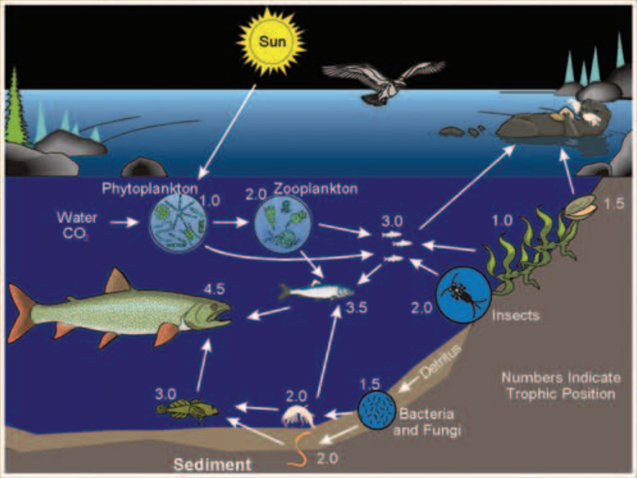
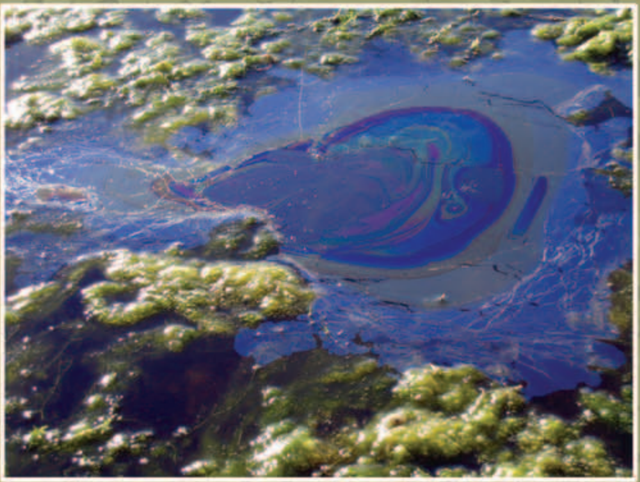
United States Environmental Protection Agency

RESEARCH AND DEVELOPMENT

Contaminated Sediment Research Multi-Year Implementation Plan 2005





NATIONAL HEALTH AND ENVIRONMENTAL EFFECTS RESEARCH LABORATORY

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Contaminated Sediment Research Multi-Year Implementation Plan 2005

Office of Research and Development
National Health and Environmental Effects Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Notice

The United States Environmental Protection Agency through its Office of Research and Development produced this multi-year implementation plan. It has been subjected to the Agency's peer and administrative review and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Foreword

The National Health and Environmental Effects Research Laboratory (NHEERL), as part of the Environmental Protection Agency's (EPA's) Office of Research and Development (ORD), serves as EPA's focal point for scientific research on the effects of contaminants and environmental stressors for both human health and ecosystem integrity. NHEERL's research helps the Agency identify and understand the processes that affect our health and environment, thereby aiding in evaluation of the risks that pollution poses to humans and ecosystems. The research is intended to address key Agency problems in a timely and responsive manner. In this context, NHEERL develops research implementation plans to achieve the following objectives:

- Optimizing responsiveness of research activities to Agency needs,
- Sharpening the focus of research programs where needed,
- Providing a forum for engagement of scientific staff on issues and approaches,
- Focusing on multi-year planning explicitly linked to Agency performance goals, and
- Providing a mechanism for prioritizing research.

NHEERL's approach builds on the ORD planning process which identifies and prioritizes research needs. ORD's research portfolio includes both core and problem-driven program areas. Currently, ORD has problem-driven research programs for air, water, waste, and pesticides and toxic substance, each of which addresses key problems faced by the respective regulatory program.

This implementation plan identifies the scientific problems and research that will be conducted by NHEERL concerning contaminated sediments, a key problem area for EPA's waste regulatory program, specifically the Superfund office (Office of Superfund Remediation and Technology Innovation, or OSRTI). The goal of NHEERL's research in this area is to help ORD address one of several long-term research goals in the waste program by improving the scientific foundation for selecting options to remedy contaminated sediments.

This document was developed by representatives from NHEERL research divisions, with significant engagement and peer review from OSRTI and other ORD laboratories and centers. In addition, the document has been reviewed by scientists external to the Agency. This implementation plan is intended to reflect research that will be conducted over the next several years. As progress is made in achieving the goals outlined in this document, it will be updated to address new and remaining challenges.

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Table of Contents

Executive Summary

This document describes the implementation plan for contaminated sediments research within the National Health and Environmental Effects Research Laboratory (NHEERL) for fiscal years 2004 - 2008. Contaminated sediments research in the Office of Research and Development (ORD) of the Environmental Protection Agency (EPA) is based on needs identified by EPA's Office of Superfund Remediation and Technology Innovation (OSRTI).

ORD has developed a multi-year research plan (MYP) to address OSRTI's needs for research. One of the long-term goals of the Contaminated Sites MYP is focused on contaminated sediments, and the NHEERL Implementation Plan provides the detailed approach that NHEERL will take to address mission-related scientific uncertainties identified in the MYP. This plan was developed in the context of the expected resource base for the program: an intramural research effort with about 8 full-time research FTEs (full-time equivalents) and associated research support resources. The Introduction provides a brief discussion of the process by which NHEERL developed this plan.

The NHEERL contaminated sediments research program described in herein contains four projects: (1) assessing impact of remedial activities on benthic communities (benthic recovery project); (2) linking residues to effects in aquatic and aquatic-dependent wildlife (residues to effects project); (3) linking chemical concentrations in water and sediment with residues in aquatic and aquatic-dependent wildlife (water and sediment concentrations to residues project); and (4) evaluating the impact of resuspension events on contaminant release and bioavailability (resuspension project). This document describes each of these projects and includes a summary of the issue, state of the science, and research needs for each project. It also describes the projected activities, resource requirements, critical path, and key products.

To the extent feasible, projects in this implementation plan blend empirical and modeling approaches to resolve the key issues. The project on benthic effects is designed to evaluate the relative utility of two different approaches to assessing the recovery/reestablishment of benthic communities after remediation. The project addressing residues-to-effects linkages is a short-term effort to assemble and evaluate existing polychlorinated biphenyl (PCB) residue-effects data for aquatic species. The project addressing water-concentrations-to-residues linkages is intended to produce a useful approach to extrapolating bioaccumulation data across ecosystems, species, and time for selected bioaccumulative toxicants. The resuspension project focuses on developing an empirical method and establishing linkages between empirical data and existing fate and transport models in order to better predict risks resulting from dredging activities.

The projects were developed with recognition that a key measure of success is the effectiveness with which critical information developed by NHEERL is transferred to the research client, i.e., to OSRTI and Superfund regional scientists and remedial project managers. Consequently, while the projects generally identify documents as the target products of the program, frequent communication between NHEERL and OSRTI will ensure timely and optimal transfer of new information.

Acronyms

ACE	Army Corps of Engineers
AED	Atlantic Ecology Division
AhR	aryl hydrocarbon receptor
APG	annual performance goal
AVS	acid volatile sulfide
BAF	bioaccumulation factor
BHQ	benthic habitat quality
B-IBI	benthic index of biotic integrity
BSAF	biota-sediment accumulation factor
CDA	Coeur d'Alene River
CFR	Clark Fork River
DAMOS	Disposal Area Monitoring System
DEA	dermal exposure assessment
DMU	dredge management unit
DNAPL	dense, non-aqueous phase liquid
DO	dissolved oxygen
EPA	Environmental Protection Agency
ERAF	Environmental Risk Assessment Forum
ERDC	Engineer Research and Development Center
ERED	Environmental Residue-Effects Database
ESB	equilibrium partitioning sediment benchmark
EcoSSL	ecological-soil screening level
ETD	Experimental Toxicology Division
FS	feasibility study
FTE	full-time equivalent
HELP	Hydrogeologic Evaluation of Landfill Performance
HSRC	Hazardous Substances Research Center
LOAEL	lowest-observed adverse effect level
LRPCD	Land Remediation and Pollution Control Division
LTG	long-term goal
LUST CA	Leaking Underground Storage Tank Corrective Action
MED	Mid-Continent Ecology Division
MNA	monitored natural attenuation
MNR	monitored natural recovery
MYIP	multi-year implementation plan
MYP	multi-year plan
NBH	New Bedford Harbor
NCEA	National Center for Environmental Assessment
NERL	National Exposure Research Laboratory
NHEERL	National Health and Environmental Effects Research Laboratory
NOAEL	no-observed adverse effect level
NRMRL	National Risk Management Research Laboratory

NTD	Neurotoxicology Division
ORD	Office of Research and Development
OSI	organism-sediment index
OSP	Office of Science Policy
OSRTI	Office of Superfund Remediation and Technology Innovation
OSWER	Office of Solid Waste and Emergency Response
PAH	polycyclic aromatic hydrocarbon
PBT	persistent bioaccumulative toxicant
PCB	polychlorinated biphenyl
PE	polyethylene
PES	particle entrainment simulator
PRB	permeable reactive barrier
RAGS	risk assessment guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RCT	research coordination team
RI	Remedial Investigation
RPCS	research planning and coordination staff
RPD	redox potential discontinuity
SF	Superfund
SPME	solid-phase microextraction
SPI	sediment profile image
SPMD	semipermeable membrane device
SQG	sediment quality guideline
tbd	to be determined
TEF	toxicity equivalence factor
TEQ	toxicity equivalents
TIE	toxicity identification evaluation
TRV	toxicity reference value
USGS	United States Geological Survey
WES	Waterways Experiment Station
WOE	weight of evidence

Introduction

Purpose and Scope

This document, the NHEERL Implementation Plan for Contaminated Sediments Research, describes the research that the National Health and Environmental Effects Research Laboratory (NHEERL) intends to perform in support of the Office of Research and Development's (ORD's) multi-year research plan (MYP) for contaminated sites research. ORD uses multi-year planning to chart the direction of ORD's research programs in selected topic areas for time periods extending up to ten years. Within EPA's Goal 3, *Preserve and Restore the Land*, two ORD multi-year plans (MYPs) have been developed: *Contaminated Sites* and *Resource Conservation and Recovery Act (RCRA)*. The *Contaminated Sites MYP* describes ORD's research supporting three Office of Solid Waste and Emergency Response (OSWER) trust fund programs for which research is authorized: Superfund (SF), Leaking Underground Storage Tank Corrective Action (LUST CA), and the Oil Spills Program. The ORD Contaminated Sites MYP has four long-term goal (LTG) areas: Contaminated Sediments, Ground Water, Soil/Land, and Multimedia.

ORD Contaminated Sediments Long-Term Goal

By 2010, improve the range and scientific foundation for contaminated sediment remedy selection options by improving risk characterization, site characterization and increasing understanding of different remedial options, in order to optimize the protectiveness to the environment and human health and the cost-effectiveness of remedial decisions.

To guide the implementation of strategic directions identified in the ORD MYPs, NHEERL develops multi-year implementation plans (MYIPs) for its major research programs. These plans are intended to ensure that NHEERL research addresses the key mission-related scientific issues that are raised in ORD MYPs in a way that maximizes benefit to the programmatic client, fully utilizes NHEERL capability, and integrates effectively with related ORD research programs. The scope of the NHEERL Contaminated Sites research program is limited to the Contaminated Sediments LTG in the ORD Contaminated Sites MYP. Consequently, this MYIP describes the NHEERL research program to support ORD's Contaminated Sediments LTG. The full text of the ORD Contaminated Sediments LTG is provided in the text box.

The annual performance goals (APGs) and associated annual performance measures (APMs) for this MYIP are those listed under the Contaminated Sediments LTG. This MYIP will provide the background and project descriptions for NHEERL's research program to achieve these APMs and APGs.

Process for Developing this Implementation Plan

Prior to FY2001, NHEERL did not have a contaminated sediment research program supporting Superfund. In FY2000, a small number of ORD FTEs (7.8) were reassigned to establish a NHEERL research program on contaminated sediments to support Superfund.

In the spring of 2003, an NHEERL contaminated sediment steering committee was created with the purpose of developing a focused NHEERL contaminated sediments research program, i.e., a program that was optimized in terms of responsiveness to client needs for ecological effects research related to contaminated sediments Superfund sites. The Steering Committee aims are as follows.

1. Establish a framework for NHEERL's Superfund contaminated sediments research program that sets a context and goals for the research consistent with (a) the Contaminated Sediments LTG 1 in the ORD Contaminated Sites MYP; (b) the ORD contaminated sediments focus groups (an across ORD sediment planning group organized by EPA's Office of Science Policy (OSP)); (c) the level of NHEERL effort available; and (d) the Laboratory's capabilities.
2. Identify critical paths necessary to achieve the goals set in the framework.
3. Articulate an MYIP that follows the critical paths to achieve the goals.
4. Monitor and review program accomplishments for purposes of communicating progress and revising plans when necessary.
5. Stimulate synergy between investigators and between divisions where appropriate.
6. Engage clients and collaborators to ensure responsiveness and linkages.
7. Suggest appropriate revisions to the ORD Contaminated Sites MYP when appropriate.

In May 2003, NHEERL's Steering Committee met at NHEERL's Atlantic Ecology Division (AED) in Narragansett, Rhode Island, with Mike Cook, director of the Superfund program (Office of Superfund Remediation and Technology Innovation (OSRTI)); Steve Ells, the OSRTI sediment team leader; and Leah Evison, the OSRTI member of the Waste RCT in order to start the development of NHEERL's Contaminated Sediment MYIP. At this meeting, a list of Superfund research priorities for ORD in seven research categories (ground water, sediment, soil/waste, multimedia and analytical, human health, and ecological research needs) was presented; and discussion of the research needs for the sediment category was initiated. The categorization of sediment research needs contained twenty-eight issues (Figure 1) grouped into three areas: (1) site characterization issues, (2) ecological and human health risk issues, and (3) development and evaluation of remedies. A complete listing of the entire Superfund program research priorities is provided in Appendix A.

The discussions at the May 2003 meeting of the NHEERL Steering Committee resulted in a narrowing of the 28 sediment issues to 10 issues (Figure 1). Although no formal criteria were developed by the Steering Committee for eliminating a research issue, the decisions were based on the appropriateness of the research issue to the mission and capabilities of NHEERL. NHEERL's research mission is centered on the effects of environmental pollutants and other anthropogenic stressors upon human and ecosystem health. Thus, research issues external to NHEERL's mission such as fate and transport of chemical contaminants, sediment stability and erosion, design and engineering of remediation options, ground water-sediment interactions, and analytical methods were eliminated. For research issues within NHEERL's mission, the narrowing process considered whether the issue required new research or could be answered with available data. The narrowing process eliminated several research issues because they could be answered with available data, and tentative plans were made for the development of fact sheets for Superfund on these issues. For each of the remaining ten NHEERL-related contaminated sediment issues, expanded descriptions were developed (Appendix B). These descriptions were then reviewed by the steering committee members with particular attention to the accuracy in reflecting the OSRTI need, relation to NHEERL mission, clarity of the text, and division management support for these topics as focal points for the next 5-6 years of research. In addition, the committee considered whether additional issues should be added.

Subsequently, in evaluating the expanded descriptions, the Steering Committee removed two of the ten remaining issues as possible focus areas (those related to dredging residuals and cleanup levels) because the issues were outside of NHEERL's mission. For the remaining eight issues, descriptions of the science tasks and the level of effort and/or time required to complete the research effort were prepared (see Appendix C and Figure 1).

The task descriptions of the science proposed for NHEERL research were then evaluated by the Steering Committee (Figure 1). Three issues were identified as highest priority from among the eight candidates for NHEERL research, while two issues were identified as high priority candidates (Appendix D).

The <u>highest priority</u> NHEERL research candidate issues were

- Residue-effect relationships: linking chemical residues in aquatic biota to levels of ecological risk to aquatic and aquatic-dependent wildlife;
- Non-Bioaccumulatives: development of appropriate remedial goals for non-bioaccumulative chemicals; and
- Resuspension: assessing the toxic and bioaccumulative effects of contaminated sediment resuspension.

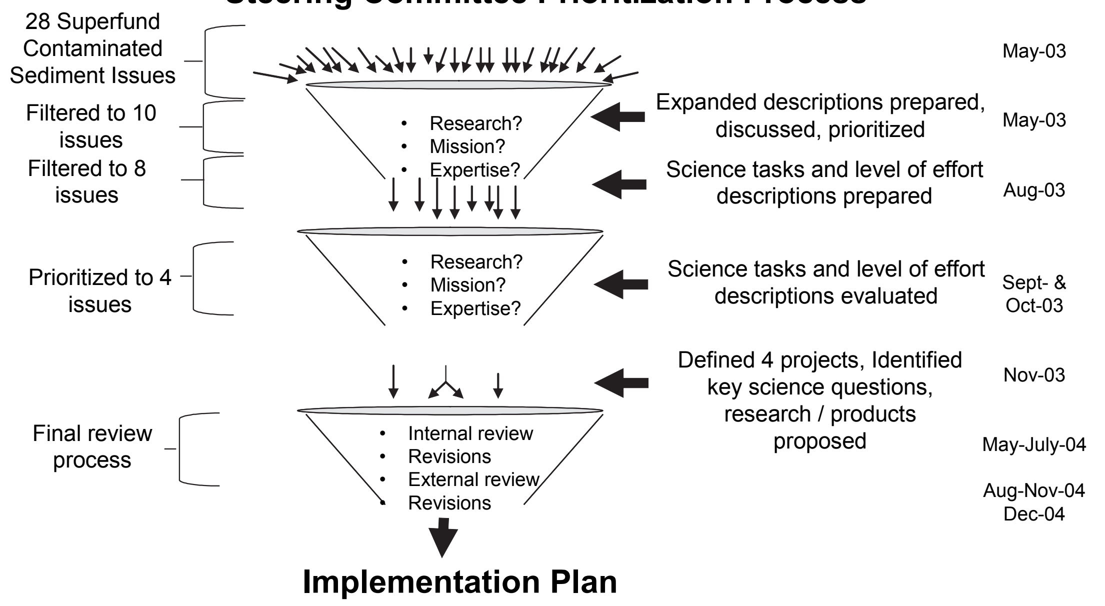
The <u>high priority</u> NHEERL research candidate issues were

- Predicting rates of recovery following remedial action: short-term impacts and
- Monitoring methods and protocols.

The <u>lower priority</u> NHEERL research issues were

- Predicting rates of recovery following remedial actions: long-term impacts;
- Developing sediment contaminant screening levels;
- Delineation of appropriate uses of total PCBs, and Aroclor-based and congener-specific PCB concentrations as the basis for assessing and managing risks from PCBs; and
- Establishing guidance on sampling biota and surface sediments at Superfund sites.

Figure 1: NHEERL Contaminated Sediments Program Steering Committee Prioritization Process



Note that in the deliberation of the Steering Committee, the research on the issue of predicting rates of recovery was sub-divided into two sub-issues: short-term impacts and long-term impacts.

In November 2003, the Steering Committee had detailed discussions (meeting in Duluth, Minnesota) on the highest priority research candidate issues and on the high priority issue of predicting rates of recovery following remedial action: short-term impacts. At the meeting, a previously assigned lead person presented (1) a summary of the issue; (2) a proposed list of research targets (products if we successfully accomplished our goals); (3) a list of precursors to achievement of the target; (4) a gap analysis for the issue based upon the state of the science; and (5) a statement of research question(s) addressing the issue along with milestones and steps. The Steering Committee discussed each item, building towards a consensus on the approach (or approaches) required to meet the research needs of the proposed issues/projects successfully. These discussions also covered the products and their timing for each issue.

Based upon the results from this meeting, project descriptions were prepared for the four highest priority sediment research issues (Figure 1) (also see "Research Project Descriptions" section). These projects are the following:

I. Integrative assessment of benthic effects from remedial activities at Superfund sites;

II. Linking residues to effects in aquatic and aquatic-dependent wildlife;

III. Linking chemical concentrations in water and sediment with residues in aquatic and aquatic-dependent wildlife; and

IV. Research to evaluate the release and bioavailability of contaminants associated with resuspended sediments and post-dredging residuals at Superfund sites.

For each research issue, the project description summarizes the issue, the state of the science, and the research needs. In addition, a list of the research targets and a description of the actual research steps and tasks required to complete the research are included. The project description also includes a section on technology transfer that describes how the products and research will be provided to OSRTI and identifies the resources (FTE and project-specific extramural dollar needs) required to accomplish the research. The resource summary is used to both ensure that the Steering Committee does not design a program requiring more resources than are available and to identify explicitly what can be done with additional resources. Finally, the project descriptions are completed with a critical path diagram, a product timeline, and references.

After the individual project descriptions in this document, a Program Summary and Management section is provided. This section summarizes the research program outputs and discusses how the research program will be managed within NHEERL.

In addition to the research projects, this MYIP includes two additional projects (Projects V and VI) describing the preparation of technical documents. Project V describes the preparation of Equilibrium Partitioning Sediment Benchmark (ESB) documents for several sediment contaminants including polycyclic aromatic hydrocarbon (PAH) mixtures, metal mixtures, and pesticides. Project VI discusses the preparation of a sediment Toxicity Identification Evaluation (TIE) document for use in freshwater and saltwater systems. Neither project involves active research, but each seeks to provide guidance on determining the contaminants causing adverse ecological effects at contaminated sediment Superfund sites.

The MYIP was reviewed internally and subsequently reviewed externally (Figure 1). The internal review included sign-off by the Steering Committee and by AED, MED (Mid-Continent Ecology Division of NHEERL), and OSRTI division directors (Appendix E) on the proposed research. Additionally, AED and MED management agreed to provide the resources for the defined efforts. External review of the MYIP was performed by four reviewers: one EPA Regional Superfund site manager and three scientists external to the Agency. Their comments were addressed by the Steering Committee and project leads such that modifications to the MYIP were made where appropriate. A "Response to Comments" document is available upon request to NHEERL.

Coordination across ORD

This MYIP provides a description of NHEERL's research program in support of ORD's Contaminated Sites MYP under EPA's Goal 3, *Preserve and Restore the Land*. The Contaminated Sites MYP for ORD is produced by the Waste Research Coordination Team (RCT) which consists of staff from ORD, OSWER, and EPA's Regions. The Contaminated Sites MYP identifies the vision and strategic directions for ORD research and lays out how the research programs of NHEERL, National Exposure Research Laboratory (NERL), National Center for Environmental Assessment (NCEA), and National Risk Management Research Laboratory (NRMRL) coordinate to accomplish the overall research goals in support OSWER.

The Office of Science Policy (OSP) coordinates, communicates, and tracks research by ORD that supports the program offices. For the Contaminated Sediments research area, OSP established eight (now reduced to five) Focus Groups for specific sediment issue areas; the Focus Groups are composed of OSP, ORD, and Superfund staff. These Focus Groups provide coordination and communication among ORD's laboratories. Additionally, the waste RCT allocates targeted funding (above base/infrastructure) via the Focus Groups for research on specific issues that are key to having ORD fulfill the vision and strategic directions identified in ORD's Contaminated Sites MYP.

The Superfund Program developed a list of research issues and needs (see Appendix A) that includes a series of non-sediment related research areas. These non-sediment research needs have been considered, evaluated, and addressed in the other three LTGs in ORD's Contaminated Sites MYP, i.e., Ground Water, Soil/Land, and Multimedia. For non-NHEERL aspects of the research needs for contaminated sediments, the NHEERL Contaminated Sediment Steering Committee includes representatives from ORD's other two laboratories (NERL and HRMRL) and NCEA. The research missions of these organizations cover non-NHEERL aspects of the research needs for contaminated sediments.

Research Project Descriptions

Research Questions for Projects I, II, III, and IV

In the process of writing the research project descriptions, the description for the research on residue-effect relationships was divided into two research project descriptions: Linking Residues to Effects in Aquatic and Aquatic-dependent Wildlife (Project II) and Linking Chemical Concentrations in Water and Sediment with Residues in Aquatic and Aquatic-Dependent Wildlife (Project III). The table below summarizes the research questions for each of the projects; detailed descriptions are provided on the following pages.

Research Questions

I. Evaluating benthic recovery monitoring methods

For assessing/predicting recovery of benthic communities at contaminated sediment sites:

- Will sediment profile image (SPI) data be more cost-effective than benthic enumeration techniques?
- Will SPI data be as accurate as benthic enumeration techniques?
- Does understanding near-bottom dissolved oxygen conditions increase prediction accuracy?

II. Predicting effects based on *in vivo* chemical residues

For estimating ecological risk at contaminated sediment sites:

- Do major gaps exist in PCB residue-effect data for aquatic and aquatic dependent wildlife?
- Will risk estimates be altered significantly by the manner in which PCB is expressed (e.g.total PCB, Aroclors, congeners, and dioxin-like congeners)?

III. Predicting residues based on chemical concentrations

For predicting bioaccumulation at contaminated sediment sites:

- Can bioaccumulation data, i.e.,biota-sediment accumulation factors (BSAFs) and bioaccumulation factors (BAFs), be extrapolated across ecosystems, species, and/or time using a hybrid empirical modeling approach?
- Will the accuracies and uncertainties of the hybrid predictions be similar to those obtained with dynamic time-variant bioaccumulation food web models?

IV. Evaluating off-site impacts from dredging

For resuspension of sediments during dredging at contaminated sediment sites:

- Do existing fate and transport models accurately predict dissolved concentrations?
- Will dissolved contaminants be released and transported?
- Will bioavailability of contaminants be increased temporarily?

Project I : Integrative Assessment of Benthic Effects from Remedial Activities at Superfund Sites

Summary of Issue

At contaminated sediment sites, the Superfund program must decide whether to leave the site alone or select a remedial option. These decisions are based in part on the relative risks to the environment and health posed by each alternative. Whatever decision is made at a site, the Superfund program must have an understanding of the potential risks to the ecosystem posed by the remedial action itself. Consequently, Superfund needs cost-effective, rapid methods to assess benthic effects before and after remedial actions (both spatially and temporally) and means to separate the effects of chemical contamination from other stressors on the benthic community. The objectives of the research are to (1) evaluate the sediment profile image (SPI) camera as a rapid and cost-effective tool to assess the short-term effects on and recovery of the benthic community after dredging at a Superfund site; (2) to evaluate and compare SPI data for benthic communities with more traditional grab/sieve metrics (e.g., benthic species enumeration); and (3) to investigate interactions between sediment contaminants and near-bottom dissolved oxygen concentrations and their relative influence on benthic community recovery.

Summary of the State of the Science

Two methods have been commonly used to assess the status of the benthic community, each with it's own advantages and disadvantages. The most traditional method, benthic organism enumeration, involves sediment collection and sieving after which the collected benthic organisms are identified and counted. This information has been used in many ways, including producing indices such as the benthic index of biotic integrity (B-IBI) developed for Chesapeake Bay (Weisberg et al. 1997). While sieving and counting benthic animals yields significant detailed information on species richness and biomass, it requires sediment collection and handling, is labor intensive, and is comparatively expensive and slow. Several of these characteristics present special problems at Superfund sites (e.g., extensive handling of contaminated sediment, cost).

Another method involves remote sensing of the benthos using SPI cameras (Rhoads and Cande 1971). This approach has also led to the calculation of several indices based on information taken from sediment profile images, such as benthic habitat quality (BHQ) (Nilsson and Rosenberg 1997) and the Organism-Sediment Index (OSI) (Rhoads and Germano 1982; 1986). Sediment profile imagery provides a rapid spatial assessment of the benthic community *in situ* and is relatively inexpensive after initial instrument acquisition costs. While these attributes can be very beneficial at Superfund sites, the camera images do not provide quantitative, comprehensive species counts.

The bulk of the existing studies utilizing SPI methods focus on benthic community recovery ("recolonization") following disposal of uncontaminated, fine-grained dredged material in estuarine or marine environments. Such disposal is quite comparable, in terms of benthic disturbance, to remedial actions such as dredging or capping: both essentially involve replacing an existing benthic substrate and associated biota with a new substrate that is initially devoid of organisms but that can become colonized over time. Therefore, literature is available that describes benthic successional patterns and responses following physical sea floor disturbance (see review by Hall 1994); and a significant number of studies specifically examined recolonization following dredging or dredged material disposal (see reviews by Newell et al. 1998; Bolam and Rees 2003).

Most past studies have utilized the traditional grab/sieving approach to evaluate benthic impacts and recovery following disposal or capping; but there are also some that have utilized SPI, either alone or in combination with grab/sieving (e.g., Valente et al. 2000; Valente and Fredette 2002). Most notably, the Corps of Engineers Disposal Area Monitoring System (DAMOS) has utilized SPI extensively for over 25 years as a cost-effective alternative to grab sampling in monitoring benthic impacts and recovery at dredged material disposal sites throughout New England (see Fredette and French 2004 and references therein). That being said, comparatively few studies have attempted to make a direct, explicit comparison between grab/sieving and SPI results obtained simultaneously to calibrate and validate the correlation, and even fewer have been conducted at Superfund sites (Fredette et al. 2002).

Diaz et al. (2002) compared the two methods directly in Chesapeake Bay and demonstrated that there were significant differences between them when classifying a particular station as having "stressed" or "good" habitat quality. The B-IBI, calculated with species enumeration data, was community-structure orientated with an emphasis on species identity and richness. The BHQ, calculated from image analysis of SPI data, was process oriented; the images recorded the end products of biological and physical processes that impact and structure the benthos (e.g., the presence of tubes, redox depth). Despite a large body of knowledge about both methods, there is still considerable debate over which metrics/indices to calculate from the data and how to best utilize both methods (e.g., alone or in combination) and their metrics. In addition, there are questions about the standardization and quality assurance of SPI images and their most appropriate use at Superfund sites.

Research Needs

Superfund needs rapid and cost effective tools that provide data appropriate for identifying and evaluating benthic quality. The question is whether the SPI approach provides enough information to adequately assess remedial effects and effectiveness as compared to the traditional enumeration procedures. We also recognize that both methods may be needed in combination (e.g., SPI for spatial coverage and sieving/counting for ground-truthing). Therefore, a study to directly compare the two methods at a Superfund sediment site would be useful.

Benthic community metrics, including but not limited to indices such as IBI and BHQ, will be comparatively evaluated to determine not necessarily which method is "best" (i.e., in a perfect world of unlimited resources and personnel, benthic enumeration is most comprehensive), but whether the SPI approach provides enough information to fill Superfund's requirement to document remedial effects and recovery at sediment sites given the realities of limited budgets and the need for timely decisions, etc.

In addition to evaluating the utility of the SPI camera, the proposed study will also address the question of what each benthic community indicator is reflecting or measuring. One advantage of any integrative indicator, such as benthic community, is that it incorporates the effects of multiple environmental conditions. In most aquatic systems, including those contaminated enough to be classified as Superfund sites, there is rarely only one stressor (e.g., contaminants) that affects the benthic condition. Contaminant stress to the benthos can be confounded by other processes, both anthropogenic (e.g., low dissolved oxygen from eutrophication) and natural (e.g., salinity gradients in estuaries, depositional/erosional processes in rivers). In the context of a regulatory program such as Superfund, it is especially important to understand exactly what an indicator is reflecting so that scientific and management assessments of remedial effects can be accurate and expectations about remedial recovery can be realistic. A drawback to both benthic assessment methods described above is the lack of a direct link between what they measure and the ability to partition observed effects among multiple stressors. Research is needed to elucidate these links and potentially confounding effects.

Proposed Research Targets

The specific objective of this research is to compare and evaluate the traditional grab/sieving method and the SPI camera method of benthic community assessment at a Superfund site. The research program will use traditional and innovative tools to understand the relationship between these metrics and sediment variables present at the site, both anthropogenic (i.e., PCBs, low dissolved oxygen) and natural (i.e., grain size, salinity, organic carbon). In addition, this research will evaluate the SPI camera as a rapid and cost-effective tool to assess the short-term effects on and the recovery of the benthic community after dredging. This effort will contribute towards our long-term goal to develop a predictive capability so that the timeframe to benthic recovery after dredging can be more accurately estimated.

Research Steps/Approaches

This research program will have three related tasks.

Task 1

SPI sampling will be conducted concurrently with benthic sampling that is already planned as part of the long-term monitoring program (Nelson et al. 1996) at the New Bedford Harbor (NBH) Superfund site. The purpose of the program is to document physical, chemical, and biological changes before, during, and after remediation. The study area encompasses large gradients of water depth, sediment type, and contamination level. One aspect of this monitoring program involves collecting sediment at 72 stations located throughout the upper, lower, and outer harbor areas (Figure 2). Three sediment collections have occurred to date: a baseline in 1993, after the Hot Spot remediation in 1995, and prior to planned remediation in 1999. These sediment samples were analyzed for 18 PCB congeners, 8 metals, sediment toxicity, organic carbon, acid volatile sulfide (AVS), grain size, and benthic species enumeration. Because the upper harbor remediation was delayed from 1999 to 2004, another round of sampling was conducted in Fall 2004.

Although SPI has been in continuous routine use as a benthic sampling technique for almost 25 years, one of the impediments to its more widespread acceptance has been skepticism on the part of many benthic ecologists who conduct studies that use the traditional grab/sieving approach. A SPI survey at each of these 72 stations will allow a direct comparison between SPI metrics and a suite of individual analyses that characterize benthic condition, including benthic enumeration data, sediment toxicity, and chemical and physical parameters. Traditional information from SPI images (depth of apparent redox potential discontinuity [RPD] layer, presence/absence of burrows) will be assessed as well as metrics such as color change. In addition, live video of the sediment surface during SPI sampling will be examined to augment SPI analyses. This data set should provide a sound basis for testing and validating the applicability of SPI to Superfund's need to assess the long-term recovery of a site over a large spatial area.

Due to fiscal constraints, the upper harbor dredging has been segmented into a number of dredge management units (DMUs). The first DMU is scheduled for dredging in Fall 2004. The long-term monitoring sediment sampling and initial SPI survey should be conducted prior to the start of dredging. The value of this research lies in the side-by-side comparison of the SPI and benthic enumeration for evaluating benthic impacts. It is our intention to repeatedly sample these sites to assess both temporal and spatial variability within a station.

<u>Task 2</u>

A second task will focus on determining how useful SPI technology is for examining the short-term effects of dredging on the benthos, as well as how fast the area is recolonized. The first DMU is scheduled to be dredged in Fall 2004. The EPA investigation on biological aspects will be complemented by the Army Corps of Engineers (ACE) extensive investigation in this DMU which will examine the physical and chemical aspects of the dredging (e.g., efficiency of the dredge, recontamination of the dredged area). Using the SPI camera, we will document the benthic recovery by collecting a specified number of SPI images in the DMU (in coordination with ACE's physical and chemical sampling) immediately before and after dredging. Because the dredging should end sometime in December and the upper harbor freezes over occasionally, it is difficult to specify the sampling frequency at this time. We propose to sample every two weeks initially as the literature indicates that estuarine recolonization should be rapid; however, sampling intervals may be modified depending on the results, degree of icing, and weather.

The spatial design of the SPI sampling will also attempt to evaluate whether there are "edge effects" (i.e., benthic recovery beginning first at the dredge area boundaries). We will conduct a parallel assessment in an adjacent un-dredged DMU to quantify any redeposition of sediment from the dredging operation and to compare the benthic community in the remediated and unremediated areas. Because of the projected lengthy time to completely remediate the site, we are cooperating with Region 1 in designing the sampling plan to also evaluate the deposition of residual contamination from dredging outside the dredge area. We will be sharing pre- and post-dredge chemistry data to correlate (if possible) with SPI images. This task should confirm hypotheses about recolonization rates, specifically at contaminated sediment sites.

<u>Task 3</u>

The final task is designed to investigate the effects of various stressors, primarily dissolved oxygen (DO), on the SPI metrics. Initially, three stations will be selected in New Bedford

Harbor for monthly monitoring beginning in early Spring 2005 and continuing until ice over. Monitoring will consist of a deployed hydrolab that records continuous water column salinity, temperature, and DO, as well as discrete benthic data collections using SPI camera images, video images, some benthic enumeration data, and sediment analysis for natural and anthropogenic chemicals and physical characteristics (e.g., excess molybdenum (Mo), grain size, organic carbon, toxic and crustal metals, PCBs, PAHs). Excess Mo accumulation in surface sediments will be investigated as a tool for determining the duration of any low DO events. Data on low DO extent and potential toxicant concentrations will be used to evaluate whether contaminant stress is the dominant cause of benthic community impairment in NBH. If a benthic community is primarily stressed by low DO, benthic recovery will differ in response to reducing contaminant concentrations from that in an area with adequate DO.

Experiments will be conducted in AED's DO system to further elucidate the relationship between the duration of low DO conditions and the formation of excess Mo under controlled conditions. In addition, we plan to calibrate the apparent RPD (using color change) measured by the SPI camera to actual RPD (using Eh). These laboratory measurements will be compared to similar field data that will be collected in cores at the three NBH monitoring stations. Task 3 (and associated products) will be refined based on examination of the first year's data collection.

Resources

It should be noted that the successful completion of Tasks 1 and 2 will be dependent upon the New Bedford Harbor long-term monitoring sampling and first DMU dredging occurring as currently scheduled. It is expected that future work will involve evaluating the applicability of methods developed in this research to additional Superfund sites to ascertain how consistently SPI metrics can be used to describe benthic condition. If the results are widely applicable, it would be advantageous to attempt to develop the ability to predict benthic recovery at dredging sites.

Year	Division	FTEs
2004	AED	2.50
2005	AED	2.50
2006	AED	2.50
2007	AED	2.50
2008	AED	2.50

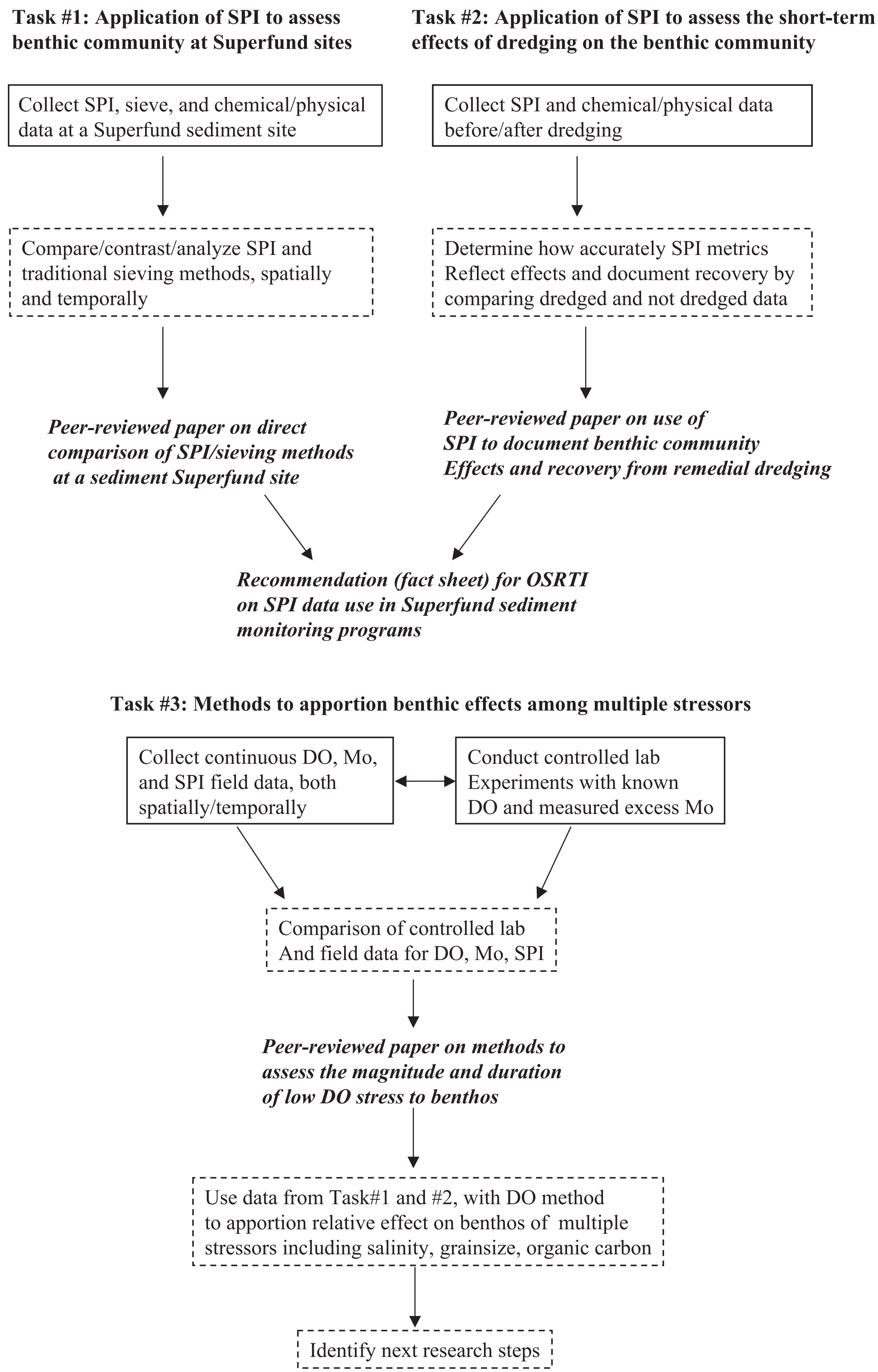
NHEERL Category D Needs

In addition to the personnel costs, benefits, supplies, equipment, etc., that are specifically associated by ORD with FTE and considered intramural resources, NHEERL uses ORD planning resources to pay laboratory indirect costs (called "ABC costs") and project-specific costs (called "Category D costs"). Listed above are the kinds of Category D needs associated with this project. Annual budget planning documents determine the dollar amounts needed.

Year	Division	Analytical Chemistry	GIS	Statistics	Field Support	Image Analysis
2004	AED					
2005	AED	yes		yes	yes	
2006	AED	yes	yes	yes	yes	yes
2007	AED	yes	yes	yes	yes	yes
2008	AED	tbd[a]	tbd	tbd	tbd	tbd

[a] *tbd = to be determined*

Critical Paths



Products

By 2008, provide assessment of the applicability of sediment profile imagery for monitoring effects of and recovery from dredging at a Superfund sediment site.*		FY08	NHEERL
	Report to OSRTI on the direct comparison of SPI/ sieving methods at a sediment Superfund site	FY06*	NHEERL-AED Barbara Bergen
	Peer-reviewed paper on direct comparison of SPI/ sieving methods at a sediment Superfund site	FY07*	NHEERL-AED Barbara Bergen
	Recommendation (fact sheet) for OSRTI on SPI data use in Superfund sediment monitoring programs	FY06*	NHEERL-AED Skip Nelson
	Report to OSRTI on the relationship between SPI and other environmental variables, particularly dissolved oxygen	FY06	NHEERL-AED Warren Boothman Laura Coiro
	Peer-reviewed paper on the relationship between SPI and other environmental variables, particularly dissolved oxygen	FY07	NHEERL-AED Warren Boothman Laura Coiro
	Peer-reviewed paper on use of SPI to document benthic community effects and recovery from remedial dredging	FY08*	NHEERL-AED Barbara Bergen

** Due dates dependent on NBH dredging occurring as currently scheduled*

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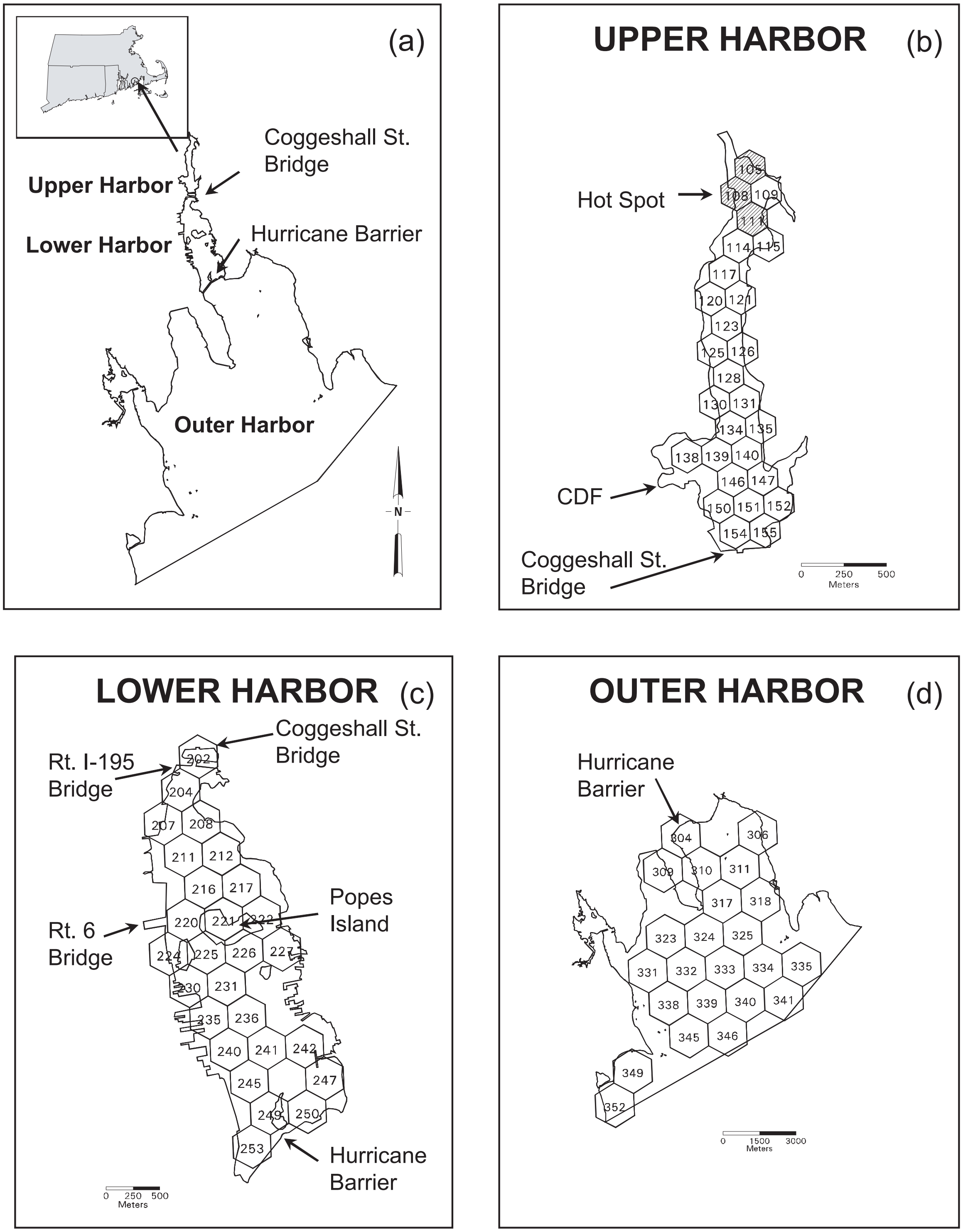
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Figure 2

Project II: Linking Residues to Effects in Aquatic and Aquatic-Dependent Wildlife

Summary of Issue

At contaminated sediment sites, the Superfund program must decide whether to leave the site alone (i.e., allow for natural recovery to occur), cap it, or dredge it. These decisions are based in part upon the relative risks to the environment and human health posed by each option. These risks, in turn, depend upon a variety of factors, including the toxicity of the chemicals of concern and the concentration of toxic chemicals likely to be found in the tissues of aquatic wildlife and aquatic-dependent wildlife. Based on an understanding of these factors, the Superfund program needs to develop critical residue values in target species for the chemicals of concern with the presumption that when the critical value or lower is achieved in the target species, the risks posed by contaminant releases from the site are acceptable. This project is focused on the first of these two factors.

For purposes of predicting toxicity for persistent bioaccumulative toxicants (PBTs)[1], chemical doses are best expressed in terms of chemical residues in tissues because chemical residues in tissues integrate doses received from all environmental exposure pathways (e.g., food, water, sediment) (McCarty and Mackay 1993). To provide well-informed projections of risk, the Superfund program must be able to assess the effects of chemical residues in the wildlife of interest based upon an understanding of the dose-response relationship for the chemical and organism. For aquatic and aquatic-dependent wildlife, species' sensitivities vary for a given chemical; in general, the dose-response relationships have similar shapes for organisms of the same family. To make remediation decisions, the Superfund program needs to be able to assess the survival, growth, and reproduction toxicity effects of chemical residues in aquatic and aquatic-dependent wildlife.

When Superfund assesses the relative risk of remediation options (i.e., to leave a site alone, cap it, or dredge it), inaccuracies in the assessment of the effects for chemical residues in organisms (and thus, populations and communities) will directly influence the decisions made concerning the remedial options. If the assessment of effects is based on inaccurate dose-response predictions, Superfund might select options which require too much or too little remediation as compared to the option which would have been chosen if the actual risks posed to the environment and human health were more accurately understood. Because remediation of contaminated sediments is often very expensive, Superfund wants and needs the assessment of effects on human health and on aquatic wildlife and aquatic-dependent wildlife to be highly accurate and precise so that contaminated sites can be remediated most cost effectively.

Superfund contaminated sediment sites are often physically and chemically complex ecosystems characterized by a variety of species, sediment types, and contaminants. In the face of this complexity, Superfund strives to be consistent in the manner in which it assesses risk and

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[1] The term "Persistent Bioaccumulative Toxicants (PBTs)" is used in a generic sense in the text.

evaluates risk management options. Such consistency can most readily be achieved when the determining variables and parameters are understood. From the perspective of providing consistency, the most problematic chemicals at Superfund contaminated sediments sites are PBTs because of their prevalence, toxicity, persistence, and bioaccumulative behavior. An additional challenge exists when the individuals responsible for making difficult decisions at Superfund sites do not have the opportunity to develop a detailed understanding of all the factors involved. When this is the case, the factors that affect the residue-effect assessment must be clearly and understandably delineated to on-site decision makers.

Summary of the State of the Science

Historically, aquatic toxicology has focused on understanding the relationship between water-based exposures and effects expressed using acute and chronic toxicity endpoints (e.g., for acute toxicity, see MED's fathead minnow database (ECOTOX 2003)). For most PBTs, there has been a historical under appreciation of the importance of dietary and maternal transfer (i.e., transfer of contaminants from the adult female to its eggs) exposure routes when performing laboratory tests. These additional exposure routes make it difficult to produce exposures (and resulting effects) which are truly representative of conditions occurring in the environment in the laboratory using water-only based exposures. Thus, measurements of acute and chronic toxicity for PBTs that are based on water-only exposures have provided less than satisfactory results because the chemical dose, when expressed as the concentration of chemical in water, does not represent the actual dose for the organism. In the last decade, our understanding of appropriate dose measures and effects endpoints for PBTs has increased greatly; and it is now recognized that for PBTs, the chemical residue in the organism (or one of its tissues) is the best measure of dose for predicting chronic toxicity (generally, reproductive endpoints) (McCarty and Mackay 1993).

We know how to develop the linkage between the concentration of chemicals in the organism (or one of its tissues) and the biological effects caused by the chemical residue when proper data exist for single chemicals and for mixtures of chemicals with common modes of action. The best examples of this linkage for PBTs are the chlorinated dibenzo-*p*-dioxins, chlorinated dibenzofurans, and planar PCBs (which all have the same mode of action). Toxicity equivalence factors (TEFs) have been developed for these chemicals and applied for fish, wildlife, and humans (Van den Berg et al. 1998). To properly develop these linkages, toxicity data with species specificity, end-point specificity, and dose-exposure consistency are required; and all three of these requirements must be consistent with the mode of action. Unfortunately, these requirements are fairly challenging to fulfill.

The scientific literature for toxicological data is composed of studies with an assortment of species, endpoints, and dosing regimes for individual chemicals. The variability and gaps in the available data result in large uncertainties in our understanding of residue-effects relationships and in the subsequent predictions made with them. An additional difficulty, beyond the issues associated with extrapolation and the filling of data gaps, is the lack of having data from the literature assembled and available so that one can develop and evaluate residue-effects relationships. Databases are being developed, e.g., the effect-residue database of Jarvinen and Ankley (1999) and the Environmental Residue-Effects Database (ERED) of US-Army Corps of

Engineers (accessible at www.wes.army.mil/el/dots); but additional data still need to be evaluated and incorporated into databases to facilitate the development and evaluation of residue-effects relationships.

Key gaps in our understanding of the linkage between the chemical residues in tissues (or organisms) and their resulting biological effects include the following:

1. Critical toxicity endpoints for single chemicals and mixtures of chemicals;
2. High quality residue-effects data for most PBTs;
3. For complex mixtures with numerous chemicals (e.g., toxaphene), how to quantify the residue in a toxicologically meaningful way across laboratory tests and ecosystems;
4. Techniques for extrapolating laboratory test data from one toxicological endpoint to another (e.g., from a growth endpoint to a fecundity endpoint);
5. Techniques for extrapolating endpoints for test species to Superfund receptor species; and
6. Translating biological effects on individuals to those manifested in populations.

Research Needs

The steering committee identified the following key scientific challenges upon reviewing the issue summary, state of the science, and gap analysis:

1. Consolidate existing toxicological knowledge and clarify data gaps;
2. Develop methods to establish biological effects with varying amounts and types of laboratory-derived toxicological data;
3. Extrapolate toxicological endpoints for laboratory test species to Superfund receptor species; and
4. Extrapolate from effects on individuals to effects on populations.

Proposed Research Targets

After assessing the research needs relative to the level of effort required to achieve them and the expertise and resources available, the steering committee concluded that the research needs required more resources than are available. Additionally, the steering committee concluded that research needs were sufficiently general in nature that ongoing research elsewhere may provide significant insights for specific chemicals and issues. Given this assessment, the steering committee identified the following research target for this project:

> Consolidate existing knowledge and clarify data gaps by assembling and evaluating a database of up-to-date PCB residue-effects data for aquatic and aquatic-dependent species.

The rationale for selecting this target included the following considerations:

1. PCBs are chemicals of high concern and interest for Superfund;
2. There is much discussion and controversy existing about how to evaluate or express PCB mixtures, e.g., total PCB, total Aroclors, homologs, and sum of the dioxin-like PCBs (toxicity equivalents, or TEQs);

3. Given the limited resources for NHEERL's Goal 3 effort, this target would not require laboratory toxicity testing and analytical chemistry support which, if done, would require more resources than available;
4. This effort would build upon the existing residue-effects database of Jarvinen and Ankley (1999), a database assembled at MED, and US-Army Corps of Engineers' ERED database;
5. MED has expertise in similar data compilation and evaluation efforts, e.g., the development of EcoSSL (ecological soil screening levels) for Superfund; and
6. Supplemental resources via ORD's Contaminated Sediment Focus Group 1: Fate and Transport Modeling and Bioaccumulation are potentially available; and MED via its AQUIRE and ECOTOX database efforts has the ability to contract out the assembling of the PCB database with these funds.

Research Steps/Approaches

To achieve the above target, two steps must be taken: (1) assemble a database of PCB residue-effects data for aquatic and aquatic-dependent species and (2) evaluate assembled data on PCB residue-effects for aquatic and aquatic-dependent species.

<u>Step 1: Assemble/consolidate a database of PCB residue-effects data for aquatic and aquatic-dependent species</u>

The following tasks are needed in order to assemble a PCB residue-effects database for aquatic and aquatic-dependent species. First, a literature search strategy must be developed. The search strategy will be built from existing literature search strategies used for the Eco-SSLs effort performed at MED. Second, the actual search needs to be conducted and the citations downloaded. Third, the citations/abstracts from searches need to be skimmed through so they can be ranked according to their potential usefulness based upon a checklist for minimum data needs. Fourth, selected data must be abstracted and entered into the database. This process will build upon the existing residue-effects database of Jarvinen and Ankley (1999) and ERED. Thus, in the third task, the checklist process would determine if a citation is already included in one of these databases. In assembling and consolidating the database, multiple measures of PCBs will be included; e.g., total PCB, total Aroclors, sum of the dioxin-like PCBs (TEQs), etc., In addition, the type of analytical method used for PCB quantification will be recorded. The database effort will be focused on freshwater and marine species which respond to dioxin-like toxicity, i.e., aryl-hydrocarbon-receptor-(AhR-)mediated toxicity, because PCB toxicity occurs via this receptor. Invertebrate species, in general, do not appear to have this receptor (Hahn et al. 1994) and are considered to be much less susceptible to AhR-mediated toxicity. Thus, invertebrate species will not be considered in the current data compilation effort.

To stimulate this effort, we obtained FY04 funds via ORD's Focus Group 1. These funds were placed onto a MED contract which supports the database efforts for AQUIRE and ECOTOX databases. Because this effort is similar to those being performed by the contract for AQUIRE and ECOTOX, this effort should move forward quite quickly.

Step 2: Evaluate assembled PCB residue-effects data for aquatic and aquatic dependent species
To evaluate the PCB residue-effects data, a number of approaches will be taken. First, we will determine the overall consistency within and among species for the data. We propose assembling no observed adverse effect levels (NOAELs) and lowest observed adverse effect levels (LOAELs) for biochemical, behavior, physiology, pathology, reproduction, growth, and mortality endpoints. These values will be compared for individual species where adequate data exist and across species to assist in evaluating data quality and variability. We also plan to examine the dose-response curves by comparing the shape, steepness, etc., of the curves. The prior comparisons are similar to those used by Superfund in developing EcoSSLs (see http://www.epa.gov/ ecotox/ecossl/SOPs.htm). Second, we will perform PCB ecological risk predictions using congener-specific, dioxin-like PCBs (TEQ), total PCB, homolog, and Aroclor exposure/dose measurements or predictions to determine comparability of the eco-risk predictions. These comparisons will help us evaluate how divergent estimates of risks are for different expressions of PCBs. It is anticipated that these assessments would be performed for Superfund sites where the appropriate data are available, and expressions of risk would be evaluated on a variety of endpoints such as critical residues in fishes and other organisms or sediment clean-up levels. Further definition of the assessment, comparison tools, and techniques will occur as the data are assembled and consolidated because these tools and techniques will be somewhat dependent upon the actual data available. Third, we will clearly define data gaps and deficiencies for PCBs so that future research activities can be optimally focused.

Among the outcomes from the evaluation effort on the PCB residue-effect data are the methods, tools, and techniques developed for screening and evaluating the toxicity data as well as for deriving residue-effect relationships with varying amounts and types of laboratory-derived toxicological data. These techniques and tools will provide a starting point from which to move beyond the PCBs to other PBTs and derivation of their residue-effects relationships for aquatic and aquatic-dependent species.

Technology Transfer

Transfer of research results from this effort will occur through a variety of mechanisms. First, peer reviewed report(s) on the evaluations of the PCB residue-effects data will be written and published. These reports will cover the (1) overall consistency within and among species for the PCB data, (2) data gaps and deficiencies for the PCBs, (3) comparisons of residue-effects relationships based on different measures of PCB, (4) comparability of eco-risk predictions using different expressions for PCBs, and (5) possibly, methods and techniques for screening and evaluating toxicity data for residue-effect relationships. Second, the PCB residue-effects database will be made available to Superfund. Additionally, after consultation with Superfund, processed outputs or tables of data from the database will be developed for use by Superfund. Third, educational seminars will be provided in consultation with Superfund about their format and content. The content of the seminars will cover the overall consistency of the PCB residue-effects data, data gaps and deficiencies, and comparability of eco-risk predictions. These seminars could be held within the ORD-OSRTI seminar series, Superfund's Environmental Risk Assessment Forum (ERAF) semi-annual meetings, or through some other to-be-determined forum. Fourth, in cooperation with Superfund, appropriate fact sheets will be written.

Resources

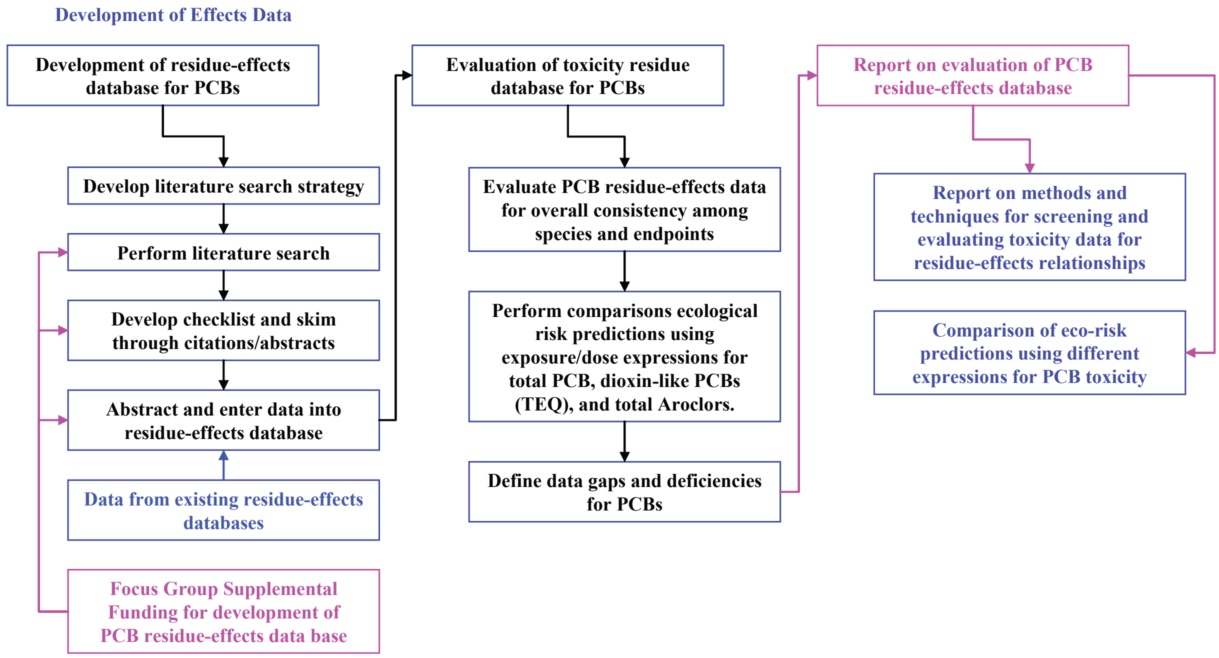
Year	Division	FTEs
2004	MED	0.25
2005	MED	0.25
2006	MED	0.25
2007	MED	0
2008	MED	0

NHEERL Category D Needs

In addition to the personnel costs, benefits, supplies, equipment, etc., that are specifically associated by ORD with FTE and considered intramural resources, NHEERL uses ORD planning resources to pay laboratory indirect costs (called “ABC costs”) and project-specific costs (called “Category D costs”). Listed below are the kinds of Category D needs associated with this project. Annual budget planning documents determine the dollar amounts needed.

Year	Division	Supplemental Funding	ECOTOX
2004	MED	yes	yes
2005	MED		yes
2006	MED		yes
2007	MED		
2008	MED		

Critical Path



Products

By 2008, provide hybrid modeling approaches using empirical field data and bioaccumulation models to extrapolate BAFs and BSAFs for PBTs across ecosystems, species, and time.		**FY08**	**NHEERL**
	Provide report on the evaluation of the PCB residue-effects database	FY06	NHEERL Lawrence Burkhard

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Project III: Linking Chemical Concentrations in Water and Sediment with Residues in Aquatic and Aquatic-Dependent Wildlife

Summary of Issue

At contaminated sediment sites, the Superfund program must decide whether to leave the site alone (i.e., allow for natural recovery to occur), cap it, or dredge it. These decisions are based in part upon the relative risks to the environment and human health posed by each option. These risks, in turn, depend upon a variety of factors, including the toxicity of the chemicals of concern and the concentration of toxic chemicals likely to be found in the tissues of aquatic wildlife and aquatic-dependent wildlife. Based on an understanding of these factors, the Superfund program needs to develop critical residue values in target species for the chemicals of concern with the presumption that when the critical value or lower is achieved in the target species, the risks posed by contaminant releases from the site are acceptable. This project is focused on the second of these two factors.

The relationships between exposure, accumulated chemical dose, and toxic effect or response must be linked in order to predict toxicity. Chemical doses are best expressed in terms of chemical residues in organisms (or one of its tissues) because these values integrate doses received from all environmental exposure pathways (e.g., food, water, sediment) (McCarty and Mackay 1993). Depending upon the effect and species, chemical residues might be expressed using different bases, e.g., residues in eggs or in liver, for different chemicals. To provide well-informed projections of risk, the Superfund program needs to accurately predict the residues of chemicals in the wildlife of interest, and these predictions must be based upon an understanding of the relationship between chemical properties and concentrations in water, sediment, and biota. For aquatic and aquatic-dependent wildlife, chemical residues in organisms vary as a function of numerous factors. These factors include the nature of the chemical, the chemical concentrations in sediment and water, the exposure duration, and the nature of the organism of interest and its food web. Consequently, to make remedial decisions, the Superfund program needs methods to predict the chemical residues in tissue that would result from different chemical concentrations in sediment and water.

When Superfund assesses the relative risk of remediation options (i.e., to leave a site alone, cap it, or dredge it), inaccuracies in the assessment of the effects for chemical residues in organisms (and thus, populations and communities) will directly influence the decisions made concerning the remedial options. If the assessment of effects is based on inaccurate dose-response predictions, Superfund might select options which require too much or too little remediation as compared to the option which would have been chosen if the actual risks posed to the environment and human health were more accurately understood. Because remediation of contaminated sediments is often very expensive, Superfund wants and needs the assessment of effects on human health and on aquatic wildlife and aquatic-dependent wildlife to be highly accurate and precise so that contaminated sites can be remediated most cost effectively.

Superfund contaminated sediment sites are often physically and chemically complex ecosystems characterized by a variety of species, sediment types, and contaminants. In the face of this complexity, Superfund strives to be consistent in the manner in which it assesses risk and evaluates risk management options. Such consistency can most readily be achieved when the determining variables and parameters are understood. From the perspective of providing consistency, the most problematic chemicals at Superfund contaminated sediments sites are PBTs because of their prevalence, toxicity, persistence, and bioaccumulative behavior. An additional challenge exists when the individuals responsible for making difficult decisions at Superfund sites do not have the opportunity to develop a detailed understanding of all the factors involved. In this case, bioaccumulation of PBTs in the aquatic food chain and the factors which affect it must be clearly and understandably delineated to on-site decision makers.

Summary of the State of the Science

The link between chemical concentrations in water and sediment with residues in aquatic and aquatic-dependent wildlife has been an area of active research for the past 2 decades; consequently, much is known about this area. The relationship between chemical concentrations in water and those in biota are defined as bioaccumulation factors (BAFs); the relationship between chemical concentrations in sediment and those in biota are defined as biota-sediment accumulation factors (BSAFs). Bioaccumulation of PBTs in aquatic food webs (and hence BAFs and BSAFs) is primarily a function of three ecosystem properties and two chemical properties.

Major determinants of bioaccumulation for PBTs in aquatic food webs:

Ecosystem Properties:

1. Sediment-water column chemical disequilibrium (Π_{socw}/K_{ow}) where Π_{socw} = sediment-water column chemical concentration quotient;
2. Benthic-pelagic composition of the food web; and
3. Length of the food web (trophic level).

Chemical Properties:

1. Hydrophobicity (K_{ow}) and
2. Rate of metabolism of the chemical in the organism and in its food web (Burkhard et al. 2003a).

Food web models that consider these processes are available for predicting chemical residues (Gobas 1993, Thomann et al. 1992). For steady-state solutions, the model predictions are generally within a factor of 2-3 of mean measured values. Additionally, these models can be solved for dynamic conditions (i.e., varying concentrations of chemicals in water and sediment change over time) and can include multiple trophic levels and a variety of benthic and pelagic organisms. Nevertheless, food web models have limitations which include the following:

1. poor accuracy for highly hydrophobic chemicals, $K_{ow} > 10^7$;
2. require detailed calibration in order to have predictive power;

3. detailed (often unavailable) food web structure and composition; and
4. are not appropriate for polar organic chemicals.

Metabolism of chemicals can be described mathematically within food web models as an additional loss process (k_m), but applications of existing food web models to metabolizable chemicals has been extremely rare. In nearly all applications of food web models, km is set equal to zero (Burkhard 1998); and, when metabolism is significant, the zero assumption underestimates the degradation/loss rate of the chemical in the organism and/or its food web.

Accumulation of nonionic organic chemicals in fish and other aquatic organisms is controlled by the lipid content of the organism (Mackay 1982). Thus, lipid normalization of chemical residues reduces the variance of concentrations of chemicals among individuals. The variance of concentrations of chemicals in sediment and the water column can be minimized by correcting for bioavailability (normalizing for organic carbon in the sediment and expressing chemical concentrations on the basis of their concentration in the freely dissolved form; DiToro et al. 1991, Burkhard et al. 2003b). These reductions in variances translate directly into reductions in variances of BAFs and BSAFs (Burkhard et al. 2003b) that are used to predict chemical residues in fish and other aquatic organisms.

Key gaps in our understanding of the linkage between the chemical concentrations in the tissue (or organism) and those in the environment include the following:

1. While approaches to field measurement of BSAFs and BAFs are available (Burkhard 2003c), techniques generally are not available for predicting how field-measured BAFs and BSAFs (measured under one set of ecological conditions, i.e., chemical disequilibrium, and food web composition and organism trophic level) change when a different set of ecological conditions develop in the ecosystem;
2. Field-measured BSAFs and BAFs are limited; these limitations include number of chemicals, aquatic organisms, ecosystem types, and ecosystem conditions even though a database is available (ERDC, see http://el.erdc.usace.army.mil/dots/);
3. Techniques for extrapolating BSAF data across ecosystem and species are not available;
4. Rates of metabolism to use in food web models are, for all practical purposes, nonexistent; and
5. Prediction for very complex chemical mixtures where not all individual components can be quantified (e.g., toxaphene) is very difficult.

Research Needs

Based upon the issue summary, state of the science, and the gap analysis, the following key scientific challenges have been identified.

1. Develop an approach to describe bioaccumulation of PBTs in aquatic food webs that enables non-bioaccumulation experts to easily understand the processes and conditions that control bioaccumulation;

2. Extend this approach to address the issues and uncertainties encountered when extrapolating bioaccumulation data across ecosystems, species, and time;
3. Broaden the range of chemical and ecosystem properties that can be addressed, i.e., the chemical's rate of metabolism and hydrophobicity (K_{ow}), ecosystem conditions of food web structure, organism trophic level, and sediment-water column concentration quotient (Π_{socw})); and
4. Validate approaches for conditions that are relevant to Superfund sites.

Proposed Research Targets

The steering committee identified the following research targets for this project after assessing research needs, the level of effort required to achieve them, and the expertise and resources available:

1. A methodology to extrapolate bioaccumulation data (BAFs/BSAFs) across ecosystems, species, and time for PBTs;
2. Demonstrations of applicability of BAFs/BSAFs for predicting ecological risks.

Research Steps/Approaches

To achieve these targets, three major steps must be taken:

1. Generation/assembly of high quality data sets,
2. Development of extrapolation techniques, and
3. Validation.

Overview of Research Steps 1, 2, and 3

The first two research steps are linked. The first step will assemble high quality bioaccumulation data sets from Lake Michigan and existing Superfund sites. The second step will use this data in developing the hybrid BSAF/BAF extrapolation approach and is composed of seven tasks:

Task 1: Develop theoretical/conceptual framework for performing the hybrid extrapolations.

Task 2: Determine the level of complexity required with the food web models for predicting the relative differences in bioaccumulation.

Task 3: Determine the minimum data quality requirements for the extrapolation process.

Task 4: Determine how to account for metabolism processes and their effects in the hybridBSAF/BAF extrapolation approach.

Task 5: Develop whole organism rates of chemical metabolism using field data; these results will feed back into Task 4.

Task 6: Evaluate the hybrid approach in field situations for prediction deficiencies and biases.

Task 7: Develop a software package (Visual Basic, Excel in-add or something else) which will perform the hybrid calculations.

The third step, Validation, will use data from a variety of Superfund sites to define the accuracy and precision as well as the usefulness of the approach developed in the second step.

Step 1: Generation/assembly of high quality data sets
In order to develop techniques to extrapolate bioaccumulation data across ecosystem, species, and/or time, data sets for individual compounds (and not mixtures) such as the individual PCB congeners, *p,p*'-DDT, or *p,p*'-DDE are required for a variety of different ecosystems, e.g., streams, rivers, lakes, reservoirs, wetlands, marshes, tidal estuaries, freshwater and marine harbors, and large coastal ecosystems. Based upon MED's experiences in generating chemical residue data for the Lake Michigan ecosystem (Burkhard et al. 2004), neither MED, nor NHEERL as a whole, has enough resources (within this area) to generate data needed for a database because this effort would require analyzing hundreds of fish, sediment, and water samples from a large variety of ecosystems. However, Superfund, as part of the Remedial Investigation/Feasibility Study (RI/FS) for each site, has been and will be performing such analyses. A detailed consideration of data requirements expected for Superfund sites resulted in the above table where importance of the data need was identified and ranked.

The ranking process considered the state of knowledge, general data availability for Superfund sites, and the ability to increase the scientific understanding of bioaccumulation processes with the collected information. The highest ranked parameters in the table are those required for calculating BSAFs because the ability to calculate BSAFs for a Superfund site would be the

Parameter		**Rank**
Congener-Specific PCB or DDT data:	fish	1°
	sediment	1°
	water	2°
Sediment TOC		1°
Structure/Composition of food web		2°
Lipid content of fish		1°
Knowledge of the spatial and temporal associations among fish, sediment, and water samples		1°
Loading history of the chemical		2°

minimum requirement for inclusion of the data into the database. Other parameters (i.e., the importance of having concentrations of chemicals in water, the composition/structure of the food web, and loading history for the chemicals of interest) were ranked lower because they are not required for calculating BSAFs.

Site measurements for the lower ranked parameters would be very useful for interpreting the finer differences among BSAFs. Although concentrations of chemical in water are ranked lower, concentrations of chemicals in water are critical for making bioaccumulation predictions when predictions are made from chemical concentrations in sediment and water (Burkhard et al. 2003a). There is too much uncertainty in the predicted residues if predictions are made using only either the chemical concentration in the sediment or the chemical concentration in the water. In this effort, we will have, at a minimum, the concentrations of chemicals in the sediment and fish. With this data alone, a set of high quality BSAFs across a wide variety of Superfund sites can be assembled. Additionally, BSAFs are not very sensitive to changes in the sediment-water column chemical disequilibrium; thus, small differences in the sediment-water column chemical disequilibrium among Superfund sites would not cause large errors when evaluating across ecosystem extrapolation techniques when only BSAFs are available.

The composition and structure of the food web information is also ranked as a lower priority. In most ecosystems and for most common species, reasonable estimates can be made or obtained from local fisheries experts if this information is not available for a Superfund site of interest. The third parameter given a lower ranking is the chemical's loading history to the ecosystem. For most Superfund sites with contaminated sediments, inputs of the chemicals of concern to the ecosystem have been stopped for some time. These sites can be considered to be in a "pseudo-steady-state" condition in which the chemical disequilibrium is declining slowly over time. This condition is a reasonable assumption for most Superfund sites and provides useful measured BSAFs. Although having loading information would be helpful in evaluating the measured BSAFs, given the above considerations, it was felt that this information was not essential for the assembling a useful BSAF database to cover a wide variety of Superfund sites.

The first research effort for accomplishing this target (Step 1: Generation/assembly of high quality data sets) is an in-house effort to develop a high quality data set from the Lake Michigan ecosystem. This effort builds upon the EPA's Lake Michigan Mass Balance Study [http://www.epa.gov/glnpo/lmmb/project.html] in which considerable resources were expended to obtain much of the required ancillary data, e.g., diets of individual fish species, sedimentation rates, and spatial and temporal variabilities in chemical concentrations. This in-house effort will result in a very high quality data set of concentrations of chemicals in all the components of the food web, in the sediment, and in the water column with all of the required ancillary data, e.g., lipid contents of the biota, organic carbon contents of the sediments, diets of the forage and piscivorous fishes, and sedimentation rates. Development of the data set will be accomplished using sediment, water, and biota samples from the Lake Michigan ecosystem by analyzing for PCBs, PCDDs, PCDFs, and PAHs using stable isotopes and mass spectrometry. Biota samples will span the entire food web and will include forage fishes (i.e., rainbow smelt, alewife [two size classes], bloater chubs [two size classes], deepwater sculpin, and slimy sculpin), piscivorous fish (lake trout), benthic invertebrates (diporeia), and plankton. One of the most significant analytical challenges for this effort is to measure the concentrations of PCDDs and PCDFs in water column samples where concentrations for these chemicals are estimated to be in the range of 0.1 to 5 fg/L in the dissolved phase, i.e., water after filtration using a 0.7 µm glass fiber filter. In order to obtain adequate chemical for mass spectrometry detection, 1,000 L water samples were collected and extracted using a continuous flow liquid-liquid extractor (Goulden extractor).

For this high quality data generation effort using the samples from the Lake Michigan ecosystem, many of the chemical analyses have been completed. On-going work includes the measurement of PCDDs and PCDFs in forage fish and PAHs in both forage and piscivorous fishes. Chemical analyses for the PCBs, PCDDs, and PCDFs will be completed in FY05; and with this data, a data set of BAFs and BSAFs will be determined for the fish species. This data set will have lower uncertainties than other data sets because all data will be measured on the same fish samples for the PCBs, PCDDs, and PCDFs with high resolution mass spectrometry. The co-measurement of all analytes eliminates the biases from measurements performed on different fish samples (i.e., one set of samples used for the PCBs and another for the PCDDs and PCDFs); and high resolution mass spectrometry increases the specificity of the chemical analyses. The commonly used analysis technique of gas chromatography with electron capture detection detects all chemicals containing electronegative elements (e.g., halogens, oxygen, sulfur, and nitrogen); whereas high resolution analysis can detect specific ions with mass differences of 0.032 amu at a mass of 320.000 amu ($M/\Delta M$ = 10,000). We estimate that the overall uncertainties in the Lake Michigan data set will be smaller, at a minimum, by approximately a factor 2½ over those observed by Oliver and Niimi (1988) based upon the tetra-, penta- and hexa-PCBs for the sediments. This difference does not include the temporal disconnects in the Oliver and Niimi (1988) data set among the collection dates for the forage fish, piscivorous fish, plankton, water and sediment samples. Sampling dates span the timeframe of 1981 through 1986. Therefore, differences in uncertainties are probably much larger than the 2½ fold factor; factors may rise to a 10-fold difference.

The second research effort for accomplishing this target (Step 1: Generation/assembly of high quality data sets) will consist of the building of data sets of BSAFs and BAFs from Superfund sites. This effort will involve culling through numerous Superfund RI/FS reports to find data of adequate quality and certainty to build the database. In general, RI/FS reports are large (multiple large 3-ring folders with hundreds of data tables); and the task of culling through the reports will take some time. For more recent RI/FS reports, site reports are available on CD-R. However, for most of the sites, the data are available only in paper copy; and inputting (scanning when possible or hand entry) and checking data will require some effort. The limitations of Superfund's RI/FS reports are anticipated to fall in the following areas: (1) an insufficiency of ancillary data (such as lipid contents of fishes and other aquatic organisms, organic carbon contents of the sediments, and dissolved and particulate organic carbon in the water column); (2) uncertainty in determining the overlap of the fish home range and the locations of sediment and water column samples for the site; and (3) the lack of measurements for chemicals with low concentrations in water column. Water column measurements are often not performed at Superfund sites having contaminated sediments because only sediment and fish data are needed to calculate the BSAFs that are used for predicting residues in the fish. Emphasis will be placed on assembling data sets which span the ranges of conditions and chemical classes that occur at Superfund sites rather than on simply assembling all available data.

Assembling BSAF and BAF data is not a small task. To help in this process, MED will work in coordination with the Superfund program office. Where possible with on going RI/FSs, MED will work with Superfund to have appropriate measurements performed so that these data sets can be included into the BSAF/BAF database as well. Additionally, MED will/has requested funds via ORD's Contaminated Sediment Focus Group 1 for the data assemblage and compilation effort (see "Resources").

In this effort, we would like to obtain a minimum number of BSAF/BAF data sets (e.g., 5 to 6) that span a variety of different ecosystems conditions and chemical parameters for adequate statistical comparisons in the subsequent analyses and calculations (see table below). This table is based upon the major determinants of bioaccumulation of PBTs in aquatic food webs (Burkhard et al. 2003a) and reflects conditions and properties which would strongly influence the bioaccumulation of PBTs in different ecosystems. Although we target obtaining data sets with the above ecosystem conditions and chemical parameters, we will obtain as many data sets as possible given the availability of appropriate data. With these data sets, we will assess extrapolation errors and uncertainties using the developed theoretical framework. Further, we will determine the sources of the extrapolation errors and uncertainties (see Step 2). With this information, we address the question of whether the extrapolation errors and uncertainties are good enough, e.g., whether the extrapolation errors are within a factor of 2; and we will identify additional data sets that may be required for further refinement. Demonstrations of the usefulness and applicability of the extrapolation technique to a large number Superfund sites would lend tremendous support to the validity of the "hybrid modeling" approach for extrapolating BSAF and BAF data (see Step 2). Therefore, acquisition of additional BSAF/

Range of Ecosystems Conditions and Chemical Parameters
Ecosystem Conditions

1. Simple and complex food web structures
2. Cold and warm water conditions
3. Species with highly benthic and highly pelagic dietary preferences
4. Fresh and salt water
5. Variety of sediment-water column disequilibriums (Π_{socw} / K_{ow})

Chemical Properties

6. Variety of chemical classes including metabolizable chemicals
7. Variety of chemical hydrophobicities (K_{ow})

BAFs data sets would greatly benefit this research effort.

Step 2: Development of extrapolation techniques

Development of techniques for extrapolating BSAF/BAF data between times, sites, ecosystem conditions, species, and combinations thereof requires an understanding of the fundamental processes controlling the extent of bioaccumulation at individual sites. Past research has demonstrated that corrections for lipid content of the organisms and chemical bioavailability (i.e., freely dissolved concentrations of the chemical in the water column and concentrations in sediments normalized to organic carbon) can greatly reduce variances of concentrations of chemicals in fish and sediments and in the variances of BAFs across ecosystems (Figure 3) (Burkhard et al. 2003b). Further, data from MED's research on Lake Michigan (Figure 4) and from preliminary comparisons (not shown here) of BSAFs suggest that BSAFs are consistent with each other within and across ecosystems. The within-ecosystem consistency is illustrated using BSAF data for lake trout from southern Lake Michigan (Figure 4).

The demonstrated consistency of BSAFs (as well as BAFs), as illustrated in Figure 4, is generally unappreciated by the general scientific community and needs to be communicated to the users of bioaccumulation data. Preliminary comparisons of BSAFs across ecosystems (data not shown) based upon data from the literature suggests that between-ecosystem relationships for BSAFs can be established. These comparisons are difficult because the data used for deriving the BSAFs are not always collected for the purposes of determining BSAFs. The number and types of ecosystems for which BSAFs are available in the scientific literature are limited. The lack of high quality BSAFs for a variety of well characterized ecosystems is precisely the need addressed by Step 1 of this project.

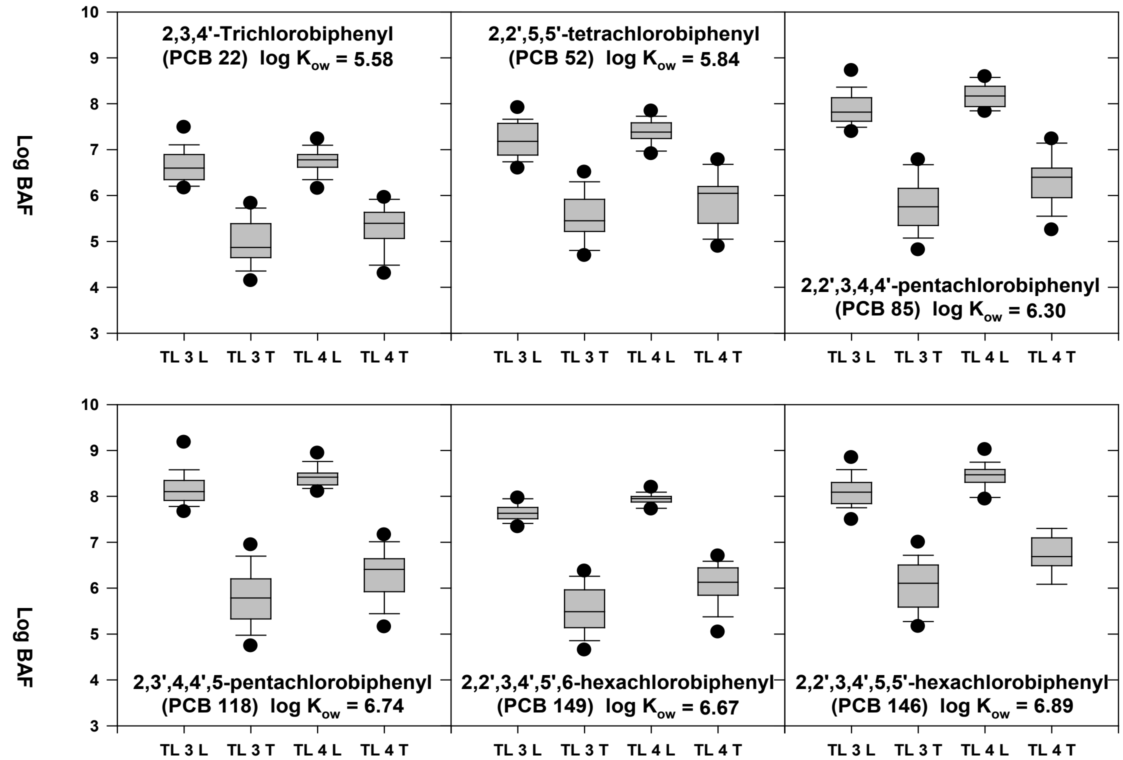


Figure 3. *Comparison of log BAFs based upon concentrations of chemical in tissue (wet weight basis) and water (total chemical in bulk water) to log BAFs based upon concentrations of chemical in tissue (lipid basis) and water (freely dissolved basis) for fishes from trophic levels 3 and 4 from Green Bay, Hudson River, and Lake Ontario ecosystems for six PCB congeners. The median (line), 25th and 75th percentiles (end of rectangles), 10th and 90th percentiles (whiskers), and 5th and 95th percentiles (dots) are shown in the box plots.*

The MED visualization approach for depicting and interpreting bioaccumulation relationships and data is a way to portray the extrapolation process to non-bioaccumulation experts. This approach is also good for designing, conducting, and interpreting bioaccumulation model-based sensitivity analyses in order to conceptualize, plan, and conduct research to develop extrapolation methods. We have characterized the use of complementary and iterative combinations of mechanistic bioaccumulation model predictions with consistent field data interpretations as a "hybrid modeling." The visualization approach has become a primary tool for interpreting and communicating hybrid modeling results. Using the visualization approach, locations of measured BSAFs in water-sediment (X-Y) chemical concentration space can be defined with respect to the positions of BSAFs extrapolated from the measured BSAFs. Because chemical properties are fixed and lipid/organic carbon variations accounted for, the extrapolation methodology will focus on changes in disequilibrium factors (especially sediment to water); trophic level of the species of concern; relative benthic versus pelagic food chain; and if necessary, differences in metabolism rates associated with differences in species in food chains

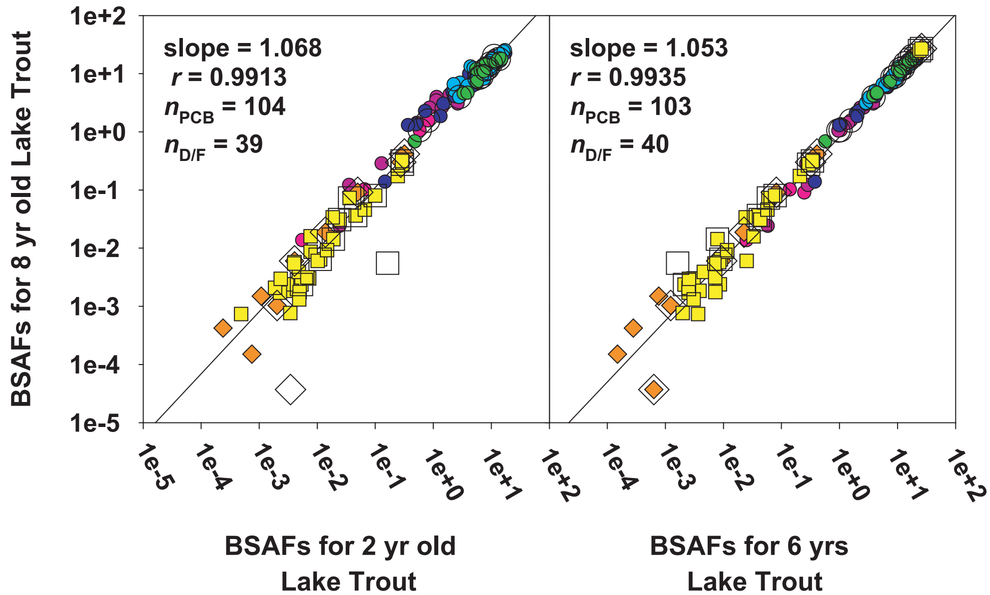


Figure 4. *Comparison of BSAF values for southern Lake Michigan Lake Trout of different age classes. The red, purple, blue, turquoise, and green points (circles) represent PCB congeners with 0, 1, 2, 3, and 4 ortho-chlorines, respectively; the yellow (squares) and orange (diamonds) points are the PCDDs and PCDFs, respectively. The encircled (PCBs), ensquared (PCDDs), and endiamonded (PCDFs) data points have non-zero mammalian toxicity equivalence factors (TEFs). For the ensquared and endiamonded data points with no internal data point, these points represent estimated BSAFs for PCDDs and PCDFs, respectively, using ½ minimum detection limit.*

Across Species Extrapolation of BSAFs from the Hybrid Modeling Approach using Lake Ontario data of Oliver and Niimi (1988) Between Forage Fish (Alewife) and Salmonids in the Lake Ontario Ecosystem.						
			Hybrid Modeling Approach*			
PCB	log K_{ow}	Field measured alewife BSAFs	Predicted relative difference	Predicted trophic level four BSAFs (salmonids)	Measured salmonid BSAFs	Difference between measured and predicted BSAFs for salmonids
47+48	5.82	0.579	1.996	1.155	1.227	0.072
49	5.85	0.491	2.040	1.001	0.692	-0.310
52	5.84	0.417	2.026	0.844	0.609	-0.235
101	6.38	1.571	2.591	4.071	2.455	-1.616
105	6.65	1.041	2.699	2.811	2.700	-0.111
110	6.48	0.813	2.644	2.150	1.526	-0.624
118	6.74	1.491	2.711	4.043	4.091	0.048
149	6.67	1.331	2.703	3.596	2.332	-1.264
180	7.36	1.424	2.468	3.515	3.776	0.261

**Relative differences were predicted using 5% lipid contents in all species, weights of 10 g and 1 kg in forage and piscivorous fishes (respectively), no metabolism, 50:50 pelagic:benthic diet for the forage fish, piscivorous fish eating only forage fish, and a disequilibrium of 25.*

The actual process of taking BSAFs derived from high quality field measurements in one ecosystem and applying them to another ecosystem (with different conditions and food web structure and composition) would be accomplished using simple food web models. The simple food web models would be used to forecast relative differences in bioaccumulation using the conditions and parameters of the two ecosystems, and these forecasted relative differences would then be used to the adjust the BSAFs measured in one ecosystem to another ecosystem. To illustrate the hybrid modeling approach, BSAFs were predicted for trophic level four salmonids using the BSAFs measured for alewife in the Lake Ontario ecosystem and forecasted relative differences between fish of trophic levels three and four (see table).

Although relative differences in bioaccumulation potential between chemicals should be amenable to extrapolation as illustrated above, calibration through acquisition of a minimum data set for the ecosystem being evaluated may be required to achieve the desired accuracy for individual BSAFs and BAFs in the new ecosystem. The intent of this research effort is to organize and validate this hybrid BAF/BSAF extrapolation methodology and thereby define its potential for applications to site assessments at different levels of specificity and cost. The advantages of the hybrid BAF/BSAF approach would be great if successfully validated. The methodology would enable Superfund to make highly accurate predictions of bioaccumulation for different Superfund sites with minimal data collection efforts. Additionally, uncertainties in the BSAFs could be even further reduced by the collection of appropriate data and incorporation of that information into the extrapolations.

The hybrid BAF/BSAF approach is on a continuum between the use of purely empirical

BSAF/BAF measurements (in both ecosystems) and complete mechanistic food web modeling for both ecosystems (in an ecosystem where the BSAF was measured and in an ecosystem where the extrapolated BSAF is desired). Depending upon the effort undertaken in developing extrapolation ratios (i.e., predicted relative differences in bioaccumulation) from the mechanistic food web models, the approach allows predictions anywhere on the continuum. In application, we expect the hybrid approach to be used in an iterative process, incorporating additional data for the site of interest as it becomes available. The hybrid approach is entirely complimentary with the mechanistic modeling approaches. In an iterative application, the hybrid model would provide the data needed for the detailed mechanistic models when higher levels of accuracy might be required in the risk assessments.

The following research tasks will be performed to determine the validity of the hybrid BAF/BSAF approach for different extrapolation scenarios and degrees of specificity. In Task 1, the theoretical and conceptual framework for performing the extrapolations will need to be developed further to determine how one would optimally make a prediction. We believe that the hydrophobicity and tendency for metabolism of the particular chemical will strongly influence the extent of bioaccumulation for the chemical at the two sites or at a given site at different times. Having the framework will allow Task 2 to be initiated. In Task 2, we will need to determine the level of simplicity in the food web model that is required to forecast the relative differences in BAFs/BSAFs. To accomplish this task, forecasts for a number of different ecosystems that have differing complexity will be made and evaluated for predictive error and uncertainty. The forecasts would initially be performed using very generic conditions and parameters for the two respective ecosystems. Subsequently, forecasts would be made using more site-specific food web models, e.g., using actual lipid contents and weights for the fishes, site-specific diet information, sediment-water column chemical concentration quotients, etc., All of these forecasts would be evaluated for their predictive error and uncertainty. Concurrently with Task 2, Task 3 will develop criteria for the data quality and requirements needed for the extrapolation process. Issues include establishing minimum data requirements and criteria to evaluate the appropriateness of the data from specific ecosystems for use in extrapolation elsewhere.

In Task 4 of Step 2, we will determine how to account for metabolism processes and their effects in the forecasts of relative differences with the food web model. The requirements for simple food web models to account for the differences in metabolic rates is unknown when large differences in metabolic abilities exist between species (e.g., eels might not be able to metabolize the 2,3,7,8-TCDD to the extent observed in teleost fish such as carp). Additionally, although food web models can account for metabolism processes in their predictions, the general lack of measured rates of metabolism for aquatic species limits our ability to account for the differences in rates of metabolism even if we wished to do so. Here, we will make forecasts for chemicals with highly differing metabolism rates (ideally including reference chemicals resistant to metabolism) and compare these forecasts to field data. Like Task 3, predictions would be made in a graded level of complexity, starting with forecasts of relative differences that assume no metabolism and moving to forecasts having more realistic metabolism rates. These predictions will allow the assessment of the importance of metabolism information into the forecasts of relative differences in the BAFs or BSAFs.

Task 5 of Step 2 will aid in resolving the question addressed in Task 4. In Task 5, rates of metabolism for individual chemicals will be determined from the field data sets developed in Task 1. This effort will involve the solving of the food web model for the k_m parameter by inputting all other required parameters for the model. In essence, the approach accounts for the residual (difference between measured and predicted residues in a fish species) with the km term. Clearly, these calculations require very high quality data for all input parameters, e.g., chemical concentrations in sediment and water, diet, weights, lipid contents, trophic level, food web structure, etc., It is hoped that enough data sets which include common chemicals and species (e.g., 2,3,7,8-TCDD in carp) across different ecosystems can be assembled. If possible, a consensus rate of metabolism could be derived for individuals from the various ecosystems. With these values, relative differences forecast by the simple food web models with the adjustment for differing metabolism rates could be performed in Task 4.

Task 6 of Step 2 will examine the theoretical framework and forecasting errors to determine whether the theoretical framework is adequate for performing the predictions. This evaluation would look for obvious and/or consistent biases in the predictions for specific chemical types or classes. If deemed necessary, Tasks 1 through 4 will be repeated until the strengths and limitations of the hybrid BAF/BSAF approach are defined sufficiently to allow methods development for Superfund applications. Task 7 of Step 2 will develop software that provides a user-friendly interface for the hybrid BAF/BSAF approach to predict relative differences and perform the extrapolations. We anticipate that the software will be written in Visual Basic and run on a PC with a Windows operating system.

An additional consideration throughout Tasks 2 through 7 is the transferability of the hybrid modeling approach to marine ecosystems which differ from freshwater systems in many ways including the widely differing set of potential species. We believe that bioaccumulation submodels for these specific species (e.g., blue crabs, lobster, scallops, and shrimp) will be required for making adequate predictions of the relative differences in bioaccumulation. Bioaccumulation models already exist for some but not all of these species. As we work through Tasks 2 through 7, this research effort will build the tools required to apply the hybrid modeling approach to marine ecosystems. Most importantly, Task 7, software for predicting the relative differences in bioaccumulation, will have to include bioaccumulation submodels for non-fish marine species.

<u>Step 3: Validation</u>

Assuming useful BAF/BSAF extrapolation methods emerge from development of the hybrid modeling approach, validation is required for successful completion of the research effort. This effort will make predictions of BSAFs that are based on extrapolation between ecosystems and (if possible) within ecosystems for pre- and post-sediment remedial action conditions. These predictions will then be compared to measured BSAFs for both relative (between chemicals) and absolute accuracies. In the critical path flowchart (see “Products” below), the validation effort is highlighted in blue and consists of a triangular flow of efforts among Prediction, Application, and Validation components. The validation effort is envisioned as a interactive exchange among these three components and would be performed for a variety of ecosystem types (e.g., rivers, lakes, estuaries, and harbors); ecosystem conditions and parameters (warm vs. cold water, freshwater vs. saltwater, sediment-water column concentration relationships, food web structure and composition, and species differences); and classes of chemicals (e.g., PCBs, PAHs, PCDD/Fs, and DDTs).

Technology Transfer

Transfer of the research results and efforts will occur through variety of mechanisms:

1. A series of fact sheets describing research to date, progress, and the state of the science for specific issues will be prepared in consultation with OSRTI. Fact sheets will be also written for OSRTI to provide guidance and applications examples for using the hybrid modeling approach. These fact sheets will be written throughout the research effort. Final summaries of the overall projects will be written at the end of the project in FY08.
2. Educational seminars will be given using a variety of mechanisms, including the ORD-OSRTI seminar series, OSRTI's ERAF semi-annual meetings, and at workshops on contaminated sediments organized by OSRTI.
3. Peer reviewed journal reports will be written and published. These reports will also be provided to OSRTI.
4. Presentations will be given at regional/national/international scientific workshops and meetings.

Resources

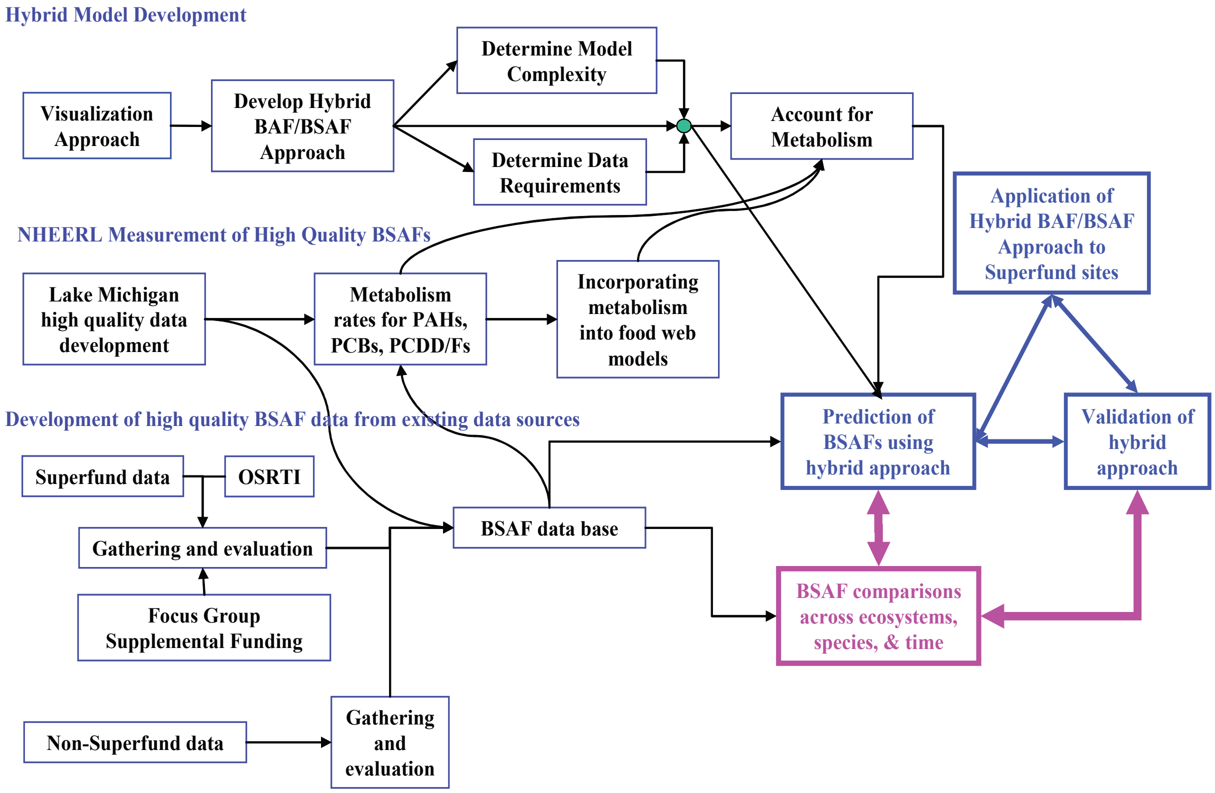
Year	Division	FTEs
2004	MED	3.75
2005	MED	3.75
2006	MED	3.75
2007	MED	4
2008	MED	4

NHEERL Category D Needs

In addition to the personnel costs, benefits, supplies, equipment, etc., that are specifically associated by ORD with FTE and considered intramural resources, NHEERL uses ORD planning resources to pay laboratory indirect costs (called "ABC costs") and project-specific costs (called "Category D costs"). Listed below are the kinds of Category D needs associated with this project. Annual budget planning documents determine the dollar amounts needed.

Year	Division	Supplemental Funding	ECOTOX
2004	MED	yes	yes
2005	MED		yes
2006	MED		yes
2007	MED		yes
2008	MED		yes

Critical Path



Products

By 2008 provide hybrid modeling approaches using empirical field data and bioaccumulation models to extrapolate BAFs and BSAFs for PBTs across ecosystems, species, and time.		FY08	NHEERL
	Provide a hybrid modeling/empirical approach for predicting BAFs, BSAFs, and resulting risks from metabolized chemicals such as dioxins and PAHs (revised wording for APM 04-6)	FY04	NHEERL Lawrence Burkhard
	Provide the methods and data necessary to parameterize and apply the hybrid modeling/empirical approach to support ecological risk assessment of bioaccumulative sediment contaminants	FY06	NHEERL Lawrence Burkhard
	Provide a fully field validated hybrid modeling/empirical approach for extrapolating BAFs, BSAFs, and predicting the ecological effects of mixtures of PBTs with differing rates of metabolism on a site-specific basis	FY08	NHEERL Lawrence Burkhard

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Project IV: Research to Evaluate the Release and Bioavailability of Contaminants Associated with Resuspended Sediments and Post-Dredging Residuals at Superfund Sites

Summary of Issue

At contaminated sediment sites, the Superfund program usually must decide whether to leave the site alone, cap it, or dredge it. This decision is based in part upon the relative risks to the environment and human health posed by each option. If the risks associated with the site are determined to be sufficiently great, dredging will frequently be used to remove the contaminated sediments and reduce the risks. In practice, dredging is the most common remedy for sites containing contaminated sediments. There are several advantages to the use of dredging, principally the removal of most of the material causing the identified risk. Simultaneously, dredging is the most expensive remedy with the greatest potential to impart short-term adverse impacts on the site and on surrounding uncontaminated areas. These potential impacts are believed to be derived primarily from the effects of the resuspension of contaminated sediments during dredging. Based on the available information (e.g., Anchor Environmental 2003, Palermo and Averett 2003, Eggleton and Thomas 2004), resuspension can result in the transport of contaminated particles from the site as well as the flux of dissolved and bioavailable contaminants into the water column. These fluxes may result in the contamination of previously clean areas.

It is worth noting that resuspension also occurs at Superfund sites under circumstances other than dredging. Natural phenomena including tidal action, currents, storm events, and bioturbation result in the resuspension of contaminated sediments (Davis 1993, Thibodeaux and Bierman 2003). Additionally, anthropogenic activities other than dredging including ship traffic result in resuspension. Consequently, beyond the risk associated with dredging, resuspension of contaminated sediments at Superfund sites is likely to occur because of these other activities. At this time, it is unknown how the magnitude and duration of dredging related resuspension risk compares to the risk associated with natural and other anthropogenic phenomena. Of course, understanding this would contribute to a better assessment of risk at Superfund sites.

Specifically for dredging and generally for other causes, the effects of resuspension occur across different temporal and spatial scales that can be placed into many categories. For example, in use at Superfund sites are the terms “near field” and “far field” effects. However, these terms can be relative and site-specific and cannot be defined as absolutes. For the research described here, the effects of interest on the basis of temporal and spatial scales are (1) transportation of dissolved and bioavailable contaminants from the immediate dredging area to areas of lesser contamination over a duration of days and (2) alteration of the bioavailability of contaminants associated with resuspended and resettled sediment (e.g., post-dredging residuals) within the dredging zone over months. In the context of this research, bioavailability is defined as the presence of the chemical form(s) of a contaminant, organic or inorganic, which readily interacts with an organism’s tissues resulting in adverse effects (toxicity) or uptake (bioaccumulation). Any geochemical, physical, or biological event associated with resuspension altering the amount of bioavailable contaminant is of concern.

This research will address the risk associated with the resuspension of contaminated sediments resulting primarily from dredging. Specifically, this research will evaluate modeling and empirical approaches for predicting and measuring the risk of increased bioavailability and bioaccumulation of organic and inorganic contaminants caused by dredging events at Superfund sites. This research will include evaluating the bioavailability of resettled contaminated sediments which constitute one form of post-dredging residuals.

Summary of the State of the Science

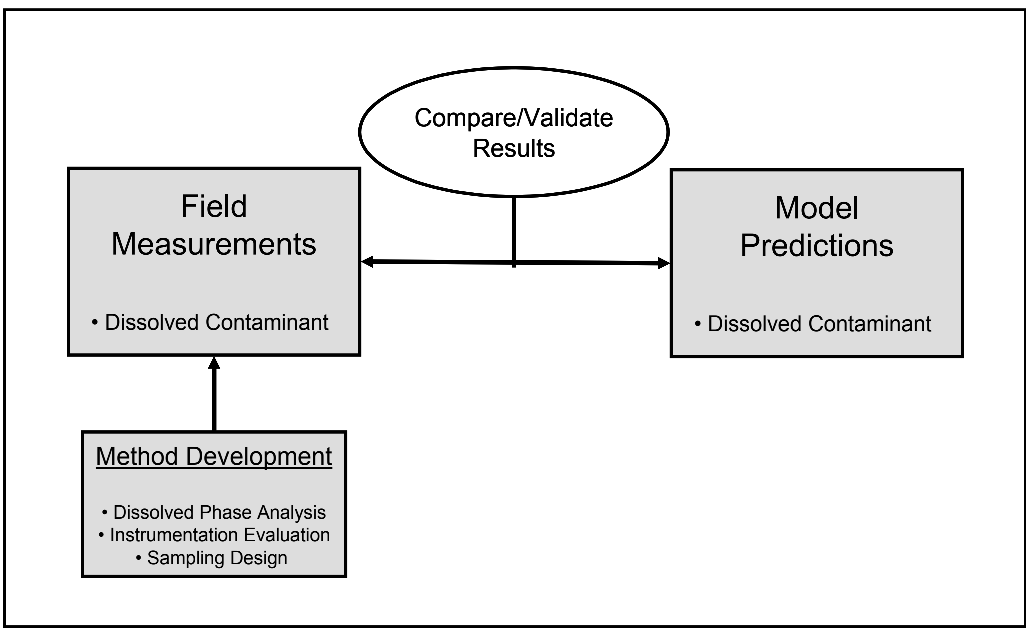
Methods and models are available for estimating the partitioning, bioavailability, and effects of contaminants in sediments under equilibrium or undisturbed conditions. For example, equilibrium-based models allow for accurate predictions of toxicity and bioaccumulation. However, when sediments are resuspended or enter a state of disequilibrium, studies have demonstrated that associated contaminants, including organic and inorganic pollutants, are released or remobilized into the water column and potentially made bioavailable (Valsaraj et al. 1997, Latimer et al. 1999, Pedersen et al. 1999, Bonnet et al. 2000, Cantwell et al. 2002, Nayar et al. 2003, Eggleton and Thomas 2004). In one study, the magnitude of disequilibria resulted in suspended solids concentrations of approximately 20,000 mg/L as compared to essentially no suspended solids under equilibrium conditions (Cantwell et al. 2002). Furthermore, in the recent review of the Hudson River resuspension standard (Eastern Research Group, Inc. 2004), the peer-reviewers expressed concern about the release of dissolved-phase PCBs resulting from resuspension. Despite the evidence of release of contaminants from resuspended sediments, the bioavailability and effects of these contaminants in terms of toxicity to or bioaccumulation by aquatic life have not been studied extensively and are not very well understood.

A few models and methods exist for estimating the extent to which contaminant remobilization is likely to occur from resuspension of contaminated sediments. For example, fate and transport models like the Army Corps of Engineers Waterway Experiment Station's (ACE-WES) ICM/TOXI, RECOVERY, and STFATE (U.S. ACE 2003). There are also some advanced, mathematically intensive fate and transport models like EFDC and ECOMSED (Imhoff et al. 2003). Empirical methods include simple (Simpson et al. 1998, 2000) and complex (Gerringa 1991, Chen et al. 2000, Gao et al. 2003) laboratory procedures while other approaches focus primarily on field studies (Calvo et al. 1991, van den Berg et al. 2001). Further, recent geochemical studies have investigated desorption mechanisms for organic contaminants under resuspension conditions (Shor et al. 2003). However, there are limitations that diminish the predictive ability and overall effectiveness of each of these methods. Models' predictive accuracy is generally unknown because most often models' results are not validated. A thorough evaluation of all such models should be performed. Methods often evaluate sediments under very specific conditions that do not reflect or approximate field conditions. Field studies do provide accurate and detailed data, but this information is site-specific and is expensive to generate. Finally, the linkage between the predicted release of contaminants and of contaminants bioavailability is weak.

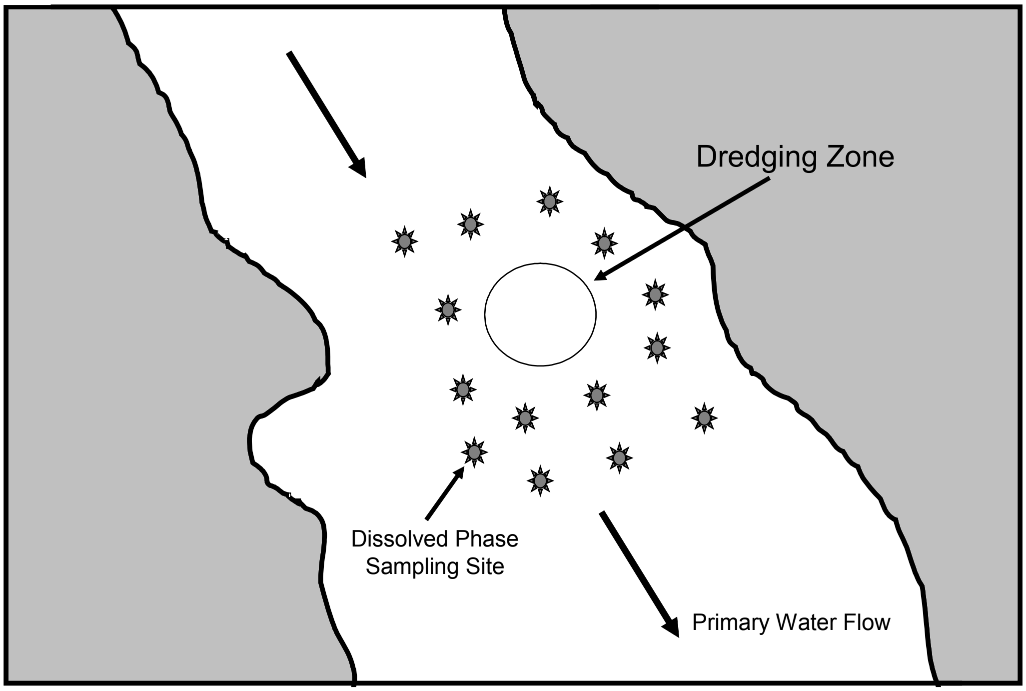
Starting in FY2004, we initiated an effort to evaluate the existing fate and transport models with regard to use with sediment resuspension. Thus far, the Army Corps of Engineers fate and transport models and some advanced, mathematically intensive models have been investigated. The ACE models focus on predicting the transport of contaminants on sediment particles and do not consider the release of dissolved and bioavailable contaminants during resuspension (U.S. ACE 2003, T. Bridges, personal communication). The advanced, mathematically intensive models like EFDC are reputed to predict the release of dissolved and bioavailable contaminants during resuspension but have not undergone any rigorous verification under laboratory or field conditions (Imhoff et al. 2003, E. Hayter, personal communication). During the evaluation of these models, both ACE-WES and NERL (i.e., T. Bridges and E. Hayter, respectively) expressed interest in collaborating with NHEERL to better characterize the risk resulting from resuspension.

A shared goal for researchers from NHEERL, NERL, and ACE-WES is to improve our understanding of the risks associated with the release of contaminants during resuspension events. A result of this shared goal is the potential to generate multiple data sets of laboratory and field data to calibrate and validate model predictions of the dredging-related release of organic and inorganic contaminants. To this end, efforts are underway to identify mechanisms for enhancing collaborations between NHEERL, NERL, and ACE-WES.

The following figure illustrates a conceptual model of the relationship between method development, field measurements, and model predictions. In each box, the objective is to perform measurements or predictions of the concentrations of dissolved organic and inorganic contaminants.



Method development generates the tools for making the measurements and provides input for the sampling design of the field component. The field measurements are performed while dredging is occurring and are specifically designed to determine the magnitude of the released dissolved contaminants. Finally, results of the field measurements are compared to the concentrations of dissolved contaminants predicted by the model. Below is a cartoon of a possible sampling design for a Superfund site undergoing dredging:



Another aspect of resuspension at Superfund sites is the resettlement of suspended sediments within the vicinity of the dredging operation (i.e., a form of residual). There is some evidence that when sediments are suspended, the bioavailability of associated organic and inorganic contaminants is altered as compared to that of the original sediment (e.g., Pedersen et al. 1999, Lin et al. 2003). Following resettlement, it is suspected that contaminants are more bioavailable (i.e., sequestering phase has been changed) or that the amount of bioavailable contaminant is greater than originally observed. One explanation for such effects are alterations of the organic carbon structure resulting from oxidation and other changes the sediment experiences when moving from reduced (sedimentary) to oxidized (water column) conditions. This issue has received very little scientific attention; research is required to determine the magnitude of any alteration in contaminant effects. Recently, NRMRL proposed to refocus part of their Superfund research effort on post-dredging residual-related research. Research in the project discussed here will seek to collaborate with the NRMRL effort wherever possible.

Based on the above discussion, the following are key gaps in our understanding of the environmental risks associated with resuspension of contaminated sediments at Superfund sites:

1. How effectively the current models of contaminant fate and transport predict the release of dissolved and bioavailable contaminants during resuspension;
2. The magnitude of release of dissolved and bioavailable contaminants during dredging from the dredging zone into the lesser contaminated areas; and
3. The effects of resuspension and resettlement on the bioavailability of sediment contaminants.

Research Needs

Based upon the issue summary, state of the science, and the gap analysis, the following key scientific challenges have been identified.

1. Link model development and field measurements to validate fate and transport models for predicting the release of dissolved and bioavailable contaminants from sediments during resuspension events;
2. Under field conditions, determine the potential for the release of dissolved and bioavailable contaminants from sediments during resuspension events; and
3. Conduct an assessment of the changes in the bioavailability of organic and inorganic contaminants occurring in contaminated sediments following resuspension and resettlement.

Proposed Research Targets

The steering committee identified the following research targets for this project after assessing research needs, the level of effort required to achieve them, and the expertise and resources available.

The objective of the resuspension research is to improve our understanding of the magnitude of risk associated with contaminated sediments resuspension. In particular, this work focuses on determining the risk associated with dredging sediments at Superfund sites contaminated with PCBs and other organic and inorganic toxic chemicals. The fundamental question involves the effects of dredging on the bioavailability of contaminants associated with sediments. Specifically, we wish to understand whether dredging causes a significant change in contaminant bioavailability via the release and transport of dissolved (and bioavailable) contaminants outside of the immediate dredging zone and/or via the alteration of the sediment phases controlling the partitioning and bioavailability of contaminants in resettled sediments.

Specific products/information resulting from this research will include the following:

1. Report evaluating fate and transport models for predicting dissolved concentrations of organic and inorganic contaminants in Superfund site sediments following resuspension events;
2. Evaluate concordance between field measurements and fate and transport model predictions of dissolved concentrations of organic and inorganic contaminants in Superfund site sediments following resuspension events (in collaboration with NERL and ACE-WES);
3. Report summarizing evaluation of approach for measuring the transport of dissolved contaminants beyond the dredging zone at selected Superfund sites; and
4. Report assessing significance of changes in bioavailability of organic and inorganic contaminants in Superfund site sediments following resuspension into the water column and resettlement to sediment bed (including residuals).

Research Activities/Approaches

To achieve these targets, three major activities must be taken.

1. Collaboration between NHEERL, NERL, and ACE-WES researchers to review and evaluate the effectiveness of existing resuspension models and compare field measurements (see below) with model predictions;
2. Research to develop a method for measuring dissolved organic and inorganic contaminants under field conditions; and
3. Research to assess changes in bioavailability of contaminated sediments resulting from resuspension and resettlement (including collaborations with NRMRL post-dredging residuals research effort).

1. Review and evaluate resuspension models

This activity has two components. In the first, available resuspension models will be reviewed for their ability to predict dissolved and bioavailable concentrations of organic and inorganic contaminants. The emphasis will be on assessing what the models under consideration do well and what they do poorly. Further, the review will inquire whether the models have undergone field verification.

For the second component, results of field measurements of dissolved organic and inorganic contaminants, discussed in detail below, will be compared to resuspension model predictions. A site visit to ACE-WES in September 2004, initiated collaboration between NHEERL and ACE-WES scientists on this activity. Discussions from this visit indicated output from the ACE's ICM/TOXI model are the data to compare with field measurements. As noted above, the data to be compared will include concentrations of dissolved organic and inorganic contaminants, as well as suspended solids and concentrations of particulate inorganic and organic contaminants. Additionally, discussions with NERL have started. Preliminary plans call for comparing the results of advanced, mathematically intensive model analyses (e.g., EFDC, ECOMSED) with results from field measurements. Based on these comparisons, model predictions and field measurements will be reviewed to ultimately calibrate and improve the operation of the model(s).

This activity will also include evaluating other relevant models by local, national, and international organizations including the United States Geological Survey (USGS) (e.g., http://woodshole.er.usgs.gov/project-pages/sediment-transport) to determine whether these models may address Superfund needs.

2. Develop approaches/methods for measuring dissolved organic and inorganic contaminants under field conditions

In this activity, the objective is to develop an approach for measuring dissolved concentrations of organic and inorganic contaminants in the water column during dredging events under field conditions. The research will have two primary components. In the first, laboratory research will be performed to develop and evaluate the approach; in the second, the developed approach will be taken into the field and used to measure water column concentrations of dissolved organic and inorganic contaminants in the waters outside of the dredging zone.

In the laboratory component, the challenge will be to develop tools for measuring dissolved contaminant concentrations. A few promising technologies are available including semipermeable membrane devices (SPMDs) which serve as surrogate organisms (Huckins et al. 1993, Hofelt and Shea 1997, Axelman et al. 1999), polyethylene (PE) samplers which use a thin synthetic film as an absorbing phase to collect dissolved contaminants (Vinturella et al. 2004, Lohmann et al. 2005), and solid-phase microextraction (SPME) in which polymer-coated fibers adsorb analytes from the dissolved phase (Arthur and Pawliszyn 1990, Mayer et al. 2000, Zeng et al. 2004). Dissolved inorganic contaminants will be investigated using iminodiacetate group-based samplers ("gellyfish") (Senn et al. 2004). To evaluate these tools, laboratory studies will be conducted using simulated resuspension events generated in exposure chambers. For these evaluations, the particle entrainment simulator (PES) (Tsai and Lick 1986) will be used. Since its development, the PES has also been used to evaluate the behavior of organic and inorganic contaminants in resuspended sediments (Lavelle and Davis 1987, Bedford 1994, Latimer et al., 1999, Cantwell et al. 2002, Cantwell and Burgess 2004). The PES is a fairly simple device consisting of a cylindrical chamber in which a sediment core from a site of interest is placed and overlying water is then added. Under "no energy" conditions, the system in the PES emulates a passive sediment-water interface. However, a perforated grid in the PES can be activated to impart known levels of energy to the sediment-water interface, causing sediment resuspension. While the simulated resuspension is occurring, the overlying water will be monitored for numerous water column parameters including pH, dissolved oxygen, and oxidation-reduction potential. Further, samples of the overlying water will be collected for measurement of the mass of suspended sediment and concentrations of contaminants in the particulate and dissolved phases including toxic metals (cadmium, copper, nickel, lead, and zinc) and organic pollutants (e.g., PCBs, PAHs). It is during these simulations that the SPMD and SPME approaches will be evaluated.

The laboratory component of the research will also serve to identify physical and chemical terms in the sediment and water column that have potential to serve as key predictors of resuspension and release of dissolved organic and inorganic contaminants. Likely key predictors include levels of AVS, organic carbon, grain size distribution, and extent of contamination. Resuspension variables (e.g., energy, duration) will also be considered.

For the field component of this activity, following the laboratory component and development of sound approaches/tools, at least three sites undergoing dredging will be studied. Field sites for consideration include New Bedford Harbor, MA; the Hudson River, NY; and one additional site not yet identified. These studies will serve to test the utility of tools developed in the laboratory and directly address the scientific needs of OSRTI. A significant part of this field work will be the development of a statistical sampling design which considers spatial and temporal variables. Consultation with AED's statistician in the development of this design will complement this work. As discussed above, results of the field studies will be compared with model estimates of resuspension and dissolved organic and inorganic contaminants.

Another direction for this research to explore is the use of sophisticated chemical probes. Such probes would incorporate technology to allow *in situ* and rapid measurement of several classes of contaminants as they enter the water column during resuspension. Incorporation of these approaches to the design discussed here will depend on the results of the initial investigations.

3. <u>Assess changes in bioavailability of contaminated sediments resulting from resuspension and resettlement</u>

Sediments from Superfund sites around the country (see sites sited above) will be used to assess whether or not the bioavailability of contaminants associated with resuspended sediments changes following settling (i.e., residuals). In these studies, sediment cores will be collected and sectioned into two identical portions. Using bioaccumulation by infaunal bivalves and/or polychaetes as the measure of bioavailability, one half of the sediments will be evaluated without any manipulation. The second half of the sediment sample will be vigorously mixed to mimic a dredging event and then allowed to settled. Because of the amounts of sediment needed for this study, the simulated dredging event will involve large-scale mechanical mixing. Following this mock dredging event, these sediments will be evaluated for bioavailability. The null hypothesis being tested is that the dredging event has no effect on contaminant bioavailability. A predominant alternative hypothesis is that dredging results in changes in bioavailability. If a change in bioavailability is observed soon after the resettlement, a second exposure maybe performed several months after the initial resuspension to evaluate the duration of the change.

An extension of this study is an investigation of the effects of resuspension and resettlement on the texture of the sediments. While the focus above is on the change of contaminant availability, resuspension will also alter the sediment grain size distribution. This change may result in organisms selecting more contaminated fine grained sediments particles to feed upon. Such alterations may have food web consequences not immediately obvious based on using bioaccumulation of contaminants by benthic fauna as the effects endpoint.

Technology Transfer

Technology transfer of the results of this research will have two principle forms: client-oriented and scientific community-oriented. First, for the client-oriented form, guidance will be provided in the form of participation in site visits, travel to Headquarters to discuss findings, development of facts sheets, and presentation of seminars. The objective of this form of technology transfer will be to provide OSRTI Headquarters and Regional personnel with information to assist them in applying the findings of the research and informing them about how the new information and tools can be used to advance decision making at Superfund sites.

The second form of technology transfer will be to the scientific community. This will take the conventional forms of peer-reviewed scientific papers and presentations at national and international scientific meetings. The purpose of this technology transfer will be to demonstrate to the scientific community and OSRTI personnel that the work performed by NHEERL is scientifically sound and accepted. In turn, this step in the technology transfer process lends confidence to OSRTI's use of NHEERL data in decision making at Superfund sites.

Resources

Year	Division	FTEs
2004	AED	1.00
2005	AED	1.00
2006	AED	1.00
2007	AED	1.00
2008	AED	1.00
2009	AED	1.00

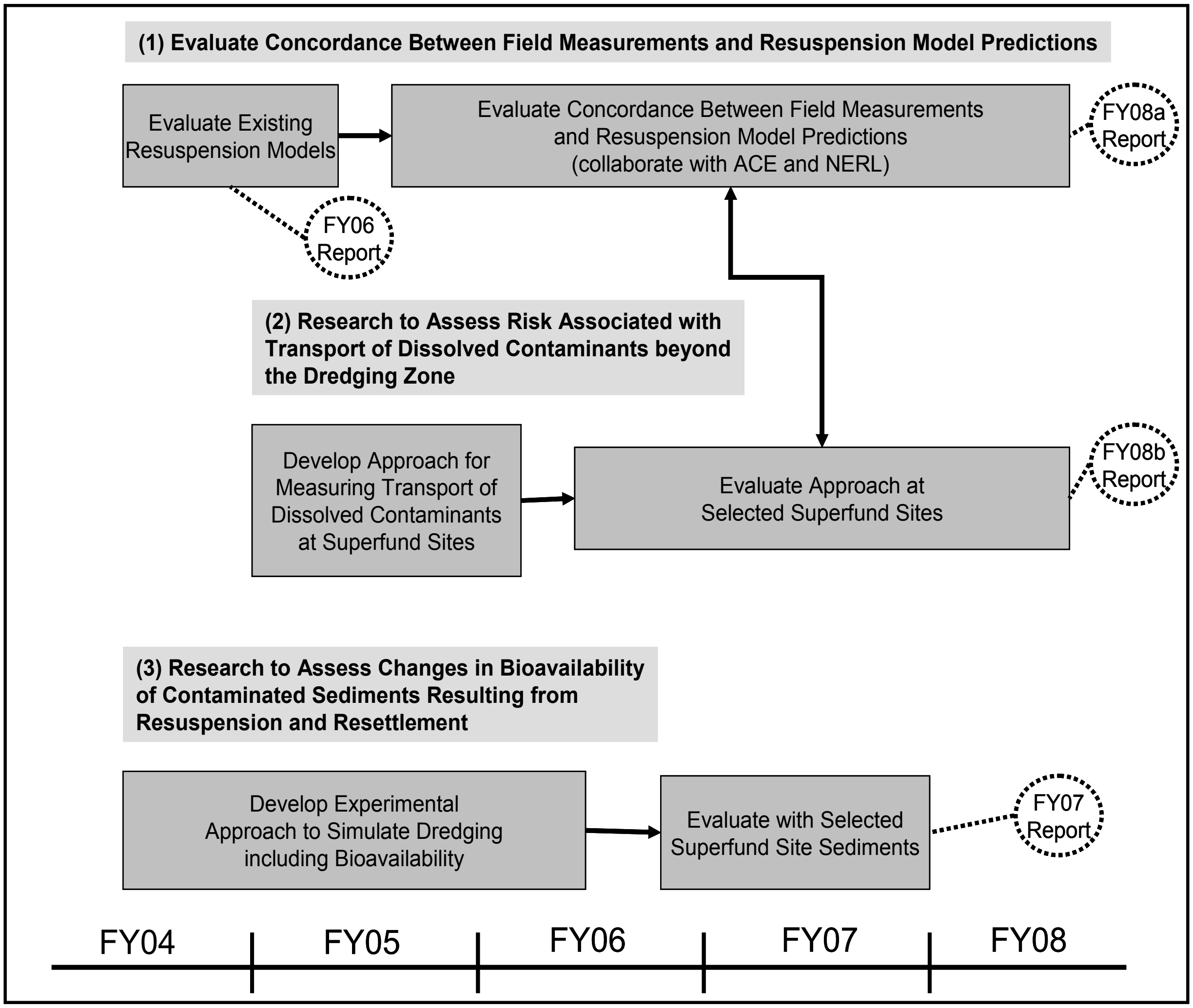
NHEERL Category D Needs

In addition to the personnel costs, benefits, supplies, equipment, etc., that are specifically associated by ORD with FTE and considered intramural resources, NHEERL uses ORD planning resources to pay laboratory indirect costs (called "ABC costs") and project-specific costs (called "Category D costs"). Listed below are the kinds of Category D needs associated with this project. Annual budget planning documents determine the dollar amounts needed.

Year	Division	Analytical Chemistry	GIS	Statistics	Field Support	Modeling
2004	AED					
2005	AED	yes		yes	yes	
2006	AED	yes	yes	yes	yes	yes
2007	AED	yes	yes	yes	yes	yes
2008	AED	tbd[a]	tbd	tbd	tbd	tbd
2009	AED	tbd	tbd	tbd	tbd	tbd

[a]*tbd = to be determined*

Critical Path



Products

By 2008, provide monitoring, measurement, and benthic screening methods and tools to characterize, assess, and communicate current conditions and the long-term performance of remedial options associated with cleanup of contaminated sediments.			NHEERL
	Report evaluating fate and transport models for predicting dissolved concentrations of organic and inorganic contaminants in Superfund site sediments following resuspension events	FY06	NHEERL Rob Burgess and Mark Cantwell
	Evaluate concordance between field measurements and fate and transport model predictions of dissolved concentrations of organic and inorganic contaminants in Superfund site sediments following resuspension events (in collaboration with NERL and ACE)	FY08a	NHEERL Rob Burgess and Mark Cantwell
	Report summarizing evaluation of approaches for measuring the transport of dissolved contaminants beyond the dredging zone at selected Superfund sites	FY08b	NHEERL Rob Burgess and Mark Cantwell
	Report assessing significance of changes in bioavailability of organic and inorganic contaminants in Superfund site sediments following resuspension into the water column and resettlement to sediment bed	FY07	NHEERL Rob Burgess and Mark Cantwell

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Project V: Preparation of Equilibrium Partitioning Sediment Benchmark Documents for the Assessment of Contaminated Sediments at Superfund Sites

Summary of Issue

This activity will publish a series of benchmark documents to assist OSRTI, the Regions, states, other federal agencies, and other entities in the assessment of contaminated sediments.

Resources

Year	Division	FTEs
2004	AED	0.10
2005	AED	0.10
2006	AED	0.10

NHEERL Category D Needs

In addition to the personnel costs, benefits, supplies, equipment, etc., that are specifically associated by ORD with FTE and considered intramural resources, NHEERL uses ORD planning resources to pay laboratory indirect costs (called "ABC costs") and project-specific costs (called "Category D costs"). Listed below are the kinds of Category D needs associated with this project. Annual budget planning documents determine the dollar amounts needed.

Year	Division	
2004	AED	No Category D needs
2005	AED	No Category D needs
2006	AED	No Category D needs

Products

By 2008, provide monitoring, measurement, and benthic screening methods and tools to characterize, assess, and communicate current conditions and the long-term performance of remedial options associated with cleanup of contaminated sediments.			NHEERL
	U.S. EPA. 2003. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Endrin. EPA-600-R-02-009. Office of Research and Development. Washington, DC 20460. U.S. EPA. 2003. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Dieldrin. EPA-600-R-02-010. Office of Research and Development. Washington, DC 20460. U.S. EPA. 2003. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: PAH Mixtures. EPA-600-R-02-013. Office of Research and Development. Washington, DC 20460.	FY04	NHEERL Rob Burgess
	U.S. EPA. 2005. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Nonionics Compendium. EPA-600-R-02-016. Office of Research and Development. Washington, DC 20460.	FY05	NHEERL Rob Burgess
	U.S. EPA. 2006. Procedures for the Derivation of Site-Specific Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Nonionic Organics. EPA-600-R-02-012. Office of Research and Development. Washington, DC 20460.	FY06	NHEERL Rob Burgess

Project VI: Preparation of Whole Sediment and Interstitial Water Freshwater and Marine Toxicity Identification Evaluations (TIEs) Guidance Document for Use at Superfund Sites

Summary of Issue

This activity will publish a guidance document to assist OSRTI, the Regions, states, other federal agencies, and other entities in the assessment of contaminated sediments.

Resources

Year	Division	FTEs
2004	AED	0.20
2005	AED	0.20

NHEERL Category D Needs

In addition to the personnel costs, benefits, supplies, equipment, etc., that are specifically associated by ORD with FTE and considered intramural resources, NHEERL uses ORD planning resources to pay laboratory indirect costs (called "ABC costs") and project-specific costs (called "Category D costs"). Listed below are the kinds of Category D needs associated with this project. Annual budget planning documents determine the dollar amounts needed.

Year	Division	
2004	AED	No Category D needs
2005	AED	Technical Editing

Products

By 2008, provide monitoring, measurement, and benthic screening methods and tools to characterize, assess, and communicate current conditions and the long-term performance of remedial options associated with cleanup of contaminated sediments.			**NHEERL**
	Ho et al. 2005. Whole Sediment and Interstitial Water Toxicity Identification Evaluation Guidance Document for Freshwater and Marine Applications. Office of Research and Development. Washington, DC 20460.	FY05	NHEERL Kay Ho

Project VII: Development of Appropriate Remedial Goals for Non-Bioaccumulative Contaminants in Sediment

Summary of Issue

This issue is not a single issue, but an aggregation of a diverse group of issues. The common thread for these issues is that they involve difficulties in assessing/predicting the toxic effects of sediment contaminants that are "non-bioaccumulative." In this context, "non-bioaccumulative" does not mean strictly that the chemicals do not bioaccumulate to any degree, but rather that the assessment of these chemicals (or exposure pathways) is not pursued using the same tools commonly applied to classic bioaccumulative chemicals such as PCBs. In general, this would mean chemicals whose primary toxic effects are expressed directly in organisms living in or on sediments (as opposed to organisms exposed to sediment-associated chemicals via the food chain). However, even this definition is not without exception.

For chemicals causing direct effects on benthic organisms, there are three primary classes of tools used to assess the likely effects of chemicals in sediments: (1) sediment quality guidelines (SQGs), (2) sediment toxicity tests, and (3) benthic community surveys. As described below, each of these have particular strengths, weaknesses, and uncertainties in their application. The uncertainties associated with these tools spawn corresponding uncertainties and controversy in ecological risk assessments conducted within the Superfund program and elsewhere.

Beyond issues surrounding these three sediment assessment tools, there are some additional noteworthy issues that have arisen in Superfund ecological risk assessments but that are not addressed explicitly elsewhere and are therefore included here. These issues include heightened toxicity of polycyclic aromatic hydrocarbons (PAHs) in the presence of UV light, often called "photo-activated toxicity." Another of these is the potential for adverse effects from dietary exposure of fish to metals (e.g., Cd, Cu, Zn) accumulated by their prey.

Summary of the State of the Science

1. <u>Sediment Quality Guidelines</u>

Sediment quality guidelines (SQGs) are chemical concentrations in sediment that are expected to cause some specified degree or probability of adverse effect in organisms exposed to the sediment. SQGs have been developed using a number of different approaches (see Batley et al. 2004), and each has its own set of strengths and weaknesses. They can be loosely grouped into two subsets, so-called "empirical" guidelines and "mechanistic" guidelines. Empirical guidelines are derived from large data sets of paired chemical concentration and sediment toxicity (effect) data, usually from field-collected sediments. Data are arrayed according to increasing degree of contamination, and specific benchmarks are chosen along this concentration gradient to delineate concentrations that are associated with varying levels or probabilities of adverse effects. As they are based on correlation, they reflect empirical association but not necessarily causation. Mechanistic guidelines are based on models of chemical/toxicological behavior of chemicals in sediment. Current mechanistic guidelines all have their roots in "Equilibrium Partitioning Theory" (Di Toro et al. 1991) which uses chemical partitioning models as the basis for predicting the toxicological potency of sediment-associated chemicals.

While there is a considerable body of work supporting the development of these guidelines, their application in sediment assessment/management frameworks remains a topic of considerable controversy. Reasons for this controversy are varied but range from misuse of the guidelines (i.e., application of the guidelines in ways inconsistent with their derivation or narrative intent) to actual scientific uncertainties in their interpretation. Details of these issues are discussed under *Research Needs* below. In addition, development of SQG has been focused on some of the more commonly studied sediment contaminants, such as DDT, PAHs, and common cationic metals. There are many chemicals for which SQG have not been developed.

2. Sediment Toxicity Tests
Sediment toxicity tests are the primary means of assessing the direct toxicological effects of field-collected sediments or of sediments spiked with known chemicals. Initial development of sediment toxicity tests focused on comparatively short-term (e.g., 10-day) exposures and on lethality as the primary endpoint. Protocols for these short-term methods are relatively well developed for several marine and freshwater test organisms. Fewer protocols for measuring longer-term and/or sublethal effects have been developed, but some are available for a subset of benthic test organisms. While the methods for these tests are fairly well standardized, their application in sediment assessment is still affected by lingering uncertainties related to their appropriate application and interpretation.

3. Benthic Community Surveys
Field surveys of benthic community composition have been conducted for decades and pre-date development of either SQGs or sediment toxicity tests. Perhaps because benthic community surveys have been conducted for a great variety of reasons beyond assessment of contaminated sediments (e.g., natural history evaluation, habitat assessment) and because the appropriateness of different techniques varies among physical habitats (e.g., stream, river, lake, estuary), there is a wide range of techniques available and relatively little overall standardization (that is not to say there are not standardized methods, but that no single method is recognized as intrinsically superior to others). Data from benthic community surveys are highly valued in ecological risk assessment because they reflect exposure of the organisms of interest to the contamination of interest. That said, these data are sometimes difficult to interpret because of intrinsic uncertainties and complexities, such as the effects of habitat (e.g., substrate type) and sampling bias, as well as uncertainties regarding what constitutes an meaningful adverse effect.

4. Photo-activated Toxicity of PAHs
Because PAHs are common sediment contaminants at Superfund sites, it is important that we have sufficient understanding of their ecological effects to assess risks appropriately. Photo-activated toxicity of PAHs results from an interaction of UV light, such as that in sunlight, with certain PAHs that have accumulated in the tissues of aquatic organisms. This interaction can lead to toxicity 2 or even 3 orders of magnitude more severe than that occurring in the absence of UV light. Because most toxicity data for PAHs are generated under laboratory lighting containing very little UV, there is clear potential for ecological risk from PAHs under field conditions to be underestimated. While there have been a number of studies published which demonstrate hazard from this mechanism, there is not currently an accepted approach for predicting risk from photo-activated toxicity. This shortcoming is clearly visible through controversies associated with

several Superfund sites where ecological risk assessors have attempted to include photo-activated toxicity in site risk assessments.

5. Dietary Exposure to Metals

Conventional wisdom has been that common metals such as copper, cadmium, and zinc express their effects primarily through waterborne exposure. This was not to say that dietary exposure did not exist, but that waterborne metal was the primary determinant of toxic effects. Studies by Woodward et al. (1994, 1995) and Farag et al. (1999) conducted at the Clark Fork River (CFR) and Coeur d'Alene River (CDA) Superfund sites introduced considerable controversy about this assumption by demonstrating reduced growth of trout fed diets prepared from field-collected invertebrates from these systems. Because these are metal-contaminated systems, the clear suggestion was that the elevated metals concentrations in the invertebrates were the cause of the reduced growth. While this appears to be a logical conclusion, there are many other published studies which indicate little effect from dietary exposure to some of the same metals elevated in the CFR and CDA. Other studies published by Hook and Fisher (2000) and Hornberger et al. (2000) have suggested effects from dietary exposure in invertebrates. Resolution of these issues is very important to Superfund risk assessments for metal contaminated sediments.

Research Needs

Each of the areas identified above involves a number of sub-issues for which research is needed to improve the ability of the Superfund program to assess and manage ecological risks.

1. Sediment Quality Guidelines

a. Refine bioavailability models
b. Address unusual/non-traditional partitioning phases (e.g., soot)
c. Develop partitioning models for additional chemical classes (e.g., metal oxy-anions, polar organic chemicals)
d. Evaluate assumptions regarding route of exposure (ingestion vs. interstitial water)

2. Sediment Toxicity Test

a. Establish and verify appropriate sediment collection, handling, and equilibration techniques
b. Evaluate means to insure exposure conditions are relevant to the field
c. Establish test methods for poorly represented taxa
d. Have greater assessment of sublethal endpoints

3. Benthic Community Surveys

a. Establish appropriate metrics for assessing adverse effects
b. Determine the magnitude of effects to be considered adverse
c. Account for habitat influences on survey data
d. Establish appropriate sampling methods

4. Photo-activated Toxicity of PAHs

a. Establish appropriate framework for assessing risk
b. Better understand UV exposure for free-living organisms
c. Determine degree of UV exposure received by benthic organisms
d. Develop means to accurately predict body residues

5. Dietary Exposure to Metals

a. Understand metal speciation in the context of metal uptake and toxicity
b. Assess relative contributions of waterborne and dietary pathways to toxicity under field exposure conditions
c. Establish a framework for integrating dietary exposure into overall risk estimate

Proposed Research Targets

While all of the above issues have scientific merit and involve research questions relevant to NHEERL's mission, it was decided that none clearly possessed greater urgency than do others described in this document. For the immediate future, no active research will be taken under this implementation plan within the realm of assessing non-bioaccumulative contaminants.

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Program Summary and Management

This Research Implementation Plan document describes NHEERL's contaminated sediment research program for the fiscal years 2004-2008. To the extent feasible, projects in the Plan are a blend of empirical and modeling approaches designed to solve key scientific problems associated with contaminated sediments. This plan is the result of a through planning process that considered a large number of scientific uncertainties raised by Superfund and distilled the research needs into four research projects. These projects were developed with recognition that success depends upon NHEERL's research products being adopted and used by OSRTI at Superfund sites. A breakdown of the FTEs assigned to each project and the total FTEs for contaminated sediments research across NHEERL is provided below. Although the number of FTEs available for this effort is small, these projects have the potential to significantly improve the risk assessments performed and decisions that are made at contaminated sediment Superfund sites.

Distribution of Effort by Project, Year, and Division							
Project ID	I	II	III	IV	V	VI	All Projects
Project Name	Benthic Recovery	Residues to Effects	Water and Sediment Concentration to Residues	Resuspension	ESB guidance documents	TIE guidance document	
	Division FTEs						
Year	**AED**	**MED**	**MED**	**AED**	**AED**	**AED**	
2004	2.5	0.25	3.75	1	0.1	0.20	7.8
2005	2.5	0.25	3.75	1	0.1	0.20	7.8
2006	2.5	0.25	3.75	1	0.1	0	7.6
2007	2.5	0	4	1	0	0	7.5
2008	2.5	0	4	1	0	0	7.5

By 2008, the research program expects to provide the following:

- Assessment of the applicability of sediment profile imagery (SPI) as a quick and accurate tool for monitoring effects of and recovery from dredging at a Superfund sediment site (Project I);
- Assessment of PCB residue-effects relationships and data gaps for fish, birds, and mammals for Superfund applications (Project II);
- A fully field-validated hybrid modeling/empirical approach for extrapolating BAFs, BSAFs, and predicting the ecological effects of mixtures of PBTs with differing rates of metabolism on a site-specific basis (Project III);
- Assessment of the concordance between field measurements and fate and transport model predictions of dissolved concentrations of organic and inorganic contaminants in Superfund sites following resuspension events (Project IV); and

- Assessment of the changes in bioavailability of organic and inorganic contaminants in Superfund site sediments following resuspension into the water column and resettlement to the sediment bed (Project IV).

The research program will be managed at the Division/Branch level. The investigators and steering committee will convene annually to review progress and to reassess projected commitments. In the event that resource changes or research findings indicate changes in emphasis are necessary, adjustments will be made to this plan. Because this research is based upon strategic research directions provided at the ORD level, findings from this program will be communicated not only to the client directly, but also through the ORD research planning process. Similarly, changes in strategic direction provided by ORD may impact this program.

Appendix A: Superfund Program Research Priorities

This list of Superfund Program Research priorities was created by the Superfund program office (currently, OSRTI) and is a description of research priorities for ORD from Superfund. This list was used as a starting point for discussions by the NHEERL Contaminated Sediments Steering Committee.

Superfund Program Research Priorities for ORD – December 12, 2002, Working Draft (See separate list for Oil Program Research Priorities)

The program's highest priority for ORD support continues to be site-specific technical support (provided both by through the Technical Support Centers and through other mechanisms) and technical support to OSRTI staff on guidance development.

The Superfund research needs are organized into the following catagories:

I. Ground Water Research Needs
II. Sediment Research Needs
III. Soil/Waste Research Needs
IV. Multi-Media and Analytical Research Needs
V. Human Health Research Needs
VI. Ecological Research Needs

I. GROUND WATER RESEARCH NEEDS

OSRTI Contact: Ken Lovelace
Although they are generally listed in order of priority, all of the items within this category are of high priority.

<u>GW-1. Technical Support</u>

1a. Providing technical assistance to EPA regional staff for site specific issues related to characterization, evaluation (e.g., modeling), and remediation of contaminated ground water.

1b. Providing technical assistance to EPA HQ staff for guidance development (e.g., serving on workgroups and/or technical reviews of draft documents).

<u>GW-2. Natural Attenuation/Bioremediation Processes</u>

2a. Research of attenuation (physical, chemical, biologic) processes affecting *inorganic (metals and metalloids) and radiologic contaminants* in ground water. This includes basic research on relevant processes and potential methods for enhancing natural processes. [Includes Projects H1, H4, and H9 on previous list]

2b. Research of attenuation (physical, chemical, biologic) processes affecting *recalcitrant* *organic contaminants (e.g., semivolatile compounds, pesticides)* in ground water. This includes basic research on relevant processes and potential methods for enhancing natural processes. [Includes Projects H1, H4, and H9 on previous list]

2c. Research of methods to *enhance bioremediation* of contaminants in ground water. [Project H7 on previous list]

2d. Research and development of improved methods for evaluating *long-term performance of monitored natural attenuation (MNA) remedies*, including plume stability, changes in hydraulic conditions, changes in biogeochemical environment, discharges to surface water (see "Emerging Issues" below), and impacts on indoor air (see "Emerging Issues" below). [Not on previous list]

2e. Development and application of natural attenuation research. This includes site characterization methods, field demonstration projects, workshops, workshop reports, and training courses. [Includes Projects H1 and M28 on previous list]

<u>GW-3. Dense, Non-Aqueous Phase Liquid Characterization and Remediation</u>

3a. Research on improved methods for locating and characterizing dense, non-aqueous phase liquids (DNAPLs) in the subsurface. This includes *geophysical* methods and techniques for measuring *mass flux* from DNAPL source areas. [Projects H5 and NH2 on previous list]

3b. Research on improved methods for remediating DNAPLs in the subsurface. This includes all possible methods for *in-situ* treatment of DNAPLs (e.g., thermal, chemical oxidation, surfactant flushing, reactive barriers, enhanced bioremediation, and other methods). [Project H3 on previous list]

3c. Development and application of DNAPL-related research. This includes field demonstration projects, workshops, workshop reports, and training courses. [Includes Project NH2 (mass flux) on previous list]

<u>GW-4. Emerging Issues</u>

4a. Research on improved methods for assessing migration of contaminants from ground water to *indoor air*. This includes improved site characterization techniques, model verification studies, and improved guidelines for use of models. [Note: an indoor air research topic should also be included under the risk issue] [Not on previous list]

4b. Research on improved methods for assessing migration of contaminants from *ground water to surface water* as needed to provide input for evaluation of environmental impacts/risks (see "Risk Issue"). This includes improved site characterization techniques. [Not on previous list]

GW-5. Field Characterization–Sampling and Monitoring Methods

5a. Research and development of improved methods for detection and measurement of contaminants in ground water. This includes basic research as well as development and field testing of methods to be used in initial site characterization as well as in long-term site monitoring. [Includes Project NH1 on previous list]

GW-6. Long-Term Remedy Performance

6a. Research and development of improved methods for evaluating long-term performance of *pump and treat systems*, including capture zone analysis, evaluation of monitoring effectiveness, optimization methods, etc., This could include improved methods for collection, tabulation, plotting, and statistical evaluation of large data sets. [Projects H10, H8 and M1 on previous list]

6b. Research and development of improved methods for evaluating long-term performance of *permeable reactive barriers (PRBs)*. This could include research and development of methods for enhancing performance of PRBs, evaluation of treatment effectiveness, monitoring effectiveness, and optimization methods, etc., [Project H6 on previous list]

6c. Research and development of improved methods for evaluating long-term performance of *vertical containment barriers*. This could include research and development of methods for verifying barrier continuity, wall embedment, and leak detection. [Project H2 on previous list]

II. SEDIMENT RESEARCH NEEDS

OSRTI Contact: Steve Ells

[Some additions still to be incorporated from focus group write-ups, plus current prioritization is still underway.]

Site Characterization Issues

SED-1. Development of Sediment Contaminant Screening Levels

SED-1. Fate and Transport Model Recommendations

What models should be recommended for various common types of sediment sites?

SED-2. Measuring Effects of Large Events on Sediment Transport

It is difficult to monitor during some large hydrologic events, especially those which involve ice scour, both because they are not easy to predict and because of physical dangers. Lacking that, are there practices we can recommend for after-the-fact measuring the effects of these events on sediment movement? [This may be a literature survey question.]

SED-3. Tools for Locating Debris

What are the best tools for locating and identifying debris (buried and surficial) in sediment (e.g., during evaluation of dredging alternatives)?

SED-4. Determination of Background Levels in Biota and Sediment

SED-5. Sampling Surface Sediments

e.g., How to sample surface fluff layer?

SED-6. Ground Water/Sediment Interactions

When should you evaluate GW-Sediment interactions?

SED-7. Evaluating Past Erosion and Deposition

What suite of empirical methods can we recommend for assessing the extent to which deposits of contaminated sediment are the result of deposition only versus the result of alternating erosion and deposition? Do we recommend a different suite of methods for different types of water bodies? Where deposits are the result of alternating erosion and deposition, are there empirical methods available to evaluate the horizontal and vertical scale of that movement, or can this only be estimated through modeling? What are common rates of erosion and deposition in various environments which are typical of Superfund contaminated sediment sites?

SED-8. Biota and Sediment Sampling Procedures

What are our research needs in this area?

SED-9. Fish Ingestion Rates

What are best practices for selecting fish ingestion rates for risk assessment and selection of cleanup levels?

SED-10. Chemical Fingerprinting to Tie Risk Drivers to Sources

For contaminants such as PCBs and others which undergo some degree of biodegradation in sediment, is research needed to better tie drivers to sources or to risk?

SED-11. Rates of Contaminant Transport through Bioturbation

How important is bioturbation in contaminant transport in different habitats? What are ranges of rates of contaminant transport for common Superfund contaminants in sediment (PCBs, metals, PAHs) in Superfund contaminated sediment environments where bioturbation may be a key transport element (e.g., estuaries, freshwater harbors, and lakes)? [Need to think more about what the real question should be here. Are more biota at risk if contaminants are moved closer to the surface, or is it a question of being more susceptible to transport by erosion?]

SED-12. Community Involvement at Large Sediment Sites

How best to collect/know community concerns at big sites?

Ecological and Human Health Risk Issues

SED-13. Prediction of Safe Biota Residue Levels and Population Recovery Times

How can we better predict time to safe contaminant residue levels in biota and biota population recovery times? What are the most uncertain elements of the models we use to make these predictions? What is driving that uncertainty? Some answers will vary by cleanup method (e.g., dredging residuals, rates of natural sedimentation); others are expected to be universal (e.g., recontamination from uncontrolled sources, large-ranging species). How can we reduce that uncertainty in some of those areas? [This may need to be broken up into several priorities.]

<u>SED-14. Critical Residue Levels for Bioaccumulative Contaminants</u>

What are the critical tissue residue levels for bioaccumulative contaminants?

<u>SED-15. Cleanup Levels for Eco-Risks</u>

How best to determine acceptable cleanup levels for eco-risks?

<u>SED-16. Dermal Exposure/Uptake from Sediment</u>

<u>SED-17. Fish Ingestion Rates</u>

What are best methods for determining what fish ingestion rates to use for risk assessments and determination of cleanup levels?

<u>SED-18. Standardized Process to Characterize Human Health and Ecological Risks from Ingestion of PCB-contaminated Fish on a Congener Basis</u>

Development and Evaluation of Remedies

<u>SED-19. Monitoring Methods and Protocols</u>

What are the best remedial action and long-term monitoring methods for various sediment remedies? Are new methods needed? Are protocols needed?

<u>SED-20. Effectiveness of Containment During Dredging</u>

How effective are silt curtains and screens? What are the best practices for monitoring and increasing their effectiveness?

<u>SED-21. Dredging Residuals</u>

How can we better predict dredging residuals in different sediment habitats. What are achievable cleanup levels?

<u>SED-22. Dredging Resuspension</u>

What are the impacts from resuspension caused by dredging? Does dredging result in increased environmental risks to aquatic receptors?

<u>SED-23. Beneficial Use of Dredged Material</u>

How to identify beneficial uses for contaminated sediments at a site?

<u>SED-24. Cost-Effective Treatment Technologies for Dredged Material</u>

<u>SED-25. Effectiveness of *In-Situ* Remedies</u>

How effective are existing monitored natural recovery (MNR) and capping remedies? What are theoretical “break-through” times for typical caps and natural deposits overlying contaminated sediment?

<u>SED-26. *In-Situ* Reactive Caps and Enhanced Bioremediation Technologies</u>

SED-27. Designing *In-Situ* Caps to Accommodate Habitat Restoration/Recovery

SED-28. Enhanced Monitored Natural Recovery

Are there effective measures to enhance MNR? Does thin layer placement speed up natural recovery? (a) Evaluate, to the extent possible, actual effectiveness of thin layer placement as a method to speed up natural recovery at contaminated sediment sites in quiescent environments. (b) Evaluate theoretical effectiveness of thin layer placement as a method to speed up natural recovery in quiescent environments, including the following aspects: What are some theoretical combinations of thickness of placed layer and contaminant movement through bioturbation in underlying sediment that result in predicted outcomes?

III. SOIL/WASTE RESEARCH NEEDS

OSRTI Contact for Landfills/Containment: Ken Skahn
OSRTI Contact for Mining: Shahid Mahmud

High Priority

SOIL/WASTE-1. Performance Monitoring for Landfill Caps

Determine appropriate methods and equipment to monitor the performance of landfill caps. What monitoring methods are needed to detect barrier breaches? What modeling methods should be used? How do contaminants affect the long-term integrity of barrier materials? OSWER is revising the landfill capping guidance document issued in July 1989 and will add requirements for monitoring the performance (prevention of infiltration) of installed landfill caps. The information prepared under this project will be the background support needed to support the new requirements. [Previously H39]

SOIL/WASTE-2. Long-Term Remedy Performance for Containment Systems

For example, persistence of contaminants and their effects if they have been stabilized or solidified; design life of physical barriers, e.g., caps, slurry walls. [Previously H40]

SOIL/WASTE-3. Management of Landfill Gas

Determine appropriate methods to monitor and measure the gas escaping from landfill units. Determine the point at which measurements would indicate it would be acceptable (based on existing regulations) to vent landfill gas in lieu of collecting the gas for beneficial use or treatment. Determine appropriate collection systems. Determine appropriate technologies for treatment of the collected landfill gas. Determine the point at which collection is no longer required and gas could be vented directly to the atmosphere. How to manage LF gas and understand its movement in capped LFs and under clay vs. phyto caps. [Previously H41]

Medium Priority

SOIL/WASTE-4. Landfills

(1) Upgrade guidance [is this same guidance as #1 above?]; (2) Need data to show if evapotranspiration and capillary barrier covers will work in arid conditions. Need criteria for designing these types of covers. [Previously M20]

SOIL/WASTE-5. Seismic Considerations for Landfill Caps and Vertical Barriers

EPA has not addressed the need to consider the effect of seismic events in the design of landfill caps and vertical containment barriers. This project would entail the search of literature for relevant research papers, reports on actual impacts to caps, and data to support recommendations on design guidelines for capping landfills in areas subject to seismic events. This information will help to support guidelines developed for the capping guidance document and determine whether subsequent guidelines are needed for vertical barriers. [Previously M21]

SOILWASTE-6. Evaluation of Alternative Designs and Materials for Caps and Barrier Walls

A newly developed landfill cap design has emerged which shows promise for use in arid environments. The evapo-transpiration cap does not rely on traditional impermeable barriers to prevent infiltration from passing through the cap, but instead relies on the depth of materials in the cap and vegetation to release moisture back to the atmosphere before the moisture can reach the bottom of the cap material. Other designs may also be viable. Information on the performance, durability, and design parameters and minimum standards for these new caps must be collected and analyzed. Performance data and design criteria recommendations for revised capping guidance are needed. New materials for landfill cap and barrier wall construction are emerging on a regular basis. Data is needed on the acceptability of these materials with regard to meeting performance requirements, durability, and relative cost. This project would require review of technical papers, data from independent testing, and consultation with other federal agencies (i.e., Army Corps of Engineers, Bureau of Reclamations, Department of Energy, etc.) to collect the needed information. [Previously M22]

SOIL/WASTE-7. Verification of HELP Model

EPA has recommended use of the HELP (Hydrogeologic Evaluation of Landfill Performance) Model in past guidance documents. The HELP Model is used widely for the design of drainage features for landfill caps as well as predicting leachate generation for municipal landfills. There is concern among designers as to the accuracy of the model. This would entail making an assessment of the accuracy of the model in predicting infiltration rates and recommendations as to the extent it should be used in the future. The effort should also include an assessment of other available models. [This is an on-going research area that may be complete by FY03? But FY02 note says "Per discussion with NRMRL, clarification is that for the short-term (and about $25-50K) need to communicate to users exactly what the model should and should not be used for. Longer-term and more expense would include expansion/correction of model."] [Previously M24]

SOIL/WASTE-8. Mining Site Research [Previously M25]
OSRTI Contact Shahid Mahmud

a. Analysis and Development of Mine Waste Technologies
Short term: analysis/inventory of existing technologies to address mine waste.
Long term: development of cost-effective technologies to address mine waste. Mine

waste includes all types including uranium. [Note: Mine Waste Technology Program (Butte, MT?) is implementing this.]

b. Mapping System/Inventory of Mine-Affected Watersheds
Need for a mapping/database system containing contaminated watersheds resulting from mining; continue using AVRIS to map mine sites.

c. Inventory of Naturally-Occurring High Arsenic
A paper study of where As is naturally occurring at high levels. Start with USGS conference proceedings May 2002 in Denver? Potential contacts: NRMRL - Paul Randall; NERL - Jane Denne

d. Develop Predictive Site Characterization Tools for Acid Mine Drainage.
[USGS may be doing this.]

<u>SOIL/WASTE-9. Optimization of SVE</u>

How best to sequence pumping; how to know when remedy is close to asymptotic levels. [Previously M27] OSRTI contact - Mike Bellot(?) [Is this still needed after NRMRL technical report FY01?]

<u>SOIL/WASTE-10. Bioavailability of Metals and Organics from Soils (Human Health and Ecological)</u> [Not sure what category this belongs in.]

Contacts: OSRTI - Steve Ells, Janine Dinan; Regions 7 & 9
Determine bioavailability of contaminants through human ingestion to support both risk assessment of contaminants in residential and industrial/commercial scenarios and to determine cleanup goals for soil remediation technologies. In particular, assess the bioavailability of lead, mercury, chromium, arsenic, and cadmium. Reference doses, benchmark guidance and RfC values need development and communication. Children of different ethnic backgrounds may have different exposures. Fish advisory values /effects differ among federal agencies. The question, then, is “If a child or adult ingests soil, what is the internal dose relative to the contaminant concentration in the soil?” A core part of this research should be a strategy for relating *in vitro* studies to empirical animal studies to human biomarker/epidemiological data. Develop and evaluate processes to reduce contaminant bioavailability. [Previously H27]

IV. MULTI-MEDIA & ANALYTICAL RESEARCH NEEDS

Analytical Research Needs - OSRTI Contact: Dana Tulis

High Priority

<u>MULTI-1. Statistical Expertise to Support Background Policy</u>

OSRTI Contact - Jayne Michaud
Provide technical expertise for statistical problems related to Superfund site activities and for implementing the new Superfund technical guidance for determining background. [Previously H32]

<u>MULTI-2. Support on-site Audits of Non-CLP Labs</u>

[Not currently being done by ORD] [Previously H37]

<u>MULTI-3. Peer Review of New Analytical Methodologies</u>

On-going need, e.g., PCBs [Previously H38]

Medium Priority

<u>MULTI-4. Phytoremediation</u>

OSRTI Contacts: Scott Fredericks, Steve Ells, Robin Anderson
Develop improved methods of remediating soil and ground water using vegetation planted and grown in the contaminated areas. Questions remain concerning what are the tolerant plant species, mechanisms of contaminant breakdown, and the rates of cleanup for key contaminants found at Superfund sites. [Previously M22]

<u>MULTI-5. Analytical Detection Limits for Bioaccumulative Chemicals</u>

OSRTI Contact – Steve Ells
The goal of this project is to develop lower analytical detection limits for chemical analyses of known bioaccumulators in water, soil, sediment, and tissue samples. [Previously M13]

<u>MULTI-6. Arsenic and Mercury</u>

OSRTI contact - Robin Anderson
Short term - engineering bulletin. Long term - if there are technologies on the horizon, it would be good to know more about them. [Note: Have fact sheets on Pb remediation methods - what we have learned. Need to know for As and Hg what technologies will and will not work. FY02 note: NRMRL suggests that OSRTI follows up with Paul Randall, NRMRL. DOE has done a number of studies/demos on cleanup of Hg-contaminated soils. There were discussions in Denver (week of May 7) about cleanup of Hg-contaminated soils. Robert Puls in Ada is contact for As-contaminated ground water.] [Previously M26]

<u>MULTI-7. May be a need for dioxin research</u>

Depending on the results of the reassessment, e.g., current technologies may be unable to reach new levels. [Previously L1]

<u>MULTI-8. Support of sample preparation for high concentration analyses</u>

OSRTI Contact - Dana Tulis
[Previously L6]

V. HUMAN HEALTH RESEARCH NEEDS

OSRTI Contact: Jayne Michaud

High Priority

HH-1. Reduce Uncertainties Associated with Dermal Exposure Assessments - Water Exposure

OSRTI contact: Dave Crawford
For water exposures, is model in Part E over- or under-estimating actual absorption, or are assumptions reasonably accurate? Additional research is necessary to determine the absorption of lipophilic contaminants (e.g. PCBs, dioxins) through the skin barrier. (Part E, is Part E of Risk Assessment Guidance for Superfund (RAGS) and addresses dermal exposures. This is Superfund's current draft guidance on dermal risk. It is considered an extension of the ORD guidance on dermal exposure, known as "Dermal Exposure Assessment" or "DEA.") [Short-term project] [Previously H20]

HH-2. Dermal Exposure Model

OSRTI contact: Dave Crawford
Refine (Part E) or develop model for estimating dermal absorption of contaminants from soil using permeability coefficients. Consider issuing as an update of DEA or Part E and evaluate efficacy of on-going methodolgy developed for reoccupancy of buildings in the vicinity of the World Trade Center. [long-term project] [Previously H21]

HH-3. Determine Dermal Toxicity Effects and Develop Dermal Toxicity Values

OSRTI point of contact: Dave Crawford
For contaminants without dermal toxicity values in IRIS, expand the database of toxicity values. For noncancer toxicity, expand the database of values (i.e., RfDs) for subchronic and acute exposures, as well as chronic RfDs. Develop values for for "point-of-contact (on skin) toxicity," including PAHs. Recommend that such values loaded into OSRTI's database of NCEA peer reviewed toxicity values. [medium-term project] [Formerly H23, and before that, part of H22, H24, and H25]

HH-4. Develop Methodology for Integrated Assessment for Residential Exposures

OSRTI point of contact: Jayne Michaud and Dave Crawford (dermal)
For various media, including vapor intrusion (indoor air), dermal exposure to building surfaces (as well as soil and water), and soil ingestion. Consider an update to Part E for dermal, use of the World Trade Center reoccupancy assessment and the recent Vapor Intrusion Guidance for the Integrated Assessment. [short-, medium-, and long-term project] [Formerly H24, and before that, part of H24]

HH-5. Improve Dose-Response Assessment

OSRTI point of contact: Jayne Michaud
Improve dose-response assessments for contaminants occurring frequently at Superfund sites considering the use of additional pharmaco-kinetic physiological models. When scientifically appropriate, develop special assessments applicable to children and women as sensitive subpopulations. When appropriate, provide methodology for assessing more sensitive or highly exposed subpopulations. Recommend that such values be considered for inclusion in

IRIS, or, alternately, the PRTV database. [Formerly H26] [Medium-term Project]

Medium Priority

HH-6. Reduce Uncertainties Associated with Dermal Exposure Assessments - Soil Exposure

OSRTI contact: Dave Crawford

Generate and intepret additional experimental data to assess reliability of Part E's estimation of dermal exposures to soil. [Medium-term project] [Previously part of H20]

HH-7. Support for the Exposure Factors Handbook

OSRTI contact: Jayne Michaud, Steve Chang

Update and expand assumptions and supporting justification for human health exposure assumptions, including soil ingestion. Questions: Will this provide sufficient information for use in Probablistic Risk Assessments? [Medium-term project] [Previously H19]

VI. ECOLOGICAL RESEARCH NEEDS

OSRTI Contact: David Charters

High Priority

ECO-1. Define Ecological Significance

Contacts: OSRTI - Steve Ells; ERASC; ORD - Focus Group 7 (has detailed plans for this FY02 - FY07)

Goal is to clearly define and describe ecological significance and to determine what levels of population and community effects are generally acceptable; i.e., will a 20% reduction in a specific endpoint still sustain a functioning, healthy ecosystem? How does EPA determine that (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 unimpacted ecosystems? [Previously H28]

ECO-2. Balancing the Benefits of Remedial Action versus Destruction of Valuable Habitats

The goal of this project would be to develop criteria and provide guidance on how to determine when there is more benefit to the existing ecosystem from leaving soil or sediment contamination in place and preserving the current habitat (although stressed) versus a destructive remedy that removes the contamination and destroys the current habitat. How do you value a habitat that is functioning, but at less-than-optimal levels versus the short- to long-term impacts on destroying the same habitat and then trying to restore it? [Previously H29]

ECO-3. Develop Predictive Models for Determining the Potential Population Level Effects

How much sediment toxicity is needed before anyone can predict that there will be significant effects on the population of concern; e.g, how many bass or mink or kingfishers can be killed before the mortality levels is expected to impact the ability of the population of biota to sustain itself at a healthy level in the area impacted by the site. [Previously H31]

ECO-4. Weight-of-Evidence Approach for Ecological Effects/Cleanup Levels

There are published papers on this process. Should Superfund adopt a similar process for consistent use at our sites? [Previously H33]

ECO-5. Support Development of EcoSSLs for Mammals, Birds, Plants, and Soil Invertebrates

[Previously H34]

ECO-6. Continue to Support and Maintain the ECOTOX Database

[Previously H35]

ECO-7. Design Toxicity Testing Procedure to Develop Toxicity Reference Values for Non-Eco-SL Contaminants

Utilize the criteria developed by the Ecological Soil Screening Level (Eco-SSL) workgroup to design a toxicity testing procedure to meet these criteria in order to generate toxicity reference values (TRVs) for additional contaminants not being addressed by the Eco-SSL workgroup or for which TRVs are lacking. [Previously H36]

Medium Priority

ECO-8. Determine Bioavailablity of Chemicals for Different Media

The central question is how does one relate concentration of a contaminant in a medium (even the medium for animal dose/response studies) to the delivered or internal dose. Answering this question would reduce a major source of uncertainty in risk assessments. [Previously M6]

ECO-9. Develop a Methodology to Evaluate the Inhalation Exposure Pathway for Mammals

[Previously M10]

ECO-10. Development of Recommended Performance Criteria to Measure the Success of Wetlands Restoration/Creation

FY02 note: No expertise within ORD. What about Midwest Hazardous Substances Research Center (HSRC)? [Previously M11]

ECO-11. Support Wildlife Research Strategy

[Previously M12]

ECO-12. Develop Terrestrial Risk Assessment Models for Various Habitats from Deciduous Forests to Deserts

[Previously M14]

ECO-13. Develop Toxicity Testing Methodologies for Amphibians, Reptiles, and Microbial Communities

[Previously M15]

ECO-14. Develop an Approach for Incorporating Dose Response Information into Ecological

Risk Assessments that Go beyond the Hazard Quotient Approach

How can the likelihood of risk be quantified when the hazard quotient is greater than 1? Develop an approach for conducting uncertainty assessment using site-specific case studies. [Previously M16]

ECO-15. Develop Tools and Methods to Better Characterize the Ecological Exposure and Effects of Multiple Chemicals, i.e., Mixtures

[Previously M17]

ECO-16. Develop an Approach for Assessing the Exposure and Effects of Contaminants to Corals

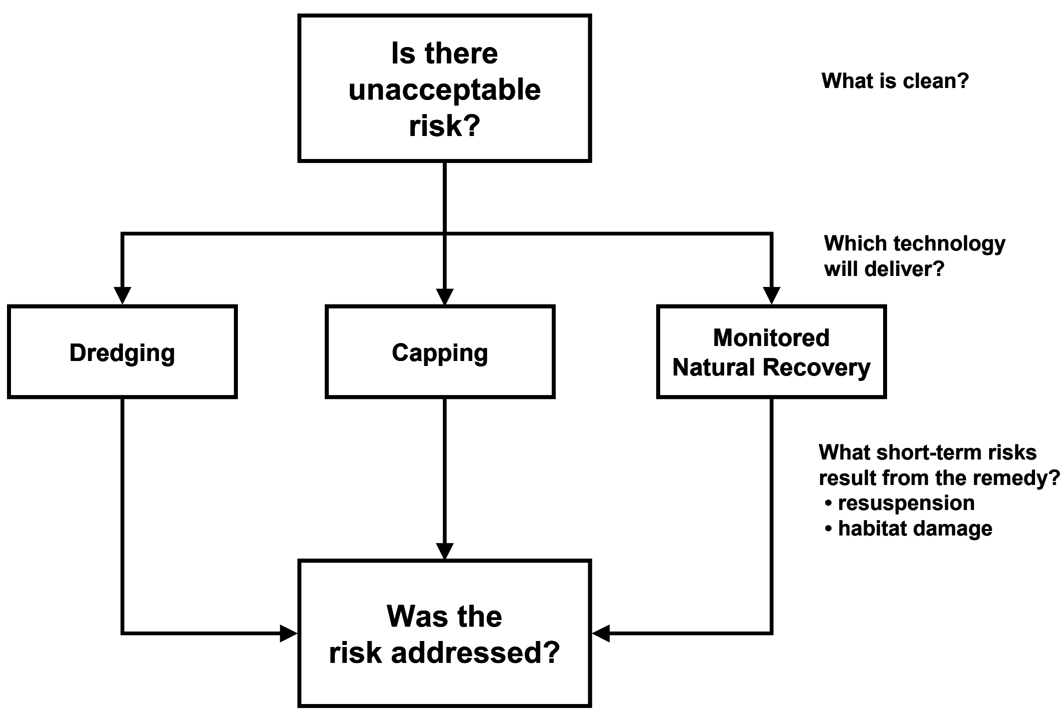
[Previously L no-number]

Appendix B: Expanded Descriptions of Ten Issues Resulting from May 2003 AED Meeting

This list of Sediment Research Issues resulted from the discussions of the twenty-eight sediment research issues of Superfund (see Appendix A) by the Steering Committee in May 2003. These discussions evaluated the appropriateness of the research issue to the mission and capabilities of NHEERL. For each of the ten research issues, an expanded description is provided below.

Sediment Research Issues

The sediment research issue descriptions were developed from a list of priorities provided by Superfund, see Superfund Program Research Priorities for ORD - December 12, 2002, Working Draft, discussed at the May 1 kickoff meeting at AED in Narragansett, RI. The following descriptions are based around the following schematic of the Superfund remediation process for contaminated sediments:



Developing Sediment Contaminant Screening Levels (SED-1)

Screening levels are used in the Superfund program as an initial evaluation as to whether individual contaminants should be included in more detailed risk assessments. They are indicators of potential risk and are not designed to be used as remedial goals; their purpose is simply to “screen in” chemicals for further evaluation. As such, their primary emphasis is to avoid false negatives; however, to be efficient screening tools, they should not be so conservative that they provide no discrimination. While screening values for direct toxic effects of contaminated sediments have been developed using several methods (e.g., EqP, ERL/ERM, TEL/PEL, AET, logistic regression), there are no widely accepted screening values for sediment-associated chemicals that cause their effects on pelagic aquatic or terrestrial wildlife species through bioaccumulation pathways.

Because they are to be used broadly, their derivation must account for a wide variety of exposure scenarios and receptors. The key scientific challenges to developing screening values arise from the differing amounts and types of available toxicological data available (differences in species, endpoints, life stage, exposure, etc.,) and the necessity of defining the linkages between the chemical concentrations in the sediment and the biota of interest. In describing these linkages, one must account for the effects upon the bioaccumulation of the chemical attributable to differences in chemical exposure arising from ecosystem conditions, food web structure, and species composition.

From a implementation perspective, screening values based upon a standardized and peer-reviewed and accepted numeric derivation technique using robust data sets are most desirable. These screening levels can be based upon a number of "indicator" species and toxicological endpoints. Effort is required to derive a generalized conceptual model (exposures, receptors, endpoints) and to develop sets of standardized procedures to be applied in deriving estimates of bioaccumulation and in establishing effect concentrations in tissues of predator and/or prey.

Establishing Guidance on Sampling Biota and Surface Sediments at Superfund Sites (SED-5, SED-8)

Several existing protocols provide guidance for sampling biota and sediments at contaminated sites (e.g., U.S. EPA, Environment Canada). However, because of the remedial activities occurring at Superfund sites, they often represent unique settings for collecting biota and sediments. For example, values that can be standardized at regular field sites like depth of sampling may not be readily determined at a Superfund site because of the presence of a cap or effects of MNR. Further, how to sample a site for surface sediments or resident biota following a dredging event may not be clear if sediments have been altered in consistency and mixed vertically or biota are no longer present. Research is needed to determine the best practices for sampling biota and surface sediments at Superfund sites, especially when measuring risk reduction after remedy implementation. Also see "Assessing the Effects of Contaminated Sediment Resuspension" discussed below.

Linking Chemical Residues in Aquatic Biota to Levels of Ecological Risk for Aquatic and Aquatic-Dependent Wildlife (SED-13 [partial], 14)

Doses of bioaccumulative chemicals to fish and wildlife are best expressed on the basis of tissue residues, in part because tissue residues integrate doses received from multiple exposure pathways (e.g., food, water, sediment). However, to use tissue residue as the basis for predicting risk, there must be an unambiguous means to link specific residue concentrations to the biological effects they cause. Ideally, the conceptual basis for this would be robust enough to be used for different chemicals and for different sites, thus providing consistency and transparency to risk assessments throughout the Superfund program. Key challenges to establishing this linkage arise from the differing amounts and types of toxicological data available; these include differences in species, endpoints, life stage tested, exposure methods (e.g., food versus water), exposure duration, and methods of quanitfying or expressing exposure.

Another need for a residue-based approach is a reliable means of relating concentrations in the physical environment (water, sediment, food chain) to residues expected in consumer organisms and/or prey for organisms of interest to the risk assessment. While direct measurements may suffice for the initial risk assessment, comparing changes in risk from different remedial alternatives will require a means to predict tissue residues resulting for altered concentrations in sediment and water as a result of remedial actions.

From the broadest perspective, tools are needed to extrapolate toxicological data, particularly among different receptor organisms. Aquatic or aquatic-dependent wildlife species of interest at different sites will likely vary; and, in many cases, available toxicological data will be available only for species other than the actual receptor species. This requires extrapolation of toxicological data among species, which relies on an understanding of the toxic mechanisms for the chemicals of concern, and extrapolation tools such as PB/TK models to predict effects in untested species.

Predicting Rates of Recovery Following Remedial Actions (SED-13 [partial])

As part of selecting and implementing a remedial alternative, it is important to have sound expectations of the rates at which reduction in risk can be expected, whether it be in the form of reduced residues in prey organisms or recovery of affected organism populations and communities. Additionally, it is important to have sound expectations of the rates at which the ecosystem recovers from the short-term impacts of the remedial alternative (e.g., understanding how fast an area recolonizes after dredging and/or deposition of capping materials and whether different types of capping material influence biological recovery). For the reduction in risk, an understanding of both the rate and magnitude of the change in exposure created by the remedial alternative (from physical/chemical modeling), as well as an understanding of the mechanisms governing the response of organisms to changes in exposure (from kinetically based bioaccumulation modeling), is required. Predicting the recovery of impacted populations and communities, as well as the recolonization of the remediated site, will require an understanding of the ecology of those organisms and of the factors and environmental conditions governing population growth and community structure.

Development of Appropriate Remedial Goals for Non-Bioaccumulative Chemicals (SED-15)

While the ecological risks from chemicals such as PCBs arise from bioaccumulation-enhanced exposure of pelagic or non-aquatic organisms, risk from other sediment contaminants is created by direct toxicity to organisms living in contact with contaminated sediments. These "non-bioaccumulative" effects may be assessed through a variety of means, including comparison of chemical concentrations in water and/or sediment to chemical specific benchmarks (e.g., sediment quality guidelines), sediment toxicity testing, toxicity identifications evaluations (TIE), or benthic community assessments. Experience has shown that at some sites, evaluations of potential risk via these different lines of evidence suggest different levels of risk or even appear to conflict. Assessment approaches are needed through which to reconcile information from these different lines of evidence and arrive at a consistent and transparent establishment of remedial objectives that will adequately address ecological risks.

Delineation of Appropriate Uses of Total PCBs, Aroclor-Based, and Congener-Specific PCB Concentrations as the Basis for Assessing and Managing Risks from PCBs (SED-18)

PCBs occur in the environment as mixtures of up to 209 different congeners, each with unique physical, chemical, and toxicological behaviors that influence risk. Early measurement and assessment techniques were developed using expressions of “total PCBs” or of “Arochlor” mixtures which are related to different formulations of PCB congeners released to the environment. These aggregate expressions of PCB exposures can lead to inaccuracies in assessing and predicting ecological risks because they fail to recognize differences in exposure and risk that result from the different environmental fate and effects of the individual congeners that comprise the environmental mixtures. Our advancing understanding of PCB risk assessment has led to the development of risk assessment techniques based on the concentrations of individual congeners and the way in which each contributes to cumulative risk. While the scientific community is in broad agreement that congener-specific assessment provides the most accurate estimates of ecological risk, implementation of this approach is impeded by concerns over differences in required analytical procedures and by selection of methods for assigning and aggregating potencies of individual congeners. Research is needed to quantify the degree to which the accuracy of risk assessment is improved by congener-specific analysis and to articulate a consistent and transparent approach for congener-specific estimation of risk into the context of Superfund sites.

Assessing the Toxic and Bioaccumulative Effects of Contaminated Sediment Resuspension (SED-22)

Dredging is the most common remedy for sites containing contaminated sediments. There are several advantages to dredging, principally, the effective removal of material causing the environmental risk. Simultaneously, dredging is the most expensive remedy with the most potential to impart short-term adverse impacts on the site and, in particular, on surrounding uncontaminated areas. These impacts derive primarily from the effects of resuspension of contaminated sediments during dredging. Based on the available data, resuspension results in the transport of contaminated sediments from the site as well as the flux of bioavailable contaminants into the water column. The resuspension of sediments may also result in the contamination of previously clean areas.

Methods are available for modeling the partitioning, bioavailability, and effects of contaminants in sediments under “equilibrium” or undisturbed conditions. However, when sediments are resuspended or enter “disequilibrium,” several studies have demonstrated that associated contaminants, including organic and metal pollutants, are remobilized. However, the bioavailability and effects of these contaminants in terms of toxicity to or bioaccumulation by aquatic life have not been extensively studied and are not very well understood. Similarly, the development of predictive models of resuspended contaminant bioavailability and toxic or bioaccumulative effects is in its infancy.

Research in this area is needed to determine the magnitude of risk associated with the resuspension of contaminated sediments resulting from dredging and other energetic events including tidal action, bioturbation, and ship traffic. This research should address the risk of toxicity and increased bioaccumulation of organic and metal contaminants during resuspension events at Superfund sites.

Monitoring Methods and Protocols (SED-19)

Superfund has an immediate need for better monitoring methods and protocols to document remedial effects and the long-term effectiveness of remedial actions. While individual measures exist (toxicity tests, bioaccumulation measurements, chemistry data, etc.), protocols to assemble these disparate measures together in a consistent manner to make management decisions at sediment sites are lacking. In addition, while it is known that the methods to monitor remedial effects and the methods to monitor long-term effectiveness are different, the pros and cons of each approach are not clearly articulated. Fact sheets are being planned which will discuss individual monitoring methods in detail; however, the protocol for an all-inclusive weight-of-evidence (WOE) approach to monitoring requires further research. The statistical sampling approaches, inherent uncertainty, and combined assessment methods for chemical, biological, and physical data need to be determined and tested at actual sites. The WOE approach also needs to be placed in a tiered format so that it can applied at a variety of sediment sites, regardless of size or funds available.

Dredging Residuals (SED-21a)

Dredging is the most commonly selected remedial option at sediment sites and the only one that removes contamination from the aquatic environment. However, there is still a significant amount of uncertainty about how effective dredging is and the amount of post-remedial contamination left. Is this “dredging residual” the result of careless dredging and/or the use of older equipment, or is it inevitable no matter which dredging equipment is selected? Is the residual dangerous relative to the benefit of mass removal? Does the risk-benefit vary in different water bodies (e.g., rivers vs. estuaries)? Quantifying and reducing this uncertainty is vital and must be accomplished soon as several “megasite” cleanups (e.g. New Bedford Harbor, Hudson River, Fox River) have selected dredging. These results could have a significant effect on the future selection of the dredging remedy.

Cleanup Levels (SED 21b)

The cleanup level at a sediment site determines the volume of sediment to be remediated. The sediment volume is a driving factor of remedial costs. Disagreements over whether cleanup levels are reached is one of the most significant arguments against active sediment remediation, particularly the use of dredging. A recent review of 50 dredging projects worldwide found extensive documentation of how cleanup levels were chosen (based on the human health and ecological risk assessments), but there was very little documentation of how it was determined that those results were or were not achieved. None of the projects had a statistically valid approach to determine how cleanup levels would be evaluated (number of samples to be taken, spatially averaged approach, etc.). It would be valuable to Superfund to promulgate guidance on a consistent approach to verify post-remedial cleanup levels. Research in this area would be integrated with studies of dredging residuals in that it is necessary to understand residual amounts and risks in order to decide on the most effective, achievable, and environmentally protective cleanup levels.

Appendix C: Description of Science Tasks and Level of Effort for Eight Research Issues

The descriptions below were developed after critical discussion of the ten issues (see Appendix B) by the Steering Committee via a series conference calls. Of the ten research issues identified in Appendix B, two issues (SED-21a and SED-21b) were removed from further consideration during these discussions because the primary research needed to address the research questions were outside NHEERL's mission. The descriptions below provide a listing of tasks and the amount of effort for the eight remaining research issues.

A. Developing sediment contaminant screening levels (SED-1)

1. This is a paper exercise.
2. The science tasks are
   a. Assembling a methodology for deriving;
   b. Evaluating its usefulness (e.g., too many false positives or negatives); and
   c. Refining methodology.
3. As we have learned in discussions with Superfund, development of an actual methodology and values will require a stakeholder process in order to move forward politically.

B. Establishing guidance on sampling biota and surface sediments at Superfund sites (SED-5, SED-8)

1. This is a paper exercise.
2. The exercise will pull together existing sampling protocols and scientific expertise to assemble useful guidance for Superfund sites.

C. Linking chemical residues in aquatic biota to levels of ecological risk to aquatic and aquatic-dependent wildlife (SED-13 [partial], 14)

1. This effort will require new science research.
2. The science tasks are
   a. Development of visualization approach,
   b. Extension of visualization approach to include extrapolation,
   c. Development of high quality field data sets to validate visualization approach for extrapolation across species and ecosystems,
   d. Development of high quality field data sets for metabolizable chemicals in aquatic ecosystems,
   e. Development of approaches for parameterizing bioaccumulation models for metabolizable chemicals,
   f. Evaluation of uncertainties in predicting chemical residues in aquatic organisms using food web models with generic and site-specific parameters and conditions, and
   g. Demonstrations and applications of the hybrid BAF/BSAF methods to Superfund applications

D. Predicting rates of recovery following remedial actions (SED-13 [partial])

1. Paper research will be required to determine whether new research is needed.
2. The science tasks are:
   a. Recovery from reduction in contamination with bioaccumulative chemicals
      (i) Apply concepts from category C above to evaluate rates of residue reduction following reduction in exposure [Note: need good information on reduction in exposure; not an effects issue.]
      (ii) Will probably need a demonstration for "validation" – may already be done (New Bedford?).
   b. Recovery from physical disturbance of removal and/or capping
      (i) Determine depth of information already available from disturbance ecology literature, and
      (ii) If existing literature is insufficient, conduct new experiments to measure recovery rates, either in experimental manipulations or by monitoring post-remedy at specific sites.

E. Development of appropriate remedial goals for non-bioaccumulative chemicals (SED-15)

1. This effort will require new research.
2. The science tasks include
   a. Develop bioavailability-based approaches for predicting the toxicity of specific chemicals (arsenic, chromium, others?) important to Superfund program, and
   b. Develop a means to assess risk from dietary exposure to metals.

F. Delineation of appropriate uses of total PCBs, Arochlor-based, and congener-specific PCB concentrations as the basis for assessing and managing risks from PCBs (SED-18)

1. This is a paper exercise.
2. The science tasks are
   a. Assembling PCB data sets which have the complete congener-specific PCB analyses (Method 1668A) for a number of Superfund sites, and
   b. Performing risk calculations and comparing results.

G. Assessing the toxic and bioaccumulative effects of contaminated sediment resuspension (SED-22)

1. This effort will require new science.
2. The science tasks are
   a. Development of toxicity and bioaccumulation testing methodology where the exposure water is created using particle entrainment simulator (PES) of Tsai and Lick (1986). The PES devices simulates resuspension of sediments in the laboratory using field collected sediment cores;
   b. Performance of testing methodology on sediment cores from Superfund sites, i.e., Passaic River (NJ), Elizabeth River (VA), New Bedford Harbor (MA), Hudson

River (NY), Anacostia River (Washington, DC), Trace Rios (AZ), Black Stone/ Woonasatocket (RI), and Taunton River (MA); and

c. Field validation of the PES-based toxicity and bioaccumulation testing methodology.

H. Monitoring methods and protocols (SED-19)

1. Initially, this is a paper exercise, and will result in a OSRTI "Weight of Evidence SMART Sheet."
2. It is hoped that exact research questions will fall out of the paper exercise.

Appendix D: Candidates for NHEERL Research in Contaminated Sediments

This table was developed by the Steering Committee after discussing the science tasks and level of effort assessments for the eight remaining sediment research issues (see Appendix C). These discussions ultimately ranked these issues into highest, high, and lower priorities. The table contains the eight sediment research issues along with the two issues eliminated (issues 9 and 10) in a prior round of discussions.

Issue	***Status***
Highest Priority	
1. Residue/effect relationships: Linking chemical residues in aquatic biota to levels of ecological risk to aquatic and aquatic-dependent wildlife. (SED-13 [partial], 14)	*This issue requires new science and is within NHEERL's mission. The two components of the issue are exposure to residue in the organism and residue-effect relationships.*
2. Non-Bioaccumulatives: Development of appropriate remedial goals for non-bioaccumulative chemicals. (SED-15)	*This issue requires new science and is within NHEERL's mission. Some further discussions are required to work out the non-bioaccumulative chemicals of concern.*
3. Resuspension: Assessing the toxic and bioaccumulative effects of contaminated sediment resuspension (SED-22)	*This issue requires new science and is within NHEERL's mission. The OSRTI's research questions are "What are the impacts from resuspension during dredging?" and "Does dredging result in increased environmental risks to aquatic organisms?"*
High Priority	
4a. Predicting rates of recovery following remedial actions (SED-13 [partial]) (Sub-issue D1 Short-term impacts)	*Short-term impacts: NHEERL needs to do some background research on "disturbance ecology" to determine if new science is required.* ***If it is required, this issue would warrant further discussion for the MYIP.***
5. Monitoring Methods and Protocols (SED-19)	*Further clarification needed to focus research issue/allow determination of "new science."*

Table continued on following page

Lower Priority	
4b. Predicting rates of recovery following remedial actions (SED-13 [partial]) (Subissue D2 Long-term prediction of chemical residues in fish)	*Long-term prediction: NHEERL in supporting role to other ORD laboratories (assumes that the problem is a fate and transport question; i.e., getting chemical concentrations in water and sediment correct in the future).*
6. Developing sediment contaminant screening levels (SED-1)	*NHEERL in supporting role to NCEA and/or OSRTI.*
7. Delineation of appropriate uses of total PCBs, Arochlor-based, and congener-specific PCB concentrations as the basis for assessing and managing risks from PCBs (SED-18)	*NHEERL should be involved in this issue. This is a technical support effort and not a research effort. Could possibility be done with contract dollars.*
8. Establishing guidance on sampling biota and surface sediments at Superfund sites. (SED-5, SED-8)	*NHEERL in supporting role to other ORD laboratories.*
Research Issues Eliminated in Prior Round of Discussions	
9. Dredging Residuals (SED-21a)	*Not within NHEERL's mission.*
10. Cleanup Levels (SED 21b)	*Not within NHEERL's mission.*

Appendix E: Commitments and Endorsements

Elizabeth Southerland, Director
    OSWER, OSRTI, Assessment & Remediation Division

Jonathan Garber, Director
    ORD, NHEERL, Atlantic Ecology Division

Janet Keough, Acting Director
    ORD, NHEERL, Mid-Continent Ecology Division

Elizabeth Southerland/DC/USEPA/US

06/16/2004 02:16 PM

To Steven Hedtke/RTP/USEPA/US@EPA

cc Robert Dyer/RTP/USEPA/US@EPA, Lawrence Burkhard/DUL/USEPA/US@EPA, Patricia Erickson/CI/USEPA/US@EPA, Lorelei Kowalski/DC/USEPA/US@EPA, Leah Evison/DC/USEPA/US@EPA, Steve Ells/DC/USEPA/US@EPA

bcc

Subject NHEERL Contaminated Sediment Research

This is to acknowledge that Superfund staff have played an active role in developing the NHEERL research implementation plan for contaminated sediment. We support the proposed research and believe that the products will be useful to the Superfund program. We look forward to continue working with the principal investigators and to help disseminate the results when available.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NATIONAL HEALTH AND ENVIRONMENTAL EFFECTS
RESEARCH LABORATORY
ATLANTIC ECOLOGY DIVISION
27 TARZWELL DRIVE • NARRAGANSETT, RI 02882

OFFICE OF
RESEARCH AND DEVELOPMENT

July 19, 2004

MEMORANDUM

SUBJECT: NHEERL Contaminated Sediments Research Implementation Plan

FROM: Jonathan Garber, Director
Atlantic Ecology Division

TO: Lawrence Burkhard, Lead
NHEERL Contaminated Sediments Steering Committee

This memorandum indicates the commitment of the Atlantic Ecology Division and its Management Team to support the research by our staff and in our Division that is proposed in the July, 2004 edition of the NHEERL Contaminated Sediments Research Implementation Plan. The research that is described in the Plan is consistent with the mission of our Division and we fully support both the individual Projects I (*Integrative Assessment of Benthic Effects from Remedial Activities at Superfund Sites*) and IV (*Research to evaluate the release, bioavailability, and adverse biological effects of contaminants associated with resuspended sediments at Superfund sites*) and the integrative and collaborative work that will accompany the broader scope of research described in the NHEERL Multi-Year Implementation Plan. The documents to be developed under Projects V and VI (Procedures and Guidance) are also recognized as important components of AED's and ORD's transfer of technology to the Offices and Regions.
We believe the scope of work proposed in this MYP for AED can be accommodated within the historical base of FTE and research support resources that our Division obtains from the ORD Waste planning process, and note that these supplementary requirements are identified in the Project descriptions. AED will provide the facilities and personnel on the time frame that is needed to accomplish the work proposed in this MYP as long as the requisite resources continue to be made available to our Division.

The Steering Committee has thoughtfully focused on the most pressing issues and needs of both the science and the Agency, and I commend them on development of this cohesive research program.

Please attach this letter of support to the necessary planning documents as our commitment to this program.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NATIONAL HEALTH AND ENVIRONMENTAL EFFECTS
RESEARCH LABORATORY
MID-CONTINENT ECOLOGY DIVISION
6201 CONGDON BOULEVARD • DULUTH, MINNESOTA 55804-2595

July 6, 2004

OFFICE OF
RESEARCH AND DEVELOPMENT

MEMORANDUM

SUBJECT: NHEERL Contaminated Sediments Research Implementation Plan

FROM: Janet R. Keough
Acting Director

Janet R. Keough

TO: Lawrence Burkhard, Lead
NHEERL Contaminated Sediments Steering Committee

This memorandum is intended to convey the commitment of the Mid-Continent Ecology Division and its Management Team to support the research by our Division proposed in the July, 2004 edition of the NHEERL Contaminated Sediments Research Implementation Plan. The research that is described in the Plan is consistent with the mission of our Division, and, at this time, we believe the scope can be accommodated within the historical base of FTE and research support resources that our Division obtains from the ORD Waste planning process, and such supplementary requirements as are identified in the Plan. The necessary personnel and facilities will be made available to accomplish the work within the time frames specified if the requisite resources continue to be made available.

I congratulate the Steering Committee on production of a forward-looking and well-organized multi-year plan and taken the needs of the Agency and translated them into a coherent research program. Please attach this memo of support to the necessary planning documents as our commitment to this program.

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Agency

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