPA, USGS, and COE WES to develop a guidance document on capping and natural attenuation.		Dave Petrovski 312-886-0997
	GLNPO	**GLNPO Grants Program.** Annual program to provide financial and technical support to state and local agencies for the assessment and remediation of contaminated sediments in Great Lakes Areas of Concern.	Ongoing Project reports posted on the web at www.epa.gov/glnpo. *GPRA 2.2*	Marc Tuchman 312-353-9184
	GLNPO	**Demonstration of Contaminated Sediment Treatment Technologies.** Joint efforts with the states of Michigan and Wisconsin perform on-site, pilot-scale demonstrations of sediment treatment technologies.	Pilot projects scheduled for FY2001. *GPRA 2.2*	Scott Cieniawski 312-353-9184 Marc Tuchman 312-353-1369

Area	**Organization**	**Description**	**Product/Estimated Date** ***GPRA APGs/APMs***	**Contact**
Human Health and Ecological Exposure (continued)	Region 5/GLNPO	**Beneficial Use Work Group.** Development of beneficial use guidelines; support to WI DNR project to develop guidance/criteria. Cooperation with state and federal agencies to perform pilot-scale beneficial use demonstrations.	Region 5 "Position Paper" on Criteria for the Evaluation of Beneficial Use Projects - FY2002. Project reports to be available on the web (www.epa.gov/glnpo) - FY2001.	Scott Cieniawski 312-353-9184
	Region 5/GLNPO	**Sediment Information Management System.** A comprehensive, multi-program sediment site information database and tracking system for sediment remediation and management.		Ken Klewin 312-886-4794
	Region 5: Water and Superfund	**FIELDS (Fully Integrated Environmental Location Decision Support) Team.** The FIELDS System combines GIS, GPS, environmental database, web site, and graphics technologies with fieldwork experience. See description under Assessment.		Tim Drexler 312-353-4367
	Region 6	**Calcasieu Estuary.** Region 6 is conducting a multi-media initiative, including the investigation and potential remediation of contaminated sediment. This is a three year pilot which will identify guidance, policy, and regulatory gaps as well as identifying better ways to coordinate large environmental responses.		RPM: John Meyer (214) 665-6742
	Region 10	Regional Sediment/Sand Management (RSM) Initiative		Joan Cabreza
	NRMRL/LRPCD	**Remediation of PCB-Contaminated Sediments.** This Congressionally-mandated study by the National Academy of Science is intended to evaluate the relative effectiveness, effects, and costs associated with a variety of methods for managing PCB-contaminated sediments.	*NAS report due to U.S. EPA and Congress, APM A81, FY01. Completed 3/01.* *GPRA 2.2*	Dennis Timberlake 513-569-7547

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Human Health and Ecological Exposure (continued)	NRMRL/LRPCD	**Dredging Performance.** The effectiveness of dredging is being documented by the combined evaluation of past projects and completion of selected projects to fill data gaps.	Report on short-term effects, FY02. Report on the environmental and human health benefits of contaminant mass removal. – Date? *GPRA 5.1*	Dennis Timberlake 513-569-7547
	NRMRL/LRPCD	**Capping Performance.** Data is being collected to determine performance of caps and the accuracy of model predictions of their performance. Selected field studies are being conducted to address specific questions related to short-term disturbances created during cap placement; permanence of cap performance; contaminant migration through caps and the accuracy of predictive models; and benthic and aquatic community responses to caps. Caps are being evaluated for applications in situ and in confined aquatic disposal sites.	Comparative report on in-situ technologies, FY04. *GPRA 5.1*	Dennis Timberlake 513-569-7547 Terry Lyons 513-569-7589

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Assessment Activities related to assessing the risk associated with human or ecological exposure to contaminants in sediments. These activities advance the state-of-the-art development and verification of methods, models, protocols, and technologies.	NRMRL/LRPCD	**Monitored Natural Attenuation.** Research is investigating past performance at sites where MNA was selected intentionally and at sites where studies have been conducted over time without remedial action. Field studies are being conducted to fill data gaps, examine specific attenuation mechanisms, and collect data on long-term performance. Selected laboratory studies are being conducted to determine rates of contaminant sorption/desorption, and rates and endpoints of contaminant degradation.	Interim report, FY01. Sorption/desorption kinetics model, FY03. Technical Resource Document, FY04. *GPRA 5.1*	Dennis Timberlake 513-569-7547 Dick Brenner 513-569-7657 Fran Kremer 513-569-7346
	NRMRL/LRPCD	**Ex-Situ Management and Treatment Technologies.** This research involves the performance of confined disposal facilities (CDFs) in managing risks from contaminated sediments disposed in hydraulic contact with the water body, treatments that can be applied to enhance the effectiveness of CDFs, and treatment/utilization of dredged material to recover CDF capacity.	Peer reviewed journal article on biotreatment of PAH - contaminated sediments, APM 159, FY99. Peer reviewed journal article on treatment of chlorinated organics in sediment, APM 160, FY99. Report on toxicity reductions from biological treatment of PAH-contaminated sediments, FY02. *GPRA 5.1*	Ed Barth 513-569-7669 Dick Brenner 513-569-7657

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Assessment (continued)	NRMRL/LRPCD	**SITE Demonstrations of Innovative Technologies.** Under the Superfund Innovative Technology Demonstration Program, three vendor technologies for contaminated sediment sites have been accepted for demonstration: Minergy's glass forming process, IGT's Cement Block process, and AquaBlok's capping process. Additional projects are in the selection process.	Individual technology evaluation reports, FY03-05. *GPRA 5.1*	Annette Gatchett 513-569-7697
	NRMRL/LRPCD	**Innovative In-Situ Treatment Technologies.** Ongoing bench research is investigating the use of hydrogen and zero-valent iron to respectively stimulate biological and chemical dechlorination of persistent chlorinated organic compounds such as PCBs, PCP, and DDT and the application of a particular microorganism to re-speciate lead into a sparingly soluble phosphate mineral.	Journal article on hydrogen addition - FY01 Journal article on Fe(0) - FY01. *GPRA 5.1*	Dennis Timberlake 513-569-7547 Greg Sayles 513-569-7607 Wendy Davis-Hoover 513-569-7206
	NCER/ STAR grants and HSRCs	Microbial Community Dynamics of PCB Dechlorination in Sediments.		G-Yull Rhee, Roger C Ellen Braun-Howland
	NCER/ STAR grants and HSRCs	Importance of Reductive Dechlorination in Chesapeake Bay Sediments Role of Sulfate Respiration.		Douglas G. Capone, J Baker, and Cynthia C.
	NCER/ STAR grants and HSRCs	Effectiveness of Regulatory Incentives for Sediment Pollution Prevention Evaluation Through Policy Analysis and Biomonitoring.		Seth Reice and Richard Andrews
	NCER/ STAR grants and HSRCs	Biotic and Abiotic Reductive Transformation of Chlorinated Solvents in Iron Reducing Sediments.		Michael L. McCormic

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Assessment (continued)	NCER/ STAR grants and HSRCs	Reduction of Herbicides in Wetland Sediments.		Theodore Klupinski
	NCER/ STAR grants and HSRCs	Nitrogen Removal in Constructed Wetlands: Enhancement of Nitrate Mass Transfer in the Denitrification Zone.		Maia Fleming
	NCER/ STAR grants and HSRCs	Investigation of the reductive transformation of chlorinated solvents in iron reducing sediments and to assess the relative contributions of biological and abiotic reactions to dechlorination.		Mike McCormick
	NCER/ STAR grants and HSRCs	Reductive Dechlorination and Degradation of Model Chlorophenols in Marine and Estuarine Sediments.		Kimberly Warner
	NCER/ STAR grants and HSRCs	Enhanced Microbial Dechlorination of PCBS and Dioxins in Contaminated Dredge Spoils.		Max M. Hõggblom and Cecilia Vargas
	NCER/ STAR grants and HSRCs	Evaluation of Placement and Effectiveness of Sediment Caps.		D. D. Reible, K. T. Valsaraj and L. J. Thibodeaux
	NCER/ STAR grants and HSRCs	Isolating Organisms Which Dechlorinate Polychlorinated Biphenyls (PCBs).		Tiedje
	NCER/ STAR grants and HSRCs	Development of a Model Sediment Control Ordinance for Louisiana.		Donald Barbe, Ph.D.

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Assessment (continued)	NCER/ STAR grants and HSRCs	Bioremediation of Sediments Contaminated with Polynuclear Aromatic Hydrocarbons.		J. B. Hughes and C. H. Ward
	NCER/ STAR grants and HSRCs	The Application of Plant Biotechnology in Bioremediation of Contaminated Sediments.		S.V. Sahi
	NCER/ STAR grants and HSRCs	Bioremediation of Contaminated Sediments and Dredged Material.		Ward, Hughes
	NCER/ STAR grants and HSRCs	The Effect of Sediment Treatment on Sediment Metabolism Rates in Marsh Mesocosms.		Cornwell (Liebert)
	NCER/ STAR grants and HSRCs	Characterization of PAH Degrading Bacteria in Coastal Sediments.		M. G. Tadros
	NCER/ STAR grants and HSRCs	Mechanisms governing the release of contaminants from sediments resuspended during dredging operations.		Davies, Voice
	NCER/ STAR grants and HSRCs	Use of chemical oxidants for the degradation of chlorinated benzenes and biphenyls in aqueous systems and sediments.		Masten, Davies
	NCER/ STAR grants and HSRCs	An Investigation of Chemical Transport from Contaminated Sediment through Porous Containment Structures.		Reible, Thibodeaux, Valsaraj

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Assessment (continued)	OW/OST/SASD	**Contaminated Sediment Pamphlet and Poster.** The Pamphlet and Poster were designed to educate the public, including citizens groups and high school students on the definition and extent of contaminated sediment, sources of contamination, remediation and pollution prevention solutions, and what citizens can do to protect sediment.	Pamphlet and the Poster were released October 1999. Pamphlet (U.S. EPA-823-F-99-006), Poster (U.S. EPA-823-H-99-001). *GPRA #2*	Scott Ireland 202-260-6091 Rich Healy 202-260-7812
	OW/OST/SASD	**Sediment Network.** Individuals from Regions (including GLNPO), HQ (OW & OSWER), and ORD that conference on a regular basis to communicate contaminated sediment issues.		Rich Healy 202-260-7812
	OW/HECD ORD/NHEERL	**OW/ORD Sediment Research Team.** A cross-program effort to coordinate research activities focusing on contaminated sediment.		Heidi Bell: 202-260-5464 Mary Reiley: 202-260-9456 Walter Berry: 401-782-3101 Dave Mount: 218-529-5169
	OSWER/OSRTI	**Superfund Sediment Forum**. Regional personnel who participate in regular conference calls about Superfund-specific issues related to sediment cleanups.	Ongoing	Sherri Clark 703-603-9043 Rich Norris 703-603-9053
	OSWER/TIO NRMRL/LRPCD	**Sediments Action Team, Remediation Technologies Development Forum.** A partnership with industry to develop or advance innovative remediation technologies.		Kelly Madalinski 703-603-9901 Dennis Timberlake 513-569-7547

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Assessment (continued)	OSWER/OSRTI	**Updating CERCLIS3**. Refining the Superfund sites database to adequately capture those sites which address contaminated sediments.	Ongoing	Sherri Clark 703-603-9043 Ernie Watkins 703-603-9011
	OSWER/OSRTI	**OW SedNet2000.** Conference calls to share information.	Ongoing	Sherri Clark 703-603-9043
Remediation/ Risk Management Activities related to remediating or otherwise managing the risks of contaminated sediments. These activities advance the state-of-the-art by development and verification of methods, models, protocols, and technologies.	OSWER/OSRTI	**Sediment Technology Video.** Development of an outreach video for project managers to use at public meetings to show citizens the different technologies that might be considered at Superfund sites.		Ernie Watkins 703-603-9011
	GLNPO	**GLNPO Sediments Web Page.** Contains Sediment Assessment and Remediation Guidance Documents, Evaluations of Bench- and Pilot-Scale Sediment Treatment demonstrations, and other technical documents. Web page address: www.epa.gov/glnpo/sediments.html	Ongoing	Marc Tuchman 312-353-9184
	NCER/ STAR grants and HSRCs	A Short Course of Remediation of Contaminated Soils and Sediments.		Kelly, Keefer, Rohde, Woldt
	Region 5: Superfund	Region 5 Sediment Web Page.	Web page (under development).	Jim Rittenhouse 312-886-1438

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Remediation/ Risk Management (continued)	Region 5: GLNPO and Superfund	**Sediment Information Management System.** A comprehensive, multi-program sediment site information database and tracking system for sediment remediation and management.	End of FY2000.	Ken Klewin 312-886-4794 Bonnie Eleder 312-886-4885
	Region 5 and GLNPO	**Great Lakes Dredging Team (GLDT).** A federal-state-private partnership with the primary objective of ensuring that the dredging of the Great Lakes harbors and channels is conducted in a timely and cost effective manner while meeting environmental protection, restoration and enhancement goals. Provides an interactive forum; works with local advocates.	Great Lakes Dredging Team web site. GLDT outreach documents: Dredging and the Great Lakes booklet; dredging case studies; developing a dredging video; "Decision Making Process for Dredged Material Management" white paper; draft TSCA/RCRA white paper; Beneficial Use Task Force; development of a beneficial use brochure; beneficial use project to facilitate state input into development of guidelines; Beneficial Use Workshop held Sept. 15-16, 1998.	Bonnie Eleder 312-886-4885 Marc Tuchman 312-353-1369
	Region 5: Water	**Mississippi River Dredging Team**. Similar objectives as GLDT		Bill Franz 312-886-7500

Area	Organization	Description	Product/Estimated Date *GPRA APGs/APMs*	Contact
Remediation/ Risk Management (continued)	Region 5	**Beneficial Use Work Group.** Develop beneficial use guidelines; support WI DNR project to develop guidance/criteria.		Scott Cieniawski 312-353-9184
	Region 5	Technology transfer and communication products	Sediment remediation video - in preparation - Superfund and Office of Public Affairs. "Environmental Results of Dredging Projects" paper/presentation Sediment Fact Sheet	Brianna Bill 312-353-6646 Jim Hahnenberg 312-353-3567 Bonnie Eleder 312-886-4885 Teresa Jones 312-886-0725
	Region 5	Great Lakes Regional Sediment Highlights	Quarterly regional sediment news	Bonnie Eleder 312-886-4885
	Region 5	**Duluth Superior Technical Advisory Committee -and- Duluth Superior Partnering Agreement.** Partnership to address maintenance of the federal navigation channel and long-term management of the dredged material.		Steve Hopkins 218-720-5738 Bonnie Eleder 312-886-4885
	Region 5	WI Sediment Advisory Committee (participant on).		Bonnie Eleder 312-886-4885

ORGANIZATIONAL UNIT KEY

OSWER/OSRTI	Office of Solid Waste and Emergency Response/Office of Superfund Remediation and Technology Innovation
OSWER/OSW	Office of Solid Waste and Emergency Response/Office of Solid Waste
OSWER/TIO	Office of Solid Waste and Emergency Response/Technology Innovation Office
OW	Office of Water
GLNPO	Great Lakes National Program Office, Office of Water, Chicago, IL.
OW/OST/SASD	Office of Water/Office of Science and Technology/Standards and Applied Science Division
OW/HECD	Office of Water/Health and Ecological Criteria Division
OAR	Office of Air and Radiation
OAQPS	Office of Air Quality Planning and Standards
ORD	Office of Research and Development
NHEERL	National Health and Environmental Effects Research Laboratory
AED	Atlantic Ecology Division
GED	Gulf Ecology Division
MED	Mid-Continent Ecology Division
WED	Western Ecology Division
NERL	National Exposure Research Laboratory
EERD	Ecological Exposure Research Division
ERD	Ecosystems Research Division
CEAM	Center for Exposure Assessment Modeling
ESD	Environmental Sciences Division
MSCTSC	Monitoring and Site Characterization Technical Support Center
NCEA	National Center for Environmental Assessment
WO	Washington Office
NRMRL	National Risk Management Research Laboratory
LRPCD	Land Remediation and Pollution Control Division
ETSC	Engineering Technical Support Center
NCER	National Center for Environmental Research
STAR grants	Science to Achieve Results (STAR) grants
HSRCs	Hazardous Substance Research Centers

APPENDIX B

EXAMPLE OF A SUMMARY SHEET

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E.5 Support the demonstration of cost-effective *ex situ* treatment technologies and identification of potential beneficial uses of treatment products.

Key Partners:
GLNPO, U.S. EPA Region 2, ORD

Actions Underway:
The demonstration of decontamination technologies along with the development of marketable end-products is being actively promoted by Region 2 and GLNPO. Region 2, working in New York/ New Jersey Harbor in cooperation with New Jersey DOT, is investigating a sediment washing process whereby a manufactured top soil and bricks are produced, and two thermal treatment processes in which a blended cement and lightweight aggregate are potential marketable final products. The sediment washing project has been completed and the blended cement and lightweight aggregate demonstrations are scheduled for FY 2002 and 2003. GLNPO is currently supporting two technologies: a glass vitrification technology which produces construction fill (with the potential for roofing shingles and floor tiles); and a thermal process examining blended cement as an end product. The vitrification project has been completed as part of a joint effort with Wisconsin DNR on the Fox River. The blended cement project, a cooperative project with Michigan DEQ, is scheduled for the summer of 2002. Through the SITE Program, ORD is providing analytical support to provide independent verification of the results of the treatment technology processes.

Actions Planned Over Next 2 Years:
Region 2 plans to complete two demonstration and report on the Cement-Lock and lightweight aggregate technologies. GLNPO will conduct the Cement-Lock process on the Detroit River sediments. Reports describing the environmental as well as economic effectiveness of all demonstrations will be completed and distributed.

Products Expected by 2006:
1. Demonstrations and final reports for above projects completed and published.
2. Complete economic evaluations of marketable final products along with development of cost estimates for running full scale operations of each technology tested.
3. Begin commercial application of decontamination technology in New York Harbor, including marketing of end-product.
4. Demonstrate applicability of treatment technology to Superfund program.

Primary Contacts:
Marc Tuchman–GLNPO
Eric Stern–Region 2

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APPENDIX C

LIST OF ACRONYMS

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AED	Atlantic Ecology Division
AET	apparent-effects threshold
APCs	areas of probable concern
APE	alkylphenol ethoxylate
ARCS	Assessment and Remediation of Contaminated Sediments
BAF	bioaccumulation factor
BSAF	biota-sediment accumulation factor
CAD	contained aquatic disposal
CASRGW	Contaminated Aquatic Sediment Remedial Guidance Workgroup
CCME	Canadian Council of Ministers of the Environment
CDF	confined disposal facilities
CEAM	Center for Exposure Assessment Modeling
CERCLA	Comprehensive Emergency Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CREM	Council on Regulatory Environmental Models
CSCT	Consortium for Site Characterization and Technology
CSMC	Contaminated Sediment Management Committee
CSMS	Contaminated Sediment Management Strategy
CSTAG	Contaminated Sediment Technical Advisory Committee
CWA	Clean Water Act
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DOC	Department of Commerce
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOT	Department of Transportation
ECGOx	ElectroChemical GeoOxidation
EDCs	endocrine disruptor compounds
EEA	essential ecological attributes
EERD	Ecological Exposure Research Division
EFDC	Environmental Fluid Dynamics Code
EMAP	Environmental Monitoring and Assessment Program
EqP	equilibrium partitioning
ERL	effects range–low
ERM	effects range–median
ESBs	Equilibrium Partitioning Sediment Benchmarks
ESD	Environmental Sciences Division
ESG	Equilibrium Partitioning Sediment Guidelines

ETV	Environmental Technology Verification
FIELDS	Field Environmental Decision Support
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FRTR	Federal Remediation Technologies Roundtable
GC/MS	gas chromatography/mass spectrometer
GC/ECD	gas chromatography/electron capture detection
GED	Gulf Ecology Division
GLNPO	Great Lakes National Program Office
GPRA	Government Performance Results Act
HECD	Health and Ecological Criteria Division
IRIS	Integrated Risk Information System
ITRC	Inter-State Technology and Regulatory Cooperation
LIF	Laser Induced Fluorescence
LOE	line-of-evidence
LRM	logistic regression modeling
LRPCD	Land Remediation and Pollution Control Division
MARAD	Maritime Administration (US Department of Transportation)
MDEQ	Michigan Department of Environmental Quality
MED	Mid-Continent Ecology Division
MPRSA	Marine Protection, Research, and Sanctuaries Act
MYP	Multi-Year Plans
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NCEA	National Center for Environmental Assessment
NDT	National Dredging Team
NERL	National Exposure Research Laboratory
NHEERL	National Health and Environmental Effects Research Laboratory
NMFS	National Marine Fisheries Service (NOAA)
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
NRC	National Research Council
NRD	Natural Resources Damages
NRMRL	National Risk Management Research Laboratory
NRSC	National Regional Science Council
NSF	National Science Foundation
NSI	National Sediment Inventory
NSQS	National Sediment Quality Survey
NYSDEC	New York State Department of Environmental Conservation
OAQPS	Office of Air Quality Planning and Standards
OAR	Office of Air and Radiation

OCRM	Ocean and Coastal Resource Management (NOAA)
OECA	Office of Enforcement and Compliance Assurance
OEI	Office of Environmental Information
OPA	Oil Pollution Act
OPPT	Office of Pollution Prevention and Toxics
OPPTS	Office of Prevention, Pesticides and Toxic Substances
ORD	Office of Research and Development
OSRTI	Office of Superfund Remediation and Technology Innovation
OST	Office of Science and Technology (OW)
OSW	Office of Solid Waste
OSWER	Office of Solid Waste and Emergency Response
OW	Office of Water
PAH	polynuclear aromatic hydrocarbons
PBT	persistent, bioaccumulative, and toxic
PCB	polychlorinated biphenyls
PEL	probable-effects level
PIANC	International Navigation Association
PRPs	potentially responsible parties
QA/QC	quality assurance/quality control
RaDiUS	Research and Development in the United States
RAP	Remedial Action Plan
RCRA	Resource Conservation and Recovery Act
RCT	Research Coordination Team
REMAP	Regional Environmental Monitoring and Assessment Program
RTDF	Remedial Technologies Development Forum
SAB	Science Advisory Board
SASD	Standards and Applied Science Division
SITE	Superfund Innovative Technology Evaluation
SPC	Science Policy Council
SQGs	Sediment Quality Guidelines
SQT	Sediment Quality Triad
STAR	Science To Achieve Results
STORET	Storage and Retrieval
TEL	threshold-effects level
TIE	toxicity identification evaluation
TIO	Technology Innovation Office
TMDL	Total Maximum Daily Loads
TSCA	Toxic Substance Control Act
U.S. ACE	United States Army Corps of Engineers
U.S. EPA	United States Environmental Protection Agency

U.S. FWS	U.S. Fish and Wildlife Service
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UVF	ultraviolet fluorescence spectroscopy
WOE	weight-of-evidence
WRDA	Water Resources Development Act
XRF	x-ray fluorescence spectroscopy

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AED	Atlantic Ecology Division
GED	Gulf Ecology Division
MED	Mid-Continent Ecology Division
WED	Western Ecology Division
NERL	National Exposure Research Laboratory
EERD	Ecological Exposure Research Division
ERD	Ecosystems Research Division
CEAM	Center for Exposure Assessment Modeling
ESD	Environmental Sciences Division
MSCTSC	Monitoring and Site Characterization Technical Support Center
NCEA	National Center for Environmental Assessment
WO	Washington Office
NRMRL	National Risk Management Research Laboratory
LRPCD	Land Remediation and Pollution Control Division
ETSC	Engineering Technical Support Center
NCER	National Center for Environmental Research
STAR grants	Science to Achieve Results (STAR) grants
HSRCs	Hazardous Substance Research Centers