Northwest Regional Sediment Evaluation Framework

Interim Final

September 2006

Idaho Department of Environmental Quality

DEQ

Washington State Department of Natural Resources

Washington State Department of Ecology

US Army Corps of Engineers®

EPA United States Environmental Protection Agency Region 10

U.S. Fish & Wildlife Service

NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce

INTERIM FINAL

SEDIMENT EVALUATION FRAMEWORK FOR THE PACIFIC NORTHWEST

Prepared by

- US Army Corps of Engineers - Seattle District, Portland District, Walla Walla District, and Northwestern Division;
- Environmental Protection Agency Region 10;
- Washington Department of Ecology;
- Washington Department of Natural Resources;
- Oregon Department of Environmental Quality;
- Idaho Department of Environmental Quality;
- National Marine Fisheries Service; and
- U.S. Fish and Wildlife Service.

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ACRONYMS AND ABBREVIATIONS

µg/kg	micrograms per kilogram
µg/L	micrograms per liter
ASTM	American Society for Testing and Materials
AWQC	ambient water quality criteria
BAF	bioaccumulation attenuation factor
BCF	bioconcentration factor
BCoC	bioaccumulative chemicals of concern
BSAF	biota-sediment accumulations factors
BT	bioaccumulation trigger
°C	degree Celsius
CBR	critical body residues
CDFB	chlorinated dioxins/furans and polychlorinated biphenyl
CFR	Code of Federal Regulations
CoC	chemicals of concern
Corps	U.S. Army Corps of Engineers
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CS	contaminated sediment
CSF	carcinogenic slope factor
CSL	Cleanup Screening Level
CSM	conceptual site model
CWA	Clean Water Act
cy	cubic yard
CZMA	Coastal Zone Management Act
DGPS	Differential Global Positioning System
DMEF	Dredged Material Evaluation Framework
DMMP	Dredged Material Management Plan
DMMU	dredged material management unit
DPS	distinct population segment
DQO	data quality objective
DSL	Department of State Lands

ACRONYMS AND ABBREVIATIONS (continued)

Ecology	Washington State Department of Ecology
ECOTOX	Ecotoxicology Database
EFH	Essential Fish Habitat
EPA	U.S. Environmental Protection Agency
ERED	Environmental Residue Effects Database
ESA	Endangered Species Act
FMP	fishery management plan
GIS	geographic information system
GPS	Global Positioning System
IDEQ	Idaho Department of Environmental Quality
kg	kilogram
LOAEL	low-observed-adverse effect level
LOER	lowest observed effect residue
LUED	lowest unquantified effect dose
mg	milligram
mg/kg	milligrams per kilogram
ML	maximum level
mL	milliliter
MMPA	Marine Mammal Protection Act
MPRSA	Marine Protection Research and Sanctuaries Act
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NAD	North American Datum
NCEA	National Center for Environmental Assessment
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAEL	no-observed-adverse effect level
NSM	new surface material
ODEQ	Oregon Department of Environmental Quality
OMC	Operational Management Committee
ORNL	Oak Ridge National Laboratories

ACRONYMS AND ABBREVIATIONS (continued)

PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
ROC	receptor of concern
PPRTV	Provisional Peer Review Toxicity Values for Superfund
PSDDA	Puget Sound Dredged Disposal Analysis
PSEP	Puget Sound Estuary Program
QA/QC	quality assurance/quality control
RCW	Revised Code of Washington
RDT	Regional Dredging Team
RfD	reference dose
RSET	Regional Sediment Evaluation Team
SAP	Sampling and Analysis Plan
SEF	Sediment Evaluation Framework
SEPA	State Environmental Policy Act
SETAC	Society of Environmental Toxicity and Chemistry
SL	screening level
SMARM	Sediment Management Annual Review Meeting
SMS	Sediment Management Standard
SQG	Sediment Quality Guidelines
SQS	Sediment Quality Standard
SSD	species sensitive distribution
TEF	toxic equivalency factor
TEQ	toxic equivalent
TRA	tissue residue approach
TRV	toxicity reference values
USFWS	U.S. Fish and Wildlife Service
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington State Department of Natural Resources

Sediment Evaluation Framework Preamble

What does this SEF do?

This Sediment Evaluation Framework (SEF) provides a framework for the assessment and characterization of freshwater and marine sediments in Idaho, Oregon, and Washington (defined as Pacific Northwest). This SEF compiles information from many documents in active use in the Pacific Northwest and updates specific portions of previous regional manuals. It is consistent with federal and state regulations and, in most cases, the techniques described here should be useful as part of the "toolbox" of methods available for sediment and dredged material characterizations. It is intended only as guidance, and best professional judgment should be practiced in determining appropriate uses of this SEF. Nothing in this SEF alters or limits agency responsibilities, or imposes mandatory requirements beyond existing statute or regulation.

This SEF is relevant to maintenance dredging and contaminated sediment (CS) cleanup-related activities. It presents an evaluation framework for sampling, sediment testing, and test interpretation. For dredging projects, it provides the basis for evaluating the suitability for unconfined open water or other disposal options. For sediment cleanup projects, it supports the evaluation of the potential risk of in-place sediments and tools to evaluate the sediments based on potential cleanup options.

Why is this SEF being prepared?

The appropriate assessment of sediments and dredged material is a critical component to all dredging or sediment assessment/disposal management activities regardless of whether the project is for maintenance of a navigation channel in Idaho or remediation of a CS site in Oregon. Therefore, it is the Regional Sediment Evaluation Team's (RSET's) intention to consolidate and revise the existing Dredged Material Evaluation Framework (DMEF) (now called the SEF for the Pacific Northwest). This SEF is a technically valuable resource for use throughout the Pacific Northwest for characterization of both freshwater and marine sediments. It also provides useful guidelines for a variety of regulatory and remediation programs that address sediment characterization and disposal issues. RSET is an interagency team, co-chaired by the U.S. Environmental Protection Agency Region 10 and the Northwestern Division of the U.S. Army Corps of Engineers. It consists of federal and state agencies with regulatory responsibilities for managing sediments. RSET is also assisted by technical consultants.

To determine the need for this SEF, RSET conducted a 3-day technical scoping workshop September 11 through 13, 2002, which included RSET members and other interested parties from federal and state agencies and regional Port authorities. The purpose of the workshop was to develop the scope for preparing an overall plan and process for updating the existing Columbia River DMEF. The workshop was also used to gauge the level of agency support for revising the existing DMEF and expanding it to include evaluation of sediments throughout the entire Pacific Northwest under a variety of regulatory programs. A consensus reached at this workshop determined that the new SEF must consider both CS evaluation projects as well as dredged material characterization issues.

Since the 2002 meeting, technical experts, regulators, and policy makers from the federal and state resource agencies as well as the private sector have worked to develop this SEF.

RSET Subcommittees

Much of RSET work is performed by subcommittees. They prepare recommendations in the form of issue papers (requesting policy guidance or other information). Issue papers are presented in Appendix C. Issue papers provide the record of RSET's deliberations. Once an issue paper is prepared by a subcommittee, it is forwarded to the policy subcommittee. The policy subcommittee's role at this point is to ensure the recommendations and supporting information are clear and necessary coordination has occurred with other subcommittees. The issue paper is then forwarded to the entire RSET for review. Changes to this SEF require concurrence of the full RSET. If agreement cannot be reached, the issue will be elevated.

The current subcommittees include the following:

- Policy,
- Sediment Quality Guidelines,
- Chemical Analyte,
- Biological Testing, and
- Bioaccumulation.

The RSET Policy Subcommittee may form other subcommittees as needed.

What agencies were involved with the development of this SEF?

A variety of representatives had major roles in preparing this SEF, including many federal and state agencies, Port authorities, and private firms. This group frequently met to coordinate the subcommittee activities and draft this SEF. Participation by affected users was sought via participation in technical subcommittees, attendance at RSET meetings, conference calls, and review of this SEF by representatives of the ports, maritime industries, tribes, and other interested parties. These representatives include the following:

- U.S. Army Corps of Engineers - Seattle District, Portland District, Walla Walla District, and Northwestern Division;
- Environmental Protection Agency, Region 10;
- Washington State Department of Ecology;
- Washington State Department of Natural Resources;
- Oregon Department of Environmental Quality;
- Idaho Department of Environmental Quality;
- National Marine Fisheries Service;
- U.S. Fish and Wildlife Service;
- Port of Portland, Port of Vancouver USA, and Oregon International Port of Coos Bay; and
- Private firms, including Tetra Tech EC, Inc., Kennedy/Jenks Consultants, Anchor Environmental, Avocet Consulting, Applied Biomonitoring, Battelle Pacific Northwest Laboratories, Columbia Analytical Services, Exponent, Hart Crowser, MEC Analytical Services, Northwestern Aquatic Sciences, URS, and Windward.

Who should use this SEF?

This SEF is designed to help anyone who wants to develop a better understanding of methodologies for assessing and characterizing sediments. RSET is writing this SEF to assist regulators, permittees, stakeholders, trustees, and the public.

How will this SEF help me?

As a regulator, this SEF provides consistent guidance for addressing sediment and dredged material characterization. While it is understood there may be a need to deviate from SEF procedures because of regulatory requirements for specific programs, this SEF provides a comprehensive “toolbox” of assessment techniques and methodologies that have been reviewed and approved by regional experts in this field. It is recognized that individual regulatory programs (e.g., Comprehensive Environmental Response, Compensation and Liability Act [CERCLA]) may have specific additional requirements other than those specified in this SEF. Therefore, if there is a chance the project could fall into another regulatory program, early coordination with RSET may be beneficial.

If seeking a dredging permit or managing a cleanup site, this SEF provides sampling, testing, and analysis strategies that can reduce uncertainties about the actions a regulator may require. Reducing uncertainties can help with project scheduling, financial planning, and project management decisions.

As a member of the public, this SEF can help determine what information regulators generally require in sediment management decisions. Finally, with the context set by this SEF and the openness and transparency of the continuous improvement process, the public will have enhanced access to regulatory decision-making regarding sediments.

How does this SEF become "Final"?

RSET expects this SEF to always be a living document with a process available to update and incorporate advances in scientific, engineering, and regulatory fields. Public comments were accepted when the draft SEF was made public in the summer of 2005. Comments were reviewed by representatives from each of the participating agencies, and changes were made as appropriate. It is expected the technical subcommittees who developed individual chapters in this SEF will continue to address the technical issues as they arise. Major revisions will be presented annually by RSET to agency staff and the interested public for review and comment. Any necessary revisions will be posted on the Corps' web site (http://www.usace.army.mil) and provided as supplements to this SEF.

What is the difference between this SEF and currently available dredging guidance documents?

While this SEF is considered a living document with a process available to update and incorporate advances in scientific, engineering, and regulatory fields, several of the following significant changes and additions are included:

- A consistent approach for characterizing in-place sediments as well as proposed dredged material,
- Draft freshwater sediment screening levels,
- Updated information on the chemical analyte lists that will need to be evaluated in different parts of the Pacific Northwest,
- Updated information on the appropriate analysis of polychlorinated biphenyls (PCBs) in sediment and tissue,
- A framework for addressing bioaccumulation, including a process for deriving scientifically defensible bioaccumulation triggers for tissues and sediments,

- A two-tier (or level) process, as opposed to the historical four-tier assessment process, consistent with emerging National Guidance (described in Chapter 4), and
- Additional editorial changes and clarifications.

How is this SEF organized?

The authors of this SEF organized it to address the overall appropriate implementation strategy for the assessment and characterization of in-place sediments and proposed dredged material. The initial chapters present the goals and structure of this SEF. Additional chapters place this SEF within the context of federal and state sediment management regulations, and discuss regulatory processes where this SEF can be applied. Subsequent chapters and appendices present the specific chemical and biological tests that are recommended with interpretation criteria as well as information on the database that has been developed to manage accumulated data.

1. GOALS, DESCRIPTION, AND ORGANIZATION

1.1 INTRODUCTION

This Sediment Evaluation Framework (SEF) manual provides a regional framework for the assessment, characterization, and management of sediments in the Pacific Northwest. The appropriate assessment of sediments is a critical component of all sediment management activities regardless of whether the project is for dredging of a navigation channel in Idaho or remediation of a contaminated sediment (CS) site in Oregon. Therefore, it is intended that this SEF, which consolidates the existing regional sediment testing guidance manuals, be technically applicable throughout the Pacific Northwest for both freshwater and marine sediment assessment. This SEF also includes a discussion of management alternatives, such as in-water and upland disposal options.

The goal of this manual is to provide the technical and regulatory bases for publicly acceptable guidelines governing environmentally safe assessment and characterization of sediments, thereby improving consistency and predictability in dredged material/sediment management. The establishment of these evaluation procedures is necessary to ensure continued operation and maintenance of navigation facilities in the region, minimize delays in scheduled maintenance dredging, reduce uncertainties in regulatory activities, and evaluate the need for cleanup activities. These SEF guidelines ensure consistency in evaluation among the various programs that regulate sediment.

This document addresses the development of a comprehensive evaluation framework governing sediment sampling, testing, and test interpretation for determining the potential risk of in-place sediments, as well as evaluating the suitability of alternative management options. This SEF ensures adequate regulatory controls and public accountability for the characterization and management of sediments.

The authors of this SEF attempted to identify the most reliable, recognized, and cost-effective sampling and analysis procedures for appropriately characterizing sediments that are also protective of the ecosystem. The authors then incorporated these procedures into this document for application to the Pacific Northwest. Chemical and biological tests and interpretation guidelines were evaluated for the purposes of this guidance document. Application of these tests and guidelines should provide suitable information to determine management (disposal) options, such as no action, in-place capping, and open water, confined aquatic, nearshore, or upland disposal. Some tests may also be useful in evaluating the chemical/biological effects of dredging activities.

This SEF distills the accumulated knowledge and experience with sediments and dredged material management in the Pacific Northwest over the last 30 years. It describes stepwise procedures for sediment assessment and is intended for use by the regulatory and regulated community. Documents containing justification for the guidelines and procedures in this SEF are contained in Chapter 2, Sediment Management Regulations, and Chapter 14, References. Full consideration was made of all pertinent state and federal laws, regulations, and guidance, including other regional sediment management programs, and this SEF is generally consistent with the guidelines of the national-level sediment assessment manuals.

1.2 SCOPE, APPLICABILITY, AND LIMITATIONS

This SEF for the Pacific Northwest is the result of a cooperative interagency/ intergovernmental program established by the U.S. Army Corps of Engineers (Corps); U.S. Environmental Protection Agency (EPA), Region 10; U.S. Fish and Wildlife Service (USFWS); National Marine Fisheries Service (NMFS); Washington State Department of Ecology (Ecology); Washington State Department of Natural Resources (WDNR); Oregon Department of Environmental Quality (ODEQ); and Idaho Department of Environmental Quality (IDEQ). These agencies have regulatory and proprietary responsibilities for sediment evaluation and management in the region, and constitute the standing members of the Regional Sediment Evaluation Team (RSET). This SEF represents an expansion toward a broader sediment management program throughout the entire Pacific Northwest. The procedures used in development of this manual were derived from, and inspired by, similar regional programs, including the successful Puget Sound Dredged Disposal Analysis (PSDDA) program for the Puget Sound region of the state of Washington, Grays Harbor/Willapa Bay Dredged Material Evaluation Procedures Manual, Portland District Corps Dredged Material Tiered Testing Procedures, and Regional 1998 Dredged Material Evaluation Framework (DMEF).

Dredging is necessary to maintain waterways and harbors used for waterborne commerce and water-related industry shipping, new port and marina construction, and environmental restoration projects. It is also necessary to ensure appropriate remedial actions are taken at CS sites. In addition to federal navigation project-related dredging (which is performed by the Corps), a number of ports, maritime industries, and private interests perform dredging and dredged material disposal. Commercial navigation and recreational boating are important factors to the economic well-being of the Pacific Northwest. From a CS management perspective, dredging is one possible remedy for dealing with contaminated in situ sediments. Dredging and disposal may also be a component of habitat restoration activities that can occur as governmental- or nongovernment-sponsored projects. The Pacific Northwest, for the purposes of this SEF, is defined as the states of Washington, Oregon, and Idaho. Dredging in the region has been a commonplace activity historically and will be an ongoing necessity for the foreseeable future under a variety of regulatory, environmental restoration, and cleanup programs.

Cost-effective sediment management is essential to the environment and economy of the region. Periodic dredging, including new work and maintenance dredging, is necessary to maintain the navigability of our waterways. For relatively clean dredged material, without significant levels of chemicals of concern (CoCs), disposal at unconfined aquatic sites is often the least costly and most environmentally acceptable alternative. Beneficial uses of sediment, including erosion control and use as fill material, are an attractive option for placement. For cleanup assessment, this manual provides the tools for assessing the need for various management actions, which may include no action, natural recovery, capping in place, or removal by dredging.

1.3 HOW TO USE THIS MANUAL

This manual is consistent with federal and state regulations and, in most cases, the techniques described herein should be useful as part of the “toolbox” of methods available for CS and dredged material characterizations. Chapters are written to enable the reader to obtain information from one technical aspect, if desired, without necessarily reading this entire manual. Many sections are cross-referenced so that the reader is alerted to relevant issues that might be covered elsewhere in this manual. This is particularly important for certain chemical or toxicological applications in which appropriate sample processing or laboratory procedures are associated with specific field sampling procedures.

The initial chapters present the goals and structure of this SEF. This chapter gives an overview of agency laws, regulations, and authorities as they relate to the assessment and characterization of CS and the dredging and disposal of sediments. Chapter 2 specifically discusses sediment management regulations for both federal and state entities.

Chapter 3 summarizes the federal and state regulatory processes necessary to receive approval (e.g., obtaining a permit) of dredging or sediment evaluation projects undertaken in the Pacific Northwest using this SEF manual. Not all process steps are described in detail, and additional information from the regulating agency may be necessary to complete all process steps.

The risk-based framework is discussed in Chapter 4. A generalized SEF to make management decisions is presented in Figure 4-3. This risk-based framework makes use of multiple lines of evidence to enable regulators and project proponents to reach management decisions. Specifically, Chapter 4 describes the process to develop a conceptual site model

(CSM) to ensure that evaluations are complete in consideration and analysis of present and future exposures, effects, and potential for human and ecological risks at the site of concern for CS projects or during the dredging and disposal process.

The methods used in sample collection, transport, handling, storage, and manipulation of sediments can influence the physicochemical properties and the results of chemical, toxicity, and bioaccumulation analyses. Addressing these variables in an appropriate and systematic manner will help ensure more accurate sediment quality data and facilitate comparisons among sediment studies. Chapters 5 through 7 provide technical approaches to perform sediment characterization studies. For example, the development of the Sampling and Analysis Plan (SAP) is one of the most critical steps in dredging or site characterization/remediation activities. Chapter 5 describes in detail the necessary information required in a SAP. Chapter 6 discusses the recommended procedures for sample acquisition and handling, and Chapter 7 lists the types of sediment testing protocols required and provides the interpretive guidelines for evaluating chemical analytical results.

Biological testing of sediment may be required when chemical testing results exceed appropriate guideline values and interpretative criteria. Chapters 8 and 9 present organized discussions on recommended biological and bioaccumulation tests and species, the quality control requirements for each test, and the interpretive criteria used for decision-making.

Chapter 10 provides an overview of the factors to be considered when selecting sediment disposal options.

Chapter 11 describes the process to follow in those rare cases when standard sediment assessment techniques are insufficient to reach a management decision.

Chapter 12 lists the necessary documentation required to be submitted to RSET upon completion of a sediment study. In addition to reporting the raw data from a given sediment characterization study or analysis, the data report should include additional quality assurance information to assure the data user that sample handling and analyses are in accordance with the SAP. The use of consistent sediment collection, handling, and storage methods will help provide high quality samples with which accurate data can be obtained.

Chapter 13 is an introduction to the beneficial use and its importance to the overall sediment management in the Pacific Northwest.

References are provided in Chapter 14.

The appendices provide additional technical support to the chapters. The technical issue papers, contributed by the subcommittees, are provided in Appendix C to allow the reader to better understand how RSET developed this SEF manual.

The information presented in this manual should not be viewed as the final statement on all the recommended procedures. Some of the areas covered in this document (e.g., sediment holding times, freshwater sediment screening levels, deriving target tissue levels) are actively researched and debated. As data from sediment monitoring and research becomes available in the future, this manual may be updated, as necessary.

1.4 FRAMEWORK OBJECTIVES

This SEF was prepared to satisfy the following five objectives:

(1) It establishes an appropriate marine and freshwater sediment characterization framework agreeable to the public, stakeholders, and regulatory resource agencies.

This regional SEF manual establishes a sediment sampling, testing, and interpretation framework acceptable to stakeholders, such as ports and private industries that maintain navigation access in the study area, and resource agencies having an interest in, concern for, or some form of permit authority relative to sediment management. Such a framework provides clarity, maximizes consistency, and allows informed discussions to take place on the need for and extent of sediment characterization for dredging and sediment management projects.

(2) It establishes a uniform framework under which the Corps will carry out federal requirements in conducting the dredging and disposal program.

The laws and regulations under which the Corps operates require the Corps, to the maximum extent practicable, to predict dredged material types, contaminant levels, and biological effects, both in water and sediments, before dredging and disposal actions can be considered environmentally acceptable. This document provides the regulatory framework that will facilitate a consistent application of regional criteria and guidelines.

(3) It establishes a uniform framework for evaluating the effects of sediment management activities on water quality.

The Pacific Northwest includes the water bodies in the states of Washington, Oregon, and Idaho. Projects actions in one state may affect another state. Because sediment management impacts affect all states, regulation of these activities should be consistent between Washington, Oregon, and Idaho.

States have statutory control over water quality impacts resulting from a neighboring state. Section 401 (a)(2) of the Clean Water Act (CWA) requires that a neighboring state be notified of actions that may affect its water quality. In order to work efficiently under this regulation, water quality requirements in a bi-state waterway must be uniform. Without uniform requirements, the implementation of water quality programs in shared water bodies may not be consistent or predictable. Section 103 of the CWA encourages states to develop uniform laws for the prevention, reduction, and elimination of pollution, and negotiate and enter into agreements or compacts not contrary to any laws or treaties of the United States.

Although the laws discussed in this SEF may well be applicable or relevant and appropriate requirements (ARARs) as defined by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) for a particular CERCLA site, this SEF is not itself an ARAR. It does not apply to any CERCLA cleanups, except to the extent determined that it is to be considered in the CERCLA site decision document. Notwithstanding any other statements in this document, this SEF does not govern CERCLA response actions. However, the “tools” described in this SEF may be useful to the CERCLA program.

(4) It establishes appropriate databases to track the long-term trends in sediment quality of specific dredging projects/locations and the river in general.

Sediment management programs require the collection and maintenance of data about projects and their characteristics. This objective includes the establishment of appropriate databases that will track sediment quality trends over time at specific locations and for the region in general. Systematic database development will provide useful input into larger planning efforts. Implementation of this framework will generate regular reporting on sediment quality and thus raise the information level available for making decisions on sediment management.

(5) It establishes procedures or references other regional/national guidance to assist in the identification and evaluation of alternative sediment management options.

This manual addresses the five basic dredged material disposal options: unconfined aquatic, unconfined upland, confined aquatic, confined nearshore, and confined upland. It is acknowledged that different sampling and testing requirements may be required for evaluating alternative management options. In all disposal options, beneficial re-use (such as wetland creation and beach nourishment) of dredged material is encouraged.

1.5 EVALUATION PROCEDURES PHILOSOPHY

Evaluation procedures consist of the sampling requirements, tests, and guidelines for test interpretation that are to be used in assessing the quality of sediment, including dredged material, and its management options. Evaluation procedures identify whether unacceptable adverse effects on biological resources or human health might result from in-place sediments or dredged material management. A regulatory decision on acceptability of material for remediation or disposal is determined from the test results. This manual defines the general requirements for evaluation of CSs and dredged material for regulatory decision-making under the National Environmental Policy Act (NEPA), Endangered Species Act (ESA), CWA, Marine Protection Research and Sanctuaries Act (MPRSA), and various state cleanup regulations.

One of the underlying principles in the preparation of this SEF is the use of a risk-based sediment assessment framework to guide assessments and management decisions by various regulatory authorities. The results of the 2002 Society of Environmental Toxicity and Chemistry (SETAC) Pellston Workshop on the "Use of Sediment Quality Guidelines and Related Tools for the Assessment of Contaminated Sediments" (SETAC 2002) were relied upon to generate the philosophical and technical underpinnings of the assessment framework that is presented in this manual. The Pellston Workshop was sponsored by SETAC and held August 17 through 22, 2002, in Fairmont, Montana. This workshop brought together 55 experts in the field of sediment assessment and management from Australia, Canada, France, Germany, Great Britain, Italy, the Netherlands, and the United States for 6 days of discussion on the use of Sediment Quality Guidelines (SQGs) and other sediment assessment tools.

One significant change from earlier guidance is the reduction in the number of testing tiers recommended in the guidance document. Previously, dredged material evaluations were conducted based on a four-tier testing framework as presented in historical Pacific Northwest regional manuals. The two-tier testing framework, as presented in the Pellston Workshop Summary, has been adopted for use with this SEF (SETAC 2002). While the same amount of data will be collected under the new SEF as the historical Pacific Northwest regional manuals, the two-tier system will be more consistent with national guidance.

1.5.1 Characteristics of this SEF

Evaluation procedures comprise the complete process of sediment assessment and incorporate a range of scientific and administrative factors. Beyond the decision to base sediment and dredged material evaluations on avoiding unacceptable adverse biological effects, effective evaluation procedures should also have certain characteristics. The following nine characteristics are inherent in the evaluation process:

- **Consistent** - Evaluation procedures must be applicable on a uniform basis as much as possible regardless of project or site variability.

- **Flexible** - Evaluation procedures must be flexible enough to allow for exceptions due to project and site-specific concerns, and adaptable to projects of any size.
- **Accountable** - The need for, and cost implications of, evaluation procedures must be justifiable to the individual stakeholder/permittee and to the public.
- **Cost Effective** - Evaluation procedures must be timely and cost-effective.
- **Objective** - Evaluation procedures must be clearly stated and logical, and applicable in an objective manner.
- **Revisable** - Evaluation procedures must be based upon best available technical and policy information, and the overall approach will be revised periodically to incorporate new information and management decisions.
- **Understandable** - Evaluation procedures must be clear and concise.
- **Technically Sound** - Evaluation procedures must be reproducible, have adequate quality assurance and quality control guidelines, and generally have standardized protocols.
- **Verifiable** - The implementation of the evaluation procedures must be verifiable. One means of judging effectiveness is monitoring at a disposal site.

1.5.2 The Need for Flexibility in Application of Evaluation Procedures

Although consistency is an important objective, it is recognized that flexibility must be maintained in the way the evaluation procedures and disposal guidelines are applied. When project-specific technical indications warrant, suitability evaluations or determinations that deviate from those indicated by the guidelines presented in this manual may be made. Consequently, best professional judgment is essential in reaching project-specific decisions. The evaluation procedures (including the disposal guidelines) require full consideration of all pertinent project factors. Flexibility will be provided by “exception.” The guidelines are expected to apply in the majority of cases. Rather than integrating flexibility into the guideline statements (by showing ranges of values or by using terms such as “may do”), exceptions to the guidelines are allowed with appropriate technical rationale and documentation, when such rationale warrants a different conclusion. A consensus between the federal agencies and the affected state(s) will be required for use of this management by exception approach. Further, this exception approach will only be used where applicable federal and/or state law does not otherwise preclude its application.

A good example of how flexibility enters into the decision-making process using evaluation procedures is the use of statistics and professional judgment in data interpretation. Statistics are primarily applied in the initial data analysis stage of the disposal guidelines. Statistical significance is used to determine if observed differences are “potentially real” when natural variability of the parameters being measured is considered. Ultimate data interpretation requires judgment on the part of a professional who is intimately familiar with the testing procedures, project specifics, and initial data analysis conclusions.

Analysis of data consists of a comparison to guideline values that are developed using statistical significance as a clear indicator of toxicity. However, ecological significance cannot be determined by this process. Determination of ecological significance requires both an understanding of the data and evaluation procedures, and evaluation of those test results based on best professional judgment.

1.6 STUDY PARTICIPANTS AND PUBLIC INVOLVEMENT

A variety of representatives had major roles in preparing this SEF manual, including many federal and state agencies, Port authorities, and private firms. This group met frequently to coordinate the subcommittee activities and draft this SEF. Participation by affected users was sought via participation in technical subcommittees, attendance at RSET meetings, conference calls, and review of this framework by representatives of the ports, maritime industries, tribes, and other interested parties. These representatives include the following:

- U.S. Army Corps of Engineers - Seattle District, Portland District, Walla Walla District, and Northwestern Division;
- Environmental Protection Agency, Region 10;
- Washington State Department of Ecology;
- Washington Department of Natural Resources;
- Oregon Department of Environmental Quality;
- Idaho Department of Environmental Quality;
- National Marine Fisheries Service;
- U.S. Fish and Wildlife Service;
- Port of Portland, Port of Vancouver USA, and Oregon International Port of Coos Bay; and
- Private consulting firms, including Tetra Tech EC, Inc., Kennedy/Jenks Consultants, Anchor Environmental, Avocet Consulting, Applied Biomonitoring, Battelle Pacific Northwest Laboratories, Columbia Analytical Services, Exponent, Hart Crowser, MEC Analytical Services, Northwestern Aquatic Sciences, URS, and Windward.

1.6.1 RSET Structure and Process

RSET's focus requires a high level of sophistication in laws and regulations that govern sediments and water quality, sediment chemistry, toxicology, engineering, and other related fields. At the same time, the science must inform a regulatory program involving numerous agencies and statutory frameworks. Therefore, RSET is designed to provide the highest caliber scientific advice combined with practicable knowledge about the administrative use of that information to ensure science-based regulation. The structure and processes outlined below support RSET's functions: continuous improvement of methods for sediment sampling, testing, and analysis to support regulatory management decisions at a region wide level, and maintenance of the sediment quality database. It is expected that RSET will provide a cooperative, interagency center of expertise on sediment assessment and management that can be accessed by different agencies and programs as the need arises.

Roles, Relationships, and Representation

The relationship among different sediment-related groups is shown in Figure 1-1. The Regional Dredging Team (RDT) structure is shown in Figure 1-2. The Executive Steering Committee is composed of upper-level management at EPA Region 10, Corps Northwest Division, NMFS, USFWS, and Maritime Administration (DOT). The Operational Management Committee (OMC) has representatives from the same agencies, as well as the states of Washington, Oregon, and Idaho. In each Corps district, there is a local dredging team that conducts day-to-day business, develops Dredged Material Management Plans (DMMPs), and elevates issues, as appropriate. The representation on the local dredging team includes tribal, federal, and state agencies, invited experts, Port representatives, and non-government organizations.

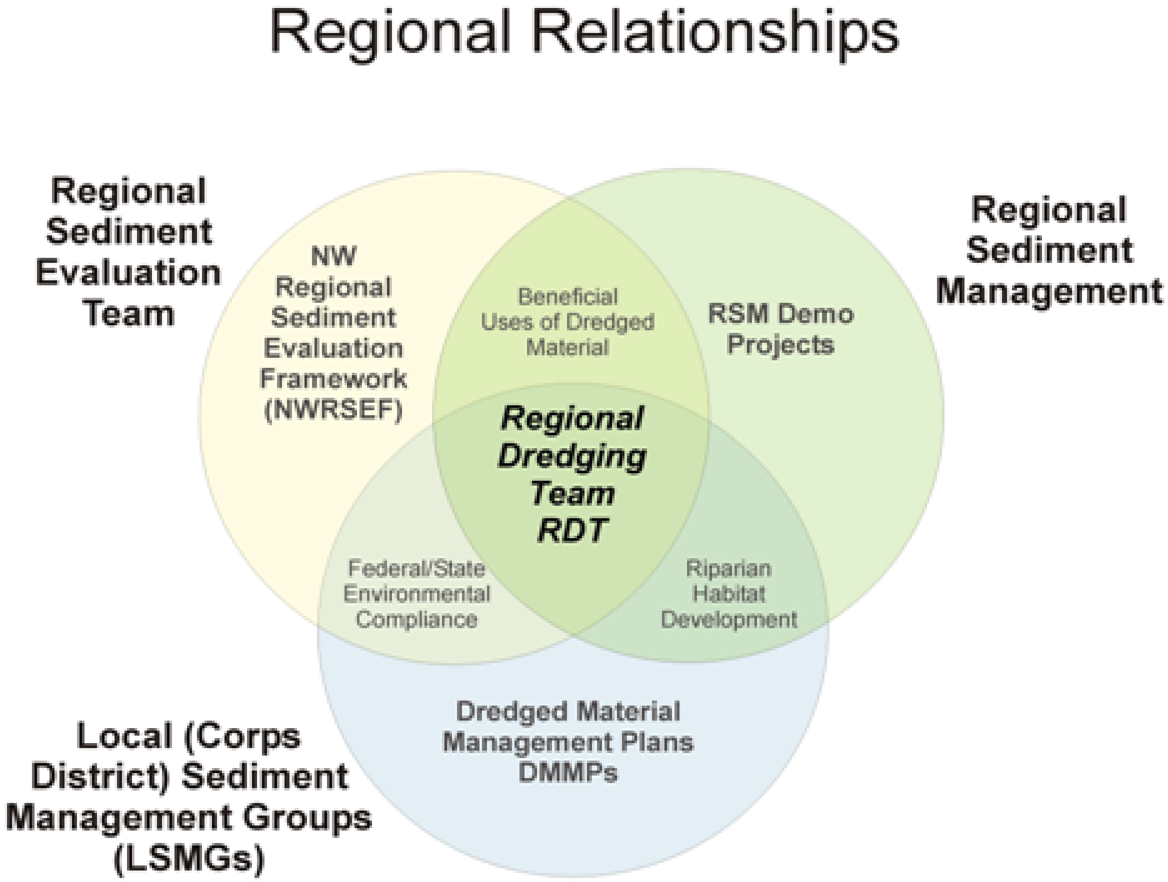


Figure 1-1. Local Corps District Sediment Management Groups

RSET reports to the Navigation Steering Committee (NSC) and OMC. The NSC provides both technical and policy guidance and feedback to RSET. Issues that cannot be resolved by RSET membership will be taken to the NSC. The OMC has primary responsibility for the support and development of the database. As issues are elevated from local dredging teams to the NSC and OMC, it will often be appropriate for RSET to advise these groups. RSET also provides region-wide analysis of sampling results to make regulatory management decisions regarding sediment characterization. To meet these responsibilities, RSET is composed of regional sediment experts and agency representatives familiar with the regulatory/sediment analysis interface. Experts may be invited in as necessary, especially as members of ad hoc technical subcommittees, which are described below.

The Executive Steering Committee, NSC, OMC, RSET, and local dredging teams are each co-chaired by the Corps and EPA.

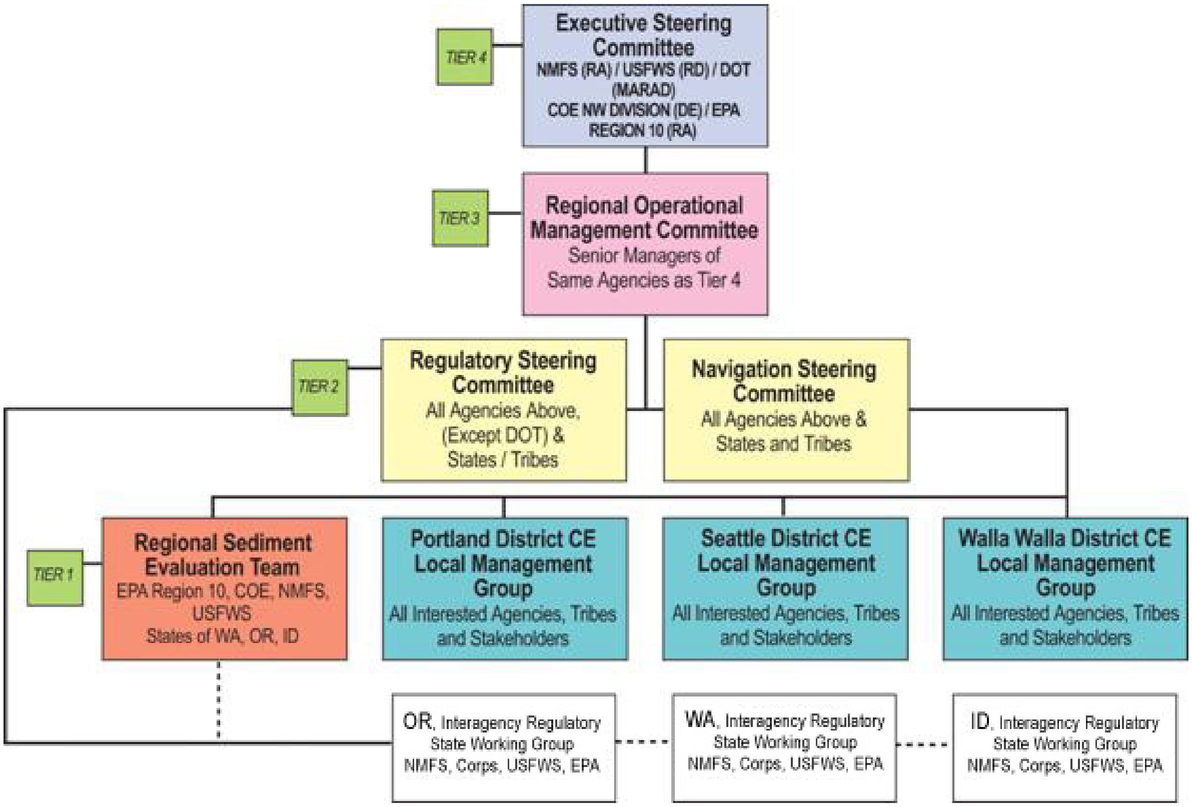


Figure 1-2. Structure of the Regional Dredging Team

Decision-making

With the exception of possible amendments to Chapter 3, which are the responsibility of the RDT, RSET operates by consensus to amend this SEF, provides guidance about the implementation of this SEF (both the technical aspects and the interface with regulatory), and supports and maintains the database.

1.6.2 RSET Subcommittees

Much of RSET work is performed by subcommittees. Subcommittees have conducted research and prepared technical and policy recommendations in the form of issue papers. Issues papers that have been developed to date are presented in Appendix C. The issue papers provide the record of RSET’s deliberations. Once an issue paper is prepared by a technical subcommittee, it is forwarded to the policy subcommittee for review and comment to ensure the recommendations and supporting information are clear and necessary coordination has occurred with other subcommittees. Each issue paper is then forwarded to the entire RSET for review. Future changes to this SEF will require concurrence of the RDT with comment and recommendations from RSET.

The current subcommittees include the following:

- Policy,
- SQG,
- Chemical Analyte,
- Biological Testing, and
- Bioaccumulation.

RSET Policy Subcommittee may form other subcommittees as needed to critically evaluate emerging issues.

1.6.3 SEF Continuous Improvement/Adaptive Management

A very important aspect of this SEF is its ability to continuously evolve. As new information becomes available, the RSET agencies will need to revise and refine all aspects of the program, and this must take place in a publicly accessible forum. The first mechanism for ensuring this is regular meetings similar to or concurrent with Sediment Management Annual Review Meetings (SMARMs). RSET shall meet at least yearly. If these meetings fail to occur, any RSET member may request, in writing, that such a meeting be held. If a meeting is not held within 3 months, the issue will be elevated to the RDT.

In January of each year, the RSET policy committee will meet and compile issues of concern and proposed changes to the program. The team will develop issue papers on those program aspects that appear in need of revision. Any RSET member or subcommittee may use the issue paper as a means of requesting a meeting. For instance, if there is a need to address a new chemical testing procedure, the Chemical Analyte Subcommittee would forward an issue paper with recommendations to the chairs of RSET’s policy subcommittee. If the subcommittee has requested a full RSET meeting to address this issue, the policy subcommittee shall convene a full RSET meeting within 3 months. If they fail to do so, the subcommittee chair may elevate the issue.

Fundamentally, RSET members share a strong commitment to making this SEF a “living document.”

1.6.4 Regulatory/Technical Sediment Interface

The interface between regulatory agencies and technical sediment issues is described in Chapter 3. RSET has a responsibility to monitor the effectiveness of this interface and to make recommendations.

1.6.5 Region-Wide Interpretation of Test Results

The Pacific Northwest as defined in this manual roughly follows the boundaries of the regional federal agencies signatory to this manual. The intention is that all federal and state agencies utilize the same evaluation process when assessing sediments for their various regulatory responsibilities in the Pacific Northwest. The one exception to this is EPA Region 10's responsibility for Alaska. EPA has suggested that this SEF be considered at a future date for use in Alaska, but it will require a similar review process to this manual to determine its suitability for the region.

It is recognized that systemic region-wide interpretation of test results will be an evolving process. Differences in test interpretation are necessary for freshwater versus marine waters, as well as due to differing pathways of concern, species of concern, and differences in state and federal agencies policies and regulations. RSET will work together assessing and interpreting sediment-related projects. For the near term, there will be case-by-case interpretations necessary until this SEF is fully developed. RSET will continually update and refine the interpretation of test results with the eventual goal of region-wide interpretation. This will require the review and approval of the NSC and, for more controversial issues, the Executive Steering Committee.

1.6.6 Database Management

RSET management and the decision-making process regarding the database are discussed in Chapter 12.

1.6.7 Dispute Resolution

Once an issue paper is sent to the Policy Subcommittee, the expectation is that the paper will be presented at the next RSET plenary meeting for discussion and resolution. The paper may be elevated to the OMC for the following reasons:

- The RSET Policy Subcommittee chooses to elevate it immediately, rather than presenting it to the full RSET for a decision;
- The Policy Subcommittee and the subcommittee presenting the paper are unable to reach resolution about the contents of the paper;
- The full RSET is unable to come to consensus and feels that (a) further deliberation or (b) referring the question back to the subcommittee is not likely to be productive;
- Once an issue paper has been presented to the Policy Subcommittee, RSET has a maximum of 18 months to resolve the issue before it is automatically elevated to NSC.

Once elevation is triggered, the Policy Subcommittee will work with the subcommittee chair to prepare a staff paper equally representing all aspects of the issue for review by NSC.

1.6.8 Public Involvement/National Environmental Policy Act

This SEF is a continuation of a sediment evaluation process started in the Pacific Northwest more than 20 years ago with the advent of PSDDA. All updates and improvements over the years to this process have had full public involvement and appropriate state and federal environmental compliance, either in the form of a 103 MPRSA or 401/404 CWA public notices and/or NEPA documentation. This SEF public involvement process will continue to fully include all affected public. This process will be finalized in a Regional 401/404/103 assessment and public notice with references to past environmental documentation. All comments received prior to or during the public notice process will be fully considered in the final version of this manual. The process will culminate with the signing of this SEF by all state and federal agencies concurring in its use as the assessment process for the Pacific Northwest.

2. SEDIMENT MANAGEMENT REGULATIONS

2.1 OVERVIEW

Several state and federal entities have regulatory or proprietary authority governing the management of contaminated sediment (CS) and dredged material. For the assessment and management of CS, federal agencies that have regulatory authority over site investigations and cleanups are EPA, USFWS, and NMFS. States exercise their regulatory authority via their cleanup statutes.

At the federal level, the Corps and EPA share the responsibility for regulating the discharge of dredged material. In the state of Washington, regulation is shared by Ecology, WDNR, and Washington Department of Fish and Wildlife (WDFW). In Oregon, this regulation is carried out by ODEQ, Division of State Lands, and Department of Land Conservation and Development. In Idaho, regulation is carried out by IDEQ.

This chapter gives a brief overview of agency laws, regulations, and authorities as they relate to the assessment and characterization of CS and dredging and disposal of sediments.

2.2 FEDERAL REGULATIONS OVERVIEW

The following sections summarize federal regulations that apply to sediments.

2.2.1 Dredged Material Management

The Clean Water Act (CWA) governs discharges of dredged material into "waters of the United States," defined as all waters landward of the baseline of the territorial sea. The Marine Protection Research and Sanctuaries Act (MPRSA) governs the transportation of dredged material seaward of the baseline (in ocean waters) for the purpose of disposal.

The geographical jurisdictions of MPRSA and CWA are indicated in Figure 2-1. As shown in Figure 2-1, an overlap of jurisdiction exists within the territorial sea. The precedence of MPRSA or CWA in the area of the territorial sea is defined in 40 Code of Federal Regulations (CFR) 230.2 (b) and 33 CFR 336.0 (b). Material dredged from waters of the United States and disposed in the territorial sea is evaluated under MPRSA. In general, dredged material discharged as fill (e.g., beach nourishment, island creation, or underwater berms) and placed within the territorial sea is evaluated under the CWA. In addition, all activities regulated by these

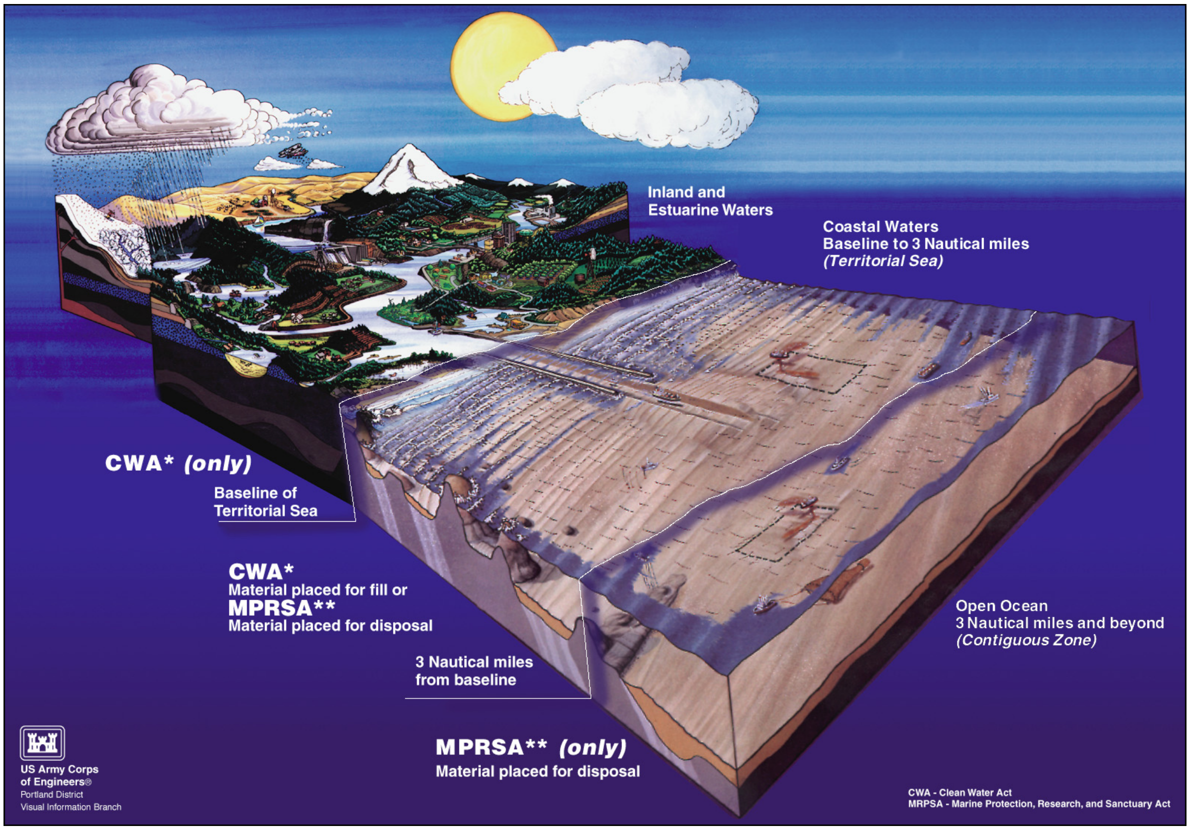


Figure 2-1. Geographic Jurisdictions of MPRSA and CWA

statutes must comply with the applicable requirements of the National Environmental Policy Act (NEPA), as well as other federal laws, regulations, and Executive Orders that apply to activities involving the discharge of dredged material. NEPA usually acts as an umbrella authority to ensure all applicable environmental requirements are complied with for federal dredging projects. Below is an overview of MPRSA, CWA, and other federal laws applicable to the regulation of dredged materials.

2.2.2 Rivers and Harbors Act Section 10/Clean Water Act Section 404

The Corps administers a regulatory program under Section 10 of the Rivers and Harbors Act of 1899, which requires a permit from the Secretary of the Army for work and construction of structures in navigable waters, and Section 404 of CWA for discharge of dredged or fill material into the waters of the United States. When a project requires a permit under both Section 10 and Section 404, one application is processed concurrently as a single Section 10/404 permit, such as when both dredging and disposal/filling are necessary, as is often the case with in-water or nearshore disposal.

The CWA applies to “waters of the United States.” The Corps’ administrative definition of “waters of the United States” extends to all waters, including lakes, streams, mudflats, wetlands, and sloughs, and "the use, degradation, or destruction of which" could affect interstate or foreign commerce. This definition includes wetlands adjacent to these waters. Section 404, therefore, covers more than Section 10 (CWA Section 502(7) and Section 230.3 of the Guidelines).

All parties, including federal agencies, are subject to regulation under Section 10 and Section 404. Though the Corps does not issue itself a permit, these same regulations govern the Corps' own dredging and disposal activities.

Section 10. A Section 10 permit is required for any dredging activity in navigable waters, regardless of the location of the disposal site. For purposes of Section 10, navigable waters generally are those United States waters below the mean high water mark and those used or usable for interstate or foreign commerce. A dredging project with no return flow to the waters of the United States would require only a Section 10 permit.

Section 404. A Section 404 permit is required only for discharges of dredged or fill material into waters of the United States. A Section 404 permit is required when dredged material is disposed in either an aquatic or nearshore environment. It is also required when dredged material will be hydraulically placed in an upland environment and effluent from the disposal will be returned to waters of the United States. This can occur where dredged material that is not dewatered is placed in nearshore or upland disposal sites.

Under Section 404(b)(1) of CWA, the Administrator of EPA has developed, in conjunction with the Secretary of the Army, Guidelines for evaluating specific proposed aquatic or nearshore disposal sites.

The Guidelines evaluate potential disposal sites based on potential impacts on the physical, chemical, and biological characteristics of the aquatic environment. The Guidelines specify the following four conditions for the selection of any aquatic site for the disposal of dredged or fill material (Section 404 (b)(1) Final Rule 40 CFR 230):

1. There must be no other practicable alternatives available that would have less adverse impacts on the aquatic environment.
2. The disposal must not result in violations of applicable state water quality standards, toxic effluent standards, marine sanctuary requirements, or requirements of the Endangered Species Act (ESA).
3. The disposal must not cause or contribute to significant degradation of the waters of the United States.

4. The permit applicant must show that all appropriate and practicable steps have been taken to minimize potential adverse impacts of the discharge on the aquatic environment.

While considering the Guidelines, the Corps conducts a public interest review and considers comments from agencies and the public. The final permit decision is based on whether the activity is in compliance with the Guidelines (including sediment quality) and a determination that the proposed activity is not contrary to the public interest. The public interest review includes a broad range of factors, from environmental concerns to public health issues to property ownership as well as compliance with other federal laws. The Corps has substantial authority to require mitigation to avoid, minimize, rectify, reduce, or compensate for resource losses. In cases where no aquatic site is proposed for disposal, the Corps' decision to issue a permit is based solely on the public interest review and not the Guidelines.

EPA retains oversight authority regarding the Corps' decision to issue a permit and may veto permit approval if it concludes that the discharge of dredged or fill materials would have an "unacceptable adverse effect" on municipal water supplies, shellfish beds and fisheries, wildlife, or recreational areas.

2.2.3 Marine Protection, Research, and Sanctuaries Act of 1972

MPRSA of 1972, as amended (Public Law 92-532), specifies that all proposed operations involving the transportation and dumping of dredged material into the ocean have to be evaluated to determine the potential environmental impact of such activities. Section 103 of MPRSA appoints the Corps as the permitting agency, subject to EPA review. Regulations are at 40 CFR 220-228. An Ocean Testing Manual has been jointly issued by EPA and the Corps (EPA/Corps 1991) in which a "tiered" testing approach is employed. Section 102 of MPRSA requires EPA, in consultation with the Corps, to develop environmental criteria that must be complied with before any proposed ocean-disposal activity is allowed to proceed. The criteria call for no unacceptable adverse effects. Section 103 of MPRSA assigns the Corps the specific responsibility for authorizing the transport of dredged material for ocean disposal at designated sites.

In evaluating proposed ocean disposal activities, the Corps is required to apply criteria developed by EPA relating to the effects of the proposed disposal activity. In addition, in reviewing permit applications, the Corps is also required to consider navigation, economic, and industrial development, and foreign and domestic commerce, as well as the availability of alternatives to ocean disposal. EPA has the primary environmental oversight role in reviewing the Corps' determination of compliance with the ocean-disposal criteria relating to the effects of the proposed disposal. If EPA determines the criteria are not met, disposal may not occur without a waiver of the criteria by EPA (40 CFR 225.2 (e)). In addition, EPA has authority under Section 102 to designate ocean-disposal sites. The Corps is required to use such sites for ocean disposal to the extent feasible. Section 103 authorizes the Corps, where use of an EPA-designated site is not feasible or a site has not been designated, to select ocean disposal sites. In exercising this authority, the Corps utilizes the EPA site-selection criteria (40 CFR 228), and the site selection is subject to EPA concurrence.

2.2.4 Coastal Zone Management Act of 1972

The Coastal Zone Management Act (CZMA) of 1972, as amended (Public Law 92-583), declared a national interest in the effective management, beneficial use, protection, and development of the coastal zone. The law grants to state and local governments the primary responsibility for planning and regulation of land and water uses in the coastal zone. The Coastal Programs Division within the National Oceanic and Atmospheric Administration's Office of Ocean and Coastal Resource Management is responsible for advancing national coastal management objectives and maintaining and strengthening state and territorial coastal management capabilities. It supports states through financial assistance, mediation, technical services, and information, and participation in priority state, regional, and local forums. States are charged with developing and administering land and water use management programs for the coastal zone. Federal projects within the coastal zone, including dredging and disposal projects, must be consistent, to the maximum extent practicable, with the approved state programs. For nonfederal projects, a required Corps permit cannot be issued until Ecology and/or Oregon Department of Land Conservation and Development has concurred that the project is in compliance with the approved coastal zone management plan. Concurrence with CZMA is assumed after a 6-month period has elapsed since the Corps' public notice.

2.2.5 Endangered Species Act of 1973

The purpose of the ESA is to conserve the Nation's natural heritage for the enjoyment and benefit of current and future generations. The ESA was passed in 1973, replacing the Endangered Species Conservation Act of 1969. Since that time, it has been amended several times. The ESA provides for the conservation of species that are endangered or threatened with extinction throughout all or a significant portion of their range, and the conservation of the ecosystems on which they depend. "Species" is defined in the ESA as including a species, a subspecies or, for vertebrates only, a distinct population segment (DPS). Pacific salmon are listed as evolutionarily significant units, which are considered equivalent to a DPS. A species is considered **endangered** if it is in danger of extinction throughout all or a significant portion of its range. A species is considered **threatened** if it is likely to become an endangered species within the foreseeable future. After a species is listed, a recovery plan is prepared that identifies conservation measures to help the species recover.

NMFS and USFWS share responsibility for implementing the ESA. Generally, USFWS manages land and freshwater species, while NMFS manages marine species, including anadromous salmon (ocean species that return to rivers to spawn). Section 7 of the ESA requires federal agencies to ensure their actions do not jeopardize endangered or threatened species or their critical habitats. If a project could affect a threatened or endangered species, consultation with USFWS and/or NMFS is required.

2.2.6 Marine Mammal Protection Act of 1972

The Marine Mammal Protection Act (MMPA) of 1972 prohibits, with certain exceptions, the take of marine mammals in United States waters and by United States citizens on the high seas, and the importation of marine mammals and marine mammal products into the United States. The passage of the MMPA gave the U.S. Department of Commerce, through NMFS, the responsibility for implementing the MMPA for all species of whales, dolphins, porpoises, seals, and sea lions. In addition, NMFS administers the provisions under the ESA for ESA-listed marine mammal species. Under these acts, NMFS works to conserve, protect, and recover marine mammal species in United States waters and on the high seas by developing national policy, implementing recovery planning, and conducting scientific research. Federal agencies are requires to consult with NMFS on actions that may affect marine mammals.

2.2.7 Magnuson-Stevens Fishery Conservation and Management Act of 1996

The Sustainable Fisheries Act (SFA) revised the Magnuson Fishery Conservation and Management Act to become the Magnuson-Stevens Fishery Conservation and Management Act (MSA). The creation of the MSA marked a significant change in NMFS' legislative mandate to manage living marine resources. In particular, the SFA brought substantial changes in the requirements to prevent overfishing and rebuild overfished fisheries. Each fishery management plan (FMP) is required to specify objective and measurable criteria for determining when a stock is overfished or when overfishing is occurring, and to establish measures for rebuilding the stock. The national standards outlined in the MSA, which represent the overall principles by which fishery management programs are developed and judged, were revised by the SFA. The MSA, as amended, contains 10 national standards for fishery conservation and management with which all FMPs must comply.

The Essential Fish Habitat (EFH) provisions of the SFA require councils to describe and identify EFH for all fisheries, and to minimize to the extent practicable the adverse effects of fishing on EFH. EFH is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." In addition, the SFA requires that other federal agencies consult with NMFS on actions that may adversely affect EFH. NMFS is required to recommend measures that can be taken by the consulting federal agency to conserve EFH.

2.2.8 National Environmental Policy Act

NEPA of 1969 was one of the first laws ever written that established the broad national framework for protecting our environment. NEPA's basic policy is to ensure that all branches of government give proper consideration to the environment prior to undertaking any major federal action that significantly affects the environment. To meet this requirement, federal agencies are required to prepare environmental assessments and/or environmental impact statements, which analyze the likelihood of impacts from alternative courses of action to meet the purpose and need of the proposed action. Dredging and disposal actions proposed by the Corps, other federal agencies, states, and the public must comply with NEPA, either through the direct preparation of a NEPA document, or through NEPA compliance associated with the granting of a CWA Section 404 permit.

2.3 TRIBAL REGULATIONS

Tribal regulations are being evaluated and addressed by the RSET agencies. It is RSET's intention to have this completed in the final SEF.

2.4 WASHINGTON STATE REGULATIONS

2.4.1 Section 401 Certification Program

Section 401 of the CWA requires state certification that any federally permitted project discharging into United States waters will not violate state water quality standards that are based on federal water quality criteria. For nonfederal dredging, Section 401 certification is a precondition to compliance with Section 404 guidelines and is required before receiving a Section 404 permit for disposal of dredged or fill material. The Section 401 certification is required when dredged material is to be placed in an aquatic or nearshore environment, or when dredged material is hydraulically placed in an upland environment where return flows may affect waters of the United States.

Ecology is the agency for certifying under Section 401 that a proposed discharge will comply with state water quality standards. As a condition of certification, Ecology may apply any requirement or policy of state law that protects aquatic habitat. In situations where the state has no jurisdiction (e.g., tribal lands and military installations), EPA provides Section 401 certification. EPA may also comment on compliance with state and federal water quality under Section 401. These conditions may be accepted by the Corps and used as conditions in the Section 404 permit.

2.4.2 Hydraulic Project Approval

A State Hydraulic Project Approval permit is required for actions affecting the natural flow of waters. This generally means any action in saltwater or a stream below the ordinary high water mark. The permit application must be acted upon by the WDFW within 30 days after receipt of the full permit application, including determination of compliance under the State Environmental Policy Act (SEPA).

2.4.2.1 Aquatic Lands Act

The Aquatic Lands Act, Revised Code of Washington (RCW), Chapter 79.90, gives WDNR proprietary authority to manage state-owned aquatic lands in trust for the public. In accordance with the Aquatic Lands Act, and implementing regulations cited as Chapter 332-30 of the Washington Administrative Code (WAC), WDNR has the power to lease state-owned aquatic lands for development and charge a fee for the discharge or use of dredged material. Aquatic or nearshore disposal sites can be subject to WDNR's management. However, WDNR does not directly control upland disposal of dredged material, except on WDNR-managed lands.

2.4.3 Model Toxics Control Act

The Model Toxics Control Act (MTCA) is the Washington State regulation governing all remedial actions. MTCA was enacted in 1988 by an initiative of the people. The law has three purposes: 1) clean up contaminated sites, 2) improve management of hazardous waste, and 3) improve the environment through pollution prevention. MTCA is the "parent" state regulation that refers to the Sediment Management Standards (SMSs) for details on sediment cleanup and source control.

2.4.3.1 Sediment Management Standards

The state of Washington has adopted SMSs as Chapter 173-204 WAC. SMSs were promulgated for the purpose of reducing and ultimately eliminating adverse effects on biological resources and significant health threats to humans from surface sediment contamination. They apply to marine, low salinity, and freshwater surface sediments within the state of Washington.

SMSs provide two levels of effects specific to the contamination of marine sediments: a "No Adverse Effects" criteria (defined as the Sediment Quality Standard [SQS]) and a "Minor Adverse Effects" criteria (defined as the Cleanup Screening Level [CSL]). These criteria guide decisions pertaining to sediment cleanup and source control actions.

The SQS represents the goal to be attained for all sediments. However, it is recognized that this goal (No Adverse Effects) may be impractical in some cases. The CSL represents an acceptable upper limit (Minor Adverse Effects level) of chemical contamination.

2.4.3.2 Shoreline Management Act

The Washington Shoreline Management Act of 1971, RCW Chapter 90.58, requires a permit for any "substantial development" within the shorelines of the state. The Shoreline Management Act defines "shorelines of the state" to include designated water bodies and their submerged beds within the state's territorial limits and all land areas 200 feet landward of ordinary high water and adjacent wetlands. Local jurisdictions have the responsibility of overseeing compliance with the Shoreline Management Act. Ecology's Shorelands Program oversees and reviews municipalities' plans and decisions as well as provides an avenue for appeals.

Local Shoreline Master Programs have been adopted as state regulations under the Administrative Procedures Act. These state regulations, as well as others affecting the quality of the shoreline environment, were approved by the Secretary of Commerce as the state's Coastal Zone Management Program. Thus, in Washington, a local Shoreline Permit, which has been issued and survived appeals, is the mechanism for determining compliance with federal CZMA.

Preferential uses for shorelines include the following (in their order of preference):

1. Recognize and protect the statewide interest over local interest,
2. Preserve the natural character of the shoreline,
3. Result in long-term over short-term benefit,
4. Protect the resources and ecology of the shoreline,
5. Increase public access to publicly owned areas of the shorelines,
6. Increase recreational opportunities for the public in the shoreline, and
7. Provide for any other element as defined in (the Shoreline Management Act) deemed appropriate or necessary.

The affected local jurisdiction may issue a shoreline substantial development permit if the proposed use is consistent with both the local Shoreline Master Program and the policies of the Shoreline Management Act. Local zoning and land use requirements are integrated with the Shoreline Master Program process.

2.5 OREGON STATE REGULATIONS

2.5.1 Coastal Program Approval

Federal projects and those projects receiving a federal permit are reviewed by the Department of Land Conservation and Development for consistency with enforceable state and local policies of the Oregon coastal management program. Projects complying with this program are issued a coastal program approval.

2.5.2 Section 401 Certification Program

Section 401 of the federal CWA requires that applicants for federal permits or licenses obtain a 401 water quality certification from the state the proposed project is located in, if the proposed activity may result in a discharge to waters of the United States. Section 401 certifications condition proposed projects as appropriate to ensure the activity will not result in a violation of state water quality standards. ODEQ is the state agency authorized to issue 401 certifications. In areas where the state does not have jurisdiction (i.e., tribal lands), EPA provides the 401 certifications. For dredging projects, a Section 401 certification is required before a Section 404 permit can be issued. Section 401 certifications for dredging projects include conditions for dredging operations and disposal, if the material is proposed to be placed in an aquatic or nearshore environment, or when dredged material is proposed to be hydraulically placed in an upland environment where return flows may affect waters of the United States.

2.5.3 Removal/Fill Permit

The Oregon Department of State Lands (DSL) issues a permit for any activity that proposes removal, fill, or alterations equal to or exceeding 50 cubic yards (cy) of material within the beds or banks of the waters of the state of Oregon. In addition, any amount of removal, filling, or alteration in state scenic waterways and areas designated essential salmonid streams requires approval from the DSL. Examples of projects that require a DSL permit include gravel mining, dredging, gold mining, placement of riprap, bulkheads, land reclamation, channel alteration or relocation, and stream crossings.

2.5.4 State Beaches

Oregon State Parks issues permits for any activity on state beaches, including placement of dredged material.

2.5.5 Solid and Hazardous Waste

Dredged sediment may be subject to state solid waste or hazardous waste rules depending on the level of contamination and how the material will be used or disposed. Figure 2-2 shows how Oregon's solid waste permitting process relates to other state or federal permits.

2.5.6 Cleanup Authority

ODEQ oversees cleanup of contaminated sites, including those involving sediments via a process that parallels the EPA Superfund process. A remedial investigation, risk assessment, and feasibility study are completed to provide the basis for selecting a remedy. Oregon has specific rules defining acceptable risk, which can be found at OAR 340-122-0115.

2.6 IDAHO STATE REGULATIONS

2.6.1 Section 401 Certification Program

Section 401 of the CWA requires state certification that any federally permitted project discharging into United States waters will not violate state water quality standards that are based on federal water quality criteria. For nonfederal dredging, Section 401 certification is a precondition to compliance with Section 404 guidelines and is required before receiving a Section 404 permit for disposal of dredged or fill material. The Section 401 certification is required when dredged material is to be placed in an aquatic or nearshore environment, or when dredged material is to be hydraulically placed in an upland environment where return flows may affect waters of the United States.

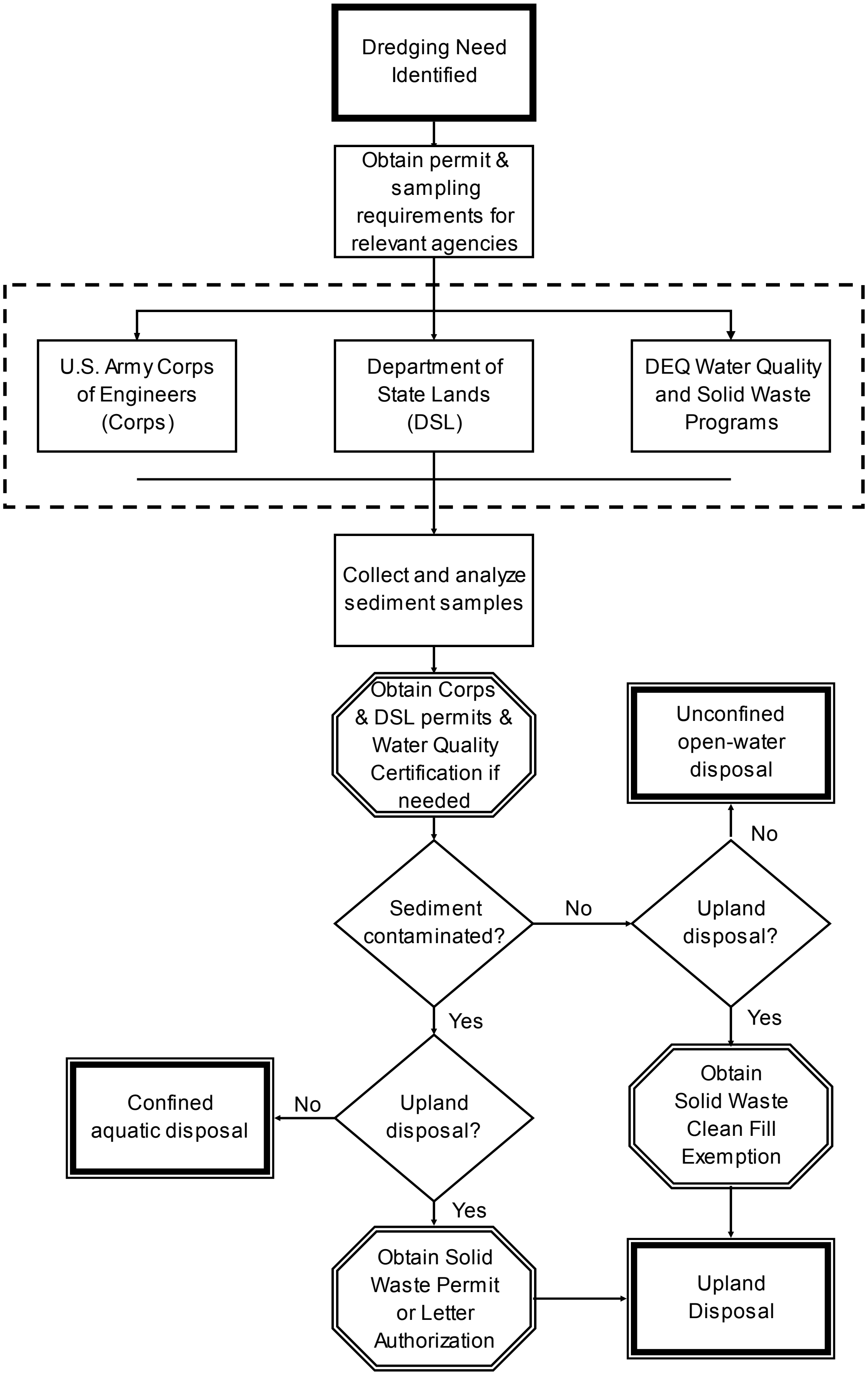


Figure 2-2. The Relationship between the ODEQ's Dredge-related Solid Waste Permits and the Permits of Other State and Federal Programs

IDEQ is the agency designated in the state of Idaho to make 401 certification decisions. Currently, the duties of this program are coordinated from the IDEQ state office and administered from six regional offices. IDEQ's certification procedure is summarized in a flowchart presented on the IDEQ web site at the following URL: http://www.deq.state.id.us/water/surface_water/401%20Guidance.pdf.

2.6.2 Other Idaho Authorities

The Idaho Department of Lands administers the Lake Encroachment permit program. The Idaho Department of Water Resources administers the Stream Channel Protection Act. Both agencies have authority over certain dredging activities.

Any land application of dredged sediments in Idaho is subject to IDEQ regulations on fugitive dust emissions. Requirements are outlined in IDEQ's Ruler for the Control of Air Pollution in Idaho (IDAPA 58.01.01.650-651).

3. REGULATORY PROCESS AND SEDIMENT EVALUATION

3.1 INTRODUCTION

This chapter focuses on the regulatory processes involved in sediment assessment and project approval. Depending upon the nature and location of the project, other regulatory or enforcement processes (state remediation, CERCLA) may also come into play.

This section discusses the regulatory processes that will be in place to manage the sediment characterization practices in the Pacific Northwest. As discussed in Chapter 2, there are many federal and state regulations that govern the management of both uncontaminated sediments and contaminated sediments (CSs). This chapter applies to all Corps activities involving sediment.

3.2 OVERVIEW

The appropriate assessment of sediments is a critical component to all dredging and site investigation sediment-impacting activities (e.g., navigation- or remediation-related dredging or disposal activities, habitat restoration efforts, etc.). As such, the formation of RSET provides a multi-agency center of sediment expertise that may be accessed by the members and agency programs for commenting and evaluating on sediment projects throughout the Pacific Northwest. RSET will be responsible for review and comment on all permitting actions under the Clean Water Act (CWA) 404/Marine Protection Research and Sanctuaries Act (MPRSA) and Corps Civil Works program.

This chapter summarizes the state and federal regulatory processes necessary to receive approval of dredging or sediment evaluation projects undertaken in the Pacific Northwest using this SEF manual. Distinctions are made among three processes, including:

1. The CWA/MPRSA permit process through the Corps' Regulatory Branch for sediment-impacting projects (e.g., new or maintenance dredging, beneficial use);
2. The verification or renewal of approval for ongoing permitted or Civil Works actions; and
3. The sediment evaluation process to evaluate the risk of in situ CSs and the ultimate remedy techniques and option(s) selected.

3.3 CONSISTENCY IN APPLICATION OF THIS SEF

One of the goals of this SEF is the consistent and predictable application of evaluation procedures to sediment-related projects. This consistent application will allow for predictability, better project planning, and the removal of delays caused by changes in project scope due to sediment issues. In addition, the application of consistent guidelines and processes will speed the regulatory review process and ultimately result in more timely review of projects and permit applications. RSET will also have a role in ensuring that the use of this SEF in the context of Section 404 of the CWA, Section 10 of the Rivers and Harbors Act, and Section 103 of MPRSA will be consistent among the three districts. The process to be used by the Corps' districts is described in Section 3.8.

3.4 REGULATORY PROCESS

Figure 3-1 illustrates the standard regulatory process for acquiring the major permits required for a new proposal (the example presented is for a generic dredging project). This process involves a second integrated process, which is the sediment material evaluation process described below. The standard process consists of a series of progressive steps applicable to most dredging projects, as summarized below:

- A Section 10/404/103 permit application is submitted to the Regulatory Branch of the Walla Walla, Portland, or Seattle District Corps, as appropriate. The permit application is forwarded to the local RSET, which then initiates the sediment/dredged material evaluation process. Note: Applicants are strongly encouraged to begin this evaluation process prior to submitting a formal application.
- The sediment evaluation process is carried out by the applicant with guidance from RSET and the Regulatory Branch. The adequacy of the resulting information is verified by RSET. If the information is determined to be adequate, the permit application is considered complete from the perspective of the sediment evaluation process. A memorandum documenting the process will be prepared, and the project is then returned to the Regulatory Branch/Project Manager to begin or continue the standard Public Notice process.
- Prior to or concurrent with the Corps' permit process, dredging proponents will be required to obtain permits/approvals from local jurisdictions and/or state agencies. Likely permits/approvals required in the state of Washington include:
    - o Shoreline Permits,
    - o Hydraulic Project Approval Permit, and
    - o Section 401 Water Quality Certification.

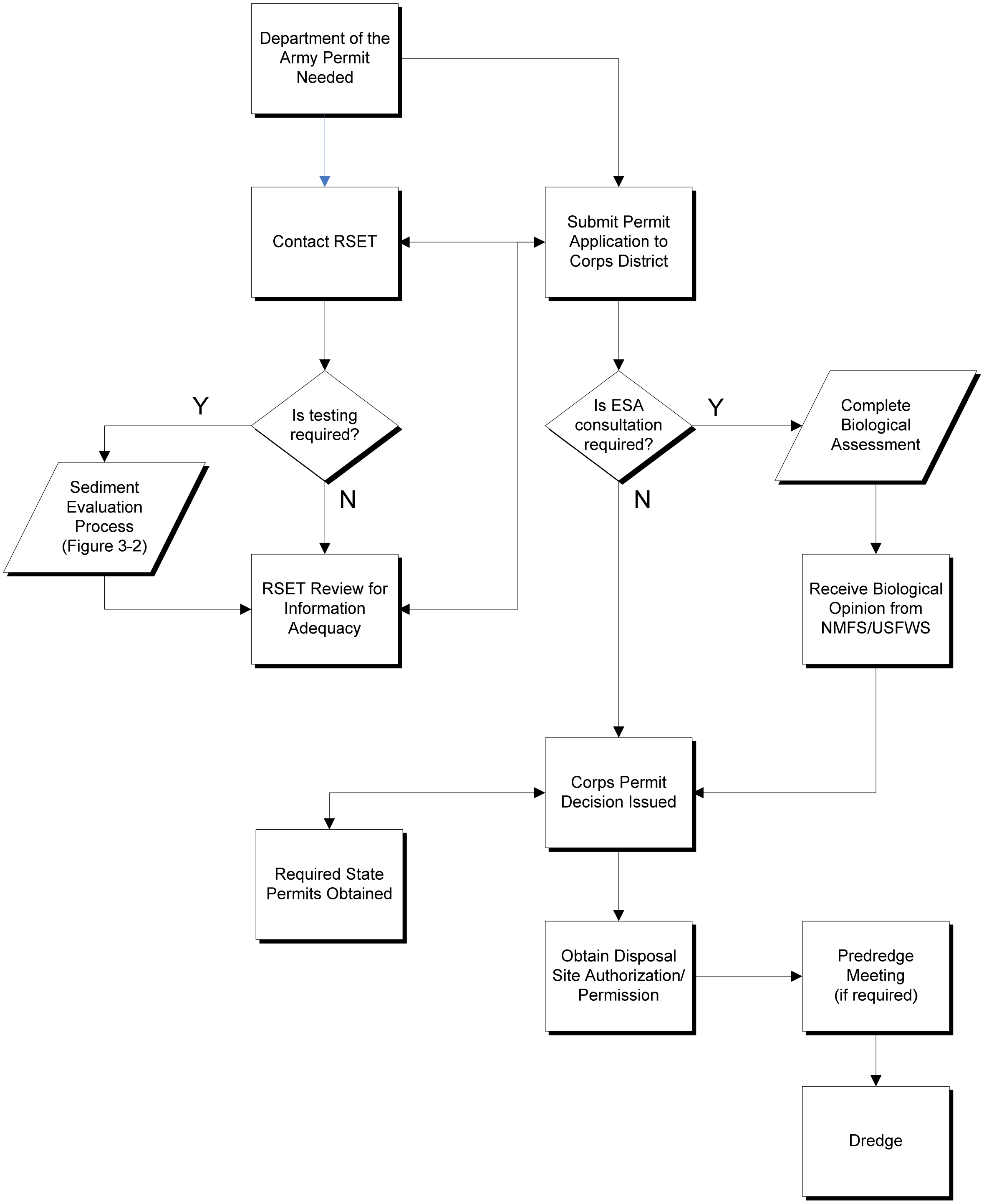


Figure 3-1. Example of New Dredging Project

Likely permits/approvals required in the state of Oregon include:

  - Removal/Fill Permit,
  - Section 401 Water Quality Certification,
  - Coastal Program Approval, and
  - State Beaches.

Likely permit/approvals required in the state of Idaho include:

  - Section 401 Water Quality Certification, and
  - Stream Alteration Permit.

- The permit approval process includes consultation between federal action agencies (Corps or EPA) to ensure that actions do not pose jeopardy to Endangered Species Act (ESA)-listed species or their critical habitat or essential fish habitat. Information developed through RSET involvement contributes to these consultations and decisions, but completion of the sediment assessment is not in itself completion of the consultations/processes.
- During the Public Notice process, the Regulatory Branch may receive comments from the general public and state and federal agencies. Comments that bring up potential issues of concern will be passed on to the proponent for response.
- In Washington, the dredging proponent must get a disposal site use authorization from WDNR if one of the approved open-water sites is involved.

The Regulatory Branch issues a Section 10/404/103 permit that incorporates the provisions of state 401 certification and other appropriate conditions that result as a response to comments, from consultation, or as revisions to the project.

3.5 RSET PROCESS

Each member agency of RSET is responsible for internal coordination, and for bringing issues and concerns regarding sediment assessment to the RSET team. RSET is organized into three state teams that correspond to the Corps' districts, with the Corps assuming coordination activities as part of its regulatory and navigation responsibilities. In addition to these state teams, a regional RSET will meet quarterly to aid in coordination of activities and to identify those issues that are of regional importance. This regional coordination will allow the agencies to leverage limited resources and ensure consistent application of this SEF.

The sediment evaluation process is integrated into both the overall permit process and the verification of existing permits (see Figure 3-2). Eventually, the RDT expects that other

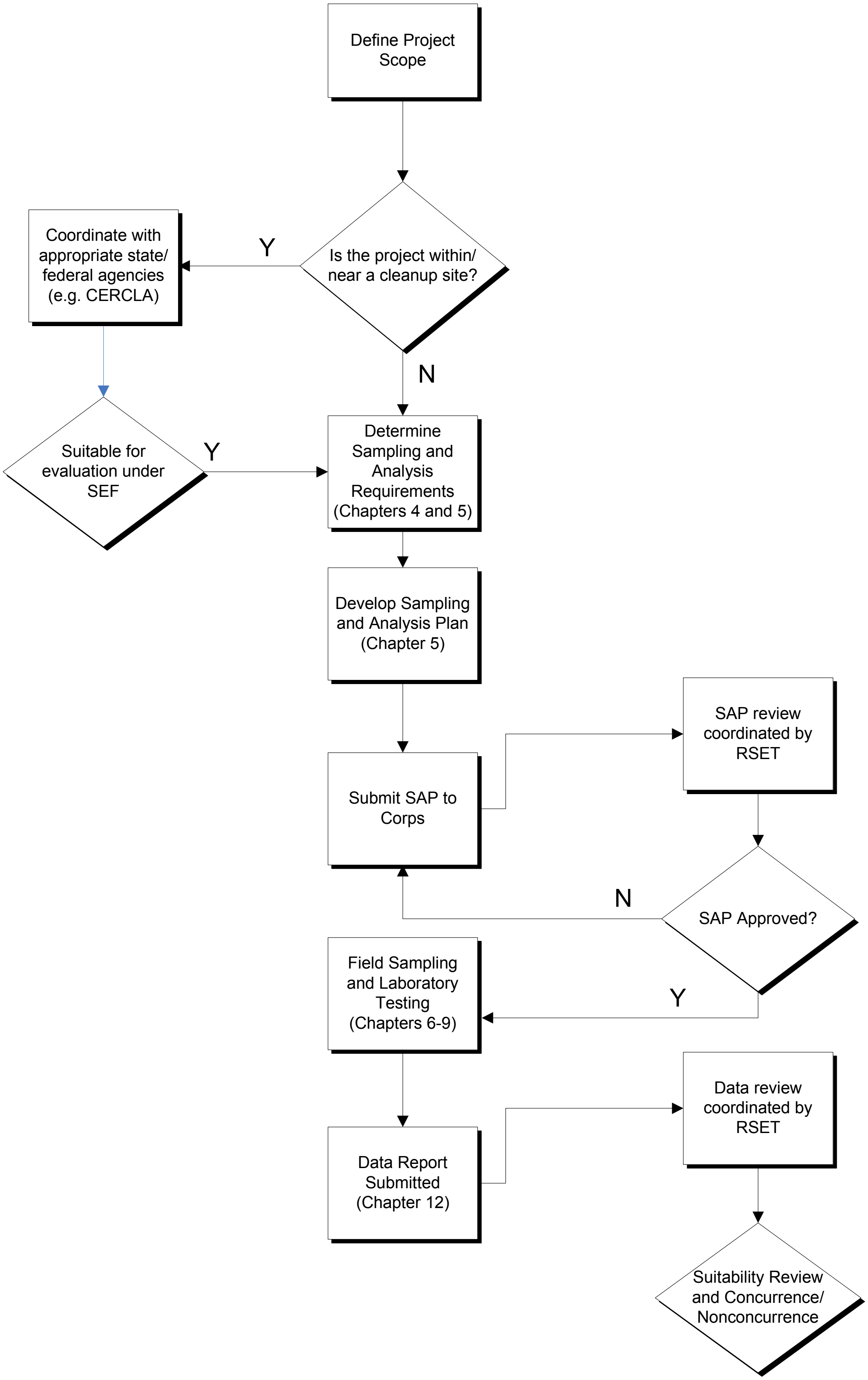


Figure 3-2. Sediment Evaluation Process

agency programs will work with RSET on specific projects. At this time, use of RSET by nonregulatory actions is discretionary for the agency or program. An information/request is submitted to RSET, either by the applicant or the Regulatory Project Manager. Some projects will require an initial screening (i.e., nationwide permits, minor actions) with no further testing or evaluation necessary. For other projects, more information will be required.

If RSET can make a favorable suitability determination based upon the existing information, a memo will be prepared and signed by the RSET State Team. This initial RSET evaluation will be completed within 30 days of receiving complete information from the applicant. No further sediment evaluation will be required. If the RSET State Team finds that the first level information is not adequate to make a suitability determination, the applicant will be advised to prepare and submit a proposed Sampling and Analysis Plan (SAP) to acquire additional information. The SAP must be approved by RSET. The RSET State Team may take up to 30 days for this review, with an additional 15 days for resolution of any existing issues and completion of documentation. Once a SAP is approved, the applicant conducts sampling and analysis of the sediment material as directed by the SAP in order to furnish the information required in one of the subsequent levels.

Once sampling is complete, the applicant prepares and submits a report of the results of the sampling and analysis effort to RSET. RSET reviews the adequacy of the information and prepares a suitability determination and distributes it for review and concurrence by the agencies that developed and approved this SEF. The review process may take up to 30 days, with an additional 15 days for issue resolution and documentation. Those projects involving large and complex data sets may require additional time for review and documentation.

3.6 CONFLICT RESOLUTION PROCESS

The agencies that participate in RSET have established a process for the review and approval of sediment assessment efforts, and developed a process for resolution of disputes when conflicting agency positions and authorities surface during the sediment assessment process. This process is a modification and extension of the RDT. The RDT was established by the Pacific Northwest Regional Administrators (Charter signed in July 2002). At present, the RDT includes the four federal agencies involved in RSET, including NMFS, USFWS, EPA, and the Corps. When an issue is elevated from the RSET Regional Team, it will go to the RDT's NSC. If a RSET issue needs to be elevated to the Operational Management Committee (OMC) (Tier 3 of the RDT), or eventually to the Executive

Administrators (Tier 4), the states will be represented at each of these levels for the duration of the RSET discussion.

3.7 VERIFICATION OF MULTI-YEAR MAINTENANCE DREDGING PERMITS

Corps' permits for maintenance dredging may be issued for a period of up to 10 years. During this time, no additional Corps permitting activity may be required. Neither the Biological Opinion from NMFS or USFWS, nor the state water quality certification are issued for 10 years. These will need to be renewed during the life of the permit. In addition, the dredged material evaluation process has a different set of approval requirements and timelines that focus on a year-to-year evaluation of maintenance dredging projects to ensure the material is still suitable for unconfined aquatic disposal. These requirements are covered under the concepts of "recency" and "frequency" described in Chapter 5. Holders of permits for maintenance dredging will have to continue to coordinate with RSET to determine if additional sampling and analysis is necessary before dredging begins in any given year. Each dredging event will be evaluated based on the state of the science, and new information may change evaluation requirements.

3.8 PROCESS FOR CORPS CIVIL WORKS DREDGING

The majority of current Corps civil works dredging involves the maintenance of existing channels and harbor ways. The coordination of maintenance dredging in federally authorized channels is governed by the process described in 33 CFR 335-338 (Discharge of Dredged Material into Waters of the United States or Ocean Waters; Operations and Maintenance). Generally, the coordination process for civil works dredging projects mirrors the regulatory program, with a few procedural exceptions. Corps dredging is subject to requirements under the National Environmental Policy Act (NEPA), CWA and amendments, MPRSA, and ESA. The general steps in coordinating Corps civil works dredging include the following:

1) A public notice is issued describing the proposed work. If a new sediment characterization is necessary, data are collected and analyzed prior to the issuance of the public notice.

2) An environmental impact statement (EIS) or environmental assessment (EA) is prepared for the project. Typically, for maintenance dredging, a "Finding of No Significant Impact" or FONSI is prepared in conjunction with the completion of a CWA Section 404 (b)(1) evaluation. If an EIS is prepared for new dredging work, Corps authorization to proceed is documented in a Record of Decision document.

For work found to have “no significant impact,” a document called a Statement of Findings (SoF) is completed at the end of the public coordination period.

3) For projects in the coastal zone, a determination of consistency with the enforceable provisions of the state coastal zone program is prepared and submitted to the appropriate state agency along with the public notice. The federal Coastal Zone Management Act (CZMA) consistency concurrence will be requested from the state.
4) If threatened or endangered species are known or suspected in the project area, the biological opinion will be checked to ensure that the activity is covered. NMFS and/or USFWS will be notified that the activity is included in the biological opinion. If the activity is not included as part of the existing biological opinion, a biological assessment for the project will be prepared.
5) Any substantive comments received as a result of the public notice will be addressed to the greatest extent practicable. Maintenance dredging is not initiated until all necessary environmental coordination is completed, including the receipt of a water quality certification from the applicable state. For ocean disposal, a letter of concurrence for the activity is required from EPA Region 10.

3.9 CONTAMINATED SEDIMENT EVALUATION

This SEF stemmed from the Puget Sound Dredged Disposal Analysis (PSDDA) program and the Dredged Material Evaluation Framework (DMEF) for the lower Columbia River; therefore, it still holds an emphasis on dredged material evaluation. The premise of this SEF is a risk-based evaluation and, as such, is an approach that could prove useful to other regulatory programs. The expectation is that for the near term, state and federal dredging and state cleanup in Washington and Oregon will be consistent with this guidance, and Idaho cleanup and EPA Superfund may find this document a useful resource. Consistency across the board with Superfund projects is a reasonable goal, but may not always be desirable or possible. With coordination between RSET and CS programs, an integrated approach is possible. Therefore, a cleanup project may follow the process outlined here, but because of site conditions, source issues, etc., deviations from the process are likely.

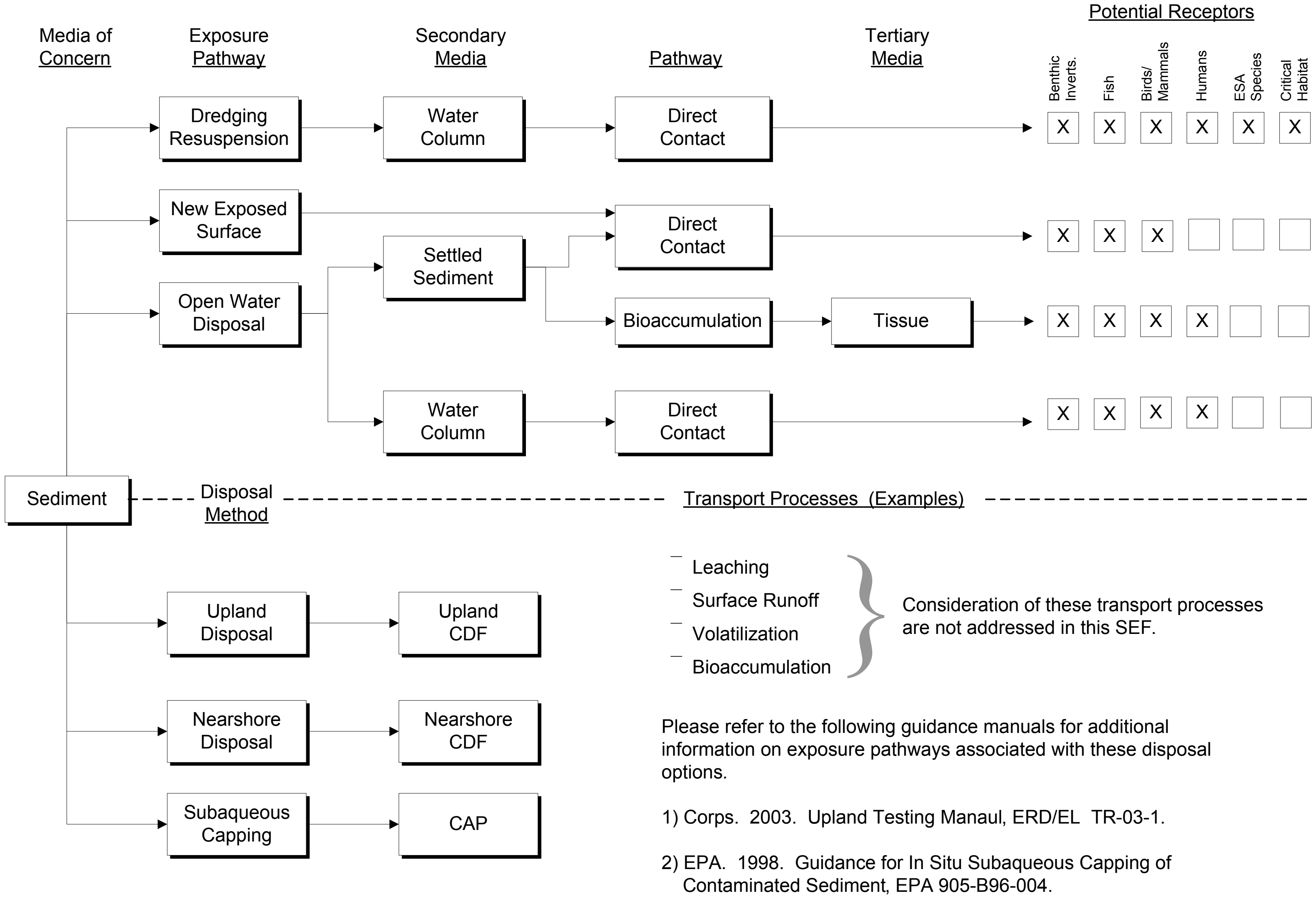
4. EVALUATION FRAMEWORK

4.1 INTRODUCTION

This SEF utilizes an evaluation framework that considers multiple lines of evidence using a phased approach process, where applicable, to reach management decisions. This section presents processes for both dredging projects managed under Corps' jurisdiction (e.g., Section 404 of the Clean Water Act [CWA] or Section 10 of the Rivers and Harbors Act) and dredging projects or site assessment projects that contain contaminated sediments. Chapter 4 discusses both types of sediment evaluation processes because the sediment assessment techniques are similar with the ultimate goal to arrive at a management decision. Also, applicants are finding that many of the routine maintenance dredging projects contain contaminated sediments (CSs). CSs are defined as unacceptable for open, in-water disposal. The risk-based framework will guide the assessment/management process by providing structure, organization, and flow for the actions to be taken in assessing risks and making management decisions.

The objectives of the risk-based framework are as follows:

- Ensure assessments are comprehensive, clear, and consistent and attempt to reduce the uncertainties of the proposed action;
- Ensure any evaluation that follows the steps of this SEF is complete in its consideration and analysis of present and future exposures, effects, and risks on human and ecological receptors of concerns, which will include consideration of threatened and endangered species at the dredging location and disposal site for dredging or CS projects;
- Consider the likelihood for all possible routes of exposure (Figures 4-1 and 4-2) and effects to ensure that required or important site-specific environmental factors are not omitted from the evaluation process;
- Provide a measure of clarity to sediment investigation and management to facilitate meaningful participation in the assessment and decision-making process by scientists, regulatory agencies, and representatives of affected communities;
- Promote active stakeholder involvement to ensure the results of the assessment can be successfully applied within the decision-making process; and



Consideration of these transport processes are not addressed in this SEF.

Please refer to the following guidance manuals for additional information on exposure pathways associated with these disposal options.

1) Corps. 2003. Upland Testing Manaul, ERD/EL TR-03-1.

2) EPA. 1998. Guidance for In Situ Subaqueous Capping of Contaminated Sediment, EPA 905-B96-004.

Figure 4-1. Dredging Generic Conceptual Site Model

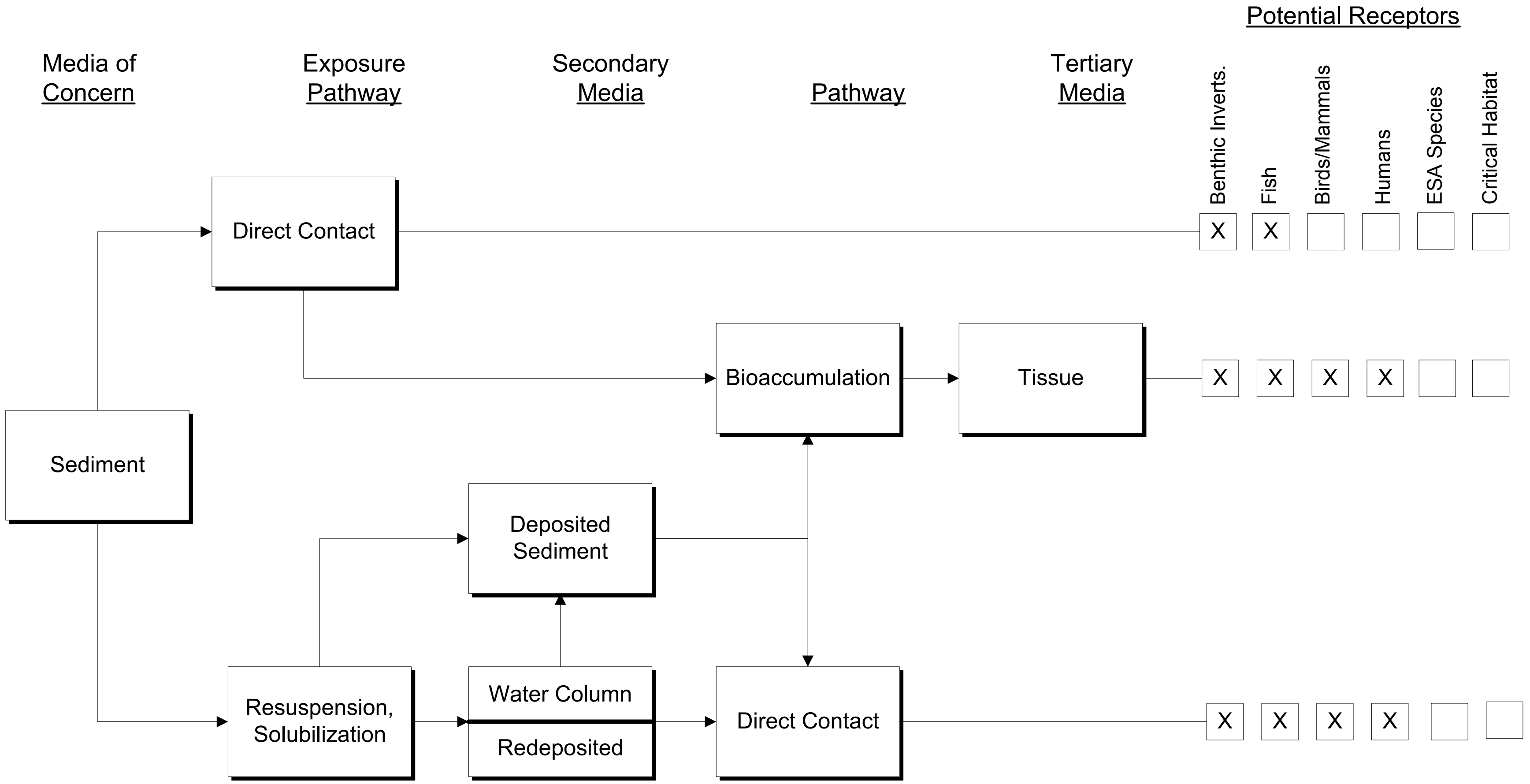


Figure 4-2. Site Investigation Generic Conceptual Site Model

- Ensure consistent and relevant application of the assessment and management process (where possible) for projects whether they are for sediment assessment or dredge material characterization.

The testing required under this guidance manual can be time consuming and expensive. One of the objectives of this manual is to develop and refine procedures that will reduce uncertainty and ultimately the time and cost of dredged material testing programs and CS investigations. The basic framework consists of a phased or iterative evaluation process that is consistent with available and upcoming national guidance. A generalized sediment evaluation framework to make management decisions is presented in Figure 4-3.

4.2 CONSIDER PROGRAM OBJECTIVES

Conceptual site models (CSMs) and project sampling and analysis plans (SAPs) are developed and used to address specific programmatic goals. Knowledge of these programmatic objectives must be factored into the assessment process to ensure a complete set of information is collected and analyzed to aid in the decision-making process. The degree of success achieved in using a specific sediment assessment framework within the context of a regulatory program will be determined in large part by the extent to which program-specific objectives are acknowledged and accounted for when designing and applying the assessment framework.

4.2.1 Conceptual Site Model

A CSM is invaluable in establishing the appropriate technical and managerial approach for addressing the specific issues associated with a project including disposal options, whether it is a dredging project or a site assessment. Concurrent with the initial data collection and analysis, a CSM for the site is also developed. A CSM identifies and describes contaminant sources, the processes linking those sources to the sediment in question, and the physical, chemical, and biological processes occurring within the sediment that affect exposure. It also defines the receptors of concern (ROCs), and describes how ROCs are exposed to the contaminants associated with the sediment. A CSM allows for a graphical representation of the relationships between receptors and resources in the environment and the stressors to which they may be exposed. The CSM can also provide an avenue for beginning to address uncertainties in the relationships and exposure pathways and presence/absence of important receptors at a particular project site or disposal location. A generic CSM for a dredging project is presented in Figure 4-1, and a generic CSM for a contaminated site assessment is presented in Figure 4-2.

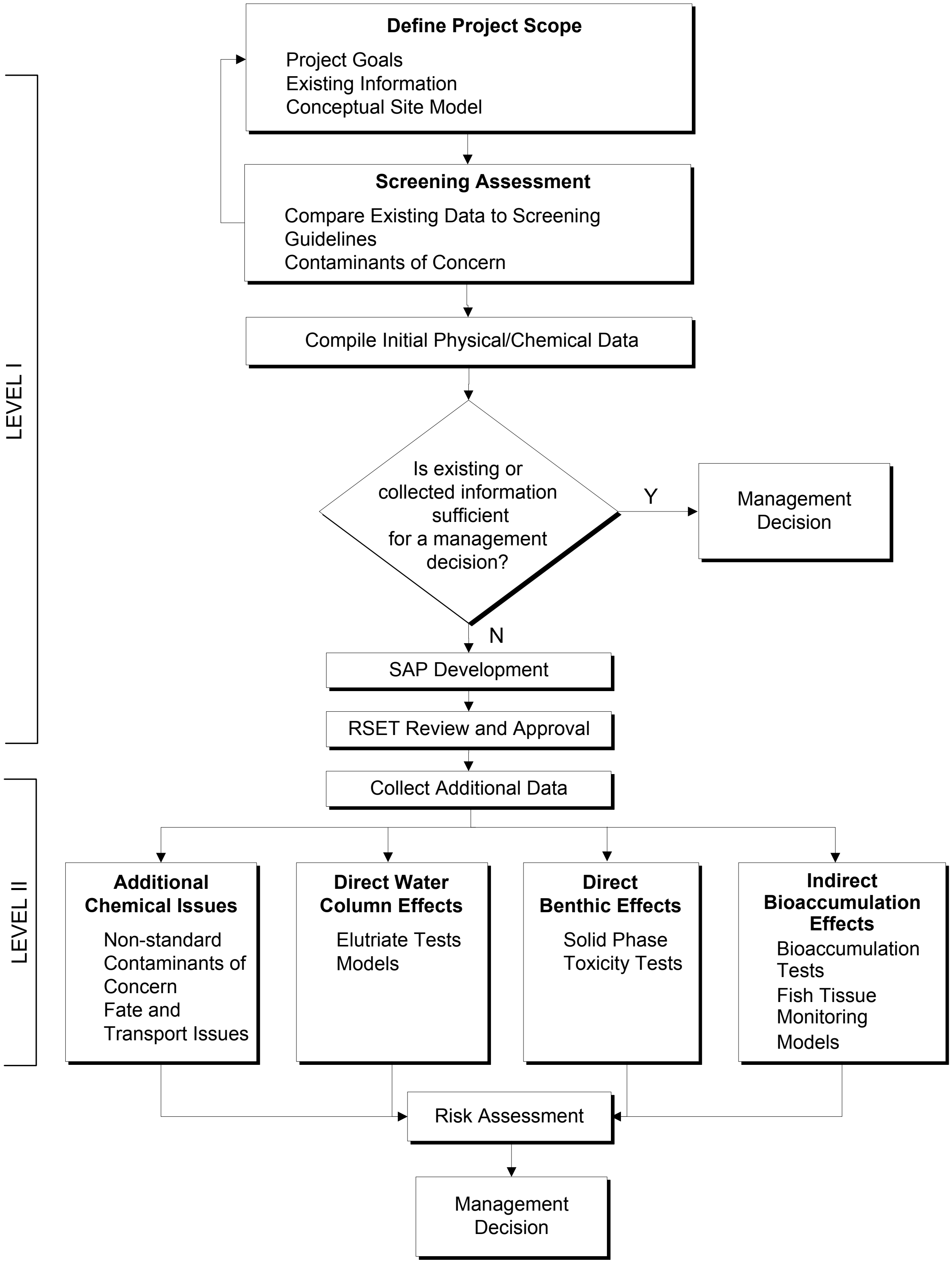


Figure 4-3. Generalized Sediment Evaluation Framework to Make Management Decisions

The CSM provides a powerful tool for both the project proponent and the regulatory agencies to communicate ecological, human health, or other issues among assessors, managers, and interested parties. The CSM identifies the complete and potentially complete exposure pathways, and provides a template to conduct exposure pathway evaluations. It also provides a means to identify relevant receptors and potential response actions. The CSM is dynamic in the sense that, when available, additional data are used to refine and increase the accuracy of the CSM, as necessary, to reflect the current understanding of the project, as well as guide in the decision-making process.

4.2.2 Developing Assessment Questions

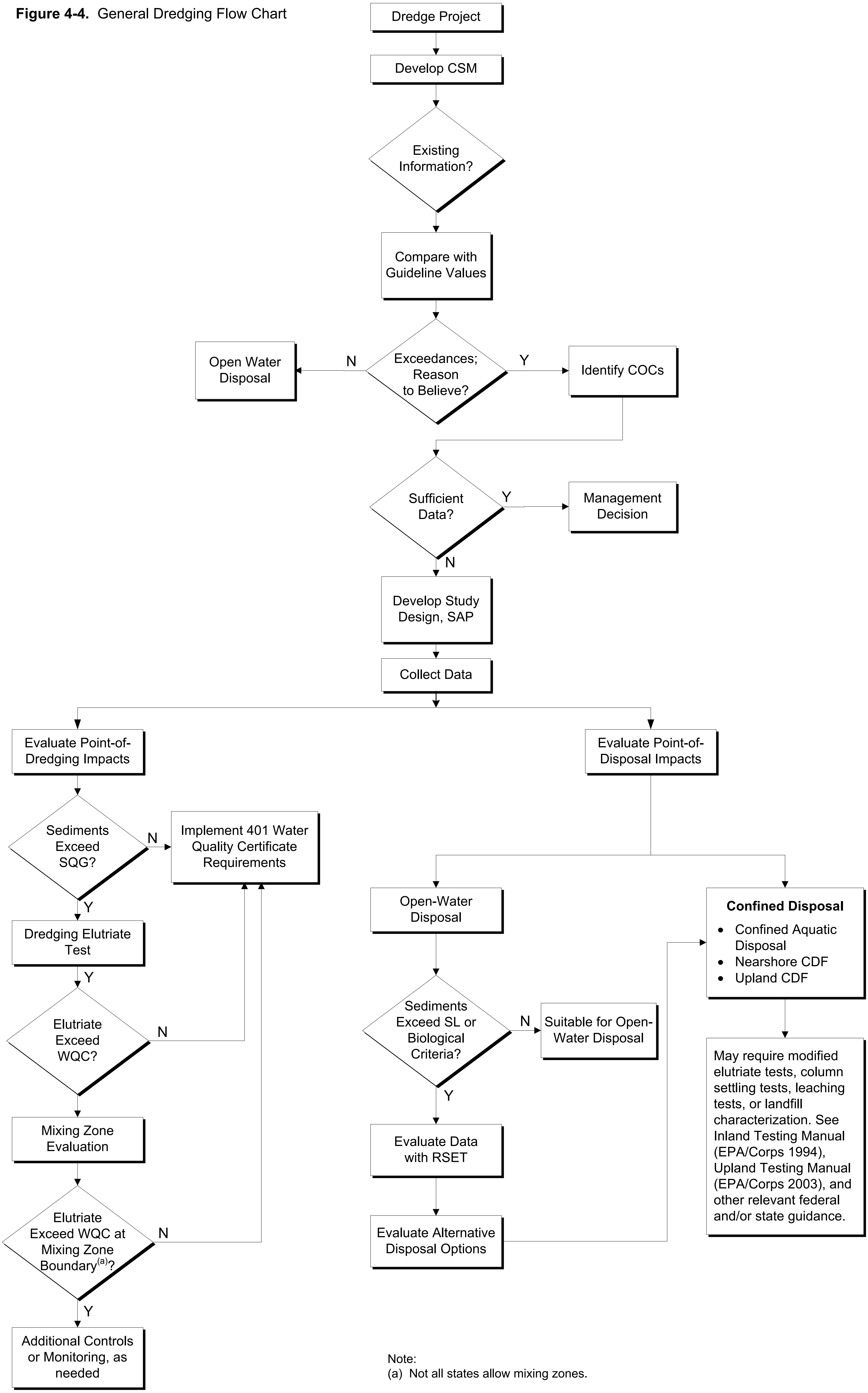
The CSM will provide a basis for developing sediment and/or site-specific assessment questions that must be answered to reach conclusions about whether the sediment/site poses risk. The design and conduct of sediment assessments should be driven by these sediment/site-specific questions. Developing these questions will lead to selecting the lines of evidence and tools that will be used in the assessment. This progression of actions is important because assessment tools vary in terms of their relevance to questions. For example, the most widely used Sediment Quality Guidelines (SQGs) typically address toxicity, but do not likely address a common assessment question: Is there a “reason to believe” that bioaccumulative chemicals in the sediment pose an unacceptable risk to upper trophic levels? Considerable effort should be devoted to formulating and refining specific and detailed questions that must be answered to reach conclusions about the nature and extent of bioaccumulative risks (see Chapter 9).

4.2.3 Dredging Projects

The primary purpose of a dredging project is to remove material to maintain or create water depths to allow for safe passage or berthing of vessels. The evaluation of dredged material is to determine whether there will be unacceptable impacts either during the dredging process or at the disposal site. Figure 4-4 provides a general flow chart of technical evaluation steps that could occur to evaluate sediments proposed for dredging and disposal. The following assessment issues are of primary concern:

- Ensuring the dredging process itself will not result in unacceptable impacts to the environment at the dredging site;
- Ensuring the disposal of dredged material will not adversely affect or degrade the disposal site (in-water or in some cases on land);

Figure 4-4. General Dredging Flow Chart



Note:
(a) Not all states allow mixing zones.

- Ensuring sediment that will be exposed after dredging will not cause unacceptable impacts at the dredging site;
- Ensuring dredging and disposal activities will not expose ROCs to contaminants at concentrations that will cause adverse effects; and
- Ensuring the suspended sediment will not result in unacceptable impacts to water quality.

4.2.4 Contaminated Sediment Projects

The primary goal of assessing CSs is to determine the potential effects of the sediments in place. The site characterization process outlined in Figure 4-5 is similar to a remedial investigation (RI) and should allow for the accomplishment of the following goals:

- Identify and quantify the contamination present in sediments;
- Understand the vertical and horizontal distribution of the contaminants in the sediments;
- Understand the physical, chemical, and biological processes and temporal trends affecting the fate and bioavailability of sediment contaminants at the site;
- Identify the complete human and ecological exposure pathways for the contamination;
- Identify current and potential human and ecological risks posed by the contaminants;
- Identify potential bioaccumulation risks; and
- Assess the degree in which disturbance of contaminants in the sediments may impact species in and around the site.

4.3 LEVELS AND MULTIPLE LINES OF EVIDENCE

This SEF uses a two-level approach risk-based framework to consider multiple lines of evidence based on risk. This SEF utilizes a two-level approach because types and amount of information necessary to reach management decisions will vary from site to site or project to project. Most dredged material characterizations and sediment cleanup assessments will involve the use of a variety of physical, chemical, and biological information to reach decisions about the presence/absence of risk and how best to manage uncertainty and evident risk when determining appropriate disposal/remediation options.

This assessment framework has been designed with levels to encourage investigations that optimize the amount of effort expended in the assessment with respect to the complexity of both the project/site and assessment questions that must be answered to reach management

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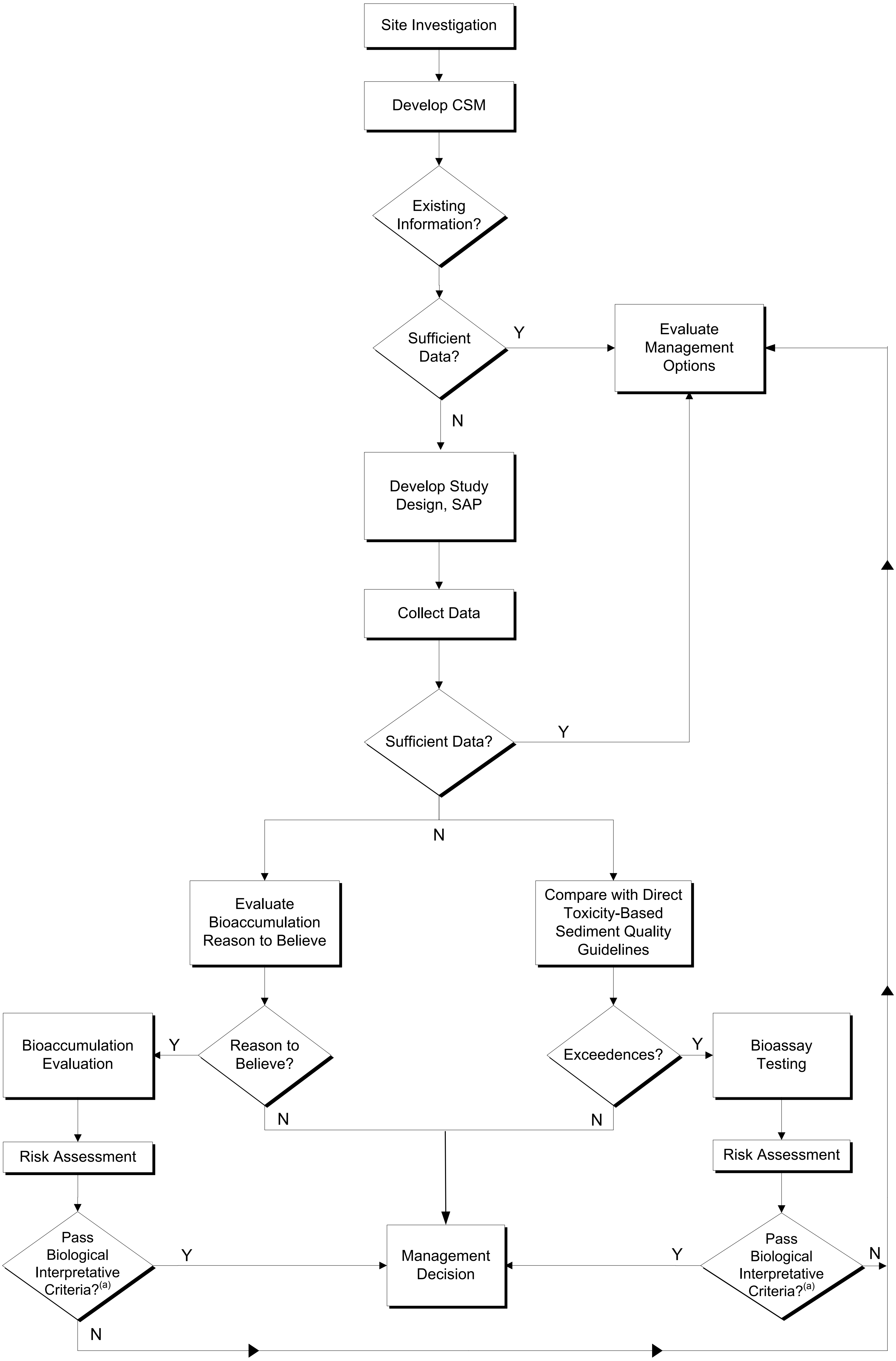
Figure 4-5. Generic Contaminated Site Assessment



(a) See Chapter 8 for Interpretative Criteria decisions. A level, as presented in Figure 4-3, is a stage in the assessment process that concludes with a decision to either:

1. Exit the assessment because sufficient information has been collected to answer questions about the need for and type of management that will be required, or
2. Continue the assessment because insufficient information exists to reach a management decision for the proposed action.

In many cases, management decisions may be possible during Level 1 of an assessment when the elements of the CSM have been completed and a decision is possible. In more ambiguous circumstances, or where the complexity of the site requires it, more comprehensive assessments and data collection may be required in a Level 2 evaluation before definitive management decisions can be made. The strength of a phased assessment framework in this SEF includes clear discussion and decision points where the need to continue the evaluation is addressed.

This risk-based framework is also structured to allow for iteration. As information is collected and analyzed during an evaluation, the assessment process must allow for making additions and refinements to the CSM and questions that are formulated during the initial stages of assessment. Such iteration allows the assessment to become more focused and remain relevant as the evaluation proceeds.

Figures 4-3 and 4-6 present the assessment and management framework for sediments. Figure 4-6 provides additional details for what is included in a Level 1 evaluation. As shown on these figures, Level 1 includes CSM development, pre-assessment, and initial assessment tasks, while Level 2 can include a more intense sediment-dredged material/site assessment, including additional chemical and/or biological testing, or modeling tasks.

The categories of information/data needs described below are used in a sequential manner for evaluating the risk of in-place sediments and the suitability of dredged material for unconfined aquatic disposal. This sequential approach is called a tiered evaluation process. At each level, a decision is made regarding the adequacy of the existing data to make a suitability determination. If existing data satisfy the CSM, they are adequate for management decision-making purposes and there is no need to proceed to Level 2. If data do not satisfy the CSM, data at the next level are required before a management decision can be made. This arrangement is summarized and illustrated in Figure 4-3 and presented in additional detail in Figures 4-4 and 4-5.

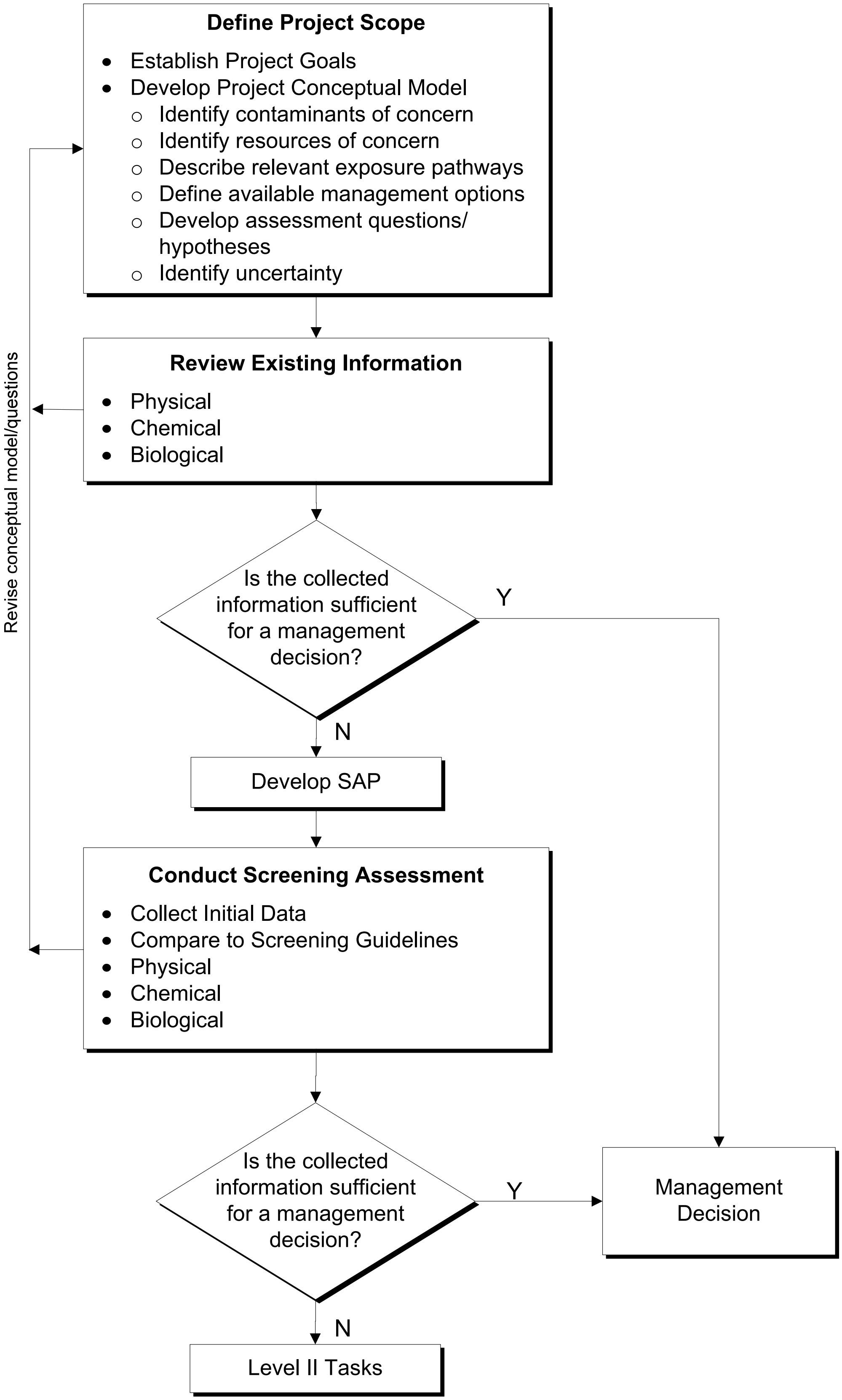


Figure 4-6. Detail of Level 1 Tasks

Transition to Level 2. The compilation and review/screening of existing information, preliminary identification of uncertainties, and other locational factors comprise the initial tasks in Level 1. In some instances, the existing information may be sufficient to address all of the elements identified in the CSM to make a management decision. The transition from Level 1 to Level 2 occurs when the screening of collected data against the CSM indicates the need for additional tasks that are required to reach a management decision, whether it is assessment of direct toxicity, indirect bioaccumulation effects, or other tasks, as shown on Figure 4-3. The transition from Level 1 to Level 2 can be triggered by exceedances of appropriate sediment screening levels, the type and magnitude of uncertainty, or other analytical results that indicate a need for more detailed assessment of the sediment or water column. For example, for a navigational dredging project, if existing information supports the CSM regarding a decision for unconfined aquatic disposal, no additional data are needed. However, if no information exists or it does not support the CSM for the initial site/sediment characterization, the project proponent will be required to prepare and submit a SAP for additional data collection. Chapter 5 describes the details of a SAP applicable to the complexities of a dredging project and associated CSM. It also discusses the guidelines for preparing and submitting the plan. Chapter 6 provides further details on the proper implementation of sediment sampling and laboratory analyses. This additional data collection may provide sufficient analytical data to make a management decision. For example, for a dredging or site investigation project, if the analytical data were all below appropriate sediment screening levels, uncertainties did not exist or were reasonably managed, and there was no “reason to believe” that bioaccumulation issues are present at the site, the investigation may be concluded at this point with the decision of no unacceptable risk from sediment/dredged material at this site.

4.4 LEVEL 1

4.4.1 Initial Assessment

During the initial assessment phase of an evaluation, the reasons why a dredging characterization study or sediment evaluation is being conducted should be defined. Projects may be contemplated to address any number of programmatic and/or regulatory goals or objectives. The reasons motivating the project will impact how the CSM is developed and how the subsequent assessment is conducted. For example, will the assessment primarily be of potential risks to a disposal site or of potential risks from the in-place sediments?

For both dredging assessments and contaminated site assessments, the initial assessment stage is generally similar.

Dredging Assessments. The most routine sediment assessments occur in support of navigation or maintenance dredging operations. The objective is to remove the sediment to allow for safe navigation and berthing and find the appropriate disposal location for the material. The results of the sediment assessment will be used to determine how the material, once removed from the channel, will be managed, or if the proposed approach poses unacceptable risks. The management alternatives range broadly from unrestricted open water disposal or beneficial uses (e.g., beach nourishment or habitat creation) for materials posing no or minimal risk to upland disposal for sediments where risks are determined (EPA/Corps 2004). Data are collected to evaluate both point of dredging impacts and point of disposal impacts. A generic dredging flow chart is presented in Figure 4-4.

Similar to a site investigation, the main objective of the initial assessment in a dredging assessment is to clearly define the goals of the project that in turn will drive and structure what information that may need to be collected during the primary assessment to facilitate the decision-making process.

The initial data collection and review should address the following assessment questions:

- When was the most recent dredging activity completed at this location?
- What are the contaminants of concern (CoCs)?
- What data on physical, chemical, toxicological, and biological characteristics are available and are these data of sufficient quality?
- What are the likely historical and ongoing sources of contaminants?
- What are the key ROCs at the dredging and disposal sites?
- What is the uncertainty associated with the data?
- How can the uncertainty associated with the data be managed?

Additionally, information about the site is evaluated to define site-specific CSM. Details of how a CSM is prepared and used is provided in Section 4.2.1. A generic CSM for dredging projects is presented in Figure 4-1.

Contaminated Site Assessments. Within the context of a site investigation program, generally some risk is presumed to exist at the site at the beginning of the assessment. In most cases, a site is nominated to such a program because available evidence exists supporting the presence of some risk. The available information compiled during the assessment will be used to determine the nature, extent, and magnitude of that risk and to aid in the identification and selection of the best set of management and/or remediation technologies to apply at the site. A generic site investigation flow chart is presented in Figure 4-2.

The main objective of the initial assessment is to clearly define the goals and CSM of the project that in turn will drive and structure what information needs to be collected during subsequent tasks to facilitate the decision-making process. The initial data collection and review should address the following questions:

- Are there local sources of contamination, either past or present (e.g., marinas and fueling areas; industrial/municipal discharges; shipping; inputs from industrial, municipal, or agricultural sources; spills and urban and residential surface runoff)?
- What chemicals may have been released from these sources (i.e., what are the CoCs)?
- What data on physical, chemical, toxicological, and biological characteristics are available, and are these data of sufficient quality?
- What are the key ROCs?

4.4.2 Primary Assessment

The primary assessment is designed to further the understanding of the project (utilizing and updating the CSM) and will begin with collecting new data. Such data may include information about contaminant sources, ROCs, and biological or chemical data from the sediment/site. This data collection effort should include a review of data quality and would culminate in identifying preliminary lists of contaminants. The types of preliminary data required are dependent on whether the assessment being conducted is a dredging assessment or a contaminated site assessment, as discussed below.

The technical data gathering aspects for the primary assessment phase of this SEF for a CS evaluation or a dredging assessment are similar. They both include 1) collecting and analyzing existing and preliminary biological or chemical data, and 2) comparing initial data to appropriate sediment and tissue guidelines.

The primary assessment for a contaminated site assessment and a dredging assessment does have differences. For example, a CS assessment typically has known or suspected sources of contamination and entails developing site-specific assessment questions aimed at delineating the areas of concern. Additionally, a CS assessment is not always associated with maintenance dredging nor does it require dredging as its alternative.

The primary assessment phase for both dredging and a contaminated site assessment both conclude with a comparison of existing or preliminary data to appropriate and relevant physical, chemical, and/or biological guidelines (see Section 7.5 for a discussion concerning the use of these guidelines). RSET then determines whether sufficient information exists to make a regulatory decision. If there is not sufficient information for a regulatory decision, the project transitions to a Level 2 assessment.

4.4.3 Use of Guidelines

The initial and primary assessment phase concludes with a comparison of existing or preliminary data to appropriate and relevant physical, chemical, or biological guidelines. There is merit in using sediment and tissue guidelines in combination with other sources of information to identify sediments at the initial assessment phase that require no further evaluation because they pose little potential for risk. For some programs, there also may be merit in incorporating approaches within the initial assessment for using sediment and tissue guidelines along with other lines of evidence to identify sediments that pose some high potential for risk.

The kinds of information and/or guidelines that can be used in combination at this stage in the assessment to reach decisions about the need for further analysis include the following:

- <u>Proximity to contaminant sources</u>. Information may include current and historical permitted or unpermitted point sources, or nonpoint sources from urban, residential, or agricultural areas. In addition, information on anthropogenic or non-anthropogenic sediment transport mechanisms such as flooding, boat traffic, or aggradation/erosion in the vicinity may also be relevant. This will allow the assumption that sediments that are far removed from sources of pollution are less likely to contain contaminants to be substantiated or disputed.
- <u>Grain size distribution of the sediment</u>. If the sediment is associated with highly erosional areas and largely composed of coarse-grained material, the sediment is unlikely to contain contaminants.
- <u>Sediment chemistry</u>. The potential for direct sediment toxicity to benthos may be assessed through the use of SQGs. Their use is intended to provide insight as to whether or not benthic toxicity is expected. Lower threshold SQGs (i.e., chemical levels associated with a low probability of toxicity) can be used along with an

evaluation of bioaccumulation potential to reach conclusions about the need for further assessment. SQGs that identify sediments with a greater likelihood for producing effects can be used to focus assessments or accelerate consideration and selection of management alternatives. The manner in which SQGs are used within an assessment framework will be determined in large measure by the objectives and constraints of the relevant regulatory programs involved, as well as the nature of the assessment questions developed during the initial assessment from the CSM. Use of SQGs must also be guided by a clear understanding of how the SQGs to be used were derived, what type and level of effects they address, their predictive ability, and their appropriate/recommended uses.

- Sediment toxicity data. Recent sediment toxicity test data can be used to reach conclusions about the need for further testing or analysis. Similarly, potential risks to ROCs beyond the benthos may also trigger the need for further testing or analysis.
- Tissue chemistry. Recent chemistry data from organisms collected at the site or in the water body surrounding the site can be compared to existing health advisory levels and bioaccumulation triggers (BTs) to reach conclusions about potential bioaccumulative risk.

In some cases, the use of guidelines, including sediment and tissue guidelines, will be used to reach conclusions that no further assessment is required because the assessment questions could be satisfactorily addressed using information available at this stage of the evaluation and the uncertainties managed sufficiently. In cases where such a comparison with guideline values results in ambiguous answers to the assessment questions concerning the presence of unacceptable risk and uncertainties cannot be sufficiently managed, the assessment would proceed to sediment/site assessment after revising, as necessary, the list of contaminants of potential concern, the CSM, and the assessment questions. In cases where the assessment questions were confidently addressed through the use of guidelines, the investigation proceeds to an evaluation and selection of management alternatives.

4.5 LEVEL 2—DREDGING ASSESSMENT

Level 2 for dredging sites consists of physical and chemical testing, biological testing, bioaccumulation testing, and special evaluations. It draws from the original or revised CSM. See Figure 4-4 for a general dredging flow chart.

4.5.1 Physical and Chemical Testing

Physical and chemical testing requirements are presented in Chapter 7. Following the Level 1 evaluation, physical and chemical testing may be required to provide a reliable screen to predict potential contaminant effects from discharge of the dredged material. The pathways of concern for potential effects are through the bulk sediment itself and/or through the water column during dredging and/or disposal. This manual (specifically Chapter 7) focuses on requirements and procedures for testing bulk sediments. Water column testing may also be required as discussed in Chapter 11.

4.5.2 Biological and Bioaccumulation Testing

Biological testing requirements are presented in Chapter 8. Biological effects tests may be necessary if Level 1 and Level 2 (physical and chemical testing) evaluations indicate the dredged material contains contaminant concentrations that may be harmful to aquatic organisms. Level 2 biological testing of dredged material will be required when chemical testing results exceed guideline values. An appropriate set of aquatic organisms and bioassays shall be used to make a determination regarding the suitability of the dredged material for aquatic disposal. Tests involving whole sediment determine the potential effects for bottom-dwelling organisms. Tests using suspension/elutriates of dredged material are used to assess the potential effects on water column organisms. A bioaccumulation evaluation is required when there has been a “reason to believe” determination that certain bioaccumulative chemicals of concern (BCoCs) may pose a potential unacceptable risk to human health or ecological health in the aquatic environments. Bioaccumulation testing is discussed in Chapter 9.

4.5.3 Special Evaluations

Special evaluations are nonroutine evaluations that require coordination between RSET and the dredging proponent to determine the specific testing required. As part of this ongoing process, RSET will continually review new tests and evaluation procedures that have been peer reviewed and are deemed ready for use in the regulatory evaluation of either CS investigations or proposed dredged material. RSET will subsequently make recommendations about their potential implementation and use. Physical, chemical, and biological testing evaluations of dredged material may result in a requirement to conduct special evaluations (see Chapter 11).

One of the following four circumstances is expected to trigger special evaluations:

1. Biological testing results (i.e., bioaccumulation tests, tissue analysis) are indeterminate;
2. Sediments/tissues contain chemicals for which threshold values have not been established;
3. Sediments/tissues contain chemicals for which the biological tests described in Chapter 7, 8, and 9 are inappropriate; or
4. Unresolved issues regarding potential risks to Endangered Species Act (ESA)-listed species.

If special evaluations are determined necessary by RSET, specific tests or evaluations and interpretive criteria will be specified by RSET in coordination with the applicant. Alternative analyses that may be conducted as part of the special evaluations may include, for example, steady-state bioaccumulation tests and a human health/ecological risk assessment.

4.6 LEVEL 2—CONTAMINATED SITE ASSESSMENT

Level 2 for contaminated site assessments consists of sediment/site assessment, evaluation and selection of management alternatives, verification and monitoring, and adaptive management and assessment. It draws from the original or revised CSM. See Figure 4-2 for a general site investigation flow chart.

4.6.1 Sediment/Site Assessment

During the sediment assessment phase of the evaluation, more comprehensive and site-specific sediment and/or data will be collected and analyzed for the purpose of clarifying the nature, extent, and magnitude of risks posed by CSs.

Decision Point. At this juncture of the evaluation, judgments are reached with the input of stakeholders regarding whether the lines of evidence analyses are sufficient for the decision-making process. Such judgments would be based on the extent to which each of the assessment questions are addressed by the evidence collected and the results of the uncertainty analysis. If the assessment is judged to be sufficient for the decision-making process, and the uncertainty is sufficiently managed and/or appropriate mitigation applied, the risks are then summarized using the CSM and other means, as appropriate, and a transition is made to evaluating and selecting management alternatives. In cases where the weight of evidence is judged to be insufficient for the decision-making process, critical uncertainties are addressed by iterating back into the assessment.

4.6.2 Evaluation and Selection of Management Alternatives

Following the SEF depicted in Figure 4-3, the management decision or evaluation of alternatives phase of an assessment can be reached either directly following the Level 1 assessment or at the conclusion of a sediment/site assessment (Level 2). Iteration between the Level 2 tasks and an appropriate management decision may be necessary. In cases where an early determination is reached during Level 1 that risks are present, additional site or process data may be needed to guide the selection of the most appropriate management alternative(s). Likewise, it may be necessary at times to conduct additional evaluations or reanalyze information collected during the sediment/site assessment to inform the process of selecting management alternatives.

Identify Risk Management Alternatives. The first action to be taken in selecting a management alternative is to assemble a list of feasible/available management options. At this stage of the selection process, the list should include the full range of possible options (i.e., there should be no presumptive management alternative). Premature culling of alternatives before collecting and analyzing sufficient information to support the selection process will invite criticism of the process, reduce credibility in the assessment, and potentially raise the risks to human and ecological ROCs. The broad range of risk management alternatives for sediment sites can be grouped into the following categories and subcategories:

- Control of ongoing sources,
- Constraints on site use in conjunction with other actions,
- In situ management,
- Monitored natural recovery,
- In-place capping with clean sediment,
- Treatment (e.g., chemical or biological),
- Ex situ management of material,
- Dredging followed by isolation (e.g., landfill, confined disposal facility), and

- Dredging followed by treatment, including physical, chemical, thermal, and biological prior to disposal.

Additional guidance on available risk-management options is available in other guidance documents (e.g., Upland Testing Manual and Guidance for In Situ Subaqueous Capping of Contaminated Sediments).

General information about each of the available or feasible alternatives should be collected. Such information would include the basic logistical and engineering elements of the alternatives, distance and routes to management sites, and a listing of site features or characteristics with the potential to impact the effectiveness of the alternative to remediate risks (e.g., hydrodynamic characteristics affecting sediment stability/mobility, geotechnical properties of the sediment, etc.). Collecting this information will help identify the need for additional data collection or analysis that may be necessary before a definitive comparison can be made of the risks and benefits associated with each of the management alternatives.

Compare the Risks Associated with Alternatives. All the management alternatives for CSs carry their own specific set of strengths and weaknesses, advantages and disadvantages, and risks. Efforts have been made to rank management alternatives for CSs in terms of their overall feasibility, effectiveness, and practicality. What has emerged from these efforts is the conclusion that there is no universally superior technology for managing CSs. One of the consequences of this commonly accepted conclusion is that the decision process used to select management alternative(s) must include a comparison of the alternatives with respect to the characteristics of the site. Because management decisions will involve reconciling tradeoffs, most sites will require using a combination of management alternatives.

5. SAMPLING AND ANALYSIS PLAN

5.1 OVERVIEW

The development of a Sampling and Analysis Plan (SAP), whether for a proposed dredging project (defined as maintenance or new dredging) or contaminated sediment (CS) investigation, is an essential step in the tiered evaluation process for those projects found to require additional information following review within Level 1. The basic sampling and analysis structure described below is patterned after those utilized to successfully evaluate dredging projects or CS projects in the Pacific Northwest. Field sampling and laboratory testing can be the most expensive part of the sediment characterization process. This is why a thorough, detailed, and approved SAP is essential prior to field work.

For dredging projects, the SAP must be designed to characterize the material proposed to be dredged. This includes the dredging prism, as well as any advanced maintenance and anticipated overdepth or side slope dredging. The new surface material (NSM) should also be sampled (see Section 5.9.4).

An important component of any sampling and testing program is pre-project coordination with all concerned personnel. This may include a face-to-face meeting. Personnel involved may include management, field, analysis/data management personnel; representatives of regulatory agencies; and the permit applicant (project proponent). The purposes of SAP coordination include the following:

- Defining the objectives and scope of the sampling effort,
- Defining the conceptual site model (CSM),
- Ensuring communication among participating groups, and
- Ensuring agreement on methods, quality assurance/quality control (QA/QC) details, and contingency planning.

The more explicitly the objectives of the program can be stated, the easier it will be to design an appropriate SAP. A complete SAP provides adequate information regarding clearly identified project descriptions, a CSM and assessment questions, maps and profiles, sampling locations, sampling procedures, volumes, sampling depths, logistical concerns, an analyte list, and analytical methodologies.

5.2 INFORMATION REQUIRED IN A SAMPLING AND ANALYSIS PLAN (BASED ON REGULATORY PROGRAM)

The sampling plan serves as the main source of information about a proposed project, the history of the project site, and the proposed methods to evaluate the sediments. The majority of the information needed in a SAP is the same whether the project is for dredging or a sediment characterization project. A SAP should contain the following general categories of information in as much detail as possible:

Level 1 Information. This level involves the gathering and documentation of existing information. This would include information such as site history; current site use; identification of potential sources of contamination; information on adjacent lands, especially known chemicals of concern (CoCs) or cleanup sites; past permitting; and an overview of previous sediment evaluations at the site. For a dredging project, the SAP should include a discussion of rank based on the CSM (see Section 5.3.1). Rank affects the number of sediment samples and analyses required of the project. More than one rank could be assigned to a single project depending upon the size of the proposed dredging area and the distribution of potential contaminant sources.

Project Description (Dredging Project). A project description for a dredging project includes a plan view of the site and a description of the action intended. The proposed dredging plan should contain such information as the depth and physical nature of the material to be dredged; advanced maintenance, side slope, and overdepth dredging; practicable widths and depths of dredging; and proposed dredging methods for determining composite sampling or delineating representative project segments. It is also recommended that proposed disposal methods and locations (e.g., unconfined or confined in-water or upland) be identified in order to review and evaluate the adequacy of the SAP.

Project Description (CS Project). A project description for a CS project includes a plan view of the site and a description of the action intended. It is also important to identify all areas of potential concern so that the sediment characterization is as effective and complete as possible.

Computation of Sampling and Analysis Requirements (Dredging Project). Project rank and volume of dredged material, development of a proposed dredging plan, identification of dredged material management units (DMMUs), and allocation of field samples are all requirements for developing a SAP. This will include bathymetry, proposed core locations, one or more cross-sections of the dredging prism, and the type and volume of sediment to be dredged.

Computation of Sampling and Analysis Requirements (CS Project). An understanding of source pathways and locations of known or suspected contamination is important. Typically, contaminated areas and areas near potential sources are sampled with greater frequency, with fewer samples outside of suspected areas of contamination. The sampling strategy (e.g., number of samples, frequency, depth, etc.) is less prescribed and usually determined through negotiations between the project proponent and regulators. Therefore, multiple figures may be required, including, but not limited to, the following:

- Figures and photographs showing potential source areas,
- Figures showing previous locations of characterizations or dredging, and
- Plan view of the site with proposed sampling locations.

Conceptual Site Model. A CSM includes identification and description of potential contaminant sources; potential processes linking sources to the sediment; physical, chemical, and biological processes occurring within the sediment that could affect exposure; and how receptors of concern are exposed to the contaminants associated with the sediment.

Sampling Procedures. Sampling procedures include the field sampling schedule, sampling technology, positioning methodology, decontamination of equipment, sample collection and handling protocols, core logging, sample extrusion, sample compositing and subsampling, sample transport, and chain-of-custody.

Physical and Chemical Testing. Physical and chemical testing includes grain size analysis, sediment conventionals, CoCs, extraction/digestion methods, analysis methods, detection limits, holding times, and QA requirements (see Chapters 6 and 7).

Biological Testing. This section includes holding time requirements, proposed testing sequence, bioassay protocols (type of media and species), bioaccumulation testing, and QA requirements (see Chapter 9).

Personnel Responsibilities. Personnel responsibilities include individual roles and responsibilities for project planning and coordination, field sampling, chemical and biological testing, QA/QC management, and final report preparation.

Submittals. Submittals include a draft SAP, final SAP with responses to comments or concerns by agencies addressed, and results of sampling and analyses written up for review and concurrence (see Section 5.6).

5.3 PROCESS OF RANKING A SITE (DREDGING)

This section contains both an initial management area ranking (Section 5.3.1) and an individual project evaluation (Section 5.3.2). The management area ranking refers to the initial rankings assigned to specific sites or reaches where dredging or sediment evaluation has historically occurred. These initial rankings serve as one of the project variables factored into the development of sediment SAPs.

The individual project component refers to the Level 1 evaluation process for a specific dredging proposal. Included in the Level 1 evaluation for specific dredging proposals are guidelines pertaining to the following:

- Exclusion from further testing based upon grain size and TOC (Section 5.6),
- Proximity to known sources of contamination,
- Frequency of dredging (Section 5.7), and
- Recency of data (Section 5.8).

5.3.1 Initial Management Area Rankings

To assign initial rankings, RSET relied on best professional judgment of Corps and EPA representatives who have been working and evaluating sediment quality data in the region. Reaches or sites where dredging may be expected or has occurred in the past are assigned one of five possible ranks: exclusionary, low, low-moderate, moderate, or high. In that order, these ranks represent a scale of increasing potential for concentrations of CoCs and/or adverse biological effects. Table 5-1 identifies the parameters that better define these rankings. The ranking system is based on the following two major factors:

1. The availability of historic information on the physical, chemical, and/or biological-response characteristics of the sediments from a reach or site; or
2. The number, kinds, and proximity of chemical sources (existing and historical) known to occur in or near a particular reach or site.

The initial management area rankings based on volume and type of sediment represent general guidance prior to evaluating existing information. Revisions to the rankings can and will occur as the result of additional information. In addition, a specific project site or reach can be reranked based upon the results of new sediment testing or by means of a partial characterization.

Table 5-1. Management Area Ranking Definitions

Ranking	Parameters
Exclusionary	Available data indicate coarse-grained sediment with at least 80 percent sand retained in a No. 230 sieve and a total organic carbon content of less than 0.5 percent TOC. Locations sufficiently removed from potential sources of sediment contamination based on historical information and/or best professional judgment. Typical locations include the mouth and mainstem channel of the lower Columbia River.
Low	Available data indicate low concentrations of CoCs and/or no significant response in biological tests. Locations with higher percentage of finer-grained sediments and organic material but few sources of potential contamination. Typical locations include adjacent entrance channels, rural marinas, navigable side sloughs, and small community berthing facilities.
Low-Moderate	Available data indicate a "low" rank may be warranted, but data are not sufficient to validate the ranking.
Moderate	Available data indicate moderate concentrations of CoCs in sediments in a range known to cause adverse response in biological tests. Locations where sediments are subject to several sources of contamination, or where existing or historical use of the site has the potential to cause sediment contamination. Typical locations include urban marinas, fueling, and ship berthing facilities; areas downstream of major sewer or stormwater outfalls; and medium-sized urban areas with limited shoreline industrial development.
High	Available data indicate high concentrations of CoCs in sediments and/or significant adverse responses in at least one of the last two cycles of biological tests. Locations where sediments are subject to numerous sources of sediment contamination, including industrial runoff and outfalls, or where existing or historical use of the site has the potential to cause sediment contamination. Typical locations include large urban areas and shoreline areas with major industrial development.

5.3.2 Project Specific Evaluations

Level 1 involves the review of all available historical information to determine if there is a reason to believe that significant contamination may be present at a proposed dredging site. Included in the Level 1 evaluation is the determination of whether the sediments to be dredged fall under a "frequency guideline." They may be excluded from further testing because they are frequently dredged and have two rounds of successive evaluation where no CoCs have been shown (Section 5.7). For projects with newly obtained sediment characterization data, recency guidelines have a bearing on the longevity of the information for decision purposes (Section 5.8). As new guidelines are developed (e.g., updated bioaccumulation triggers [BTs]), existing data may need to be subjected to a one-time review to ensure sediments are still below the new guidelines.

Review of Historical Information. The agencies involved in the review and approval of dredging projects in the region can and do serve as a source of historical information about sediments and proposed dredging locations. The agencies share a common responsibility to make available any and all such information. However, the compilation of all available historical information about sediment quality or potential sources of contamination for a specific dredging project is the responsibility of the project proponent. An accurate compilation of historical data can result in substantial cost savings. For example, qualified data may eliminate or reduce the need for testing, help limit the number of contaminants tested, and reduce the amount of dredged material needed to be tested.

Quality Assurance of Existing Data. The value of historical data is controlled by its reliability, which in turn depends upon the quality, timeliness, and completeness of the data. For example, 22-year-old data may provide valuable input on a historical contaminant source that no longer exists, even though it cannot be used for determinations of suitability. In contrast, recent data from a well designed sampling effort may be sufficient to make a final suitability determination on a project, or substantially reduce additional testing requirements. The following types of information are required to use existing data for suitability determinations:

- Sampling and analytical methods for both chemistry and biological tests,
- Chemical detection limits (see Table 7-2),
- Biological test control sediment, and
- QC measures for both chemistry and biological tests.

5.4 DETERMINATION OF SAMPLING AND ANALYSIS REQUIREMENTS

The following guidelines specify the maximum volume of dredged material that can be represented by a single analysis. The guidelines are considered “the minimum requirements.” Therefore, the dredging proponent may opt, or regulatory agencies may require, additional analyses for volumes less than the maximum.

a) **Dredged Material Management Units.** In determining the number of samples and analyses required to fully characterize project sediments, the concept used is a DMMU. A DMMU can represent the total volume of sediment to be dredged for a small project, or it can be a subunit of the total volume of a larger project. Typically, a DMMU represents a unit of sediments similar in nature that can be characterized by a single sediment analysis. Thus, a separate decision can be made for each DMMU that can be characterized and dredged separately from other sediment in the project. The acceptability of dredged material for unconfined aquatic disposal is determined for individual DMMUs independently of other management units within the project, and is based on the results of the analysis representing that DMMU.

Table 5-2 presents the maximum volume of sediment in a DMMU that can be characterized by a single analysis based on predetermined area ranking. The presence of heterogeneous or discrete layers in the dredge cut may warrant further subsampling or assignment of a smaller DMMU. Dredging proponents have the option to propose smaller DMMUs. For example, if 25 percent of the sample volume is visually different from the rest of the sediment profile and can be sampled and dredged separately, an additional DMMU may then be warranted. The volume for a DMMU ranked high is based upon the ability to discretely handle each barge load of material separately. Subsequent DMMU volumes in Table 5-2 are based upon the best professional judgment of RSET and a need to provide a general guide based upon volume.

b) **Sampling Intensity (Dredging Project):** The number of samples required of a proposed project, or that can be composited or combined for a single analysis, will be determined on a case-by-case basis using best professional judgment. The number of samples and the compositing scheme will vary depending upon such factors as (1) a reason to believe that contamination may exist at the surface or in subsurface sediments, (2) the heterogeneity of the sediments, (3) the project rank, (4) the aerial extent of a DMMU, and (5) the proposed depth of dredging. In general, sampling intensity will increase with suspected contamination, higher project ranking, greater aerial extent, increasing depth, or the occurrence of stratification. In heterogeneous sediments, typically a minimum of three samples composited for one analysis is used to characterize a single DMMU.

Table 5-2. Dredged Material Management Units

Ranking	Heterogeneous	Homogeneous
(Volumes in cubic yards)		
Exclusionary	NA	NA
Low	50,000	100,000
Low-Moderate	35,000	70,000
Moderate	20,000	40,000
High	up to 5,000	up to 10,000

Notes:
1. Volumes are based upon barge load capacity of 5,000 cubic yards.
2. The volume for a DMMU ranked high is based upon the ability to discretely handle each barge load of material separately. Subsequent DMMU volumes are based upon the best professional judgment of RSET and a need to provide a general guide based upon volume.
3. NA = not applicable

c) **Sampling Intensity (CS Project):** The sampling strategy (e.g., number of samples, frequency, depth, etc.) is less prescribed and usually determined during negotiations between the project proponent and regulators. In addition, a CS investigation is more concerned with horizontal and vertical extent of contamination. Samples are typically not composited but rather handled and tested on an individual basis. Samples may be divided by depth based on stratification and likelihood of contamination.

5.5 DETERMINATION OF DREDGED MATERIAL VOLUMES

The volume of dredged material determines, in part, the minimum number of sediment samples and analyses required for full characterization of a dredging project. The potential volume of sediment is usually determined from a pre-sampling bathymetric survey. The calculation of dredged material volume must include the following:

- Advance maintenance dredging, which is a term used to describe additional dredging cut or width in locations known to shoal very rapidly. Advance maintenance refers to the removal of a sufficient volume of sediment to ensure a reasonable length of time before having to dredge again.
- Sediments anticipated to slough from the side slopes and from under piers and wharves during dredging.
- Overdepth dredging, which is a term used to account for the limited ability of dredges to achieve a precise depth of cut. Overdepth dredging refers to the partial removal of sediment 1 to 2 feet deeper than the planned depth of dredging.
- Sediments to be removed below the dredging prism to allow for a sufficient cap to be placed, or to remove sediment with higher concentrations than were previously at the surface. This will be necessary in areas where NSM needs to be isolated from the environment.

The calculation and/or differentiation of dredged volume may be affected by one of the following variables:

a) **Heterogeneous Sediments.** Heterogeneous sediments are those in which the physical characteristics are dissimilar within the sampling depth. Characteristics of such sediments include obvious layering of sediments, lenses of dissimilar material (either in grain size or color), or obvious gradation of sediment size. Sediments that are deposited over a long period of time may be heterogeneous in nature.

In heterogeneous sediments, the volume of dredged material may be differentiated either by discrete sediment lenses or by depth. If a discrete lens is present in the sediment profile, volumes may be calculated on the basis (depth and areal extent) of that lens. To qualify for a separate characterization, however, the volume of the discrete lens must be amenable to being dredged separately from other sediment occurring in the dredging prism.

The depth for sample compositing should be determined using the CSM in projects with heterogeneous sediment lacking discrete lenses. Heterogeneous sediment projects must divide the volumes between a "surface layer" (e.g., the top 2 to 4 feet below existing sediment surface) and a "subsurface layer" down to the bottom of the planned dredge cut. The volumes comprising each of the layers must be calculated separately. The practical depth of a cut based on proposed dredge technology is considered a manageable unit of dredged material. For example, it is the typical cut depth achieved by one drop of a bucket clamshell dredge in unconsolidated sediments.

b) Homogeneous Sediment. Homogeneous sediments appear the same in physical characteristics throughout the sampling depth and lack obvious color striations, layering, or sorting of grain size. For shoals that are dredged frequently or new projects that involve the dredging of native material, the entire dredging prism may be considered homogeneous, and the volume need not distinguish between surface and subsurface layers.

5.6 PREPARATION AND SUBMITTAL OF A DRAFT SAMPLING AND ANALYSIS PLAN

A draft SAP is prepared once the project proponent has an understanding of the project objectives. The project objectives are defined as a dredging project or a sediment characterization project for a potential cleanup. The draft SAP describes the CSM, selected number of samples and analyses, specific sampling locations, and DMMUs for dredging projects.

In applying the above SAP concepts for a dredging project, DMMUs are typically determined by the rank, volume, and type of sediment specified in Table 5-1. The DMMU volumes are only for a dredging project and may be modified during SAP development and review. Additional sampling and/or analyses beyond the minimum number may be required based on the CSM to achieve an appropriate SAP and ultimately a dredging plan. Sample stations may be added and/or moved to select different, equally representative spots to ensure uniformity of acceptability throughout the project. Stations may be moved or added in response to information on point sources, spills, or new CoCs, or to acquire data that help draw boundaries between clean sediments and CSs.

The draft SAP must be submitted to the appropriate subgroup of RSET for review (see Chapter 3). Note: If the SAP requires extensive corrections and changes, resubmittal and review by RSET may be necessary prior to proceeding with sampling. RSET will prepare a letter of approval to proceed with the sampling effort with recommended corrections or changes to the draft SAP. Such corrections and changes must be reflected in the final SAP that is submitted to RSET with the report containing the results of the sampling and analysis effort.

5.7 FREQUENCY OF DREDGING GUIDELINE

The frequency of dredging guideline provides a second method by which dredged material may be excluded from further testing for specific periods of time. The frequency guideline pertains to dredging projects that occur on a frequent basis, such as every year or, at most, every 2 or 3 years. Such dredging commonly reflects a situation of routine and rapid buildup of shoals with relatively homogeneous sediments. The quality of the sediment at the dredging site tends to stay the same for successive years, barring any significant changed condition at or upstream of the site.

To qualify for consideration under the frequency guideline, a project requires full characterization of sediments for two successive dredging events. Provided the sediments are found suitable for unconfined aquatic disposal for each dredging event, the “frequency” of additional characterization after that will depend upon the rank of the project site determined by the results of the first two rounds of testing.

In effect, the frequency guideline specifies a period of time in which a qualified dredging project is “excluded” from having to do any further testing. The time durations provided for by the frequency guidelines are the same as for the “recency of data” guidelines described below. That is 2 years for high ranked areas, and 5, 6, 7, and 10 years for moderate, low-moderate, low, and exclusionary ranked areas, respectively. Areas or projects ranked exclusionary under Section 5.9.1 do not need to be considered under the frequency guideline because they have already qualified for exclusion from further testing on the basis of grain size and total organic carbon.

5.8 RECENCY OF DATA GUIDELINE

The recency of data guideline refers to the duration of time for which newly obtained and qualified physical, chemical, or biological information is considered adequate for decision-making without further testing. Recency guidelines are based on the area or project site rankings that, in turn, reflect a consideration of the presence and operating status of contaminant sources located at or near the area to be dredged. The recency guideline for exclusionary, low, low-moderate, and moderate ranked areas is 10, 7, 6, and 5 years, respectively. In high ranked areas, the recency guidelines allow characterization data to be valid for a period of 2 years.

The recency guidelines do not apply when a known "changed" condition has occurred since the most recent sampling effort, such as an accidental spill or the siting of a new discharge outfall. For subsurface sediments, the potential for contamination from groundwater sources must also be considered. As new guidelines are developed (e.g., updated BTs), existing projects data may need to be subjected to a one-time review to ensure that sediments are still below the guidelines.

5.9 SAMPLING AND ANALYSIS CONSIDERATIONS FOR SPECIAL CASES

The following sections discuss special types of sediment evaluation. These special cases will be evaluated by RSET on a case-by-case basis. These include the requirements for establishing exclusionary status, methods for confirming project ranking, exceptions for small projects, and evaluation of sediment exposed by dredging.

5.9.1 Establishment of Exclusionary Status

This section provides a process to establish an exclusionary status for projects or project locations that would likely qualify as exclusionary, but are lacking data to validate such a determination. Typically such areas or projects would already be ranked low or low-moderate and exist in a high current location. Three factors have to be considered to establish an exclusionary status: (1) the potential influence of active point sources of contamination on the sediments to be dredged, (2) the grain size of the sediments, and (3) the total organic carbon contents in the sediments.

Sediment samples obtained for the initial determination of an exclusionary status should be taken to the full depth of the proposed dredge cut by a core sampling device. Core sampling indicates the grain size distribution of the sediments for the entire depth of the dredge cut. However, core sampling is not always possible in very compact coarse sandy substrates. Some reaches of the Columbia River, for example, cannot be sampled by coring devices because of the inability to position a research vessel in high currents or drive a coring device into very compact, coarse sandy sediment. In such cases, the inability to use a coring device or the ability of a grab sampler to characterize the material to be dredged will have to be documented in the final sampling report. Sediment samples obtained to "confirm" an existing exclusionary status (see Section 5.9.2) may be taken with a suitable grab sampler as long as a representative sample can be obtained.

5.9.2 Confirmation of Project Ranking

Confirmatory sampling and analysis is primarily intended for application to frequently dredged projects ranked low or exclusionary. It should be done at least as often as called for under the frequency guidelines. The main purpose of confirmatory sampling is to re-affirm the historical record and show that no significant environmentally unacceptable changes have occurred to the project sediments. Confirmatory sampling is also intended to be accomplished at lesser cost, but with an acceptable level of confidence in support of an existing project ranking or suitability determination. Confirmatory sampling shall duplicate earlier sediment testing as much as possible, thereby providing spatial and analytical consistency between testing periods.

If the results of confirmatory sampling and analysis indicate the project or shoal sediments have changed significantly for the worse, project reranking to a higher level and further sampling may be necessary.

5.9.3 Exceptions for Small Projects

For small projects, as defined in Table 5-3, the cost of testing must be balanced against the environmental risks posed by a very small volume of dredged material. Small volumes generally represent low potential risk that unacceptable adverse effects will result at the disposal site from the specific and/or cumulative discharges. These no test volumes have been evaluated by Puget Sound Dredged Disposal Analysis (PSDDA) (Management Plan Report, Phase II 1989, Kendall 1990, Stirling 1995*)*. As a result, a small volume of sediment to be removed at a dredging site can obviate the need for testing.

Table 5-3. “No Test” Volumes for Small Projects

Ranking	**“No Test” Volume**
Low	Less than 10,000 cy
Low-Moderate	Less than 1,000 cy
Moderate	Less than 1,000 cy
High	Not Applicable
Note: cy = cubic yards	

To clearly define what constitutes a small project, there are two key qualifiers. First, intentional partitioning of a dredging project to reduce or avoid testing requirements is not acceptable. Second, recognizing that multiple small discharges can cumulatively affect a disposal site, “project volumes” are defined in as large a context as possible. One example of this latter qualifier is recurring maintenance dredging of a small marina where “project volume” will be the projected dredging volume over a 5-year period. Another example is a multiple-project dredging contract where a single dredging contractor conducts dredging for several projects under a single contract or contract effort. Again, the "project volume" will be summed across all projects, as will any sampling and compositing efforts prior to testing.

Small projects in low, low-moderate, or moderately ranked areas, volumes for which no testing need be conducted are shown in Table 5-3. There is no "no test" volume for high ranked areas. In the absence of conclusive evidence of unsuitable sediments, projects with these or lesser volumes will be considered suitable for unconfined aquatic disposal.

5.9.4 New Surface Material Exposed by Dredging

Dredging operations can alter the condition of a project site by exposing a new surface layer of bottom material to direct contact with biota and the water column. This aspect of dredging must be considered during preparation of the SAP because, for some projects, the newly exposed surface could have greater concentrations of CoCs than existed before dredging. This issue will be evaluated on a case-by-case basis by RSET during review of the SAP. Testing of NSM may be required in high and moderate ranked areas.

Several options were considered for inclusion as decision guidelines pertaining to the issue of newly exposed surface material. One of the following courses of action may be triggered to address the disposition of, and responsibility for, NSM that might be left following a dredging operation:

- If dredging results in the exposure of NSM having higher chemical concentrations than the sediment that was dredged, the dredging proponent may be required to over-dredge the site or cap the newly exposed bottom material. Final decisions pertaining to the need to over-dredge or to cap will be based upon the results of appropriate biological tests.
- If dredging results in the exposure of NSM as clean as, or cleaner than, the overlying sediments, no additional requirements are triggered under this manual. There may be additional requirements under the cleanup process.

Surface sediments with elevated concentrations of CoCs are present adjacent to the dredging site, but not in the site proposed to be dredged, will be considered on a case-by-case basis, depending on the regulatory context. Issues to be considered include potential future recontamination of the newly dredged area from adjacent sediments, the relative size of the adjacent contaminated area, and whether or not the dredging proponent is liable for cleanup of the adjacent area.

6. SAMPLING PROTOCOLS

6.1 OVERVIEW

When required, sampling and testing must be coordinated far enough in advance of dredging or site characterization/remediation activities to allow time for chemical testing, possible biological (toxicity and/or bioaccumulation) testing, and data review. An accurate assessment of the physical, chemical, and biological characteristics of proposed dredged sediment or sediment under characterization is dependent upon the collection of representative samples. Steps must be taken during the sampling process to ensure that samples accurately represent the area to be assessed. This chapter discusses the recommended procedures for sample acquisition and handling. This is the first step in the quality assurance/quality control (QA/QC) process that is needed to guarantee reliable data for dredged material evaluation or sediment characterization, monitoring, and cleanup. Failure to meet these requirements or follow any specified procedure will likely cause rejection of the testing results. A number of regional programs have developed standard sampling protocols. This chapter and the associated appendices provide an overview of these widely accepted practices.

Pre-sampling bathymetric surveys should be conducted to provide information on current shoaling patterns, the character of the dredge prism, and volumes of sediment present at the time of sampling. For proposed dredging projects, the timing of sampling should be coordinated with RSET. Coordination of timing is not as critical for sediment characterization projects, but early and frequent coordination with the local regulatory agency is crucial.

6.2 SAMPLING APPROACH

If sampling and analysis are required for a project, the applicant will be required to sample the sediment for chemical and, if necessary, biological analyses. The recommended volume needed for each type of analysis is listed in Table 6-1. There are four alternative sampling approaches for both proposed dredging and sediment characterization projects, including:

Alternative 1: Collect enough sediment for physical (grain size) characterization only.

Alternative 2: Collect only enough sediment to conduct physical and chemical analyses. If biological testing is necessary, re-sampling will be required.

Table 6-1. Sample Storage Criteria

Sample Type	Holding Time	Sample Size[1]	Temperature[2]	Container[3]	Archive[4]
Particle Size	6 months	100-200 g (150 mL)	4°C	1-liter glass	X
Total Solids	14 days	125 g (100 mL)	4°C	(combined)	
Total Volatile Solids	14 days	125 g (100 mL)	4°C		
Total Organic Carbon	14 days	125 g (100 mL)	4°C		
Ammonia	7 days	25 g (20 mL)	4°C		
Metals (except Mercury)	6 months	50 g (40 mL)	4°C		
Semi-volatiles, Pesticides, and PCBs	14 days until extraction 1 year until extraction 40 days after extraction	150 g (120 mL)	4°C -18°C 4°C		
Total Sulfides[5]	7 days	50 g (40 mL)	4°C[5]	125 mL plastic	
Mercury	28 days	5 g (4 mL)	-18°C	125 mL glass	
Volatile Organics	14 days	100 g (2-40 mL jars)	4°C	2-40 mL glass[6]	
Bioassay	8 weeks	4 liters	4°C[7]	5-1 liter glass	
Bioaccumulation	8 weeks	16 liters	4°C[7]	16-1 liter glass	

1/ Recommended minimum field sample sizes for one laboratory analysis. Actual volumes to be collected have been increased to provide a margin of error and allow for retests.
2/ During transport to the lab, samples will be stored on ice. The mercury and archived samples will be frozen immediately upon receipt at the lab.
3/ All containers should have Teflon® lined lids. Containers should be laboratory provided pre-cleaned certified containers for the specified analyses. The laboratory may request a different sample size than specified in this table.
4/ For every test sediment or DMMU, a 250 mL container is filled and frozen to run any or all of the analyses indicated.
5/ The sulfides sample will be preserved with 5 mL of normal zinc acetate for every 30 g of sediment.
6/ The volatiles jars should be filled with zero head-space.
7/ Headspace purged with nitrogen.
g = grams; mL = milliliter; °C = degrees Celsius; PCBs = polychlorinated biphenyls; DMMU = dredged material management unit

Alternative 3. Collect sufficient sediment for physical, chemical, and biological tests. Archive adequate sediment for biological testing pending the results of the chemical analysis.

Alternative 4: Collect sufficient sediment for physical, chemical, and biological tests. Run these tests concurrently.

The sampling approach should be clearly documented in the Sampling and Analysis (SAP), as outlined in Chapter 5. The selection of either Alternative 3 or 4 is encouraged if chemical analysis is anticipated, because they provide chemical and biological data on subsamples of a single homogenized sample. These alternatives are also advantageous because they both preclude the cost involved with collection of additional sediment. Alternative 4 is the least time consuming, and is likely the most economical when the need for biological testing is expected (note the sediment holding times in Table 6-1). For Alternative 2, biological analysis can proceed without re-analysis of sediment chemistry, in the case of dredging projects. Re-analysis of sediment chemistry may be useful in order to correlate previous levels of contaminants at each sampling station to the current levels of contaminants in sediments used for biological testing. Biological samples must be taken from the same stations as the sediment chemistry samples.

Biological testing is used to provide data for an impact assessment of the contaminants of concern through use of toxicity and bioaccumulation tests with appropriate, sensitive organisms (see Chapter 8, Biological [Toxicity] Testing). Toxicity testing is used to determine the potential effects from a direct contact perspective for benthic organisms. Bioaccumulation testing is used to determine the potential for uptake of sediment contaminants for benthic organisms.

6.3 POSITIONING METHODS

Accurate positioning of sampling stations is essential in investigations of sediment characteristics. All samples should be obtained as close as possible to the target locations provided in the project SAP. All sediment sampling locations should be recorded to a horizontal accuracy of ±2 meters (or as approved in the SAP). Such accuracy can be obtained by survey landmarks and a variety of positional hardware, such as a Global Positioning System (GPS). Commercial-grade GPS receivers are available that provide real-time sub-meter accuracy. However, other uncontrollable factors such as water currents or wind drift will reduce the usefulness of the sub-meter accuracy GPS. If sampling locations are referenced to a local coordinate grid, the local grid should be tied to the North American Datum (NAD) (NAD 1983) to allow conversion to latitudes and longitudes. The use of a standard horizontal datum will allow sediment quality data to be accurately mapped, including display and analysis using geographic information system (GIS) software.

6.4 SAMPLING METHODS

For dredging projects, the goal of sediment sampling for characterization of each individual dredged material management unit (DMMU) is to collect a sample (or a number of composited samples) representative of the DMMU. The agencies have established minimum sampling requirements based on volumetric measurements, tabulated in Chapter 5. For sediment characterization projects, discrete individual samples should be collected in a manner such that the data will be representative of current conditions at the site. Compositing of sediment samples is not recommended for site characterization or environmental cleanup projects, unless approval is obtained during the initial planning stage of the collection efforts.

The type of sampling required, however, depends on the type of project. Dredging projects are concerned with the contaminant concentrations found throughout and beneath the dredge prism. Sediment characterization projects are generally interested in determining the vertical and horizontal magnitude and extent of the contaminants to ascertain current environmental impacts in lakes, rivers, estuaries, and coastal waters. Each sediment program will employ different sampling devices.

Core samplers and grab samplers are two types of sediment sampling devices. Core samplers are typically used to sample thick sediment deposits, collect sediment profiles for the determination of the vertical distribution of sediment characteristics, or characterize the entire sediment column. Grab samplers are typically used to collect surficial sediments for the assessment of the horizontal distribution of sediment characteristics. The sampling methodology to be used should be presented in the SAP along with the rationale for its use.

6.4.1 Core Sampling

Core samplers are used to obtain sediment samples for geological characterizations and dating, investigate the historical input of contaminants to aquatic systems, and characterize the depth of contamination at a site. One limitation of core samplers is that the volume of any given depth horizon within the profile sample is relatively small. Depending on the number and types of analyses required, repetitive sampling at the site might be required to obtain the desired quantity of material from a given depth. There are several methods available for obtaining core samples, including gravity cores, Gus samplers, augers with split spoons, hydraulic push cores, box cores, piston cores, and vibracorers. Vibracorers are the most commonly used coring device in sampling programs in United States because they are able to collect deep cores in most types of sediments, yielding excellent sample integrity. The methodology chosen will depend on equipment availability, cost, anticipated sediment recoveries, and sediment matrix.

Only samples that are correctly collected should be used for subsequent testing. Core samples should meet the following acceptability conditions (EPA 2001):

- The core sampler is not inserted at an angle or tilted upon retrieval.
- The core is collected the required depth to meet the study objectives, with no loss of sediment.

6.4.2 Grab Sampling

Grab samplers consist either of a set of jaws that shut when lowered onto the surface of the sediment or a bucket that rotates into the sediment when it reaches the bottom. Grab samplers have the advantage of being relatively easy to operate, readily available, moderately priced, and versatile in terms of the range of substrate types they can effectively sample. There are several different methods for obtaining surface samples, including Peterson, Shipek, Ponar, Ekman, and van Veen. These samplers are effective in most types of surface sediments and in a variety of environments. Grab sampler capacities range from approximately 0.5 L to 75 L. If a sampler does not have sufficient capacity to meet the study plan requirements, additional samples can be collected and composited to obtain the requisite sample size. When using grab samplers, care should be taken to prevent washout, which results in loss of surficial, fine grained sediments that are often important from a biological and contamination standpoint. In addition, grab samples should be visually inspected to ensure that the following acceptability conditions are satisfied (EPA 2001):

- The sampler is not overfilled, ensuring the sediment surface is touching the top of the sampler.
- Overlying water is present (indicates minimal leakage). This overlying water should be removed prior to processing and storage by siphoning, not decanting.
- The overlying water is clear or not excessively turbid.
- The sediment-water interface is intact and relatively flat, with no sign of channeling or sample washout.
- The desired depth of penetration has been achieved.
- There is no evidence of sediment loss (incomplete closure of the sampler, penetration at an angle, or tilting upon retrieval).

6.5 SAMPLE COLLECTION AND HANDLING PROCEDURES

Proper sample collection and handling procedures are vital to maintain the integrity of the sample. If the integrity of the sample is compromised, the analysis results may be skewed or otherwise unacceptable. Sample collection and handling include procedures for decontamination, sampler deployment, sample logging, sample extrusion, compositing, subsampling, sample transport, chain-of-custody, archiving, and storage, all of which need to be addressed in the SAP. Guidance can be found in the Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual (EPA 2001), which contains detailed information on sample handling procedures. Project proponents are urged to contact RSET for the latest protocols. General guidance can be found in Appendix B, and is summarized below.

6.5.1 Decontamination Procedures

Sampling containers are typically decontaminated by the laboratory or manufacturer prior to use. For most sampling applications, site water rinse of sampling equipment in between stations is normally sufficient (Puget Sound Estuary Program [PSEP] 1997). However, when sampling multiple locations, including some that are suspected of known contamination, a site water rinse may not be sufficient to minimize cross-contamination of sampling equipment between stations. In these cases, it may be necessary to decontaminate sampling equipment in-between stations. An approach recommended by the American Society for Testing and Materials (ASTM) (2000) for field samples of unknown composition includes (non-toxic) soap and water wash, distilled water rinse, acetone or ethanol rinse, and site water rinse. If sediment can be sampled from the interior of the sampling device and away from the potentially contaminated surfaces of the sampler, it might be adequate to rinse with water between stations. All decontamination rinsate water shall be collected and properly disposed. The use of dedicated sampling equipment such as bowls and spoons can reduce the amount of decontamination required in the field.

6.5.2 Sample Collection

The appropriate vessel or sampling platform is one of the most important considerations in preparing for field sampling. The vessel must be appropriate for the water body type, and should provide sufficient space and facilities to allow collection, any on-board manipulation, and storage of samples. The vessel should provide space for storage of decontamination materials, as well as cleaning sampling gear and containers to avoid cross-contamination.

Sampling procedures and protocols will vary depending on the sampling methodology chosen.

Grab samplers penetrate to different depths depending on size, weight, and the sediment substrate. Careful use of grab samplers is required to avoid problems such as loss of fine-grained surface sediments, mixing of sediment layers during impact, over penetration, lack of sediment penetration, and loss of sediment from tilting or washout during ascent. Regardless of the sample methodology chosen, the speed of descent should be controlled, with no “free-fall” allowed, and after sample collection, the sampling device should be lifted slowly off the bottom.

Core sampling methodology should include the means for determining when the core sampler has penetrated to the required depth, such as a tape measure or lead line, and referenced to the bathymetry (tide, river stage, and/or river datum corrected, if necessary). The sampling location must be referenced to the actual deployment location of the sampler, not another part of the sampling platform such as the bridge of a sampling vessel.

Only sediments that are correctly collected with grab or core sampling devices should be used for subsequent physical, chemical, and biological testing. Acceptability of grabs can be ascertained by noting that the sampler was closed when retrieved, is relatively full of sediment (but not overfilled), and does not appear to have lost surficial fines. Core samples are acceptable if the core was inserted vertically in the sediment and an adequate depth was sampled.

6.5.3 Volatiles and Sulfides Subsampling

The volatiles and sulfides subsamples should be taken immediately upon extrusion of cores or immediately after accepting a grab sample for use. For composited samples, one core section or grab sample should be randomly selected for the volatiles and sulfides sampling before compositing, because homogenization may lead to loss of volatiles and semivolatiles.

6.5.4 Field Measurements and Observations

Field measurements and observations are critical to any sediment collection study, and specific details concerning sample documentation should be included in the study plan. As samples are collected, and after the volatiles and sulfides subsamples have been taken, logs and field notes of all samples should be taken and correlated to the sampling location map. Data to be noted in field logs include, but are not limited to, time and date of sample, sample identification, weather conditions, field/subcontractor representatives, sampling method, depth to mudline (tide corrected, river stage, and/or river datum, if necessary), sediment compaction (typical in core samples), sediment characteristics (texture, odor, visual), and presence of debris and/or benthos. Photographs of the sampling stations and sediment samples are often useful to ensure the correct stations were sampled and to document weather and water conditions during sampling. Additionally, photographs of core samples can document sediment horizons, historical changes, and vertical extent of contamination.

6.5.5 Compositing and Subsampling

Compositing refers to combining aliquots from two or more samples and analyzing the resulting pooled sample (Keith 1993). Compositing is often necessary when a relatively large amount of sediment must be obtained at each sampling site (e.g., to conduct several different physical, chemical, and biological analyses). Compositing might be a practical, cost-effective way to obtain average sediment characteristics for a particular site, but not to dilute a heavily contaminated sample.

The decision to subsample and/or composite sediment samples within or among stations depends on the purpose and the objectives of the study, the heterogeneity of the sediments, the volume of the sediment required for analytical and/or biological testing, and the degree of statistical resolution that is acceptable. Subsampling and compositing might be accomplished in the field if facilities, space, and equipment are available, or alternatively, in a laboratory setting following sample transport.

Subsampling is useful for collecting sediment from a specific depth of a core sample, splitting samples among multiple laboratories, obtaining replicates within a sample, collecting a sufficient volume of sediment for (potential) biological testing, or forming a composite.

Prior to subsampling from a grab sampler, the overlying water should be removed by slow siphoning using a clean tube (PSEP 1997). If the overlying water is turbid, it should be allowed to settle, if possible. Subsampling can be performed by using a decontaminated spoon or scoop (Note: sediment that is in direct contact with the sides of the grab sampler should be excluded as a general precaution against potential contamination from the device). Subsamples from individual grab samples should be placed into a decontaminated mixing bowl. When the required volume of sediment is retrieved, the sediment can be mixed to form a homogeneous sample. Mixing can be accomplished by hand mixing or by use of a mechanical mixer. Once the sediment is homogenized, the subsample can then be placed into clean, pre-labeled container(s) depending on the type of analyses.

There are various methods for subsampling sediment cores including gradual extrusion, dissection of a core using a jigsaw, reciprocating saws, use of a segmented gravity corer, a hand corer, or scoops or spoons. Sediment that comes into contact with a cutting device should not be used for physical, chemical, or biological testing due to potential contamination. Generally, when the sediment is extruded from the core tube, it is important to observe the core for total length, compaction, depth stratification, sediment characteristics (texture, odor, visual), and presence of debris and/or benthos. The sediment core can be separated into sections of desired thickness using a cutting device. Cutting devices range from stainless steel shear knives to Teflon® or nylon string. When the required volume of sediment from each section is retrieved, the sediment can be mixed to form a homogeneous sample. Once the sediment is homogenized, the subsample can then be placed into clean, pre-labeled container(s) depending on the type of analyses.

6.5.6 Sample Storage, Sample Transport, and Holding Times

Transport and storage methods should be designed to maintain structural and chemical qualities of sediment and pore water samples. If the sediment cores are not sectioned or subsampled in the field, they may be stored upright, in the core liner or core barrel, and secured in either a transport container (e.g., cooler or insulated box) with ice or ice packs for intact transportation to the laboratory. If sectioning or subsampling of the sediment cores takes place in the field, the samples are usually transferred to the laboratory issued containers for storage. Sediments collected using grab samplers are usually transferred to the laboratory issued containers in the field for storage.

Proper storage conditions should be achieved as quickly as possible after sampling. For those parameters that are preserved via refrigeration (i.e., chemical and toxicity testing) samples should be stored in the field in refrigerated units on board the sampling vessel or in insulated containers containing ice or frozen ice packets. Sediment containers should be stabilized in an upright position in the transport container. If a sample is to be refrigerated, the sample container should be filled to the brim to reduce oxygen exposure. If a sample is to be frozen (archived), the sample container should be filled to approximately 90 percent of its volume (i.e., 10 percent headspace) to allow for expansion of the sample during freezing.

Proper sample storage is critical to accurate assessment of sediment toxicity. Limits for effective holding times are governed by sediment type and contaminant characteristics (ASTM 2000). Because these qualities are not always known, a general recommendation is store sediments and interstitial water in the dark at 4 degrees Celsius (°C) (SETAC 2001). Table 6-1 outlines the storage and holding time requirements for each type of analysis.

6.5.7 Chain-of-Custody Procedures

Samples delivered to the laboratory should be accompanied by a chain-of-custody record that includes the name of the study, location of the collection, date and time of collection, type of sample, sample name or number, number of containers, analyses required, and the collector's signature. Sample transport and chain-of-custody procedures are listed in Appendix B.

6.6 QUALITY ASSURANCE/QUALITY CONTROL CONSIDERATIONS

Accuracy in the field should be assessed through the use of appropriate field equipment and trip blanks, and achieved through adherence to all sample handling, preservation, and holding time requirements. Field blank samples should be analyzed to check for procedural contamination that may cause sample contamination. Equipment rinsate blanks should be used to assess the adequacy of decontamination of sampling equipment between individual sample collections. Trip blanks should be used to assess the potential for contamination of samples due to contaminant (i.e., volatile organic compounds) migration during sample shipment, handling, and storage. Procedures for preparation of field blanks, equipment rinsate blanks, and trip blanks should also be described. Accuracy of the field instruments should be assessed by using daily instrument calibration and calibration checks. Field blank, equipment rinsate blank, and trip blank analysis frequencies should also be specified.

6.6.1 Trip Blanks

Trip blanks are used to detect volatile organic compound (VOC) contamination of samples during sample shipping and handling. Trip blanks are 40-milliliter (mL) volatile organic analysis (VOA) vials of ASTM Type II water that are filled in the laboratory, transported to the sampling site, and returned to the laboratory with VOC and VPH samples. Trip blanks are not opened in the field. The planned frequency for trip blanks is one trip blank per cooler containing samples for VOC analysis.

6.6.2 Equipment Rinsate Blank Samples

Equipment rinsate blanks (ERB) are samples of ASTM Type II water passed through and over the surface of decontaminated sampling equipment. The rinse water is collected in sample bottles, preserved, and handled in the same manner as the samples. ERBs are used to monitor effectiveness of the decontamination process. The planned frequency for ERBs is one per day per equipment type. If more than one type of equipment is used to collect samples for a particular matrix, an ERB is then collected and submitted for each representative group of equipment. Typically, ERBs are analyzed for the same analytes as the corresponding samples collected that day.

6.6.3 Field or Decontamination Water Blanks

Field blanks are samples of the source water used for decontamination. This blank is used to monitor for potential contaminants introduced from the water source during field decontamination procedures. Typically, at least one sample for each source of water or one field blank per lot number of analyte-free water for a specified event will be collected and analyzed for the same parameters as the corresponding field environmental samples. If more than one lot number of ASTM Type II water is used, or if potable water from more than one location is used, additional field blanks are collected because these constitute different sources.

6.6.4 Duplicate (Blind) Field Samples

"Blind" duplicate field samples are collected to monitor the precision of the field sampling process. Duplicates will be collected for surface water samples only, because the inherent variability of sediment and tissue samples precludes obtaining a true duplicate. The identity of the duplicate sample is not noted on the laboratory chain-of-custody form. The field team leader will choose at least 5 percent (1 in 20) of the total number of sample locations known or suspected to contain moderate contamination, and duplicate field samples will be collected at these locations. The identity of the duplicate samples is recorded in the field sampling logbook, and this information is forwarded to the data quality evaluation team to aid in reviewing and evaluating the data. The source of the blind field duplicate for the QA samples will not be revealed to the laboratory. The blind field duplicate sample will have a unique sample identification number on the chain-of-custody form sent to the laboratory such that the laboratory cannot determine its source.

6.7 ARCHIVING ADDITIONAL SEDIMENT

In areas where the exposed sediment is anticipated to be contaminated at levels greater than the in situ sediment, a sample will be collected and archived from the first foot below the dredging design depth, which must include an allowance for over dredging or advanced maintenance. Samples should be archived individually, not composited, especially where the applicant has proposed large DMMUs. This will allow possible future analysis to evaluate chemical concentrations in the newly exposed sediment if this is deemed necessary by RSET.

The archived sediment must be frozen. Because the holding time for mercury will likely be exceeded, and sediments for volatiles analysis cannot be frozen, mercury and any volatile chemicals of concern (CoCs) will not need to be analyzed for the archived sediments unless these chemicals are anticipated to be a problem in the newly exposed sediments. In this case, analysis will need to occur immediately.

6.8 DATA SUBMITTAL

A key component of the sampling effort is the completeness of the data package submitted for regulatory review. Chapter 12 contains detailed information regarding data submittal requirements.

7. PHYSICAL AND CHEMICAL TESTING

7.1 OVERVIEW

The physical and chemical characterization of sediments is designed to provide a reliable screen of the potential for biological effects from in-place contaminated sediments (CSs) or dredged material that is subjected to open-water disposal. The pathways of concern for biological effects are through the bulk sediment itself and through the water column during sediment removal or disposal activities. This chapter focuses on requirements and procedures for testing and interpreting chemical analytical results of bulk sediment. Guidelines for evaluating water column effects during dredging and disposal are provided in Chapter 11.

Interpretive guidelines for evaluating chemical analytical results consist of chemical screening levels and bioaccumulation criteria. Chemical screening levels have been developed for the standard list of chemicals of concern (CoCs), as shown in Table 7-1, which are designed to be protective of direct biological effects to benthic and aquatic organisms. The entire analyte list of CoCs (Table 7-1) should normally be tested for at all sites and dredging projects. Exceedance of chemical screening levels triggers the need for bioassay testing, as discussed in Chapter 8. In addition, the presence of contaminants not accounted for in the dataset used to develop Sediment Quality Guidelines (SQGs) may trigger bioassay testing. Bioaccumulation criteria are currently under development for bioacculative chemicals of concern (BCoCs). Exceedances of bioaccumulation criteria, or in the interim, elevations above reference, may trigger the need for bioaccumulation testing, as described in Chapter 9.

The marine SQGs have been used since 1988, with some updates, and validated through environmental studies of cleanup sites and dredged material disposal sites. Freshwater SQGs have been more recently developed in 2002, and have not been as extensively validated, though additional validation studies are planned in the next few years. Therefore, the freshwater SQGs are considered interim guidelines until more data can be collected and validation studies completed. Agencies may require bioassay testing to be conducted concurrently with chemical analyses to provide additional data, particularly in areas where there are few existing data, for chemicals not represented in the database, and for chronic or sublethal endpoints. It is expected that these additional studies would be focused on larger and more complex cleanup sites and dredging projects so as not to present an undue burden on small applicants.

Table 7-1. Sediment Quality Guidelines for Standard Chemicals of Concern

		Marine				**Interim Freshwater**	
Chemical	**CAS (1) Number**	**SL1 (dry weight**	**SL2 (dry weight)**	**SL1 (3) (mg/kg-OC)**	**SL2 (3) (mg/kg-OC)**	**SL1 (dry weight**	**SL2 (dry weight)**
Metals (mg/kg)							
Antimony	7440-36-0	150	150				
Arsenic	7440-38-2	57	93			20	51
Cadmium	7440-43-9	5.1	6.7			1.1	1.5
Chromium	7440-47-3	260	270			95	100
Copper	7440-50-8	390	390			80	830
Lead	7439-92-1	450	530			340	430
Mercury	7439-97-6	0.41	0.59			0.28	0.75
Nickel	7440-02-0	---	---			60	70
Silver	7440-22-4	6.1	6.1			2.0	2.5
Zinc	7440-66-6	410	960			130	400
Polynuclear Aromatic Hydrocarbons (µg/kg)							
Total LPAH	---	5,200	5,200	370	780	6,600	9,200
Naphthalene	91-20-3	2,100	2,100	99	170	500	1,300
Acenaphthylene	208-96-8	560	1,300	66	66	470	640
Acenaphthene	83-32-9	500	500	16	57	1,100	1,300
Fluorene	86-73-7	540	540	23	79	1,000	3,000
Phenanthrene	85-01-8	1,500	1,500	100	480	6,100	7,600
Anthracene	120-12-7	960	960	220	1,200	1,200	1,600
2-Methylnaphthalene	91-57-6	670	670	38	64	470	560
Total HPAH	---	12,000	17,000	960	5,300	31,000	55,000
Fluoranthene	206-44-0	1,700	2,500	160	1,200	11,000	15,000
Pyrene	129-00-0	2,600	3,300	1,000	1,400	8,800	16,000
Benz(a)anthracene	56-55-3	1,300	1,600	110	270	4,300	5,800
Chrysene	218-01-9	1,400	2,800	110	460	5,900	6,400
Benzofluoranthenes (b+k)	205-99-2	3,200	3,600	230	450	600	4,000
	207-08-9						
Benzo(a)pyrene	50-32-8	1,600	1,600	99	210	3,300	4,800
Indeno(1,2,3-c,d)pyrene	193-39-5	600	690	34	88	4,100	5,300
Dibenz(a,h)anthracene	53-70-3	230	230	12	33	800	840
Benzo(g,h,i)perylene	191-24-2	670	720	31	78	4,000	5,200
Chlorinated Hydrocarbons (µg/kg)							
1,4-Dichlorobenzene	106-46-7	110	110	3.1	9		
1,2-Dichlorobenzene	95-50-1	35	50	2.3	2.3		
1,2,4-Trichlorobenzene	120-82-1	31	51	0.81	1.8		
Hexachlorobenzene	118-74-1	22	70	0.38	2.3		

Table 7-1. Sediment Quality Guidelines for Standard Chemicals of Concern (continued)

		Marine				**Freshwater**	
Chemical	**CAS[1/] Number**	**SL1 (dry weight)**	**SL2 (dry weight)**	**SL1[2/] (mg/kg-OC)**	**SL[2/] (mg/kg-OC)**	**SL1 (dry weight)**	**SL2 (dry weight)**
Phthalates (ug/kg)							
Dimethyl phthalate	131-11-3	71	160	53	53	46	440
Diethyl phthalate	84-66-2	200	200	61	110		
Di-n-butyl phthalate	84-74-2	1,400	1,400	220	1,700		
Butyl benzyl phthalate	85-68-7	63	900	4.9	64	260	370
Bis(2-ethylhexyl) phthalate	117-81-7	1,300	1,900	47	78	220	320
Di-n-octyl phthalate	117-84-0	6,200	6,200	58	4,500	26	45
Phenols (µg/kg)							
Phenol	108-95-2	420	1,200				
2-Methylphenol	95-48-7	63	63				
4-Methylphenol	106-44-5	670	670				
2,4-Dimethylphenol	105-67-9	29	29				
Pentachlorophenol	87-86-5	400	690				
Miscellaneous Extractables (µg/kg)							
Benzyl alcohol	100-51-6	57	73				
Benzoic acid	65-85-0	650	650				
Dibenzofuran	132-64-9	540	540	15	58	400	440
Hexachlorobutadiene	87-68-3	11	120	3.9	6.2		
N-Nitrosodiphenylamine	86-30-6	28	40	11	11		
Pesticides (µg/kg)							
p,p'-DDE	72-54-8	16					
p,p'-DDD	72-55-9	9					
p,p'-DDT	50-29-3	34					
Aldrin	309-00-2						
alpha-Chlordane	12789-03-6						
Dieldrin	60-57-1						
Heptachlor	76-44-8						
gamma-BHC (Lindane)	58-89-9						
Total PCBs	---	130	1,000	12	65	60	120
Tributyltin[3/]							
TBT pore water (µg/L)	56573-85-4	0.15	---				
TBT dry weight (µg/kg ion)		---	---			75	75

Notes:
1/ CAS = Chemical Abstract Service Registry Number
2/ Screening levels are normalized by the fraction of organic carbon, expressed as mg/kg-OC.
3/ Tributyltin is a Chemical of Special Concern, not a Standard List Chemical of Concern. See *Testing, Reporting, and Evaluation of Tributyltin Data in PSDDA and SMS Programs* at URL http://www.nws.usace.army.mil/dmmo/8th_arm/tbt_96.htm
--- = No numerical criterion for this chemical
µg/kg = micrograms per kilogram
µg/L = micrograms per liter
mg/kg = milligrams per kilogram

This chapter includes a number of updates and revisions to previous guidance documents (EPA/Corps 1998a, 2000), including the following:

- Updated sediment screening level guidelines (Table 7-1), including both dry-weight and equivalent carbon-normalized values for marine sediments, development of guidelines for freshwater sediments, and removal of outdated bioaccumulation triggers (BTs) (currently under development, see Chapter 9);
- Updated chemical analytical methods and quantitation limits for sediment testing (Table 7-2);
- Development of recommended chemical analytical methods and quantitation limits for tissue testing (Table 7-3);
- Revision of the dredging exclusionary criterion to a total organic carbon (TOC) basis rather than total volatile solids (TVS) basis (Section 7.4);
- Inclusion of additional constituents (TPH, organophosphorus pesticides) as chemicals of special concern (Section 7.5.2), and development of procedures for evaluating and nominating emerging chemicals for inclusion in the SEF (Section 7.5.3);
- More explicit specifications for data quality requirements (Section 7.7); and
- Generalization of evaluation methods and criteria to be consistent to the extent possible between dredging projects and CS investigations.

7.2 GENERAL TESTING PROTOCOLS

Recommended chemical analytical methods and quantitation limits for sediment testing are presented in Table 7-2. These testing and analytical protocols generally follow the latest version of the Recommended Protocols for Measuring Selected Environmental Variables in Puget Sound (Puget Sound Estuary Program [PSEP] 1996), Methods for Collection, Storage, and Manipulation of Sediments for Chemical and Toxicological Analyses (EPA 2001), and Appendix F: Methods for Chemical and Physical Analysis, Great Lakes Dredged Material Testing and Evaluation Manual (EPA/Corps 1998b). RSET must approve any modifications of these protocols. Any requests for modifications to these protocols should occur during the preparation of the project Sampling and Analysis Plan (SAP) (see Chapter 5).

Table 7-2. Recommended Analytical Methods and Quantitation Limits for Sediment

Parameter	Prep Method	Analysis Method	Sample Quantitation Limit (SQL) [1/]
Conventionals:			
Total Solids (%)	---	EPA 2450-G	0.1
Total Organic Carbon (%)	---	EPA 5310B mod	0.1
Total Sulfides (mg/kg)	---	PSEP 1997	1.0
Ammonia (mg/kg)	---	Plumb 1981	0.1
Grain Size (%)	---	ASTM D-422 mod	1.0
Metals (mg/kg):			
Antimony	EPA 6010/6020 [2/]	EPA 6010/6020	0.5
Arsenic	EPA 6010/6020	EPA 6010/6020	5
Cadmium	EPA 6010/6020	EPA 6010/6020	0.5
Chromium	EPA 6010/6020	EPA 6010/6020	5
Copper	EPA 6010/6020	EPA 6010/6020	5
Lead	EPA 6010/6020	EPA 6010/6020	5
Mercury	EPA 7471	EPA 7471	0.05
Nickel	EPA 6010/6020	EPA 6010/6020	5
Silver	EPA 6010/6020	EPA 6010/6020	0.5
Zinc	EPA 6010/6020	EPA 6010/6020	5
Polynuclear Aromatic Hydrocarbons (µg/kg):			
LPAH			
Naphthalene	EPA 3550-mod	EPA 8270	20
Acenaphthylene	EPA 3550-mod	EPA 8270	20
Acenaphthene	EPA 3550-mod	EPA 8270	20
Fluorene	EPA 3550-mod	EPA 8270	20
Phenanthrene	EPA 3550-mod	EPA 8270	20
Anthracene	EPA 3550-mod	EPA 8270	20
2-Methylnaphthalene	EPA 3550-mod	EPA 8270	20
HPAH			
Fluoranthene	EPA 3550-mod	EPA 8270	20
Pyrene	EPA 3550-mod	EPA 8270	20
Benzo(a)anthracene	EPA 3550-mod	EPA 8270	20
Chrysene	EPA 3550-mod	EPA 8270	20
Benzofluoranthenes	EPA 3550-mod	EPA 8270	20
Benzo(a)pyrene	EPA 3550-mod	EPA 8270	20
Indeno(1,2,3-c,d)pyrene	EPA 3550-mod	EPA 8270	20
Dibenzo(a,h)anthracene	EPA 3550-mod	EPA 8270	20
Benzo(g,h,i)perylene	EPA 3550-mod	EPA 8270	20

Table 7-2. Recommended Analytical Methods and Quantitation Limits for Sediment (continued)

Parameter	Prep Method	Analysis Method	Sample Quantitation Limit (SQL) [1/]
Chlorinated Hydrocarbons (µg/kg):			
1,4-Dichlorobenzene	EPA 3550-mod	EPA 8270	20
1,2-Dichlorobenzene	EPA 3550-mod	EPA 8270	20
1,2,4-Trichlorobenzene	EPA 3550-mod	EPA 8270	20
Hexachlorobenzene (HCB)	EPA 3550/3540	EPA 8270/8081	10
Phthalates (µg/kg):			
Dimethyl phthalate	EPA 3550-mod	EPA 8270	20
Diethyl phthalate	EPA 3550-mod	EPA 8270	20
Di-n-butyl phthalate	EPA 3550-mod	EPA 8270	20
Butyl benzyl phthalate	EPA 3550-mod	EPA 8270	20
Bis(2-ethylhexyl)phthalate	EPA 3550-mod	EPA 8270	100
Di-n-octyl phthalate	EPA 3550-mod	EPA 8270	20
Phenols (µg/kg):			
Phenol	EPA 3550-mod	EPA 8270	20
2 Methylphenol	EPA 3550-mod	EPA 8270	20
4 Methylphenol	EPA 3550-mod	EPA 8270	20
2,4-Dimethylphenol	EPA 3550-mod	EPA 8270	20
Pentachlorophenol	EPA 3550-mod	EPA 8270	100
Miscellaneous Extractables (µg/kg):			
Benzyl alcohol	EPA 3550-mod	EPA 8270	50
Benzoic acid	EPA 3550-mod	EPA 8270	100
Dibenzofuran	EPA 3550-mod	EPA 8270	20
Hexachloroethane	EPA 3550-mod	EPA 8270	20
Hexachlorobutadiene	EPA 3550/3540	EPA 8270/8081	10
N-Nitrosodiphenylamine	EPA 3550-mod	EPA 8270	20
Pesticides/PCBs (µg/kg):			
DDE (p,p'-, o,p'-)	EPA 3540	EPA 8081	2
DDD (p,p'-, o,p'-)	EPA 3540	EPA 8081	2
DDT (p,p'-, o,p'-)	EPA 3540	EPA 8081	2
Aldrin	EPA 3540	EPA 8081	2
Chlordane	EPA 3540	EPA 8081	2
Dieldrin	EPA 3540	EPA 8081	2
Heptachlor	EPA 3540	EPA 8081	2
Lindane	EPA 3540	EPA 8081	2
Total PCBs	EPA 3540	EPA 8082	10
Tributyltin (µg/L) [3/]:			
TBT in pore water (µg/L Ion)	NMFS/Hoffman	Krone 1989	0.03
TBT in sediment (µg/kg)	NMFS	Krone 1989	5

Notes:

[1/] SQLs are based on dry sample weight assuming no interferences; site-specific method modifications may be required to achieve these SQLs in some cases.

[2/] Includes hydrochloric acid digestion per EPA 3050-B.

[3/] Tributyltin is a chemical of special concern; analysis of this constituent in pore-water or bulk sediment will be determined on a project-specific basis.

EPA Method 3550 is modified to add matrix spikes before the dehydration step, not after.

mg/kg = milligrams per kilogram; µg/kg = micrograms per kilogram; µg/L = micrograms per liter; % = percent;

ASTM = American Society for Testing and Materials

Table 7-3. Recommended Analytical Methods and Quantitation Limits for Tissue

Parameter	Prep Method	Analysis Method	Sample Quantitation Limit (SQL) [1/]
Conventionals			
Lipids (%)	Bligh/Dyer	Bligh/Dyer	0.01
Metals (mg/kg)			
Arsenic	EPA 3050B/ PSEP	EPA 200.8/ 6010/ 7060A	0.05
Cadmium	EPA 3050B/ PSEP	EPA 200.8/ 6010/ 7131A	0.05
Lead	EPA 3050B/ PSEP	EPA 200.8/ 6010/ 7421	0.10
Mercury	EPA 7471	EPA 7471	0.01
Polynuclear Aromatic Hydrocarbons (µg/kg)			
Fluoranthene	3540C, 3541 or 3550B	EPA 8270-SIM	1 - 5
Pyrene	3540C, 3541 or 3550B	EPA 8270-SIM	1 - 5
Miscellaneous Semivolatiles (µg/kg)			
Hexachlorobenzene (HCB)	3540C, 3541 or 3550B	EPA 8081	1
Pentachlorophenol	3540C, 3541 or 3550B	EPA 8270-SIM	25
Pentachlorophenol	3540C, 3541 or 3550B	EPA 8151	5
Pesticides (µg/kg)			
DDE (p,p'-, o,p'-)	3540C, 3541 or 3550B	EPA 8081	2
DDD (p,p'-, o,p'-)	3540C, 3541 or 3550B	EPA 8081	2
DDT (p,p'-, o,p'-)	3540C, 3541 or 3550B	EPA 8081	2
Chlordane (alpha, gamma)	3540C, 3541 or 3550B	EPA 8081	2
Oxy-chlordane	3540C, 3541 or 3550B	EPA 8081	2
Nonachlor (trans, cis)	3540C, 3541 or 3550B	EPA 8081	2
PCBs (µg/kg) [2/]			
PCB Aroclors	3540C, 3541 or 3550B	EPA 8082	5 - 10
PCB Congeners	3540C, 3541 or 3550B	EPA 8082	0.5 - 1.0
PCB Congeners (Low Level)	EPA 1668A	EPA 1668A	0.05 - 0.1
Dioxins/Furans (ng/kg) [3/]			
TCDD	EPA 8290/ 1613	EPA 8290/ 1613	1
Dioxins/Furans	EPA 8290/ 1613	EPA 8290/ 1613	1 - 5
Organotins (µg/kg) [3/]			
Tributyltin	EPA 3550B or NMFS	Krone	10

Notes:
[1/] All sample quantitation limits are expressed on a wet-weight basis
[2/] Selection of PCB analytical method will be determined on a project-specific basis
[3/] Dioxins/furans and tributyltin are chemicals of special concern; analysis of these constituents will be determined on a project-specific basis
mg/kg = milligrams per kilogram; µg/kg = micrograms per kilogram; ng/kg = nanograms per kilogram

7.3 CONVENTIONAL TESTING PROTOCOLS

Conventional parameters should be analyzed according to the following specifications:

Grain size: Measurement of grain size will be determined following the measurement techniques specified in American Society for Testing and Materials (ASTM) D 422 (modified). Measurement requires use of a sedimentation sieve series consisting of the following sieve sizes: 5 inch, 2.5 inch, 1.25 inch, 5/8 inch, 5/16 inch, No. 5, No. 10, No.

18, No. 35, No. 60, No. 120, and No. 230. Material passing the 230 sieve determines the percent fines. Reporting will include both the percent of sediment retained in each sieve as well as the percent passing. Hydrogen peroxide will not be used in preparations for grain size analysis, because hydrogen peroxide breaks down organic aggregates and may therefore overestimate the percent fines. Hydrometer analysis will be used for particle sizes finer than the 230 mesh.

Water content will be determined using ASTM D 2216. Sediment classification designation will be made in accordance with U.S. Soil Classification System, ASTM D 2487, using the results of the grain size analysis.

<u>Total Organic Carbon</u>: A modified EPA Method 5310B is recommended for analysis of TOC in sediment samples. A description of the modified TOC method recommended for use in the Pacific Northwest is provided in Bragdon-Cook (1993). TOC is a key index parameter that affects the adsorptive capacity and bioavailability of organic contaminants in sediments.

The analysis of other conventional parameters may also be required, as listed in Table 7-2. In particular, analysis of ammonia and sulfides may be useful in interpreting bioassay test results (see Chapter 8), and determining whether conventional parameters may be contributing to sediment toxicity.

7.4 GRAIN SIZE/ORGANIC CARBON SCREENING

An initial screen of bulk sediment quality may be conducted using grain size and TOC results. The purpose of this initial screen is to characterize sediments likely to have minimal amounts of fine-grained sediment and sedimentary organic matter and therefore lower potential for adsorption and retention of CoCs. Most commonly, this type of screen is used in large navigational dredging projects with mid-channel sand deposition. This type of screen may not be conducted in areas adjacent to known current or historical sources of contamination and is therefore generally not suitable for CS investigations.

Sediments with TOC contents less than 0.5 percent have a high probability of no adverse effects in bioassay tests, with the exception of certain eastern watersheds (see below). If the results are less than 20 percent fines in the grain size analysis and less than 0.5 percent TOC, and there are no known current or historical sources in the vicinity of the project site, the material may qualify for unconfined aquatic disposal based on exclusionary status. If the results are higher than 20 percent fines <u>or</u> greater than 0.5 percent TOC (i.e., the results exceed either or both of the guidelines), or the site may have been impacted by current or historical sources, the sediment must undergo chemical analysis for CoCs.

Certain watersheds east of the Cascades that are influenced by mining activities will be excluded from using this screening criterion and will be required to collect chemistry data. Metals and other inorganic constituents are the predominant CoCs associated with mining, and the toxicity of sediments in mining regions may be more related to clay mineral content than organic carbon content.

7.5 CHEMICAL TESTING PROTOCOLS AND GUIDELINES

There are three categories of CoCs that are considered in developing testing requirements for dredging projects. These CoC lists may also be consulted when developing a scope of work for CS investigations; however, CS investigations are generally more tailored to site-specific conditions and more focused on defining the nature and extent of CoCs that are known or suspected based on current or historical activities and/or previous sampling data.

The three categories of CoCs include the following:

- **Standard CoC List:** Default list of constituents analyzed in a majority of dredging projects. Past studies have shown that many of the CoCs on the standard list are relatively widespread in the Pacific Northwest and may have multiple sources.
- **Chemicals of Special Occurrence:** Constituents to be considered for analysis in special areas or in association with particular sources, activities, or land uses. Testing will be required only when those sources, activities, or land uses are present or have historically been present in the vicinity of the project site.
- **BCoCs:** Constituents with potential for bioaccumulation in higher-level organisms (e.g., humans, fish, birds, mammals). See Chapter 9 and Appendix A for a discussion and list of BCoCs.

7.5.1 Standard List of Chemicals of Concern.

The standard CoCs are listed in Table 7-1, along with sediment quality screening level guidelines, which are discussed later in this chapter. Recommended analytical methods and quantitation limits are presented in Table 7-2. The standard CoCs include constituents with one or more of the following characteristics:

- A demonstrated or suspected adverse biological or human health effect,
- A relatively widespread distribution above natural or background conditions in the Pacific Northwest,

- A potential for remaining in a toxic form for long periods (i.e., years or decades) in the environment (environmental persistence), and/or
- A potential for entering the food web (bioaccumulative).

If Level 1 research on current and historical site activities, analysis of existing analytical data, or analysis of new data collected in accordance with SEF guidelines shows that certain CoCs are not present in the project vicinity, these chemicals need not be included in any further testing unless there is a changed condition at the site.

Table 7-1 presents the dry-weight interpretive marine and freshwater guideline values for each chemical. These guideline values are described further in Section 7.8. The values in this table are predictive of direct toxicity to benthic and epibenthic organisms; bioaccumulation-based values have not yet been developed for sediments, but will be added to this table once they are available (see Chapter 9 for bioaccumulation testing requirements). Table 7-2 presents recommended preparation methods, analytical methods, and sample quantitation limits (SQLs) for sediments. These methods have generally been able to achieve SQLs required for interpretation and screening of chemical data. Other methods may be proposed to RSET for approval during the SAP review.

7.5.2 Chemicals of Special Occurrence

Chemicals of special occurrence may be associated with specific activities, industries, or land uses. They may exhibit localized concentrations, but they are not believed to be widespread in the Pacific Northwest. The following chemicals of special occurrence will be considered for inclusion in sediment testing programs when there is a reason to believe a current or historical source of these chemicals is or has been present:

Butyltins (including tributyltin, or TBT). Butyltin testing per the method of Krone et al. (1989) may be required in areas affected by vessel maintenance and construction activities, marine shipping, and frequent vessel traffic (e.g., shipyards, boatyards, marinas, marine terminals). In marine sediments, pore water analysis has been shown to improve the reliability of toxicity predictions and is generally recommended over bulk sediment analysis (Michelsen et al. 1996); TBT pore water extraction protocols are described in Hoffman (1998). At some marine sites, however, analysis of TBT in bulk sediment may be appropriate, either on a dry-weight or carbon-normalized basis (EPA 1996). In freshwater environments, analysis of TBT in bulk sediment on a dry-weight basis is preferred.

Dioxins/furans. Testing for polychlorinated dibenzodioxins and polychlorinated dibenzofurans (PCDD/PCDF) may be required in areas potentially impacted by known sources of dioxin/furan compounds, or in areas where the presence of dioxin/furan compounds has been demonstrated in past testing. A P450 biomarker test may be utilized to screen for the presence of dioxin-like compounds (associated with the induction of the Ah-receptor). However, care must be used in interpreting the results of such a test as other compounds that interact with the Ah-receptor (such as polycyclic aromatic hydrocarbons [PAHs] and polychlorinated biphenyls [PCBs]) will also show a positive result in this test. Analysis by EPA Method 1613 or 8290 is recommended.

Organophosphorus Pesticides. Testing for organophosphorus pesticides and potentially other types of pesticides (i.e., triazines) may be considered in areas dominated by agricultural land use and in sediments affected by cropland runoff, particularly in certain eastern drainages where large portions of the watershed are under cultivation. Analysis by EPA Method 8141 is recommended (see RSET Issue Paper No. 4 in Appendix C).

Total Petroleum Hydrocarbons (TPHs). Testing for TPHs may be considered at sites where quantities of petroleum product have been released to the aquatic environment (e.g., crude oil or fuel spills, waterfront tank, or pipeline leaks). EPH/VPH analysis (extractable and volatile petroleum hydrocarbons) provides quantitation of aliphatic and aromatic carbon ranges and is the recommended analytical method (Ecology 1997). Gross TPH determinations (i.e., quantitation of gasoline-, diesel-, and oil-range constituents, per NW-TPH or comparable methods) may be useful as a screening tool to help map the distribution of petroleum spills, but appears to be of limited value in predicting sediment toxicity (see RSET Issue Paper No. 2 in Appendix C).

Guaiacols. Guaiacol and chlorinated guaiacols may be required in areas where kraft pulp mills are located. Only guaiacol, and not chlorinated guiacols, will be measured near sulfite pulp mills because these mills do not use a bleaching process.

Resin Acids. Resin acids may be required analytes in areas of pulp mills. Resin acids may include abietic acid, dehydroabietic acid, dichlorodehydroabietic acid, isopimaric acid, and sandaracopimaric acid.

7.5.3 Evaluation and Nomination of Emerging Chemicals

An “emerging chemical” may be added to the list of chemicals of special concern if it is found at least occasionally in sediments of the Pacific Northwest at levels of concern likely to be associated with ecological or human health effects, including direct effects to aquatic organisms and/or indirect effects through bioaccumulation. If it is unclear whether the chemical is present in sediments at potentially toxic levels, federal, state, and/or local agencies should be encouraged to collect additional data (e.g., through regional monitoring programs or special research projects) until sufficient data are available to evaluate the chemical for inclusion in the SEF.

In considering a candidate chemical for inclusion as a chemical of special concern, the regional database and technical literature will be reviewed to determine whether a listing is warranted, not warranted, or indeterminate because of insufficient data. The weight-of-evidence for establishing a reason to believe the chemical is causing sediment toxicity will consider the following:

- Local/regional contaminant sources (usage rates, industrial associations),
- Environmental occurrence (frequency and magnitude of detection in regional monitoring data),
- Toxicity (presence in the environment above ecological or human health toxicity thresholds),
- Persistence (half life, ability to degrade), and
- Mobility (hydrophobicity, partitioning behavior).

A chemical of special occurrence may be promoted to the standard CoC list if the chemical is found to be prevalent in sediments of the Pacific Northwest at concentrations commonly associated with biological effects, and if a sufficient body of data has accumulated to allow the development of reliable sediment quality guidelines. The development of sediment quality guidelines will typically require 100 or more synoptic data points (i.e., paired chemical and biological testing results) from multiple studies and environments over a range of concentrations.

On the other hand, a chemical may be delisted from the standard CoC list if the chemical is no longer prevalent in the Pacific Northwest at levels of concern, if the chemical is shown to have reduced toxicity based on more recent toxicological data, and/or if concentrations have dropped significantly below the historical levels upon which the listing was based. The rationale for listing or delisting chemicals as chemicals of special concern or standard CoCs will be considered on a case-by-case basis using the criteria listed above during periodic reviews of the SEF.

7.6 TISSUE TESTING

Recommended tissue analytical methods and quantitation limits are presented in Table 7-3 for primary (List 1) BCoCs. These testing and analytical protocols generally follow the latest version of the Recommended Protocols for Measuring Selected Environmental Variables in Puget Sound (PSEP 1996) and Guidance for Assessing Chemical Contaminant

Data for Use in Fish Advisories (EPA 2000a). RSET must approve any modifications of these protocols. Any requests for modifications to these protocols should occur during the preparation of the project SAP (see Chapter 5).

7.7 DATA QUALITY AND REPORTING

7.7.1 Quality Assurance/ Quality Control

To support sediment management decisions, it is imperative that quality assurance/quality control (QA/QC) procedures be implemented during field and laboratory activities. It is also important that the quality of the data be evaluated and reported. Field and laboratory QA/QC procedures are generally tailored to the scope and complexity of the project and the level of risk being managed. For example, a state or federal sediment cleanup investigation will require a more rigorous QA/QC program than a small dredging project in a low-risk area.

QA/QC measures, control limits, and contingency response procedures are outlined in a QA/QC chapter of the SAP for dredging projects, and in a Quality Assurance Project Plan (QAPP) for CS investigations. Field QA/QC procedures are described in Chapter 6. Standard laboratory QA/QC procedures may include, depending on the particular method and analyte, matrix spikes/matrix spike duplicates, laboratory duplicates, method blanks, surrogate spikes, laboratory control samples, calibration protocols, and other procedures necessary to quantify the accuracy and precision of the analytical results. Laboratory QA/QC procedures are generally prescribed in the analytical method specifications or in laboratory standard operating procedures (SOPs).

7.7.2 Analytical Sensitivity

Analytical sensitivity is characterized by method detection limits (MDLs) and sample quantitation limits (SQLs, also known as reporting limits, practical quantitation limits, etc.) (EPA 1989a, DOD Quality Systems Manual 2005). The MDL is a minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero. MDL studies are generally conducted using ideal, laboratory-prepared samples of a spiked clean matrix. The SQL is established by the low standard of the initial calibration curve or low-level calibration check standard. At a minimum, the SQL should be three to five times the MDL.

To generate appropriate and useable data, achieve data quality objectives, and support accurate sediment management decisions, the SQLs should be less than the screening levels listed in Table 7-1, in particular, SL1, the lower screening level.

Regarding data quality, the following three scenarios are possible:

- **SQL is less than SL1**. All reasonable steps should be taken, including additional cleanup steps, re-extraction, etc., to keep the SQLs below the sediment screening levels. Assuming all other QA/QC criteria are met (see Section 7.7.1), this produces data of the highest quality.
- **MDL exceeds SL1**. In this scenario, the analytical method used is not sufficiently sensitive to make an informed sediment management decision. An undetected result with an MDL exceeding the SL1 will generally be considered an exceedence of the SL1 unless it can be demonstrated that all reasonable steps were taken to control the MDL and SQL, including additional cleanup procedures, re-extraction and re-analysis, as necessary. In such cases, RSET may consider the results of other analytes in the same class of compounds, site history, existing sediment quality data from the site vicinity, and other lines of evidence to determine whether the elevated MDL represents a significant data gap and a potential false negative result.
- **MDL is less than SL1; SQL exceeds SL1**. In some circumstances, matrix interference, high water content, or other sample characteristics may compromise the sensitivity of the analytical method. However, it must be shown that all reasonable steps were taken to control the SQL, including additional cleanup procedures, re-extraction and re-analysis, as appropriate. These data are generally acceptable for use in sediment management decisions, but will be qualified as having lower precision and accuracy and greater uncertainty.

For undetected compounds, laboratories should report both the MDL and the SQL. If problems or questions arise regarding the ability to achieve sufficiently low MDLs and SQLs, the project proponent should contact RSET. In all cases, sediments or extracts should be kept under proper storage conditions until the chemistry data are deemed acceptable by the regulatory agencies (see Table 6-1). This retains the option for re-analysis and lower-level quantitation, if necessary.

7.7.3 Reporting of Estimated Concentrations below the SQL

Laboratories have the ability to identify and provide an estimated quantitation of CoCs at concentrations below the SQL and above the MDL; however, quantitations in this region have a lower accuracy and precision compared to quantitations above the SQL (i.e., third scenario in Section 7.7.2). Laboratories shall be required to report estimated values between the MDL and the SQL; typically these values will be qualified with a "J" flag because they are below the lowest calibration standard.

7.7.4 Chemical Summations

Several chemical groups are reported as a summation of individual compounds. Summations are reported for PAHs, low- and high-molecular weight polycyclic aromatic hydrocarbons (LPAHs and HPAHs), and total PCBs. Other chemical groups (e.g., carcinogenic PAHs, PCB congeners, dioxins/furans) are typically summed using weighting factors proportional to the relative toxicity of the individual constituents (see Toxicity Equivalency Factors below). The rules for chemical summation are as follows:

- The group summation is performed using all detected concentrations. Undetected results are considered zero value and are not included in the sum. (Note: Other statistical approaches for treatment of nondetected values may be used in other regulatory programs; for example, risk assessments conducted under CERCLA and state cleanup investigations may use one-half detection limit values for chemical summation purposes).
- The estimated values between the MDL and the SQL (i.e., J-flagged values) are included in the summation at face value.
- If all constituents in a chemical group are undetected, the group sum is reported as undetected, and the highest SQL of all the constituents is reported as the SQL for the group sum.

PAHs. LPAHs include the following compounds: naphthalene, 2-methylnaphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene. HPAHs include the following compounds: fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b+k)fluoranthenes, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene. Total PAHs includes the sum of all LPAH and HPAH compounds.

Total PCBs. Total PCB aroclors includes the sum of the following aroclors: Aroclor-1016, 1221, 1232, 1242, 1248, 1254, and 1260. If present, Aroclor-1262 and Aroclor-1268 should be reported, but not included in the total PCB summation. It should be noted that total PCBs calculated by summing PCB aroclor mixtures is not comparable to total PCBs calculated by summing individual PCB congeners due to fundamental differences in the methods of analysis and quantitation.

Toxicity Equivalency Factors. Toxicity equivalency factors (TEFs) are often used in risk assessment calculations to sum certain chemical groups (in particular, carcinogenic PAHs, PCB congeners, and dioxins/furans) based on the potency values of the individual compounds. TEFs have been applied to both sediment and tissue data to provide a toxicity-based chemical index concentration; however, there may be varying partitioning and bioaccumulation behavior of the compounds comprising the TEF. As a result, it is generally recommended that sediment-tissue partitioning relationships (i.e., biota-sediment accumulation factors [BSAFs]) be evaluated on the basis of individual chemicals rather than the summed concentrations of a chemical group.

The use of TEFs for addressing human health risks has been approved by EPA as well as international organizations (e.g., World Health Organization), and is therefore an acceptable approach under this SEF. Draft TEFs for addressing ecological risks to mammals, birds, and fish have been developed for PCBs and dioxins/furans (EPA 2003a); however, considerable uncertainty remains as to the accuracy of the draft values and the underlying toxicological basis for their use. Therefore, draft wildlife TEFs may be used as part of a weight-of-evidence approach, but they should not be the sole criterion for making ecological risk decisions until additional field and laboratory validation studies are completed to ensure the accuracy and reliability of these values.

7.8 BENTHIC INTERPRETIVE GUIDELINES

Chemical screening levels have been developed to predict and manage potential adverse biological effects on benthic and epibenthic organisms that may be associated with the sediment chemical concentrations. The screening levels may be used to evaluate benthic risk associated with in place sediments, or if dredging is proposed, the newly exposed sediment surface and the unconfined open-water disposal site, as applicable. Biological tests serve to integrate chemical and biological interactions of contaminants present in a sediment sample, including the availability for biological uptake, by measuring the toxic effects on appropriately sensitive benthic organisms in bioassay tests (see Chapter 8).

The RSET screening levels listed in Table 7-1 are derived from regional toxicity data from sediment sites in the Pacific Northwest. Two screening values were developed based on different criteria for the acceptability of the sediment bioassay results. The lower screening level (SL1) corresponds to a concentration below which adverse effects to benthic organisms would not be expected, and the upper screening level (SL2) corresponds to a concentration at which minor adverse effects may be observed in the more sensitive groups of benthic organisms (see PSEP 1988, Ecology 1991, 1995, 2003).

If BCoCs are present at levels of concern, a separate bioaccumulation assessment will need to be performed for both dredging projects and contaminated sediment investigations to assess the potential for contaminant accumulation in the tissue of higher-level organisms. For BCoCs, RSET is in the process of developing tissue and possibly sediment bioaccumulation triggers (BTs). BTs for tissues will be developed first to allow routine evaluation of tissue data, either on a project-specific or regional basis. Sediment BTs may eventually be developed based on tissue BTs, for specific disposal sites, watersheds, or projects (see Chapter 9 for further discussion).

7.8.1 Data Sources

Sediment quality values for marine sediments were developed using the Apparent Effects Threshold (AET) approach. These values are well established in the Pacific Northwest and have been in use for over a decade in regional dredging programs (e.g., EPA/Corps et al. 1988, 1998a), at federal cleanup sites (e.g., Commencement Bay, EPA 1989b), and at State of Washington cleanup sites (per Sediment Management Standards 1995, Chapter 173-204 WAC). The marine screening levels in Table 7-1 are derived from the Washington State Sediment Management Standards (SMS) to the extent they are available. Because some of the SMS values are normalized to organic carbon, equivalent dry-weight values were calculated using the same regional database and methodology, as presented in PSEP 1988. Because the SMS has not promulgated marine sediment quality values for chlorinated pesticides, these values were taken from the lowest AETs reported in Corps et al. 1996.

More recently, the State Washington developed and published freshwater sediment quality guidelines using the Floating Percentile Method, which strives to optimize the balance between the sensitivity and reliability of the guidelines (Ecology 2003). The freshwater SQG model was developed in 2002 based on approximately 276 paired sediment chemistry and four acute bioassay endpoints from 19 areas throughout western Washington and Oregon. Additional regional data sets will be available in the near future to update the existing data sets and allow for a revised set of freshwater SQGs, which will include greater geographic scope and chronic/sublethal bioassay endpoints. The process being implemented for regular updates to the SEF will be followed to allow for appropriate, periodic updates to the interim freshwater SQGs.

In the meantime, project and site managers should be aware that the freshwater SQGs are likely to be more representative of benthic effects in areas west of the Cascades, with traditional industrial and urban sources. Areas east of the Cascades, or areas affected by agriculture and mining wastes, may require supplemental bioassay testing.

7.8.2 Freshwater vs. Marine Screening Levels

RSET will follow the specifications of the Inland Testing Manual, in which salinities less than 1 ppt are considered freshwater, salinities greater than 25 ppt are considered marine, and salinities between 1 and 25 ppt are considered estuarine. This is consistent with the definition of marine environments in the SMS for the State of Washington (greater than 25 ppt in sediment pore waters); however, the SMS definition of freshwater environments is slightly more restrictive (less than 0.5 ppt in sediment pore waters) (WAC 173-204-200[11, 12, and 14]) and transitional brackish water environments must be evaluated on a case-by-case basis (WAC 173-204-330). Biological testing organisms must be carefully selected in estuarine (brackish water) conditions, because some organisms are more tolerant of these transitional environments (e.g., the amphipod *Eohaustorius estuarius;* EPA/Corps 1998a). In estuarine environments, RSET should be consulted to determine which set of chemical screening levels is more appropriate.

If sediments are proposed for open-water disposal, the sediment testing program should be structured to determine potential impacts to the aquatic community at the point of disposal. Therefore, the selection of an appropriate set of screening levels (e.g., freshwater or marine) will be based on the location of the disposal site. For example, if freshwater sediments are proposed to be dredged and disposed at an open-water marine site, marine screening levels and test organisms are appropriate for assessment of impacts at the point of disposal. It should be noted that subjecting freshwater sediments to marine bioassay testing protocols presents particular challenges, and the sediments should be allowed sufficient time to equilibrate with seawater before marine organisms are introduced.

7.8.3 Dry Weight vs. Carbon-Normalized Values

For all dredging projects and freshwater contaminated sediment investigations, dry-weight based screening levels will be used.

For marine contaminated sediment investigations conducted under the Washington SMS, many of the semivolatile organic constituents (including PAHs, chlorinated hydrocarbons, phthalates, PCBs, and miscellaneous extractables) are regulated on the basis of organic carbon-normalized concentrations (dry weight concentration divided by the fraction of organic carbon). Under the SMS, carbon-normalized screening levels are appropriate to use for marine sediments with a carbon range of 0.5 to 4 percent TOC (Michelsen and Bragdon-Cook 1992, Bragdon-Cook 1993). If sediments are outside this range (either carbon rich or carbon poor), dry-weight values are generally used.

For marine contaminated sediment investigations conducted in other states and regulatory programs, it is expected that dry-weight based screening levels will generally be preferable. Dry-weight and carbon-normalized sediment quality values have been shown to provide similar levels of predictive reliability (PSEP 1988, Ecology 1991, 2003); however, dry-weight based values are simpler to implement. The dry-weight and carbon-normalized marine values are both derived using the same database and statistical methodology (i.e., AET method).

7.8.4 Dredging Projects

SL1 values are intended to identify chemical concentrations that are at or below levels at which there is no reason to believe dredged material disposal would result in unacceptable adverse effects to benthic organisms. In addition to the benthic screening level assessment presented in this chapter, a separate bioaccumulation assessment will also need to be performed if there is reason to believe BCoCs are present at levels of concern (see Chapter 9).

Sediments in dredged material management units (DMMUs) containing chemical concentrations at or below SL1 levels and bioaccumulation criteria (when available) are judged to be suitable for unconfined open-water disposal. Sediments proposed for open-water disposal with one or more chemical concentrations exceeding SL1 levels and/or bioaccumulation criteria will require follow-up bioassay testing and/or bioaccumulation testing, respectively. In addition, agencies may require supplemental bioassay testing for freshwater areas, particularly in regions or for chemicals not well-represented by the existing dataset.

Such biological testing provides a more site-specific measurement of the potential for the sediments to cause biological effects to aquatic life or higher-level receptors. In such cases, biological testing results will take precedence and “override” the chemistry results. If one or more chemicals are present at concentrations above SL1 guidelines or bioaccumulation criteria (when available), and follow-up biological testing is not pursued, the associated DMMU will be determined unsuitable for open-water disposal.

Sediments that exceed SL1 levels or bioaccumulation criteria and fail follow-on biological testing, if such testing is pursued, will generally need to be managed in an alternative and more protective manner (e.g., in a confined disposal facility such as a confined aquatic disposal site, nearshore fill site, upland disposal facility, commercial landfill, etc.). If sediments are intended to be placed in a confined disposal facility, and thus removed from direct contact with the aquatic environment, bioassay and bioaccumulation testing will not be necessary. However, other tests may be required (e.g., elutriate or leachate tests) depending on the location and configuration of the facility (EPA/Corps 2003; see also Section 11.4).

7.8.5 Contaminated Sediment Projects

The screening levels presented in Table 7-1 are designed to be protective of direct toxicity effects to benthic organisms. As such, these screening levels are also useful for protecting the invertebrate prey base of salmonid species listed under the ESA. Development of sediment quality values for protection of ESA-listed salmonids is a subject of ongoing research.

If there is reason to believe BCoCs are present at levels of concern, an assessment of indirect effects caused by bioaccumulation of contaminants in fish/shellfish and higher-level receptors must also be performed, as discussed in Chapter 9.

In the State of Washington, the use of the SMS is required by regulation at **all sediment cleanup sites** (see Chapter 173-204 WAC). The SMS includes marine Sediment Quality Standards (SQSs) and Cleanup Screening Levels (CSLs), set at the lowest and second-lowest AET values, respectively, and equivalent to the SL1and SL2 values in Table 7-1. The CSL values define minor adverse effects levels above which contaminated sediment sites are defined and prioritized for state cleanup investigations. Sites with sediment concentrations below the CSL but above the SQS are considered a lower priority but may still be considered for active cleanup, source control measures, or environmental monitoring. The marine SL1 and SL2 values provided in Table 7-1 may be used in a similar manner to rank and prioritize contaminated sediment sites, provided this approach is consistent with the regulatory program(s) having jurisdiction over the site.

Per the SMS, the SQS values are considered cleanup *goals* for contaminated sediment projects. Cleanup *standards*, however, which are used to define the extent of the remedial action, are established on a site-specific basis within an allowable range of values between the SQS and the CSL, in consideration of the natural recovery potential of the site, engineering feasibility, and cost.

The marine SQVs provided in Table 7-1 may be used by other regulatory agencies to assess marine/estuarine contaminated sediment used in a similar manner to define cleanup goals and cleanup standards, provided this approach is consistent with the regulatory program(s) having jurisdiction over the site.

The freshwater SQVs presented in Table 7-1 are interim values, which were derived with the goal of balancing false negatives and predicted-no-hit efficiency rates with false positives and predicted-hit efficiency rates. The reliability of these guidelines will be presented in an appendix (Evaluation of Reliability of Proposed Freshwater Sediment Quality Guidelines) at a later date. RSET intends to validate the methodology used to derive the freshwater SQGs, and there will be further assessment of the reliability of the screening values to estimate potential toxicity. The incorporation of larger sediment bioassay datasets developed over the last few years that represent greater regional representation will be vital for developing a refined set of sediment screening criteria. As discussed previously, agencies may require bioassay testing to be conducted for sites that have sediment concentrations of analytes below the interim SL1 Freshwater SQGs to assist in the validation of these interim values.

8. BIOLOGICAL (TOXICITY) TESTING

8.1 OVERVIEW

Biological effects testing may be necessary if the Level 1 evaluation indicates the test sediment contains contaminant concentrations that may be directly or indirectly harmful to aquatic organisms. Level 2 biological testing of sediment will be required when chemical testing results exceed appropriate guideline values and interpretative criteria. A standard suite of bioassays is used to make a determination regarding the potential for unacceptable risks to benthic receptors from in-place contaminated sediments (CSs) or the suitability of dredged sediment for aquatic disposal, approved upland disposal, or beneficial reuse. Tests involving whole sediment determine the potential effects for bottom-dwelling (benthic) organisms. Tests using suspension/elutriates of sediment/dredged material are used to assess the potential effects on water column organisms. A bioaccumulation evaluation (Level 2 task) is required when there is an established “reason to believe” that bioaccumulation endpoints may pose a potential risk to human health or ecological health in the aquatic environment through the bioaccumulation exposure pathway (Chapter 9).

Prior to the 1980s, the assessment of water and sediment quality was often limited to physical and chemical characterizations. However, quantifying chemical concentrations alone is not always adequate to assess potential adverse environmental effects, interactions among chemicals, or bioavailability of chemicals to aquatic organisms. Because the relationship between total chemical concentrations and biological availability is poorly understood, when regulatory guideline values or interpretative criteria are exceeded, controlled laboratory bioassay and bioaccumulation tests are performed to provide additional lines of evidence for environmental effects.

The approach most often adopted is to expose representative aquatic/benthic species to appropriate test media to assess lethal and sublethal effects and, if appropriate, conduct an evaluation of bioaccumulation potential. These tests provide information about different possible adverse biological effects in the environment. In addition, testing using multiple species reduces uncertainty about the results and limits errors in interpretation of these tests.

This chapter includes information on recommended bioassay tests and species, quality control requirements for each test, and the interpretive criteria used for decision-making. References are provided for more detailed information on test protocols and test interpretation. Chapter 9 provides information on bioaccumulation tests.

8.2 SEDIMENT SOLID PHASE BIOLOGICAL TESTS

Biological testing can be conducted to measure effects on organisms exposed to the water column or to whole sediment. The biological testing suite discussed in this section addresses solid phase toxicity testing using whole sediment. Both marine and freshwater species used for bioassay testing are specified. Several additional biological tests are under development or review and may be added in the future. Biological test species are selected based on the salinity conditions at the potentially contaminated site under investigation or the open-water disposal site considered for the dredged material. For dredging projects in freshwater systems that plan on the use of the marine/ocean disposal sites, marine bioassays will be required (if such biological testing is necessary).

8.2.1 Marine Bioassays

Marine bioassays are required when the test sediments and/or the proposed disposal location for dredged material are in a brackish or saline environment, as opposed to freshwater environments (see Section 8.2.2).

- 10-day Amphipod Acute Mortality Test
  - *Rhepoxynius abronius*
  - *Ampelisca abdita*[1]
  - *Eohaustorius estuarius*[2]
- Chronic Test
  - *Neanthes arenaceodentata* (Los Angeles karyotype) 20-day growth test
- Sediment larval test
  - Echinoderm
    - *Dendraster excentricus*[3]
    - *Strongylocentrotus purpuratus*
    - *Strongylocentrotus droebachiensis*
  - Bivalve
    - *Crassostrea gigas*
    - *Mytilus species*

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[1] May be substituted if test sediment contains greater than 60 percent fines

[2] May be considered for substitution if test sediment is greater than 60 percent fines and salinity is less than 25 parts per thousand

[3] Recommended echinoderm species

The protocols to be used to run the recommended marine bioassays are described by the Puget Sound Estuary Program (PSEP), and can be found in Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments (PSEP 1995). These PSEP protocols are consistent with national guidance on bioassay testing.

Amphipod Species Substitution. The hierarchy of amphipod selection begins with *Rhepoxynius abronius* as the primary recommended species and *Ampelisca abdita* and *Eohaustorius estuarius* as secondary substitutes, depending on test sediment grain size and salinity. *Rhepoxynius abronius* has been shown to be responsive to high percent fines in sediments, particularly high clay content sediments, and has been shown to exhibit mortalities greater than 20 percent in clean, reference area sediments with this grain size (DeWitt et al. 1988, Fox 1993). The regulated party may wish to consider substituting *Ampelisca abdita* for *Rhepoxynius abronius* when fines exceed 60 percent. *Ampelisca* is relatively grain size insensitive to concentrations of fines greater than 60 percent. Any proposed species substitutions must be submitted to appropriate regulatory agency prior to use, and the substitutions must be documented in the Sampling and Analysis Plan (SAP) for the proposed dredging project or site investigation/risk assessment.

8.2.2 Freshwater Bioassays

The following freshwater bioassays will be required when the test sediment and/or the proposed disposal location for dredged material is in a low salinity (generally 5 parts per thousand [ppt] or below) environment:

Amphipod - *Hyalella azteca* 10-day Mortality Test

Midge - *Chironomus tentans* 10-day Mortality and Growth Test

Standard protocols exist for each of these tests, established both by American Society for Testing and Materials (ASTM) and EPA (ASTM 1995, EPA 1994). Either protocol may be used for the freshwater bioassays. Adherence to the protocol performance standards aids in interpreting bioassay responses by limiting effects from factors other than sediment toxicity due to the contaminants of interest. Additionally, longer term biological tests have been developed by ASTM (ASTM 2000) and may be required under certain circumstances by the regulatory agencies. These include the *Hyalella azteca* 28-day mortality and growth test and the *Chironomus tentans* 20-day mortality and growth test.

8.2.3 Bioassay Testing Performance Standards

This section contains the specific quality assurance/quality control (QA/QC) requirements for solid phase biological testing. The parameters covered include:

- Negative Control and Reference Sediment,
- Quality Control Limits for the Negative Control Treatment,
- Quality Control Limits for the Reference Treatment,
- Positive Control, and
- Water Quality Monitoring.

General procedures are given first, followed by specific performance standards for each bioassay. These standards aid in interpreting the bioassay responses because they control for environmental effects that may produce confounding factors not associated with the toxicity of the contaminants of interest. Table 8-1 summarizes the performance standards for negative controls and reference sediment following the bioassay-specific procedures.

Negative Controls. Negative control sediments are used in bioassays to check laboratory performance. Negative control sediments are clean sediments in which the test organism normally lives (or are cultured) and which are expected to produce low mortality. Negative control reliability must be demonstrated.

The sediment larval test utilizes a negative seawater control rather than a control sediment. The seawater control will be collected from a location approved by the DMMO/DMMT or appropriate local regulatory agency (PSEP 1995).

Reference Sediment. Agency regulations prescribe the use of bioassay reference sediments for test comparison and interpretations that closely match the grain size characteristics of the test or disposal site sediments. The reference sediment provides a point of comparison for evaluating the potential effects of the test sediment. If chemical concentrations in the reference area are not well-documented, a complete chemical characterization may be required. However, all reference sediments should be analyzed for total solids, total volatile solids, total organic carbon, ammonia, sulfides, and grain size (PSEP 1995).

All bioassays have performance standards for reference sediments. Failure to meet these standards may result in the requirement to retest. In some cases, control sediments can be substituted for reference sediments if they have similar characteristics (PSEP 1995).

Replication. For marine bioassays, five laboratory replicates of test sediments, reference sediments, and negative controls will be run for each bioassay. For freshwater bioassays, eight laboratory replicates of test sediments, reference sediments, and negative controls will be run for each bioassay (per ASTM and EPA guidance).

Positive Controls. A positive control (sometimes called the reference toxicant test) will be run for each bioassay. Positive controls are chemicals known to be toxic to the test organism and provide an indication of the sensitivity of the particular organisms used in a bioassay. Positive controls are generally performed on spiked fresh/sea water and compared with historical laboratory reference toxicity test results to confirm that organism responses are within control limits established by the testing laboratory.

Water Quality Monitoring. Water quality monitoring of the overlying water will be conducted for the bioassays. This consists of daily measurements of salinity, temperature, pH, and dissolved oxygen for the amphipod and sediment larval tests. These measurements will be made every 3 days for the *Neanthes* marine bioassay. Ammonia and sulfides will be determined at test initiation and termination for all tests. Monitoring will be conducted for all test and reference sediments and negative controls (including seawater controls, if used). Parameter measurements must be within the limits specified for each bioassay. Measurements for each treatment will be made on a separate chemistry beaker set up to be identical to the other replicates within the treatment group, including the addition of test organisms.

Bioassay-Specific Procedures - Marine

Amphipod Bioassay. This test involves exposing amphipods to test sediments for 10 days, and counting the surviving animals at the end of the exposure period. Daily emergence data and the number of amphipods failing to rebury at the end of the test will be recorded as well. The control sediment has a performance standard of 10 percent mortality. The reference sediment has a performance standard of 20 percent mortality greater than the control sediment. For example, if the control sediment yields 7 percent mortality, the reference sediment performance standard is 27 percent mortality. Test species selection is discussed in Section 8.2.1.

Sediment Larval Bioassay. This test monitors larval development of a suitable echinoderm or bivalve species in the presence of test sediment. The test is run until the appropriate stage of development is achieved in a sacrificial seawater control. At the end of the test, larvae from each test sediment exposure are examined to quantify abnormality and mortality.

The seawater control has a performance standard of greater than 70 percent mean normal survivorship in seawater control. The reference sediment has a performance standard of 35 percent normalized combined mortality and abnormality (NCMA) greater than the seawater control performance.

Initial counts will be made for a minimum of five 10-milliliter (mL) aliquots. Final counts for seawater control, reference sediments, and test sediments will be made on 10-mL aliquots.

The sediment larval bioassay has a variable duration (not necessarily 48 hours) determined by the developmental stage of organisms in a sacrificial seawater control.

Ammonia and sulfides toxicity may interfere with test results for this bioassay. Aeration will be conducted throughout the test to minimize these effects, if required. Please refer to recent Sediment Management Annual Review Meeting (SMARM) Clarifications on how to minimize the potential influence of confounding factors such as ammonia.

***Neanthes* Growth Test.** This test utilizes the polychaete *Neanthes arenaceodentata* in a 20-day growth test. The growth rate of organisms exposed to test sediments is compared to the average individual growth rate of organisms exposed to a reference sediment. The control sediment has a performance standard of 10 percent mortality. The reference sediment has a performance standard of 80 percent of the control average individual growth rate and 20 percent mortality.

Bioassay-Specific Procedures - Freshwater

Amphipod 10-day Survival Bioassay. This bioassay measures the survival of the amphipod *Hyalella azteca* after a 10-day exposure to the test sediment. The control has a performance standard of 20 percent absolute mean mortality. The reference sediment performance standard is 25 percent absolute mean mortality.

Amphipod 28-day Survival/Growth Bioassay. This test measures the survival and growth of the amphipod *Hyalella azteca* after a 28-day exposure to the test sediment. The control has a performance standard of 20 percent absolute mean mortality and a growth performance standard of 0.15 milligram (mg) minimum mean individual biomass. The reference sediment performance standard is 30 percent absolute mean mortality and 0.15 mg minimum mean individual biomass for growth.

Midge 10-day Survival/Growth Bioassay. This bioassay measures the survival and growth of the midge *Chironomus tentans* after a 10-day exposure to the test sediment. The control has a performance standard of 30 percent absolute mean mortality and a growth performance standard of 0.6 mg minimum mean wet weight or a 0.48 mg mean ash-free dry weight per individual (per EPA). (Ash-free dry weights are regarded as a more accurate weight.) The reference performance standard is 30 percent absolute mean mortality and 80 percent of the final negative control growth weight.

Midge 20-day Survival/Growth Bioassay. This test measures the survival and growth of the midge *Chironomus tentans* after a 20-day exposure to the test sediment. The control has a performance standard of 32 percent absolute mean mortality and a growth performance standard of 0.48 mg minimum mean individual biomass. The reference sediment performance standard is 35 percent absolute mean mortality and 80 percent of the final negative control growth biomass.

Table 8-1. Summary of Marine and Freshwater Bioassay Test Performance Standards

Marine Bioassays	**Performance Standards**
Amphipod Mortality	Negative control ≤ 10 percent mortality Reference sediment ≤ negative control mortality + 20 percent
Juvenile Infaunal Growth	Negative control ≤ 10 percent mortality Reference sediment ≤ 20 percent mortality Final reference sediment growth ≥ 80 percent of final negative control growth
Sediment Larval NCMA	Seawater control ≥ 70 percent mean normal survivorship Reference sediment ≥ 35 percent x seawater control NCMA
Freshwater Bioassays	**Performance Standards**
Amphipod 10-day Mortality	Negative control ≤ 20 percent mortality Reference sediment ≤ 25 percent mortality
Amphipod 28-day Mortality and Growth	Negative control ≤ 20 percent mortality Final negative control growth ≥ 0.15 mg/individual Reference sediment ≤ 30 percent mortality Final reference sediment growth ≥ 0.15 mg/individual
Midge 10-day Mortality and Growth	Negative control ≤ 30 percent mortality Final negative control growth ≥ 0.48 mg ash-free dry weight/individual Reference sediment ≤ 30 percent mortality Final reference sediment growth ≥ 80 percent of final negative control growth
Midge 20-day Mortality and Growth	Negative control ≤ 32 percent mortality Final negative control growth ≥ 0.48 mg/individual Reference sediment ≤ 35 percent mortality Final reference sediment growth ≥ 80 percent of final negative control growth

8.2.4 Bioassay Interpretive Criteria

The response of bioassay organisms exposed to discrete test sediment in a site investigation or for use in a risk assessment, or composited sediment representing each dredged material management unit (DMMU) will be statistically compared to the response of these organisms in reference treatments (or default to control treatments if the reference sediment does not meet specified performance standards). Depending on the purpose of the sediment evaluation, this will determine whether in-place sediment at a site under investigation poses an unacceptable risk to ecological receptors or, in the case of dredged material, is suitable/unsuitable for unconfined aquatic disposal.

Biological test interpretation in the Pacific Northwest relies on two levels of observed response in the test organisms. These are known as "one-hit" or "two-hit" failures. The bioassay-specific guidelines for each of these response categories are listed below. In general, a one-hit failure is a marked response in any one biological test. A two-hit failure is a lower intensity of response. It must be found in two or more biological tests for the test sediment to potentially cause adverse impacts to ecological receptors at a contaminated site, or found unsuitable for aquatic disposal in a dredged material situation. At the moment, only acute bioassay tests are available for use in freshwater ecosystems. Additionally, longer term sediment bioassays have been developed (ASTM 2000) and may be required in certain circumstances by the regulatory agencies.

One-Hit Failure. When **any one** biological test shows a test sediment response relative to the negative control and reference sediment that exceeds the bioassay-specific response guidelines and is statistically different from the reference, the in-place sediments are considered to potentially cause adverse impacts to ecological receptors at a contaminated site, or the DMMU is judged to be unsuitable for aquatic disposal. The acceptable methods for determining statistical significance are in EPA/Corps 2000, PSDDA User's Manual.

Two-Hit Failure. When **any two** biological tests show test sediment responses, which are less than the bioassay-specific guidelines for a one-hit failure (e.g., the freshwater amphipod bioassay requires a mean test mortality greater than the mean reference mortality plus 15 percent), but show a lower level effect and are statistically different from the reference sediment, the in-place sediments are considered to potentially cause adverse impacts to ecological receptors at a contaminated site, or the DMMU is judged to be unsuitable for aquatic disposal.

For example, in a freshwater amphipod bioassay, the mean test mortality was 40 percent, the mean reference mortality was 30 percent, and the two results were statistically different. Also, in a freshwater midge bioassay, the mean test mortality was 20 percent, the mean reference mortality was 10 percent, and the two results were statistically different. In this case, mean test mortalities were below the mean reference mortalities plus bioassay-specific guidelines (15 percent for the amphipod and 20 percent for the midge). However, the test sediments elicited lower level effects in mortality as evidenced by statistical differences from the reference sediments in both tests, qualifying as a two-hit failure.

This interpretation of solid phase biological test results will be used for decision-making in environmental cleanup of CSs under state and federal guidelines, the Clean Water Act (CWA) Section 404(b)(1) evaluation/Section 401 water quality certification process, and the Marine Protection Research and Sanctuaries Act (MPRSA) Section 103 evaluation process. The application of these interpretive guidelines to a set of sample test results is described in EPA/Corps 2000, PSDDA User's Manual.

The determination of a "statistically different" response involves two conditions: First, the response in the tested CS or in the tested DMMU must be greater than 20 percent different from the control response; and second, a statistical comparison between mean test and mean reference responses must show a significant difference. The appropriate method for making the latter determination is discussed in EPA/Corps 2000, PSDDA User's Manual. This reference also contains a description of the Biostat bioassay software developed by the Corps. This software contains the appropriate statistical tests to determine sediment suitability.

Marine Bioassays

Amphipod Bioassay. For the amphipod bioassay, mean test mortality greater than 20 percent absolute over the mean negative control response, and greater than 30 percent absolute over the mean reference sediment response, and statistically different from the reference (alpha = 0.05), is considered a one-hit failure.

Juvenile Infaunal Growth Test. Juvenile *Neanthes* growth test results that show a mean test individual growth rate less than 80 percent of the mean negative control growth rate, and less than 50 percent (relative) of the mean reference sediment growth rate, and statistically different from the reference (alpha = 0.05), is considered a one-hit failure.

Sediment Larval Bioassay. For the sediment larval bioassay, test and reference sediment responses are normalized to the negative seawater control response. This normalization is performed by dividing the number of normal larvae from the test or reference treatment at the end of the exposure period by the number of normal larvae in the seawater control at the end of the exposure period, and multiplying by 100 to convert to percent. The normalized combined mortality and abnormality (NCMA) is then 100 minus this number. If the mean NCMA for a test sediment is greater than 20 percent, 30 percent absolute over the mean reference sediment NCMA, and is statistically different from the reference (alpha = 0.10), it is considered a "hit."

NCMA (in percent) = 100% – (number of normal larvae from test or reference treatment / number of normal larvae from seawater control) x 100.

Freshwater Bioassays

Amphipod 10-day Survival Bioassay. For the amphipod bioassay, mean test mortality greater than 15 percent over the mean reference response, and statistically different from the reference (alpha = 0.05), is considered a hit.

Amphipod 28-day Survival/Growth Bioassay. For the amphipod 28-day survival bioassay, mean mortality in the test sediment greater than 25 percent over the mean reference response, and statistically different from the reference (alpha = 0.05), is considered a hit. For the growth test, a mean reduction in biomass greater than 40 percent and statistical significance is considered a hit.

Midge 10-day Survival/Growth Bioassay. For the midge 10-day mortality test, a mean mortality in the test sediment of 20 percent over reference and statistically different from reference (alpha = 0.05) is a hit. For the midge 10-day growth test, a mean reduction in biomass greater than 40 percent and statistical significance is considered a hit. If either or both endpoints fail the guideline, the test is considered a hit.

Midge 20-day Survival/Growth Bioassay. For the midge 20-day mortality test, a mean mortality in the test sediment of 25 percent over the mean reference response, and statistically different from the reference (alpha = 0.05), is considered a hit. For the growth test, a mean reduction in biomass greater than 40 percent and statistical significance is considered a hit.

Table 8-2. Summary of Freshwater and Marine Bioassay Test Interpretive Criteria

Marine Bioassays	**Test Criteria ("one-hit" failure)**
Amphipod Mortality	Mean test mortality > mean negative control mortality + 20 percent AND Mean test mortality > mean reference mortality + 30 percent AND Statistical difference between test and reference (alpha = 0.05)
Juvenile Infaunal Growth	Mean test growth rate < 80 percent of mean negative control growth rate AND Mean test growth rate < 50 percent of mean reference growth rate AND Statistical difference between test and reference (alpha = 0.05)
Sediment Larval NCMA	Mean test NCMA > 20 percent AND Mean test NCMA > mean reference NCMA + 30 percent AND Statistical difference between test and reference (alpha = 0.10)
Freshwater Bioassays	**Test Criteria ("one-hit" failure)**
Amphipod 10-day Mortality	Mean test mortality > mean reference mortality + 15 percent AND Statistical difference between test and reference (alpha = 0.05)
Amphipod 28-day Mortality and Growth	Mean test mortality > 25 percent AND/OR Mean test biomass < 60 percent of mean reference biomass (i.e., greater than 40 percent reduction of biomass from reference) AND Statistical difference between test and reference (alpha = 0.05)
Midge 10-day Mortality and Growth	Mean test mortality > mean reference mortality + 20 percent AND/OR Mean test biomass < 60 percent of mean reference biomass (i.e., greater than 40 percent reduction of biomass from reference) AND Statistical difference between test and reference (alpha = 0.05)
Midge 20-day Mortality and Growth	Mean test mortality > mean reference mortality + 25 percent AND/OR Mean test biomass < 60 percent of mean reference biomass (i.e. greater than 40 percent reduction of biomass from reference) AND Statistical difference between test and reference (alpha = 0.05)

8.3 REFERENCE SEDIMENT COLLECTION SITES

Bioassays must be run with reference sediments that are well-matched to the test sediments for grain size and other sediment conventionals such as total organic carbon. The sampling protocol used for the collection of reference sediment can affect its performance during biological testing. The following guidelines should be followed when collecting reference sediments:

- Use experienced personnel,
- Follow protocols,
- Sample from a biologically active zone,
- Avoid anoxic sediment below the redox potential discontinuity (RPD) horizon, and
- Use wet-sieving method.

The wet-sieving protocol is used in the location of an appropriate reference station. Wet-sieving is imperative in finding a good grain size match with the test sediment. Wet-sieving is accomplished using a 63-micron (#230) sieve and a graduated cylinder; 100 mL of sediment is placed in the sieve and washed thoroughly until the water runs clear. The volume of sand and gravel remaining in the sieve is then washed into the graduated cylinder and measured. This represents the coarse fraction; the fines content is determined by subtracting this number from 100. Wet-sieving results will not perfectly match the dry-weight-normalized grain size results from the laboratory analysis, but should be relatively close.

In some areas of the Pacific Northwest region, the Corps and EPA have identified locations suitable for use as reference sites. Reference site selection will be made on a case-by-case basis with information and guidance provided by the Corps and EPA. Reference site grain-size should match, as closely as possible, that of the test sediment and/or the disposal environment. In the absence of a match, the agencies will select coarser grained sediment for use, contingent upon the selected bioassay test organism. This is likely to yield better test performance and be environmentally conservative. Reference site selection and reference sample collection must be coordinated with RSET, as well as any other state or federal agency with regulatory interest in the bioassay results.

9. BIOACCUMULATION EVALUATION

9.1 OVERVIEW

Bioaccumulation testing is conducted following chemical analysis if there is a reason to believe chemicals present in project or site sediments may be contributing to levels in invertebrate or fish tissues that could be harmful to aquatic life, aquatic-dependent wildlife, or humans eating fish and shellfish. Alternatively, the project proponent may opt to conduct bioaccumulation testing concurrently with sediment chemistry if it appears likely that it will eventually be required or if other project constraints exist, such as a need for rapid decision-making.

Currently, this evaluation is conducted on a case-by-case basis. Contaminant concentrations in sediments or tissue that may be harmful have not been fully evaluated or finalized by either dredging or cleanup programs. Work is currently underway to calculate science-based bioaccumulation triggers (BTs) for both tissues and sediments. These BTs will address the long-term effects of bioaccumulative chemicals of concern (BCoCs) in sediments, whether at the disposal site or at a cleanup site. Impacts associated with dredging residuals may also occur at the point of dredging or downstream. These are difficult to quantify, yet there is an increasing awareness that this route of exposure can be important. The RSET agencies will continue to discuss the best methods of controlling and assessing the impacts of dredging residuals containing BCoCs (see Chapter 11).

Reason to believe will evolve and become progressively more certain and less conservative as BTs are calculated and finalized. A key concept behind reason to believe is there should be evidence that tissue levels are above levels of concern in the waterbody, and concentrations of the same chemical(s) are also elevated above levels of concern in the project or site sediments. Once BTs are established for tissues and sediments, this dual determination will establish reason to believe that contaminants could be bioaccumulating to levels of concern, which will trigger bioaccumulation testing. An interim process for establishing reason to believe is presented in Section 9.3, and relies on elevation above reference in tissues and sediments.

Bioaccumulation testing is normally conducted using multiple species, which reduces uncertainty about the results and limits errors in interpretation of these bioassays.

There are three basic methods that can be used to evaluate bioaccumulation potential:

- **Laboratory Bioaccumulation Testing.** Sediments from the site or project area are collected and taken to a laboratory, where several species are exposed to the sediments under controlled conditions. Ideally, the chemicals reach steady-state equilibrium between the sediments and tissues of the test species.
- **In Situ Bioaccumulation Testing.** Organisms of the tests species are placed in the field in webbing or cages and exposed to sediments at the site or project area for a specified length of time. This approach more accurately represents conditions in the field, but can be more time-consuming.
- **Collection of Field Organisms.** Fish and/or benthic infauna (frequently shellfish) may be collected from the site or project area for chemical analysis of contaminants in tissues. Species to be collected are selected based on their site fidelity, representativeness of feeding guilds at the site, exposure and feeding strategies, and commercial, recreational, and cultural significance. This approach can be less costly and time-consuming, but is primarily applicable to evaluation of the bioaccumulative effects of in situ sediments, or those where the highest concentrations are known to be at the surface.

Laboratory bioassays are most appropriate when the bioaccumulation potential of material proposed for dredging needs to be assessed and concentrations are likely to be higher in the subsurface sediments than at the surface. Because in situ tests and field organisms are primarily exposed to surface sediments, these approaches are more appropriate for evaluating sediments that may remain in place, such as those proposed for natural recovery or those already deposited at a dredged material disposal site. The bioaccumulation testing approach should be selected to address all the potential routes of exposure identified in the conceptual site model.

Regardless of how the bioaccumulation data is collected, the resulting tissue concentrations are compared to values that are protective of three exposed populations – aquatic life, aquatic-dependent wildlife, and human populations. Tissue and sediment data can be used together to derive biota-sediment accumulation factors (BSAFs), which can in turn be used to develop sediment BTs for cleanup or dredging. Bioaccumulation test results could still be used on a project-specific basis to override predictions of bioaccumulation based on sediment BTs.

This chapter includes information on the identification of BCoCs, establishing reason to believe for triggering bioaccumulation testing, recommended bioaccumulation tests and species, the quality control requirements for each test, and the interpretive criteria (BTs) used for decision-making. References are provided for more detailed information on test protocols and test interpretation.

9.2 BIOACCUMULATIVE CONTAMINANTS OF CONCERN

The identification of BCoCs plays a major role in establishing reason to believe that a bioaccumulation evaluation needs to be performed, particularly in the absence of tissue and sediment BTs. BCoCs can be identified at several levels. RSET intends to use the approach to identifying BCoCs outlined in Hoffman (2005), along with the lists of chemicals generated by that approach (see Appendix A). The approach relies on a review of the occurrence of contaminants in sediments and tissue, chemical properties of contaminants such as K_{ow}, known toxicity of the contaminants to human and ecological receptors, and comparison of tissue levels to available residue-effects levels. Contaminants are placed on one of several lists depending on the amount of information available and the weight-of-evidence indicating their potential to bioaccumulate, prevalence in the region, and toxicity.

RSET made one modification to the approach outlined in Hoffman (2005). In the EPA approach, all standard divalent metals were placed on List 1 because they have been measured in tissues at concentrations exceeding residue-effects levels. It is recognized, however, that aquatic species bioaccumulate trace metals to varying degrees and with varying toxicological consequences depending on their ability to regulate trace metals. Thus, many of these metals do not substantially bioaccumulate, and retention of them on List 1 would likely lead to an unnecessary number of bioaccumulation evaluations. These metals were divided into those likely to bioaccumulate based on having organic forms and those not likely to bioaccumulate, and placed on List 1 or List 4 accordingly.

This initial list of BCoCs is based largely on marine data from west of the Cascades. Freshwater areas may have different patterns of use and occurrence; therefore, certain analytes could be assigned to different lists. RSET is in the process of accumulating freshwater tissue data to evaluate the presence or absence of bioaccumulative chemicals in tissues in Oregon, Washington, and Idaho, and until this can be completed, the marine BCoC list will be used for both freshwater and marine areas. Analytical methods and detection limits associated with the List 1 BCoCs are provided in Chapter 7.

It is also anticipated and encouraged that agencies will refine the RSET-wide BCoC list based on regional data. The term “region” in this context means a connected waterbody which, based on size, geography, or other factors, would be expected to encompass the home ranges of a variety of fish and wildlife receptors. Examples might include the lower Duwamish River along with Elliott Bay, or the lower Willamette River (below Willamette

Falls). Rather than developing an all-encompassing narrative description of a region, a list of regions in each Corps district will be developed and appended to the SEF.

The RSET-wide list is available as a default for areas where more specific data is not available. As soon as reasonably possible, tissue data should be reviewed by waterbody to identify a subset of BCoC, which are detected at elevated levels in tissues for each waterbody. This will only be possible in areas where sufficient tissue data have been collected; however, this may include the most contaminated areas where tissue assessments are currently or have previously been conducted. In this manner, the BCoC list can be narrowed down for each waterbody to include only those chemicals that are currently detected in tissues above reference area concentrations (assuming that detection limits are appropriate). As soon as BTs are available for tissues, the list can be narrowed further to those chemicals that exceed these screening values.

This approach is intended to avoid requiring project proponents to conduct bioaccumulation testing for contaminants that may be on the RSET-wide BCoC list because they are present in other areas, but not the project area. For example, industrial chemicals found in urban waterways west of the Cascades may not be likely in agricultural areas east of the Cascades. However, if a project is located in an area where a regional BCoC list has not been developed, a BCoC list for a larger region would still apply. For example, a Puget Sound-wide list could be used, or the RSET-wide list provided in Appendix A.

Smaller site- or project-specific areas are not appropriate for the purposes of establishing BCoC lists, as fish and affected wildlife may range widely beyond these areas and be affected by more than one source of contaminants. It is also important from a policy perspective to have consistency among projects within an operational area, such as a federally authorized navigable waterway or large Superfund site. However, cleanup programs may opt to conduct bioaccumulation testing and require cleanup of smaller areas of sediment impacted by BCoCs, if localized risks to aquatic life, wildlife, or humans exist. For the same reasons, cleanup sites are not limited to the regional BCoC lists developed to streamline dredging evaluations.

9.3 REASON TO BELIEVE

The approach used to evaluate reason to believe will become more focused over time as first tissue BTs, then sediment BTs, become available. A fundamental principle behind bioaccumulation-based sediment BTs is that there is a demonstrated relationship between concentrations of bioaccumulative contaminants in sediments and in tissues of aquatic life living in the area. However, the exact concentration in sediment that will lead to unacceptable levels of bioaccumulation is unknown and likely varies among waterbodies due to many site-specific factors. To move forward in the face of these unknowns, RSET will rely on establishing multiple lines of evidence to develop a reason to believe that bioaccumulation would or would not likely occur at an individual site.

As discussed above, the first step in establishing reason to believe is to identify the list of BCoCs in tissues in the waterbody affected by the project (Figure 9-1). This may be the disposal site area for dredging projects, or the waterbody within which a contaminated site is located. The generic BCoC list provided in Appendix A may be used if no tissue data are available for an area. If tissue data are available for a waterbody, tissue concentrations may be compared either to tissue BTs (if available) or to reference area tissue concentrations (if no BTs are yet available) to identify the specific BCoCs in tissues in that waterbody.

The tasks involved in identifying the BCoC list are shown above the dashed line in Figure 9-1, and would generally be carried out by the agencies, as resources allow. Activities in the central part of the flow chart would be carried out by project proponents or responsible parties, and decisions in the final part of the flow chart would be made by the agencies.

If no tissue data exist or existing data have not yet been compiled for an area, reason to believe would be based on concentrations of all List 1 BCoCs that are detected in sediments (see Appendix A). The second step is to review the sediment chemistry data for the BCoCs in tissues in the waterway, and compare them to sediment BTs. If sediment BTs are not available, comparison to sediment concentrations in reference areas could be used to determine whether BCoCs are elevated in the sediments. Thus, chemicals present in sediment and in regional tissues at elevated levels would establish a sufficient reason to believe.

The project proponent may alternatively choose to present information indicating the chemical is not present at levels of concern in tissues, based on compilation or collection of tissue data and a risk assessment addressing the three pathways for which BTs will be derived, consistent with the methods outlined in Section 9.8. Finally, if the project design would reduce concentrations of bioaccumulative chemicals below detection limits (e.g., dredging into native sediments), bioaccumulation testing need not be conducted.

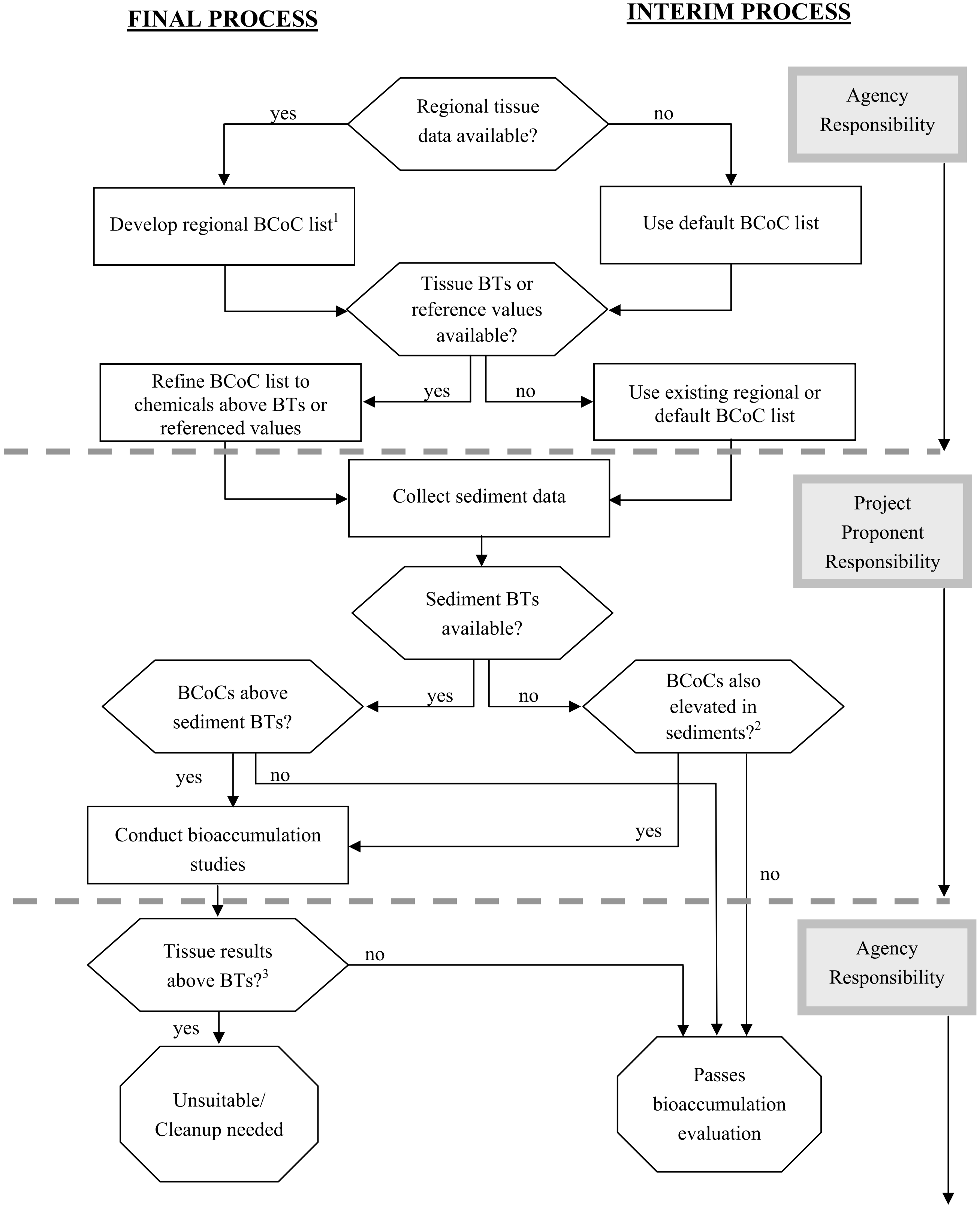

Figure 9-1. Bioaccumulation Evaluation Framework

[1] As agency staff and funding allows.

[2] Subject to small project exemptions (see Table 5-3).

[3] Until tissue BTs are available program-wide, risk-based evaluation criteria will be developed as needed on a project-by-project basis, consistent with current practice.

Elevation above reference will be a central part of reason to believe in the interim period before tissue and sediment BTs are developed. The first step in this process is to establish reference areas suitable for the cleanup site or disposal site in question. Reference area performance standards (i.e., attributes that reference areas should meet) are described in PSEP (1991). These generally include low contaminant concentrations, low bioassay responses, and a healthy benthic community. Reference areas for the Puget Sound and associated chemical concentrations are identified in PSEP (1991), and are likely applicable to other marine areas and disposal sites. Other areas, such as freshwater environments, will require more detailed evaluation. The Corps and other agencies are actively evaluating potential reference areas within the region, and should be contacted for project-specific recommendations.

Once reference areas have been established or selected, whether on a programmatic or site-specific basis, contaminant concentrations typical of the reference area can be established and used to identify a level above which sediment or tissue concentrations would be considered to be elevated (e.g., above the 90th percentile of the reference range). The exact statistic that would be used depends on the distribution and quantity of the data for the reference area, and may vary by chemical class (depending on factors such as whether most of the data are detected or undetected). Chemical concentrations for the Puget Sound reference areas are provided in PSEP (1991). A similar analysis will be conducted for other reference areas as they are identified.

Basing reason to believe on tissue and sediment elevations above reference in the interim before BTs can be established, while somewhat unavoidable, is likely to increase the number of bioaccumulation evaluations that will be required. These additional evaluations and testing results will provide the data needed to back-calculate sediment BTs over time. However, for smaller projects, this additional testing may be an unreasonable burden. Therefore, the no-test volumes for small dredging projects, as defined in Table 5-3, will also apply to bioaccumulation evaluations. Cleanup sites have no minimum volume or area requirements and bioaccumulation evaluations may be required by the agencies at their discretion if other “reason to believe” criteria are met.

In areas with sufficient regional tissue and sediment data, BSAFs may be developed that will allow back-calculation of sediment BTs. In general, these BSAFs would apply to the same size areas as the waterbody-specific BCoC lists, and be based on the same tissue data, along with co-located sediment data. Alternatively, bioaccumulation testing results could be used. BSAFs may be calculated by the agencies or by project proponents as needed and as resources allow. The existence of these values will refine and streamline reason to believe by providing sediment screening values that would trigger bioaccumulation testing.

However, in some cases these back-calculated values may be below natural or regional background concentrations. In that case, a more programmatic means may need to be identified to decrease sediment contaminant concentrations or bioavailability in an area to acceptable levels (e.g., additional source control or employing best management practices during dredging), if possible. In the meantime, comparisons to reference would be made as described for the interim process.

This interim approach will be updated as tissue and sediment BTs are developed.

9.4 LABORATORY BIOACCUMULATION TESTING

The Ocean Testing Manual and Inland Testing Manual provide information on bioaccumulation tests for freshwater and marine sediments. Two bioaccumulation tests are required, utilizing species from two different trophic niches representing a suspension-feeding/filter-feeding and a burrowing deposit-feeding organism.

For marine sediments, a 28-day bioaccumulation test will be conducted with both an adult bivalve (*Macoma nasuta*) and an adult polychaete (*Nereis virens, Nepthys,* or *Arenicola marina*).

For freshwater sediments, the test will be conducted with the oligochaete (*Lumbriculus variegates*) and another species to be determined at the time of testing. Selection of additional approved species for freshwater bioaccumulation testing is in progress; this section will be updated once a recommendation has been reached and public review has taken place.

The test exposure duration will normally be 28 days utilizing the EPA protocol (Lee et al. 1989), after which a chemical analysis will be conducted of the tissue residue to determine the concentrations of BCoCs. However, some high K_{ow} contaminants (e.g., polychlorinated biphenyls [PCBs], TBT, DDT) may not reach equilibrium between the sediments and tissues of the test species over the duration of a 28-day test. In these cases, modifications to the test may be required to extend its duration to up to 45 days (Dredged Material Management Plan [DMMP] 2000). Alternatively, the residue measured at the end of a 28-day test could be adjusted upward using an estimate of the proportion of the final steady state concentration reached in 28 days. The steady state adjustment of 28-day measured tissue residues can be made using procedures in Feijtel et al. (1997). The Inland Testing Manual (EPA/Corps 1998c) also provides a method to adjust steady state residue estimates for chemicals that take longer than 28 days to equilibrate between sediment and tissue. However, the Feijtel et al. (1997) adjustment is based on more recent studies and data than is the Inland Testing Manual steady state adjustment.

Protocols for tissue digestion and chemical analysis will follow the PSEP recommended procedures for metals and organic chemicals (PSWQAT 1997b,c).

Laboratory testing is the method of choice when subsurface sediments are to be dredged or cleaned up. Subsurface sediments may have higher concentrations than surface sediments, because each of the following two methods assesses primarily surface sediments.

9.5 IN SITU BIOACCUMULATION TESTING

Consensus-based American Society for Testing and Materials (ASTM) (2001) protocols have been developed for in situ caged bivalves that can be used to assess bioaccumulation potential and associated biological effects from contaminants in marine, estuarine, and freshwater species. In situ testing can also help integrate toxicity and bioaccumulation testing because effects endpoints such as survival, growth, and reproduction have been developed for some bioaccumulation test species, and can be measured in the same organisms.

The main advantage of this approach is the ability to characterize exposure and effects over space and time and under environmentally realistic test conditions at the specific project or site in question. The main disadvantage is the cost, although costs do not increase incrementally with time as in laboratory toxicity or bioaccumulation tests because daily maintenance is not required. Other disadvantages include the potential for confounding factors in the field, the difficulty of locating suitable reference sites, and the lack of exposure to subsurface sediments that may be a concern in dredging projects.

In situ test organisms other than bivalves are also available, and these methods are evolving in both marine and freshwater environments. Please see RSET Issue Paper 20 for a complete discussion of marine and freshwater species that are available and the basis for the recommendations below.

9.5.1 Marine/Estuarine In Situ Tests

Marine and estuarine bivalves have long been used in monitoring programs throughout the United States and internationally, and protocols for their use are well-established (see ASTM 2001). Species that are indigenous to the Pacific Northwest and appropriate for estuarine or marine salinities include:

- **Mussels –** *Mytilus trossulus*, *M. californianus*, *M. galloprovincialis* (*M. edulis* is also frequently used),
- **Oysters –** *Crassostria gigas*, *Ostrea lurida*, and

- **Clams –** *Macoma balthica*, *Protothaca staminea*, *Venerupis japonica*.

Other selections are also possible; see ASTM (2001) for a complete list of marine and estuarine species, their geographic distributions, and salinity tolerances.

9.5.2 Freshwater In Situ Tests

Because fewer freshwater in situ projects have been completed in the Pacific Northwest, a thorough review was conducted to evaluate which species might be appropriate. Based on the criteria identified above, three groups of organisms are recommended as satisfying the criteria and being present in the Pacific Northwest. In order of preference these are 1) bivalves, 2) gastropods, and 3) decapods (crayfish) (Salazar and Salazar 1998). Freshwater protocols are also provided in ASTM (2001).

Corbicula fluminea is recommended as the first choice for in situ freshwater assessments of bioaccumulation potential because it has been used extensively in laboratory testing, field monitoring, and in situ assessments of both toxicity and bioaccumulation potential (however, *Corbicula* should not be used in areas where it has not yet been introduced). Either a gastropod or freshwater crayfish would be potentially useful as a second species. *Lumbriculus variegates* (an oligochaete) has also been suggested by several agencies as a potential species that could be used. Further identification of appropriate in situ species will be conducted by RSET as needed.

9.6 COLLECTION OF FIELD ORGANISMS

Recommended guidelines for collection and processing of tissue samples can be found in PSWQAT (1997a), and guidelines for analysis of metals and organics in tissue samples can be found in PSWQAT (1997b,c). Additional considerations for collecting and analyzing tissue samples for bioaccumulation assessments can be found in Exponent (1998). Selection of field organisms for sampling must be done on a project-specific basis in consultation with the agencies.

9.7 INTERPRETIVE GUIDELINES FOR BIOACCUMULATION DATA

Currently, bioaccumulation testing is required when there is reason to believe that specific CoCs may be accumulating in target tissues at levels of concern. Reason to believe was previously established by comparing sediment concentrations to BTs. However, most of these existing sediment BTs were based on the DMMP program's screening levels (SLs) and maximum levels (MLs), which were themselves derived from sediment toxicity tests rather than bioaccumulation tests or bioaccumulation-based risk evaluations (PSDDA 1988).

Therefore, there has been a recognized need to update the BTs to be directly reflective of potential toxicity through bioaccumulation exposure pathways. Because the original sediment BTs were not based on actual bioaccumulative risks and may be higher than levels protective of human health and wildlife, these original sediment BTs have been removed from this SEF and are no longer used to establish reason to believe (see Section 9.3). It should be noted that recently the Seattle District DMMP has calculated an updated sediment BT for PCB Aroclors and a porewater BT for TBT. These more recent BTs were calculated using risk-based procedures consistent with the bioaccumulation-based protocols outlined in this chapter, and are appropriate for use as interim BTs until final BTs can be calculated by RSET.

To develop updated tissue and sediment BTs, the RSET Bioaccumulation Subcommittee determined the first step was to identify BCoCs. A draft list of BCoCs is provided in Appendix A (adapted from Hoffman [2005]). Next, RSET will need to establish scientifically defensible BTs for fish and shellfish tissues based on three individual receptor groups: aquatic life (including Endangered Species Act [ESA] species), wildlife such as birds and mammals that eat primarily fish and aquatic invertebrates, and human health. Methods for developing tissue BTs for each of these three receptor groups are addressed more specifically below.

The most significant obstacle in pursuing the traditional dredging program approach is establishing BTs for sediments that are scientifically defensible because of the site-specific nature of BSAFs. Nevertheless, the subcommittee recognizes this as a clear goal of the dredging program. It will simplify the decision process for applicants and reduce the cost of testing. Ultimately, RSET envisions that site-specific or region-specific BSAFs will be available with which DMMOs can develop sediment BTs.

9.7.1 Bioaccumulation Triggers for Tissues

Tissue triggers are expected to be used by both dredging and cleanup programs to identify target levels that may be applied region-wide. Developing tissue triggers is the first step toward establishing sediment triggers and/or a watershed-wide approach to source reduction, and would also serve as the criteria to which the results of bioaccumulation testing would be compared. The Bioaccumulation Subcommittee identified several groups of receptors for which tissue triggers need to be established:

- Human consumption of fish and shellfish,
- Wildlife consumption of fish and invertebrates, and

- Aquatic life, including ESA listed and special status species (fish, mussels, snails, etc.).

Tissue levels for the first two sets of receptors will be based on back-calculation using established risk assessment techniques and receptors common in the Pacific Northwest (see Section 9.8). Tissue levels for protection of aquatic life will be based on tissue-residue-effects data contained in databases such as the Environmental Residue Effects Database (ERED), once appropriate quality assurance has been applied. Note that this approach will not protect fish against contaminants that do not appreciably bioaccumulate in tissues, such as tetrachloroethene, or contaminants whose parent compound is rapidly metabolically transformed to other compounds, such as Aldrin and many polycyclic aromatic hydrocarbons (PAHs). Sediment Quality Guidelines (SQGs) for such contaminants will need to be developed separately by the SQG Subcommittee or the Bioaccumulation Subcommittee.

Each of the above receptor groups is protected under all of the regulatory programs addressing sediments; therefore, it is assumed that generally the lowest of the applicable levels will be used. However, the approaches and input values used to derive each of the levels must be transparent and readily available for review, as some aspects may vary on a site-specific basis. For example, fish consumption rates may vary by region, disposal site, or watershed, as may the wildlife and ESA receptors present.

Cleanup site managers, and to some degree dredging agencies, should be provided the opportunity to modify the values based on good science and site-specific factors, as long as the modifications are recorded in an appropriate document such as a suitability determination or record of decision. In addition, the RSET manual itself may include multiple sets of BTs for different purposes. For example, human health exposure scenarios may be very different at a deepwater dredged material disposal site than in an urban waterway. The need for multiple sets of BTs at a programmatic level will be assessed further as tissue BTs are continually developed.

9.7.2 Bioaccumulation Triggers for Sediments

The general consensus in the scientific and regulatory community is that it is difficult to accurately back-calculate sediment triggers from tissue levels using literature-derived BSAFs from field studies, due to large uncertainties in BSAFs for the same chemical derived from different data sets (PTI 1995). This is largely due to differences in sediment geochemistry, bioavailability of contaminants, and food webs from one area to the next, as well as an assumption of equilibrium, which may not actually exist in many environments. To date, no regulatory program in North America has established sediment BTs applicable over large areas, such as a multi-state region. However, BSAFs can be developed on a site-specific, watershed, or disposal site basis using tissue data paired with sediment data from the home range of the species being evaluated. Care must be taken to ensure the BSAF is meaningful (i.e., there is a statistically significant regression curve or sufficient paired sediment/tissue data to calculate a mean with low variability) (Exponent 1998). It is also important to take into account the home range of the species sampled and pair the sediment and tissue data accordingly. Methods for calculating statistically meaningful BSAFs and draft BSAFs for several non-polar organic compounds are presented in PTI (1995) and Exponent (1998).

For the purposes of the dredging program, the most relevant BSAF may be at the disposal site, since this is where the material will reside after dredging and the long-term exposures of concern may occur. BSAFs for the waterbody of origin may also be used to determine the effects of dredging residuals or contaminants released during dredging. It may be possible to use past monitoring data to develop disposal site-specific BSAFs that can be applied to derive sediment BTs for each disposal site (or for a set of disposal sites that are similar in nature and receptors, such as ocean disposal sites along the coast of Oregon or those in Puget Sound). In deriving and applying such BSAFs, it will be important to consider whether sediment characteristics affecting bioavailability are similar at the disposal site and in the dredged material being disposed there.

Similarly, BSAFs may be developed for certain chemicals and watersheds as part of large Superfund site evaluations, and under source control (e.g., total maximum daily load) and National Resource Damage Assessment processes. In these cases, it may be more productive to use a geographic information system (GIS)-based approach to determine which areas of sediment in the site or watershed need to be cleaned up to reduce overall loading to a level that would, in turn, reduce tissue concentrations to acceptable levels. This may be accomplished by identifying the factor by which tissue concentrations need to be reduced (e.g., to 50 percent of current levels), and then using GIS tools to identify areas that, if cleaned up, would reduce the area-weighted average sediment concentration within that organism's home range to 50 percent or less of its previous value. This could also be a method for designing and evaluating large dredging projects in contaminated areas, in terms of the dredged material (and any residuals) as a source prior to, during, and after dredging, and evaluating these sources in the context of regional bioaccumulation concerns.

Because of both environmental and programmatic differences, it is not necessary or even possible to use the same approach or have the same criteria for bioaccumulation in sediments. For example, tissue triggers may be developed to be protective of a wide variety of regional wildlife receptors and human exposure scenarios, but which ones will apply at any given site or disposal site will vary depending on the environment in which that site is located and the uses that are present. BSAFs used to back-calculate from tissue levels to sediments may also vary depending on geochemical conditions and food webs present in each environment. Superfund sites with parties having the resources to conduct complex food web modeling or monitoring evaluations may develop site-specific sediment BTs, compared to small dredging projects in which standardized ratios or BSAFs calculated from regional regressions may be employed. It is most important that all programs and agencies have consistent, protective tissue levels as the same goals, and are working toward meeting these watershed-wide values in a manner that best meets their project needs.

9.7.3 Collection of Missing Data

For areas where not enough data exist to establish watershed BCoCs, determine reason to believe, or develop BSAFs, it is recommended that the agencies and the regulated community share the burden of data collection. A single database is needed to maintain bioaccumulation data, and an agency should be identified to manage the database. For consistency with the sediment data management system, SEDQUAL is recommended because it has the capability of maintaining tissue as well as sediment data.

9.8 DERIVATION OF BIOACCUMULATION TRIGGERS

This section identifies the proposed methods for calculating tissue BTs for each of the three identified exposure pathways. These tissue BTs would be used to focus the BCoC list by region, and as criteria against which the results of bioaccumulation testing can be compared to determine whether sediments are suitable for open-water disposal or require cleanup. As the first step in this process, the Bioaccumulation Subcommittee has established methods and equations for use in these calculations. The Subcommittee is currently compiling potential input parameters for use in the equations from projects that have been widely reviewed and approved regionally, which will allow tissue BTs to be derived for the wildlife and human health exposure pathways.

Derivation of tissue BTs for aquatic life based on tissue residue effects data is a more resource-intensive process and, in this case, the Subcommittee has recommended relying on existing species sensitivity distribution (SSD) and water quality criteria-based values as a starting point, with some updating and review. However, the water quality criteria-based approach has a number of disadvantages and uncertainties that make it most appropriate as an interim approach, only to be used on a provisional basis if there are not yet enough data to develop a SSD. SSDs should be calculated before attempting to back-calculate to sediment BTs. Once a complete set of tissue BTs has been assembled, sediment BTs can be derived. Methods for deriving sediment BTs are currently reserved and will be addressed as the next step in the process.

Derivation methods for both tissue and sediment BTs contain assumptions and methods that may result in very low values, although every attempt will be made to derive values that are realistic while still being protective. Concentrations below background or reference values are a possibility and will need to be evaluated and addressed. A necessary step following the derivation of any draft BTs will be not only public review and comment, but a "dry run" or ground-truthing exercise will occur to ensure the derived values are implementable in the dredging and cleanup programs for which they are intended.

9.8.1 Tissue Bioaccumulation Triggers for Aquatic Life

The toxicity of bioaccumulated chemicals to aquatic biota can be evaluated with a tissue residue approach (TRA) toxicity assessment. By associating the toxic response of aquatic biota with the tissue concentration of the chemical causing the effect, complicating factors associated with exposure media-based (i.e., water and sediment) dose-response studies can largely be eliminated. Toxic effects can then be directly expressed as a function of tissue residues. Elimination or minimization of confounding factors, such as bioavailability, is the great advantage of using tissue residues to evaluate toxicity of environmental contaminants compared to evaluating toxicity using chemical concentrations in water, sediment, or diet.

The main precept of the TRA is that it generates critical body residues (CBRs), such as LR_{50}s, LR_{10}s, or lowest observed effect residues (LOERs), for a given toxicant that exhibit relatively low variability among species. The reduced variability in the biological response compared to exposure media concentrations associated with toxicity (e.g., LC_{50}) is highly desirable for generating tissue BTs that are protective of all species. Additionally, CBRs for many of the primary BCoCs are based on an extensive quantity of literature associating tissue residues with adverse effects, and some causal relationship studies between whole body tissue concentrations and the biological response, allowing the TRA approach to be highly technically defensible.

Because data from a variety of taxa are used to generate the CBRs and corresponding BTs, for most contaminants, the CBRs will be the same for fish and invertebrates. Not all CBRs will have broad taxonomic application and exceptions will occur (e.g., TBT); however, for most chemicals, the species sensitivity distributions for fish and invertebrates largely overlap. Each compound or class of compounds will be evaluated for its ability to represent toxicity for a wide range of species.

9.8.1.1 Protocols for the Development of Tissue Bioaccumulation Triggers

Thus far, the following three methods by which tissue BTs can be developed have been identified:

1. SSDs of existing tissue residue-effects literature,
2. Bioaccumulation modeling using existing water quality criteria as an input into the model, and
3. CBRs defined on a molar basis for chemicals with known modes of toxic action.

Tissue BTs can be developed for some chemicals using existing residue-effects information in the technical literature. For chemicals without sufficient residue-effects information in the literature, a bioaccumulation model or knowledge of the molar concentration of the chemical in tissue associated with toxicity would need to be used to develop tissue BTs, with an increased uncertainty of the usefulness of the guidelines. If the mode of action of a chemical is known, a tissue BT could be developed by back-calculating from the molar concentration of that chemical in tissue associated with toxicity.

One issue of concern that applies to both the bioaccumulation modeling and species SSD generation approaches is selection of the toxicological endpoints to incorporate into BT derivation. EPA's past methodology for deriving ambient water quality criteria (AWQC) (Stephan et al. 1985) considers contaminant effects on survival, reproduction, and growth. Consistent with more recent AWQC approaches, RSET intends to incorporate behavioral studies with ecologically relevant endpoints into tissue BT derivation. However, behavioral studies will be carefully screened to ensure that they are of high quality and reflect a bioaccumulation endpoint (e.g., related to contaminants in tissues rather than in water).

RSET believes the most scientifically defensible tissue BTs will be derived from using measured residue-effects information from a number of species to calculate the BT. The SSD approach provides the greatest opportunity to utilize all available residue-effects information for a given chemical to derive its tissue BT; thus, the SSD approach will be used for tissue BT derivation. For chemicals where sufficient literature data are not available to derive tissue BTs using the SSD approach, either the bioaccumulation modeling or molar residue approaches can be used to develop tissue BTs, although with greater uncertainties associated with the calculated BT. Each of these approaches is described in further detail below.

9.8.1.2 Species Sensitivity Distribution Approach

The species sensitivity distribution approach uses existing toxicological literature in a manner similar to the existing EPA methodology used to develop AWQC (Stephan et al. 1985). It is the approach used in Europe to derive water quality criteria, and has also been used to derive sediment quality criteria such as the Long and Morgan (1991) effects range-low values and Washington's sediment management standards. As used in water quality criteria development, the SSD is generated from laboratory toxicity data.

SSDs are most commonly expressed as cumulative distribution functions (CDFs) of the toxicity of a chemical to a set of species. When toxicity data (such as a set of LC50 values for a number of species) are rank ordered from low to high (or high to low), generation of the SSD as a cumulative distribution function permits one to identify a concentration at which a defined proportion of the species comprising the SSD is not adversely affected. One of the primary assumptions of the SSD approach is that it represents the true but unknown distribution of toxicity data for all aquatic species. The larger the toxicity data set used to derive an SSD, the more likely it is that this assumption will be met. Thus, tissue BTs derived from SSDs containing larger amounts of toxicity data are more likely to accurately define tissue residues that, if not exceeded, are protective of fish.

One important consideration is making sure that ESA-listed species are represented in the data set, either directly or through a similar surrogate. Each SSD will be examined to ensure that species are included that are representative of ESA-listed species. If no tissue reside data are available for appropriate species, water quality data may be evaluated to determine the relative sensitivity of ESA-listed species to toxicants compared to species that are included in the SSD.

ERED, available at http://el.erdc.usace.army.mil/ered/ (Bridges and Lutz 1999), and Jarvinen and Ankley (1999) are the primary sources of residue-effects information that can be used to develop SSDs.

The toxicity datasets used to develop water quality criteria employ a statistically derived description of the concentration-response curve, such as an LC_{50} or EC_{20}. By contrast, much of the available tissue residue-effects literature describes only one point on a dose-response curve (e.g., a residue resulting in a 38 percent reduction in survival relative to control survival). Other residue-effects literature commonly contains no description of the magnitude of the observed effect, the proportion of species responding to a given tissue residue, or a statistically derived descriptor of the dose-response curve. This literature, all of which contains information termed the lowest unquantified effect dose (LUED), may be of limited utility in the derivation of tissue BTs, while comprising a substantial portion of the available residue-effects literature. However, if it is assumed that LUED values are analogous to LOERs, a species sensitivity distribution can be generated with both tissue-based LUED and LOER data, providing a sizable increase in the amount of literature available for use in developing SSDs.

For development of tissue BTs, a decision must be made regarding at what level of effect (or the proportion of species to be protected) the tissue BT should be set. Consistent with EPA's AWQC derivation methodology, RSET intends to use the 5th percentile of an SSD derived from the adverse effects data for survival, reproduction, growth, and behavior as the selected BT. Each SSD will be examined to determine where species representative of ESA-listed species fall within the distribution. An additional lower threshold value may be used in cases where it would be necessary to protect an ESA-listed species, to be applied in areas where those species are present.

A potential difficulty with using measured residue-effects data to derive tissue BTs is data availability. There is less information available in the literature on tissue residues associated with toxicity than there is on water column or sediment concentrations associated with toxicity. This does not preclude the use of literature data to derive tissue BTs, but the limited available information for many chemicals will limit both the number and reliability of tissue BTs derived using SSDs. Hence, this approach will only be used as sufficient data become available for each BCoC, and one of the two methods below may be used in the meantime.

9.8.1.3 Bioaccumulation Modeling Approach

At its simplest, a tissue BT could be derived from the product of a water quality criterion and a bioconcentration factor (BCF) (or bioaccumulation attenuation factor [BAF]). This approach for developing tissue BTs has previously been proposed by several investigators (Dyer et al. 2000, Shephard 1998, Nendza et al. 1997, Calabrese and Baldwin 1993, Cook et al. 1992). As many water quality criteria and BCFs are already available, this approach could be used to quickly generate tissue BTs for a number of chemicals. The simpler bioaccumulation models are not data intensive, which is potentially a large advantage during the development of tissue BTs.

Through a review of the existing residue-effects literature, Shephard (2004) demonstrated that the product of existing EPA water quality criteria and a standardized set of BCFs resulted in tissue screening concentrations for aquatic life were lower than 94.5 percent of measured tissue residues associated with adverse effects on survival, reproduction, and growth. This is in excellent agreement with the intended 95 percent level of protection for aquatic genera, which is the goal of the EPA water quality criteria (Stephan et al. 1985).

However, because this approach is frequently overprotective, the SSD approach described above will be used in preference.

Another observation made by Shephard (2004) was that no statistically significant differences exist in tissue residues associated with toxicity in marine and freshwater biota. This leads to the possibility that generally applicable tissue BTs can be generated from bioaccumulation models, eliminating the need to derive separate sets of tissue BTs for marine and freshwater biota.

Tissue BTs derived from a bioaccumulation model have many uncertainties. These uncertainties include the accuracy of water quality criteria used as an input to the model, and the appropriateness of using a single BCF or BAF to derive generally applicable tissue BTs. Addressing these uncertainties during tissue BT development may result in BTs with large safety factors relative to the safety factors of tissue BTs derived from SSDs.

Measured contaminant residues in field collected fish tissues that exceeded tissue guidelines generated by both a bioaccumulation model and a SSD were found to be statistically significantly correlated with fish community health in a statewide survey of fish in Ohio (Dyer et al. 2000). The Dyer et al. (2000) study is one of the few studies available that has simultaneously evaluated the predictive utility of tissue guidelines developed from both bioaccumulation models and SSDs.

9.8.1.4 Molar Residues Associated with Known Modes of Toxic Action

Since the finding by McCarty (1986) that lethal tissue residues of chemicals in fish whose mode of action is narcosis are relatively constant when expressed on a molar basis (e.g., millimoles of chemical per kilogram of body weight, or mmol/kg), an extensive amount of research has been performed to quantify molar residues of both individual chemicals and mixtures of chemicals with the same mode of action associated with toxicity. Ranges of molar residues in aquatic biota tissues for chemicals with a number of modes of action are summarized in McCarty and Mackay (1993).

Most if not all of the available literature used to generate the molar residue-effect ranges in McCarty and Mackay (1993) can also be used to generate SSDs. A large advantage of the molar residue approach, shared with the bioaccumulation modeling approach to tissue BT derivation, is that BTs can be calculated for many chemicals with little or no toxicity information. In the case of the molar residue approach, the minimum data requirements to derive tissue BTs are knowledge of the mode of action of the chemical and the range of residues associated with toxicity for other chemicals sharing the same mode of action.

Several potential difficulties exist with the molar residue approach. Although all organic chemicals are believed to be at least as toxic as their potential to elicit narcosis, many chemicals that are narcotics during short-term lethality tests have other modes of action during chronic exposure periods. Thus, it cannot be assumed that just because some information exists documenting a chemical elicits narcotic toxicity during short-term lethality testing, it will also be a narcotic during longer term exposures. Some chemicals, particularly metals, have multiple modes of action, making it difficult to define a molar residue protective of all potential toxic effects. The mode of action for some chemicals is not currently known, precluding the use of the molar residue approach to derive tissue BTs for such chemicals.

9.8.1.5 Chemicals for Which Tissue Residue Values Cannot Be Derived

In theory, tissue residue values for protection of fish and invertebrates can be derived for any chemical or compound that is bioaccumulated into aquatic biota tissues. In practice, tissue residues associated with toxicity have seldom been measured for organic chemicals that are freely water soluble, or at least have a high water solubility. As shown by McCarty et al. (1991), for organic chemicals with a log $K_{OW} < 1.5$, the chemical concentration in the water phase of the organism dominates toxicity, and total body residues associated with toxicity should be similar to the respective threshold LC_{50} in water.

Tissue BTs for fish and invertebrates should not be derived for chemicals that fall into the following three rather broad categories:

1. Chemicals that do not appreciably bioaccumulate but are nevertheless toxic,
2. External toxicants such as contact herbicides, and
3. Chemicals that are rapidly biotransformed into more (or less) toxic metabolites relative to toxicity of the parent compound.

Some chemicals are quite toxic without appreciable bioaccumulation. Cyanide is one example of a highly toxic chemical with a low bioaccumulation potential. Most chemicals in this group have high water solubility and may not preferentially partition from water to tissues, resulting in low tissue residues associated with toxicity. These chemicals are unlikely to be on lists of bioaccumulative chemicals, reducing the need for tissue BTs for this group.

External toxicants do not need to enter the body of an organism to elicit toxicity. In addition to contact herbicides that act by destroying the cell wall of the plant, a few other chemicals can act as external toxicants under some circumstances. Iron and aluminum are two chemicals that, under certain conditions of water quality, form flocculent materials that coat the gills of aquatic species, causing death by suffocation without entering the body of the organism. As another example, oil coating a bird may cause hypothermia and death.

The toxicity of some compounds is enhanced by transformation (biological, chemical, or physical) after they have been bioaccumulated. For example, the chlorinated insecticide Aldrin is rapidly (within a few hours or days) metabolically transformed to the more toxic Dieldrin (Canadian Council of Ministers of the Environment 1995) by most aquatic species. Under these conditions, the concentration of the parent compound in tissue may have little or no relationship to the toxicity of the transformation product. The largest group of chemicals this applies to is PAH compounds. Some PAH compounds are metabolically transformed into more toxic PAH epoxides; the chemical form often responsible for the carcinogenic effects of some PAHs. Other PAHs are photochemically activated, which enhances the toxicity of bioaccumulated parent PAH compounds. Available tissue residue-effects literature for PAHs shows substantial variations among body residues associated with the same toxic endpoint, which cut across taxonomic lines. This variability makes it difficult to develop a single PAH tissue BT that is protective of all species.

Existing data do not currently permit development of generally applicable tissue residue values for either individual PAH compounds or mixtures of PAHs. The Bioaccumulation Subcommittee recommends that RSET not attempt to develop tissue BTs for either individual PAH compounds or PAH mixtures at this time. PAH toxicity to aquatic species can be evaluated by comparing their concentration in water or sediment to existing environmental guidelines, standards, or criteria. However, tissue BTs for protection of wildlife and human health can be derived using the methods discussed in Sections 9.8.2 and 9.8.3.

9.8.1.6 Sensitivity of Endangered Species to Chemicals

Relatively few toxicity studies have been performed with endangered species, or at least with the specific ESA-listed stocks, strains, or subspecies of species that are more common elsewhere in their range. EPA, USFWS, and USGS have combined to fund several studies of the contaminant tolerance of several ESA-listed aquatic species, primarily fish, in recent years (Besser et al. 2001, Dwyer et al. 1999). The findings of these studies have provided support for the hypothesis that most water quality criteria are protective of ESA-listed aquatic species. On a body residue basis, additional support for this hypothesis is available from studies with the ESA-listed bull trout (*Salvelinus confluentus*). Studies with cadmium (Hansen et al. 2002a) and copper (Hansen et al. 2002b) have found that while whole body residues associated with toxicity are low, they are not as low as residues associated with toxicity in other aquatic species.

However, it is not assumed that the methods described above will be protective of ESA-listed species in every case. Residue-effects data will be reviewed for appropriate surrogate species for an ESA-listed species (e.g., rainbow trout for listed salmonids) during the development of each tissue BT to determine whether or not each value can be considered protective of ESA-listed species. In addition, if the value that would be protective of ESA-listed species is lower than the selected SSD threshold, the value that would be protective of ESA-listed species will be identified along with the standard threshold value for use in areas with related ESA listings.

9.8.2 Tissue Bioaccumulation Triggers for Aquatic-Dependent Wildlife

This section provides the approach to be used to develop BTs for aquatic-dependent wildlife. This BT represents the concentration or target level of a bioaccumulative contaminant in a prey item that is considered protective of birds and mammals that prey on aquatic species such as fish or invertebrates. Thus, contaminants present in prey items at or below the trigger level will not harm the most sensitive life stage of bird or mammal predators. Because it can be difficult and costly to directly measure tissue concentrations in higher order receptors, prey items are considered sentinels, which can be monitored to determine if action is warranted to protect aquatic-dependent wildlife from bioaccumulative chemicals in a watershed. Though sediment ingestion is another pathway by which chemicals can enter aquatic dependant wildlife, the dietary pathway tends to be the dominant source for bioaccumulative chemicals (Bridges et al. 1996).

It is important to note that tissue BTs for aquatic-dependent wildlife may not be protective of the prey species themselves. Rather, the BTs are derived based on Toxicity Reference Values (TRVs) previously established and reported for the protection of sensitive life stages of higher trophic level species. Therefore, TRVs for the receptors identified in a watershed must be available to calculate BTs for aquatic-dependent wildlife.

9.8.2.1 Defining Aquatic-Dependent Wildlife Receptors

Recognizing the difficulties of developing tissue BTs on a site-specific basis, guidance is provided here for developing tissue BTs for wildlife prey items that are more broadly applicable to a wide range of areas. If the wildlife sentinel species discussed herein are for some reason less appropriate for a particular site or project, the same general approach may then be used to develop BTs for the prey items of additional wildlife species. However, it is likely that the concepts presented in this paper will be applicable to most if not all areas where BCoCs that could impact higher trophic level wildlife are present.

Certain avian and mammalian receptors are frequently considered as "representative" or sentinel wildlife receptors as shown in Table 9-1. These include the great blue heron, belted kingfisher, merganser, osprey, and bald eagle, which all consume large amounts of fish in their diets. Most of these receptors are found in both freshwater and marine environments. Depending on the type of water body under consideration, shorebirds (such as the stilt, avocet or sandpiper) may also serve as representative receptors because these birds typically consume aquatic invertebrates including insects and crustaceans, which may bioaccumulate metals/metalloids to a higher degree than fish consumed by predominantly fish-eating birds. Mammals that commonly feed on crustaceans and fish in watersheds include river otter, sea otter and mink.

Table 9-1. Common Aquatic-dependent Wildlife Receptors in Freshwater and Marine Systems

Candidate Wildlife Receptors	Scientific Name	Present in RSET Region?	Dominant Food Items
Birds			
Great Blue Heron	*Ardea herodias*	Yes	Fish, crustaceans, small mammals
Belted Kingfisher	*Ceryle alcyon*	Yes	Fish and crayfish
Red-Breasted Merganser	*Mergus serrator*	Yes	Small fish
Black-Necked Stilt	*Himantopus mexicanus*	Yes (summer)	Aquatic (including emergent) insects, small fish
American Avocet	*Recurvirostra Americana*	Yes (summer)	Mostly crustaceans and insects (including emergent)
Spotted Sandpiper or Western Sandpiper	*Actitis macularia or Calidris mauri*	Yes	Aquatic insects, mollusks, worms, crustaceans
Bald Eagle	*Haliaeetus leucocephalus*	Yes	Fish, fish-eating and non-fish eating birds, some mammals
Osprey	*Pandion haliaetus*	Yes	Fish
Mammals			
North American River Otter[1/]	*Lutra canadensis*	Yes	Fish predominantly. Also crustaceans (crayfish)
Northern Sea Otter[2/]	*Enhydra lutris lutris*	Yes	Marine fish, shellfish, and invertebrates
American Mink[1/]	*Mustela vision*	Yes	Crustaceans (crayfish), fish
Steller's Sea Lion	*Eumetopias jubatus*	Yes	Marine fish, salmon, macroinvertebrates
Orca Whale	*Orcinus orca*	Yes	Fish, marine mammels

[1/] Predominantly a freshwater species

[2/] Predominantly a marine species

9.8.2.2 Development of Tissue Bioaccumulation Triggers

Tissue BTs will be derived after selecting the receptor species and identifying TRVs from the literature that are protective of the receptors. The TRVs selected from the literature provide information about the likelihood of biological effects to aquatic-dependent wildlife (e.g., reduced survival, growth, and reproduction), and address what level of bioaccumulation constitutes an "unacceptable adverse effect." Key parameters identified for use in modeling come from the literature and are based on studies specific to the receptor. Additional site- or project-specific parameters can be used to fine-tune the model and potentially adjust the tissue BT in an area if warranted.

TRVs from the scientific literature or other noted data sources will be the primary focus when developing the generic prey tissue BTs for RSET. Two types of TRV studies are of greatest relevance to setting wildlife prey item tissue BTs: dietary TRV and egg-based TRV studies. The approach for establishing tissue BTs using each type of TRV study is presented below.

9.8.2.3 Establishing Prey Tissue Bioaccumulation Triggers Using Dietary Toxicity Reference Value Studies

The most straightforward way to determine if concentrations of BCoCs are of concern in wildlife prey items is to compare concentrations measured in these organisms at a site to the dietary test concentrations from a well-conducted TRV study for the wildlife species of interest. The TRV ideally should represent a no-observed-adverse effect level (NOAEL). Where a NOAEL is not available, a low-observed-adverse effect level (LOAEL) can be considered, although LOAELs may not be protective of listed species and safety factors may need to be incorporated in the assessment. The use of dietary studies for establishing TRVs makes the implicit assumption that the dietary exposure pathway is of greater importance than other exposure pathways such as incidental sediment ingestion. This is generally the case for most receptors, although the sediment ingestion pathway can be of high importance for receptors such as shorebirds.

TRV studies should be based on sensitive toxicity endpoints such as reproduction as a matter of priority. Also, the dietary TRV selected should be protective of the most sensitive life stage of a receptor for a particular test chemical (i.e., if a test chemical exerts toxicity at lower concentrations to developing embryos or juveniles compared to adults, then a TRV protecting these more sensitive life stages should be used in the assessment). TRV studies with toxicity endpoints relative to impacts on growth and survival may also be considered when more sensitive reproductive endpoint TRV studies are not available. The studies should be dietary to have maximum relevance to establishing tissue BTs for use at in-place contaminated sediment (CS) sites and dredging/disposal sites. For the dietary approach, injection or other non-dietary based studies have less relevance in establishing tissue BTs because the goal in establishing tissue BTs is to determine what levels in wildlife food could cause them harm and be easily monitored.[4] Fortunately, many dietary studies are available for BCoCs in the scientific literature and can be used for establishing tissue BTs for wildlife protection.

Commonly used databases containing wildlife TRV studies include EPA's Soil Screening Levels (EPA 2003b), Oak Ridge National Laboratories (ORNL) Toxicological Benchmarks (ORNL 1997), EPA's Ecotoxicology Database (ECOTOX) (ECOTOX 2003), and the Corps' ERED (ERED 2003). The scientific literature should be consulted in cases where TRV studies are not available from these sources.

The tissue BT is established using the NOAEL (or LOAEL with adjustment) dietary test concentration from a well-conducted TRV study. As an example, the selenium NOAEL for mallards is 4 milligrams per kilogram (mg/kg) in the diet (Heinz et al. 1989). Therefore, if selenium concentrations greater than 4 mg/kg in aquatic invertebrates or fish at a given site are measured, it could be concluded that there is a potential risk to aquatic-dependent birds feeding on these organisms. Ideally, an adjustment for the difference in food ingestion rate to body weight ratios between the test wildlife species in the TRV study and the species of interest at the site should be made. This adjustment is made as follows:

$$\mathbf{Tissue\ BT} = \mathbf{C_{tissue}} \cdot \frac{\mathbf{FIR_{test}}}{\mathbf{BW_{test}}} \cdot \frac{\mathbf{BW_{site}}}{\mathbf{FIR_{site}}}$$

Where:

Tissue BT = Allowable prey concentration for wildlife (mg/kg)
C_{tissue} = Chemical concentration in TRV test diet (food item)
FIR_{test} = Food ingestion rate of TRV test species (kilogram [kg]/day)
BW_{test} = Body weight of TRV test species (kg)
BW_{site} = Body weight of site species (kg)
FIR_{site} = Food ingestion rate of site species (kg/day)

Food ingestion rates and body weights of site-specific wildlife species of interest can be determined from many literature sources, including EPA's Wildlife Exposure Factor Handbook (EPA 1993a). Site-specific species with a higher food ingestion rate to body

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[4] Gavage studies can be considered if well-conducted dietary studies are not available for a BCoC. Gavage represents forced oral administration to the stomach using oil, water, or capsule. Resulting tissue BTs established from this type of study should be interpreted with greater caution. As a matter of priority well-conducted dietary studies are always the preferred type of TRV study.

weight ratio than that of the test species would have a lower tissue BT and vice versa. Similarly, allometric scaling for the TRV to account for differences in body weight may be applied, which can also be found in EPA (1993a).

9.8.2.4 Establishing Prey Tissue Bioaccumulation Triggers Using Egg-Based Toxicity Reference Value Studies

The dietary model above can be used for establishing tissue BTs protective of wildlife for many organic and inorganic compounds. However, some types of chemicals such as DDE, PCBs, "dioxin-like"[5] compounds (EPA 2003c), mercury, and selenium (Fairbrother et al. 1999, Adams et al. 2003) have demonstrated effects on avian development at the level of the egg. In these cases, developing tissue BTs based on eggs is more appropriate than the dietary pathway because the reproductive effects and corresponding TRVs are based on concentrations in bird eggs rather than in the diet, as the dietary pathway model above may not result in tissue BTs that are sufficiently protective.

Estimated egg-based TRVs (NOAELs or LOAELs) are available for fish-eating birds for PCBs (calculated as total PCBs) and DDE (Custer et al. 1999, Elliott et al. 1996, Wiemeyer et al. 1984, 1988, 1993, Yamashita et al. 1993), and an egg-based approach would be the preferred method for assessing these particular chemicals. Examples and explanations of using the egg-based approach can be found in EPA (2003c) and other references (Giesy et al 1995, USFWS 1994).

A simple egg-based model for developing tissue trigger levels follows below.

$$\textit{Tissue BT} = \textit{TRV}_{egg} / \textit{BMF}_{egg}$$

Where:

Tissue Trigger Level (mg/kg) = Tissue concentration in prey protective of avian predators

TRV_{egg} = Egg-based Toxicity Reference Value (mg/kg)

BMF_{egg} = Biomagnification factor from prey to egg (unitless); includes biomagnification from prey to adult, followed by adult to egg

The BMF_{egg} value can be derived from site-specific data (if available) or from the literature. Examples of site-specific derivation of BMFs can be found in Henny et al. (2003), USFWS (2004), and Braune and Norstrom (1989). Other methods for estimating BMFs can be found in USFWS (1994).

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[5] Compounds that demonstrate "dioxin-like" effects include dioxins, furans, and some PCB congeners (EPA 2003a).

9.8.3 Tissue Bioaccumulation Triggers for Human Health

This section provides a proposed approach to deriving BTs in aquatic tissues that would be protective of human health. For the purposes of this assessment, only human health risks associated with consumption of bioaccumulative chemicals in fish or shellfish are considered. At some sediment sites, it may be necessary to also consider other potential pathways (e.g., direct human contact with sediments). However, where fish and shellfish consumption is one of the potential exposure pathways, the food-related pathway typically is a more substantial contributor to site risks than direct contact with sediments. Thus, initial focus on fish and shellfish consumption is appropriate.

Tissue BTs will need to address both carcinogenic and non-carcinogenic effects of BCoCs through application of a carcinogenic slope factor (CSF) for carcinogenic effects and a reference dose (RfD) for non-carcinogenic effects. EPA-approved toxicity values are described on the EPA Integrated Risk Information System web site[6] and EPA's Provisional Peer Reviewed Toxicity Values for Superfund (PPRTV).[7] Additional interim toxicity values can be obtained by contacting EPA's National Center for Environmental Assessment (NCEA).[8]

Tissue BTs for carcinogenic effects of BCoCs can be calculated using the following general algorithm:

$$TissueBT\ (mg/kg) = \frac{TR \times AT_c \times BW}{EF \times ED \times FI \times IR \times 0.001\ kg/g \times CSF}$$

Tissue BT = target tissue concentration in fish or shellfish tissue (mg/kg wet weight)

TR = target risk for individual carcinogens

AT_c = averaging time (exposure duration (years) x 365 days/year)

BW = body weight (kg adult or child)

0.001 = conversion of grams fish to kg

EF = exposure frequency (days/year)

ED = exposure duration (years)

FI = fraction of intake assumed from site

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[6] http://www.epa.gov/iris/search.htm

[7] http://hhpprtv.ornl.gov/

[8] http://cfpub2.epa.gov/ncea/cfm/aboutncea.cfm?ActType=AboutNCEA

IR = ingestion rate for fish or shellfish (g/day)

CSF = carcinogenic slope factor $(\text{mg/kg-day})^{-1}$

For non-carcinogenic effects, the following algorithm can be used to derive tissue BTs for fish and shellfish tissue:

$$TissueBT\ (mg/kg) = \frac{THQ \times BW \times AT_n \times RfD}{EF \times ED \times FI \times IR \times 0.001\ kg/g}$$

Tissue BT = target tissue concentration in fish or shellfish tissue (mg/kg wet weight)

THQ = target hazard quotient

AT_n = averaging time (exposure duration (years) x 365 days/year)

BW = body weight (kg adult or child)

0.001 = conversion of grams to kg

EF = exposure frequency (days/year)

ED = exposure duration (years)

FI = fraction of intake assumed from site

IR = ingestion rate for fish or shellfish

RfD = reference dose for non-cancer effects (mg/kg-day)

9.8.3.1 Selection of a Target Risk and Hazard Index.

For carcinogenic effects of BCoCs, a total cumulative target risk level of 10^{-5} (upper-end) is proposed, which is consistent with regulatory requirements set out by ODEQ and Ecology. This risk level represents the middle of the risk range (10^{-4} to 10^{-6}) typically identified as acceptable by EPA and allows for exposure to multiple carcinogenic BCoCs. To achieve this risk level, tissue BTs for individual BCoCs are set at risk levels of 10^{-6}.

In deriving tissue BTs for non-cancer endpoints, a cumulative hazard index of 1.0 is proposed. In order to not exceed this cumulative level, initial tissue BTs for individual BCoCs will be derived through application of a hazard index of 0.1 for screening. Where multiple BCoCs are present at concentrations greater than the non-cancer tissue BT, site managers may consider additional evaluation to determine whether the BCoCs identified at the site could affect the same target organs at the concentrations present. If this is not the case, it may be appropriate to adjust the resulting BTs to result in a cumulative hazard index of 1.0.

9.8.3.2 Selection of Receptor Population and Endpoint

It is desirable to have a single tissue BT to address all human health considerations. However, the tissue BT will need to be protective of both adults and children consuming fish and shellfish. The tissue BT will also need to be protective of both the carcinogenic and non-carcinogenic effects of BCoCs. Where EPA has both a CSF and an RfD available for a BCoC, the carcinogenic effect will typically provide the lowest risk-based concentration for various reasons, including the assumption that there is no threshold for carcinogenic effects. However, in some contexts, there may be some BCoCs for which the tissue BT calculated based on non-cancer endpoints is lower (more health-protective) than that derived based on the CSF. In addition, depending on the consumption rates assumed for adults and children, the tissue BT for non-carcinogenic effects may be lower for children consuming fish than for adults, particularly at the 10^{-5} cancer risk level. Thus, once the target risk level and the consumption rates are selected for use in deriving tissue BTs, these considerations will need to be evaluated to derive a tissue BT protective of all receptors and endpoints.

9.8.3.3 Exposure Assumptions

As described above, the tissue BTs will be derived to be protective of all populations (e.g., recreational, subsistence, Native American) and endpoints. To meet this objective, fish consumption rates for various populations present in the region will need to be reviewed to determine the most representative rates for adults and children. Because consumption rates are highly variable among various populations, it may be beneficial to derive more than one set of rates depending on the specific situation. Where site-specific consumption rate studies have been conducted, risk managers may determine whether they should be applied on a case-by-case basis.

Although studies of tribal consumption rates have estimated fish and shellfish consumption rates for children, most studies of recreational fish and shellfish consumption have focused on adults only; therefore, some rates may need to be developed based on adults, with some consideration of their likely applicability to children. Because recreational rates are much lower than those identified for subsistence populations and because not all sites are locations for subsistence fishing, it may be appropriate to calculate separate tissue BTs for recreational and subsistence populations and determine on a site-by-site basis which is most appropriate as the basis for a tissue BT.

An additional area for consideration is the fraction of seafood harvest that may be affected by site-specific contamination. Issues that may be considered include resource sustainability, site area, overall harvest area, fidelity of site use, the role multiple smaller site remediation/disposal actions may have on larger systems, and policy regarding acceptable risks associated with resource use independent of location. It is proposed that the generic tissue BTs be initially developed based on a default fractional intake of 100 percent followed by potential evaluation of alternate fractional intakes based on the aforementioned factors.

Some cooking methods change the concentrations of some BCoCs in fish and shellfish. However, given the variability in cooking methods applied by various populations in the region, cooking loss factors are not proposed for the generic tissue BTs.

9.8.3.4 Bioaccumulation Triggers for Compounds with Common Toxic Mechanisms

Tissue contaminant concentrations that trigger sediment bioaccumulation testing are usually computed for individual compounds. However, deriving BTs on a compound by compound basis is not always appropriate when compounds of similar chemical structure and a common toxicity mechanism are present. In such cases, BTs may be developed on a chemical class basis. Chlorinated dioxins/furans and polychlorinated biphenyls (CDFBs) and carcinogenic polycyclic aromatic hydrocarbons (cPAHs) are chemical classes recommended to calculate BTs at the group level.

Using a toxic equivalency approach to determine exceedance of a BT for CDFBs. The toxicity of CDFBs as a group may be assessed using a toxic equivalency approach. Each compound within the CDFB group is assigned a toxic equivalency factor (TEF) describing the toxicity of that CDFB relative to the toxicity of a reference compound, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). A CDFB that is equal in toxicity to TCDD would have a TEF of 1.0. A compound that is half as toxic as TCDD would have a TEF of 0.5, and so on. Multiplying the tissue concentration of a CDFB by its TEF produces the tissue concentration of TCDD that is equivalent in toxicity (TEQ) to the CDFB concentration of concern. Computing the TEQ for each CDFB in a tissue sample followed by summing all TEQ values permits expression of all CDFB concentrations in terms of a total TCDD toxic equivalent tissue concentration (i.e., total tissue TCDD TEQ).

$$\text{Total tissue TCDD TEQ} = \sum_{n=1}^{k} C_n \text{ x } \text{TEF}_n$$

If the total tissue TCDD TEQ exceeds the BT for TCDD, sediment bioaccumulation testing is warranted.

There have been several efforts to develop TCDD TEFs for dioxin/furans and PCBs having TCDD like toxicity (EPA 2000b). The most recent effort occurred at an expert meeting organized by the World Health Organization (WHO) in 1997 (Van den Berg et al. 1998). The WHO effort examined a number of lines of evidence to develop a consensus based list of TEFs. The results of the 1997 WHO effort have been incorporated into EPA's draft dioxin reassessment (EPA 2000b). Table 9-2 provides the WHO 1997 TEFs for dioxins and furans. Table 9-3 provides the WHO 1997 TEFs for PCBs.

Using a relative potency approach to determine exceedance of a BT for cPAHs.
Unlike CDFBs, many of which are resistant to metabolism by aquatic biota, cPAHs may be metabolized by aquatic biota to compounds that do not pose human health risks (Varanasi et al. 1989). It is important to note that the toxicity of cPAH compounds is still very much an area of active research. Another issue is that current analytical methods may not be capable of detecting cPAH concentrations of concern. The ability of different biota classes (e.g., fish, crustaceans, and mollusks) to metabolize cPAHs is variable (James 1989). Fish are generally thought to efficiently metabolize cPAHs (Varanasi et al. 1989). In contrast, mollusks metabolize cPAHs to a low or negligible extent (James 1989). The need for assessing risks posed by cPAHs as a group is of particular concern in dredging situations affecting shellfish resources.

The toxicity of multiple cPAHs may be evaluated using the relative potency approach. This approach involves comparison of the cancer causing ability of a particular cPAH to a reference compound, benzo[a]pyrene (BaP), by means of a relative potency factor (RPF). A cPAH with an RPF of 1.0 would be as effective as BaP in inducing cancer. A cPAH with an RPF of 0.5 would be half as effective as BaP in inducing cancer, and so on. Multiplying the concentration of a cPAH by its RPF produces the concentration of BaP having equivalent cancer inducing ability (BaP Eq) to the cPAH concentration in question. By computing the BaP Eq for every cPAH in a tissue sample and then summing all BaP Eqs, the concentrations of all cPAHs in the tissue sample may be expressed in terms of a total BaP Eq concentration.

$$\text{Total tissue BAP Eq} = \sum_{n=1}^{k} C_n \text{ x } \mathrm{RPF}_n$$

If the total tissue BaP Eq exceeds the BT for BaP, sediment bioaccumulation testing is warranted.

Table 9-2. WHO 1997 TEFs for dioxins and furans

Compound	TEF
Polychlorinated dibenzodioxins	
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-HxCDD	0.1
1,2,3,7,8,9-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1,2,3,4,6,7,8-HpCDD	0.01
1,2,3,4,6,7,8,9-OCDD	0.0001
Polychlorinated dibenzofurans	
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.05
2,3,4,7,8-PeCDF	0.5
1,2,3,4,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-HpCDF	0.01
1,2,3,4,6,7,8,9-OCDF	0.0001

Table 9-3. WHO 1997 TEFs for PCBs

IUPAC #	Compound	TEF
77	3,3’,4,4’-TCB	0.0001
81	3,4,4’,5-TCB	0.0001
105	2,3,3’,4,4’-PeCB	0.0001
114	2,3,4,4’,5-PeCB	0.0005
118	2,3’,4,4’,5-PeCB	0.0001
123	2’,3,4,4’,5-PeCB	0.0001
126	3,3’,4,4’,5-PeCB	0.1
156	2,3,3’,4,4’,5-HxCB	0.0005
157	2,3,3’,4,4’,5’-HxCB	0.0005
167	2,3’,4,4’,5,5’-HxCB	0.00001
169	3,3’,4,4’,5,5’-HxCB	0.01
189	2,3,3’,4,4’,5,5’-HpCB	0.0001

Abbreviations: T-tetra, Pe-penta, Hx-hexa, Hp-hepta, O-Octa, DD-dibenzodioxin, DF-dibenzofuran, CB-chlorobiphenyl, IUPAC-International Union of Pure and Applied Chemistry

RPFs have been developed by EPA for seven cPAHs (EPA 1993b). These RPFs are based on the ability of cPAHs to induce mouse skin tumors. Table 9-4 provides the RPFs for these compounds.

Consensus on cPAH RPF values is not as great as the consensus reached on human CDFB TEFs. The California EPA Office of Environmental Health Hazard Assessment has prepared a list of cPAH RPFs (California EPA 1999) to support air toxics risk assessment that is much more extensive than EPA's list. The RPF development approach used by California EPA considers a wider range of endpoints and datasets than EPA. Further discussion on the source and values for RPFs should be considered for subsequent drafts of this SEF.

Table 9-4. EPA RPFs for cPAH

Compound	**TEF**
Benzo[a]pyrene	1.0
Benz[a]anthracene	0.1
Benzo[b]fluoranthene	0.1
Benzo[k]fluoranthene	0.01
Chrysene	0.001
Dibenz[a,h]anthracene	1.0
Indeno[1,2,3-cd]pyrene	0.1

9.9 SEDIMENT BIOACCUMULATION TRIGGERS

[RESERVED]

10. DISPOSAL ALTERNATIVES EVALUATION

10.1 INTRODUCTION

In previous chapters we discussed the need for a CSM and appropriate sampling and analysis procedures to enable sound management decisions. This chapter discusses the need for disposal site identification to further focus data collection and evaluation to ensure the characterization is adequate to meet disposal objectives. This chapter is not intended to evaluate disposal options or make engineering recommendations, but rather to introduce the user to the potential options and concepts that govern their use. The Corps and EPA have written many guidance documents on disposal and the factors that need to be considered and evaluated to determine the best disposal option. Please refer to the Dredging Operations and Technical Support Program (DOTS) (http://el.erdc.usace.army.mil/dots/) for guidance documents and publications.

Dredging for maintenance of navigational depths, deepening of berthing areas, or removal of contaminated sediments (CSs) is typically conducted in industrial urban areas where a general understanding of the sediment quality is known. While the majority of dredged materials are considered acceptable for a wide range of disposal alternatives, contaminant levels in some sediment have produced concern that dredged material disposal, especially in open waters and wetlands, may adversely affect water quality and aquatic life (Permanent International Association of Navigation Congresses [PIANC] 1990). Determining the appropriate disposal option can be one of the costliest, time-consuming, and controversial aspects of the project. Thus, having at least an initial understanding of the preferred disposal alternative will be valuable during the characterization and permitting process.

Understanding the requirements of the proposed disposal location is an important step to include in the conceptual site model (CSM) because sediment evaluation should always have a clearly defined purpose and objective(s) whether it is for maintenance dredging or CS dredging. To assist in this evaluation, many agencies like the Corps and EPA, and technical subcommittees like PIANC, have developed comprehensive, yet simplified approaches to the identification, development, evaluation, and selection of environmentally and economically preferable alternatives for the handling and treatment of clean sediments and CSs. The following sections summarize the likely alternatives for dredged material disposal, and discuss much of the relevant information needed to assess and develop dredged material disposal alternatives.

10.2 DISPOSAL OPTIONS

The removal, transport, and placement of dredged sediments are the primary components of the "dredging process." In design and implementation of any dredging project, each part of the dredging process must be closely coordinated to ensure a successful dredging operation (EPA/Corps 2004). Planning for maintenance dredging projects involving uncontaminated sediment can be quite different from planning for a remedial dredging project. The main goal of a maintenance dredging project is to remove sediment to the appropriate navigational depth, and most of the planning tends to be directed to meeting this goal. The main goal for CS dredging projects is usually the improvement and protection of the environment, as well as navigation. Therefore, project managers for these projects are often forced to plan for all situations to be discussed with the regulatory and scientific community.

The major disposal options in the Pacific Northwest consist of the following:

- Unconfined Open Water
- Beneficial Use (see Chapter 13 for additional details)
- Confined In-water (Capping)
  - Thin Cap
  - Thick Cap
- Dredging with Confined Disposal
  - Confined Aquatic Disposal
  - Nearshore Fill
- Upland Disposal

Other management options may also exist (e.g., natural recovery), but are not discussed in detail in this document.

10.3 EVALUATION OF DISPOSAL OPTIONS FOR UNCONTAMINATED SEDIMENTS

In 1972, Congress enacted the Marine Protection Research and Sanctuaries Act (MPRSA) (also known as the Ocean Dumping Act) to prohibit the dumping of material into the ocean that would unreasonably degrade or endanger human health or the marine environment. Virtually all material that is ocean dumped today is dredged material (sediments) removed from the bottom of water bodies in order to maintain navigation channels and berthing areas.

Ocean dumping cannot occur unless a permit is issued under MPRSA. In the case of dredged material, the decision to issue a permit is made by the Corps, using EPA's environmental criteria and subject to EPA's concurrence. For all other materials, EPA is the permitting agency. EPA is also responsible for designating recommended ocean dumping sites for all types of materials.

The criteria and procedures for ocean dumping permits for dredged material are covered by EPA's ocean dumping regulations at 40 CFR Parts 220 to 229. These regulations also cover the criteria and procedures for designation and management of ocean dumping sites.

All proposed dredged material disposal activities regulated by the MPRSA and Clean Water Act (CWA) must also comply with the applicable requirements of the National Environmental Policy Act (NEPA) and its implementing regulations. In addition to MPRSA, CWA, and NEPA, a number of other federal laws, Executive Orders, etc., must be considered in evaluation of dredging projects.

The geographical jurisdictions of MPRSA and CWA are indicated in Figure 2-1 in Chapter 2. As shown in Figure 2-1, an overlap of jurisdiction exists within the territorial sea. The precedence of MPRSA or CWA in the area of the territorial sea is defined in 40 CFR 230.2 (b) and 33 CFR 336.0 (b). Material dredged from waters of the United States and disposed in the territorial sea is evaluated under MPRSA. In general, dredged material discharged as fill (e.g., beach nourishment, island creation, or underwater berms) and placed within the territorial sea is evaluated under the CWA.

There are currently estuarine and ocean sites in Grays Harbor and Willapa Bay on the Washington Coast, ocean disposal sites off Coos Bay and the mouth of Columbia River in Oregon, as well Puget Sound Dredged Disposal Analysis (PSDDA) disposal sites in Puget Sound and flow lane disposal sites in the Columbia River. Table 10-1 gives descriptions and coordinates for these sites.

10.4 EVALUATION OF DISPOSAL OPTIONS - CONTAMINATED SEDIMENTS

Identification of reasonable disposal sites for CSs must take into account scientific methods that evaluate multiple criteria, including ecologic, geologic, hydrogeologic, economic, social, and other factors. CSs can be removed by dredging, either through mechanical means (i.e., clamshell) or with suction (i.e., hydraulic cutterhead dredge).

Evaluation of a CS disposal site looks at direct and indirect physical impacts. Direct physical impacts include, but are not limited to, changes in hydrologic and hydrogeological conditions, habitat, and aesthetic conditions. The initial storage capacity must be sufficient

Table 10-1. DMMP: Puget Sound Disposal Site Characteristics

Site	Area (acres)	Depth (feet)	Disposal Zone Diameter (feet)	Target Area Diameter (feet)	Disposal Site Dimensions (feet)	Site Coordinates (NAD83: Lat/Long)	Positioning VTS/DGPS
Anderson Island (nondispersive site)	318	442	1,800 (circle)	1,200 (circle)	4,400 by 3,600 (ellipsoid)	Lat: 47° 09.42’ Long: 122° 39.47’	DGPS
Bellingham Bay (nondispersive site)	260	96	1,800 (circle)	1,200 (circle)	3,800 by 3,800 (circular)	Lat: 48° 42.82’ Long: 122° 33.11’	DGPS
Commencement Bay (nondispersive site)	310	540 to 560	1,800 (circle)	1,200 (circle)	4,600 by 3,800 (ellipsoid)	Lat: 47° 18.21’ Long: 122° 27.91’	VTS
Elliott Bay [1/] (nondispersive site)	415	300 to 360	1,800 (circle)	1,200 (circle)	6,200 by 4,000 (Tear drop shape)	Lat: 47° 35.91’ Long: 122° 21.45’	VTS
Port Gardner (nondispersive site)	318	420	1,800 (circle)	1,200 (circle)	4,200 by 4,200 (circular)	Lat: 47° 58.85’ Long: 122° 16.74’	DGPS
Port Angeles (dispersive site)	884	435	3,000 (circle)	none	7,000 by 7,000 (circular)	Lat: 48° 11.67’ Long: 123° 24.94’	VTS
Port Townsend (dispersive site)	884	361	3,000 (circle)	none	7,000 by 7,000 (circular)	Lat: 48° 13.61’ Long: 122° 59.03’	VTS
Rosario Strait (dispersive site)	650	97 to 142	3,000 (circle)	none	6,000 by 6,000 (circular)	Lat: 48° 30.87’ Long: 122° 43.56’	VTS

Notes: VTS = USCG Vessel Traffic Service; DGPS = Differential Global Positioning System; NAD = North American Datum

[1/] The original disposal site coordinates were shifted 300 feet to the south by the PSDDA agencies in 1991 following disposal site monitoring. The disposal zone was not changed, so the coordinates plotted within the disposal zone will show the target zone center coordinates are off center to the south relative to the disposal zone.

to guarantee both solids retention and discharge of clarified water, complying with discharge standards. If determined beneficial, consolidation measures are implemented to increase the long-term storage capacity.

10.5 CONFINED IN-WATER DISPOSAL (CAPPING)

The principle behind confined in-water disposal (capping) is that when the sediments are capped, the contaminants will no longer be bioavailable or transferred within the environment (Palermo et al. 1998). Capping occurs when the costs of removal are deemed greater than the benefit and navigation depths are not of primary concern.

There are generally two types of caps, including:

- Thin Cap. A thin cap typically occurs in areas with less sediment contamination and consists of clean sands/silts less than 3 feet thick without armoring.
- Thick Cap. A thick cap typically occurs in areas with greater sediment contamination and consists of clean sands/silts greater than 3 feet thick with armoring to protect from scouring.

10.5.1 Capping Benefits

Capping has a positive impact on the long-term quality of ecological functions provided by habitats. Chemical contamination and existing surficial debris that degrade these habitats are isolated from the environment. The loss of existing biota is considered to be an acceptable cost of remediation in areas where the benthos is currently stressed, depauperate, or a pathway for contaminant transfer to higher trophic levels exists. Over time, and coupled with successful source control, the waterways can be expected to constitute much-improved habitat for invertebrates, fish, and birds.

10.5.2 Thin Cap

Thin capping, also known as enhanced natural recovery, is often used where hazards presented by CS to human health and the environment is low. Thin capping improves the chemical or physical properties of the upper riverbed, which constitute the biologically active zone. Thin capping typically has a target thickness of 1 foot or less and is used in low-energy environments. The cap material would be determined during design. The added material supplements natural sedimentation and enhances the natural recovery process, producing variation in the coverage depths and allowing for considerable mixing between the contaminated and clean layers. The result is a riverbed consisting of mounds of clean material and areas where no cap is evident. Enhanced natural recovery has been successfully applied to the West Harbor Operable Unit of the Wycoff/Eagle Harbor Superfund Site located off of Bainbridge Island, Washington.

10.5.3 Thick Cap

Placement of a thick cap placed over a problem area is intended to effectively contain and isolate the CSs from the overlying water column and habitat. In navigational areas where the total thickness of CS is not removed, a thick cap could be placed over the dredged area. The cap needs to be thick enough to resist erosion from mechanical scour, wave action, or burrowing organisms. In addition, the cap needs to be designed to prevent contaminant migration through the cap into the surrounding water body. Minimum cap thickness is developed in the engineering evaluation, but it is typically greater than 3 feet. The most common type of capping material is a dredged sand or upland sand. Placement of a thick cap in areas where it would raise the channel bottom above the required navigational depth would require modification of the navigation channel or limiting the size of ships and vessel traffic.

Evaluation of the potential for scour (e.g., boat scour, tidal or river fluctuations, and erosive outfall discharges) may require the placement of armoring. Armoring typically consists of quarry spalls or light, loose riprap obtained from an upland quarry or pit. A filter material may be required between the cap and armor layers to prevent the armor from sinking into the cap.

10.6 CONFINED AQUATIC DISPOSAL

Confined aquatic disposal (CAD) is defined as placing sediments in an existing subaquatic pit or excavated pit and capping it with a thick cap section. The primary long-term contaminant transport pathway for a CAD is contaminant migration through the cap and re-exposure of contaminants to the marine environment. This can occur through contaminant migration, bioturbation, or cap erosion. Therefore, a CAD may be of limited value in areas where future dredging would disturb the site or where currents and wave climate and physical disturbance by navigation (e.g., anchor-dragging or propeller wash) could impact the cap. The primary design component of a CAD facility is the physical (i.e., thickness and gradation) and chemical quality of the cap, depth and topography of the site, and currents at the site. CADs can generally be built without a net loss of habitat and in some instances a net gain.

10.7 NEARSHORE CONFINED DISPOSAL FACILITY

Nearshore confined disposal facilities (CDFs) typically involve placing the sediments designated for confinement in the shallow subtidal/intertidal environment surrounded by an engineered structure (berm or dike) for containment of dredged material. The confinement dikes or structures in a CDF enclose the disposal area above any adjacent water surface, isolating the dredged material from adjacent waters during placement (Figure 10-1). In this document, confined disposal does not refer to subaqueous capping or CAD.

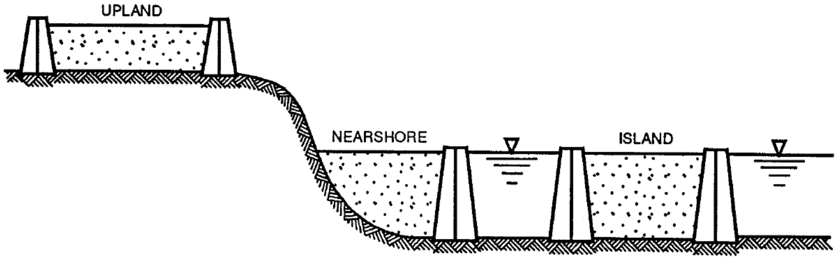

Figure 10-1. Upland, Nearshore, and Island CDFs

CDFs provide an excellent opportunity to confine the dredged material and incorporate development of upland areas to improve berthing areas. Filling a basin with dredged sediment must consider the potential effects on existing structures in the adjacent upland area, because the weight of the fill could cause compression of underlying and immediately adjacent soils. The result could be settlement of the upland ground surface in the vicinity of the filled area. Existing structures in the immediate area that are pile-supported could experience a lesser degree of settlement, primarily resulting from compression that occurs in soils underlying the pile tips, as well as downdrag of compressing soils along the pile sides.

Nearshore CDFs generally result in a net loss of aquatic habitat that may require mitigation. Management options may be needed to meet the requirements of direct physical impacts and CDF site capacity. These options involve dewatering, consolidating, or reducing the size of dredge, or enlarging the site by previous excavation, higher dikes, or larger area. Geotechnical considerations also need to be taken into account if the site is going to be used as a berthing area or shore-side facility.

10.8 UPLAND DISPOSAL

Upland disposal facilities can include either existing municipal landfills (mixed), or on-site monofills that are dedicated solely to the sediment remediation project. For either type of landfill, the sediments would need to be hauled to the site via a truck or hydraulic line with effluent discharge back to the water body, and subsequent dewatering would be required.

10.8.1 Solid Waste Landfills

Existing solid waste landfills are now accepting CSs. These landfills have evaluation methods and standards for acceptance criteria for transport and disposal. Landfill operators should be contacted directly to determine sampling, testing, and reporting requirements. Existing landfills have means and methods to handle the sediments and ameliorate the potential contaminant transport pathways.

10.8.2 Upland Confined Disposal Facilities

Upland CDFs are defined as disposal facilities that are developed on site or adjacent to the dredge location where the project proponent has responsibility for the development and management of the CDF. The main challenge of a newly constructed CDF is to eliminate contaminant transport pathways. Primary pathways for short-term contaminant transport are loss to the water column during transport, rehandling, and dewatering at the upland disposal site. Primary long-term contaminant transports are lost through the containment media (dike material, liners, or ground surface). Upland disposal can be turned into a benefit by filling low spots or capping other more contaminated soils and then sequestering the sediments by placing a permanent cap (e.g. asphalt), thus allowing use of the remediated site.

In Washington, upland disposal facilities need to be designed and constructed in accordance with the Minimum Functional Standards for Solid Waste Handling Washington Administrative Code (WAC) 173-304.

Characteristics used to evaluate upland placement sites include the following:

- Site configuration and access;
- Topography, runoff patterns, and adjacent drainage;
- Groundwater levels, flow, and direction;
- Soil properties; and
- Proximity to ecologically sensitive areas and/or human resources.

10.9 OTHER MANAGEMENT OPTIONS

Natural Recovery. Natural recovery of CS may occur over time through a combination of several processes, including chemical degradation, diffusion from the sediment matrix into the water column, burial of CS under newly deposited clean material, and mixing of the CS with clean sediments above and below through bioturbation. Expected rates for natural recovery are generally within 10 years or less of the sediment remedial action (provided source control is in place). A monitoring program verifies natural recovery.

The suitability for natural recovery is a function of many factors, including the contaminant type, enrichment ratio, sedimentation rate, source inputs, currents, and mudline slope. Natural recovery can be a relatively cost-effective remedial solution for areas in which low to moderate enrichment ratios are predicted to reduce over time to below the defined sediment quality objectives based on modeling. However, in more highly CSs, natural recovery or enhanced natural recovery may not successfully remediate the sediment to below the sediment quality objective within a negotiated time frame, so more active remedial methods need to be considered.

11. SPECIAL EVALUATIONS

11.1 OVERVIEW

Chapters 4 through 10 provide a framework for the assessment and characterization of freshwater and marine sediments for dredging projects and contaminated sediment (CS) investigations. In most cases, the methods and procedures provided will be sufficient to evaluate the potential risk of in-place sediments, as well as the potential environmental effects of dredging and disposal activities. In some cases, however, additional information may be needed above and beyond the standard suite of physical, chemical, and biological tests to make an informed sediment management decision. This chapter briefly describes the types of special evaluations that may be required on a case-by-case basis. Because of their unique and site-specific nature, the design of sampling and analytical procedures for special evaluations will require close coordination with RSET.

The following circumstances, for example, may warrant conducting a special evaluation to resolve ambiguities or uncertainties in the sediment management decision-making process:

- Biological testing results (i.e., bioassay tests, bioaccumulation tests, tissue analyses) are indeterminate;
- Sediments and/or tissues contain chemicals that are likely present in toxic amounts, but for which screening levels or threshold values have not yet been established;
- Sediments and/or tissues contain chemical mixtures that are suspected of causing synergistic or antagonistic effects;
- Sediments and/or tissues contain chemicals for which the biological tests described in Chapters 8 and 9 are inappropriate;
- Additional information is needed regarding potential risks to Endangered Species Act (ESA)-listed species, particularly if spawning areas or highly functional juvenile rearing areas may be impacted by project activities;
- Dredging, disposal, or other in-water construction activities have the potential to cause unacceptable water quality impacts; or
- Site conditions and/or dredging methods could potentially generate significant quantities of contaminated dredging residuals.

If special evaluations are determined necessary by RSET, site-specific tests or evaluations and interpretive criteria will be specified by RSET in coordination with the applicant. Special evaluations may include, but are not limited to, the following:

- Steady-State Bioaccumulation Test (Section 11.2),
- Human Health/ Ecological Risk Assessment (Section 11.3),
- Elutriate Testing (Section 11.4), and
- Evaluation of Dredging Residuals (Section 11.5).

11.2 STEADY-STATE BIOACCUMULATION TEST

In a special evaluation, bioaccumulation testing may be necessary to determine the steady-state concentrations of contaminants in organisms exposed to the dredged material when compared with organisms exposed to the reference material. Testing may be done in the lab or, in rare cases, in the field, as described in Sections 11.2.1 and 11.2.2, respectively. Testing options may include time-sequenced laboratory exposures in excess of the standard 28 days to reach a steady-state concentration. Special evaluations of data collected will follow the interpretation guidance specified in Chapter 9.

11.2.1 Time-Sequenced Laboratory Testing

This test is designed to detect statistically significant differences, if any, between steady-state bioaccumulation in organisms exposed to the dredged sediments and steady-state bioaccumulation in organisms exposed to reference sediments. If organisms are exposed to biologically available contaminants under constant conditions for a sufficient period of time, bioaccumulation will eventually reach a steady-state (equilibrium) in which maximum bioaccumulation has occurred, and the net exchange of contaminant between the sediment and organism is zero.

The necessary species, apparatus, and test conditions for laboratory testing are similar to those utilized for the Level 2 bioaccumulation test. Discussions should occur between the project proponent and RSET or appropriate agencies to determine an appropriate study design based on the constituents of interest. For example, potential study designs could include running the test over a longer time period than 28 days. Additionally, tissue subsamples taken from separate containers during the exposure period can be collected to provide the basis for determining the rate of uptake and elimination of contaminants. From these rate data, the steady-state concentrations of contaminants in the tissues can be calculated.

11.2.2 Field Assessment of Steady-State Bioaccumulation

Measuring concentrations in field-collected organisms may be considered as an alternative to laboratory exposures. A field sampling program designed to compare project site and reference tissue levels provides an indication of whether contaminants at the project site are contributing to bioaccumulation in excess of ambient conditions in the watershed. The appropriate selection of species to target for field collection is an important component of study design. Life history parameters such as trophic status, feeding guilds, habitat preferences, and foraging ranges should be considered and discussed with RSET and/or appropriate agencies prior to conducting such a field program to ensure consistency with project objectives.

This assessment involves measurements of tissue concentrations from individuals of the same species collected within the boundaries of the project site and a suitable reference site. A determination is made based on a statistical comparison of the magnitude of contaminant tissue levels in organisms collected within the boundaries of the reference site with organisms living within the project site. However, collecting a sufficient number of individuals of the same species, size range, and age at both the reference site and the project site can make this type of assessment difficult. Temporal and spatial trends in bioaccumulation can violate steady-state assumptions and further confound data interpretation. For these reasons, steady-state bioaccumulation tests are generally performed in the laboratory. Nevertheless, field measurements of tissue burdens are often a critical part of the weight of evidence in a bioaccumulation assessment and can be designed to address specific questions required for regulatory decision-making (see Chapter 9).

11.3 HUMAN HEALTH/ECOLOGICAL RISK ASSESSMENT

When deemed appropriate by RSET, a human health and/or ecological risk assessment may be required to evaluate a particular chemical of concern (CoC), such as dioxin, mercury, PCBs, etc. National guidance on chemicals such as dioxin is subject to rapid changes as new information becomes available. Project-specific risks to human health or ecological health should be evaluated using the best available current technical information and risk assessment models.

A risk assessment must be developed on a case-specific basis and be formulated with all interested parties participating. If a risk assessment is the method of choice for a special evaluation, either as a stand alone task or in conjunction with bioassay tests and/or tissue analysis, it must be accomplished with RSET and all parties actively participating.

11.3.1 Oregon State Risk Assessment Guidance

The state of Oregon's cleanup law emphasizes risk-based decision-making. State statute and rules require that human health and ecological risk be given equal consideration. ODEQ oversees cleanup of contaminated sites, including those involving sediments via a process that parallels the EPA Superfund process. A remedial investigation, risk assessment, and feasibility study are completed to provide the basis for selecting a remedy. Oregon has specific rules defining acceptable risk, which can be found at OAR340-122-0115.

ODEQ has developed an ecological risk assessment process that utilizes a multi-level approach. The multi-level approach, with review at each major decision point, is intended to facilitate more efficient use of resources, which ensures necessary work is done and risk managers receive information sufficient to support effective remedial action decisions. Components of the Guidance for Ecological Risk Assessment can be downloaded by visiting the following web site: http://www.deq.state.or.us/wmc/cleanup/ecocover.htm.

For human health risk assessments, both statute and rules provide the option of performing either a deterministic risk assessment or a probabilistic risk assessment. ODEQ has developed a guidance document for each of these options. Copies of ODEQ's Human Health Risk Assessment Guidance Documents can be downloaded by visiting the following web site: http://www.deq.state.or.us/wmc/cleanup/hh-intro.htm.

11.3.2 Washington State Risk Assessment Guidance

The state of Washington has adopted Sediment Management Standards (SMSs) as Chapter 173-204 WAC. SMSs were promulgated for the purpose of reducing and ultimately eliminating adverse effects on biological resources and significant health threats to humans from surface sediment contamination. They apply to marine, low salinity, and freshwater surface sediments within the state of Washington, and can be found at the following web site: http://www.ecy.wa.gov/biblio/wac173204.html.

Copies of Ecology's Human Health Risk Assessment Guidance Documents as Chapter 173-340 WAC under MTCA can be downloaded by visiting the following web site: http://www.ecy.wa.gov/biblio/9406.html.

11.3.3 Idaho State Risk Assessment Guidance

The IDEQ Risk Evaluation Manual (REM) presents a roadmap for evaluating risk, from discovery through clean up. This manual presents a description of the steps in the risk evaluation process and general information related to the data requirements and implementation of the risk evaluation process. It is a manual to determine whether groundwater, surface water, or soil at a particular location is contaminated to the extent it poses a human health risk. It will help evaluate whether an investigation or cleanup is needed and, if so, what its scope and nature should be. This manual provides a consistent method for addressing contamination.

Copies of the IDEQs REM can be downloaded by visiting the following web site: http://www.deq.idaho.gov/Applications/Brownfields/index.cfm?site=risk.htm.

11.3.4 Additional Existing Risk Assessment Guidance

EPA (U.S. Environmental Protection Agency). 1998. Guidelines for Ecological Risk Assessment. USEPA EPA/630/R095/002F 01 April 1998. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC, 175 pp. Available at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=12460.

EPA. 1989. Risk Assessment Guidance for Superfund, Volume 1 – Human Health Evaluation Manual, Part A, Interim Final. EPA/540/1-89/0002. Publication 9285.7-01A. Office of Emergency and Remedial Response, Washington, D.C. Available at: http://www.epa.gov/superfund/programs/risk/tooltrad.htm#gdec.

EPA. 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (interim final). Environmental Response Team, Edison, NJ. Available at: http://www.epa.gov/superfund/programs/risk/tooltrad.htm#gdec.

U.S. Army Corps of Engineers. 1999. Risk Assessment Handbook Volume I: Human Health Evaluation. EM 200-1-4. Available at: http://www.usace.army.mil/inet/usace-docs/engmanuals/em200-1-4/toc.htm.

U.S. Army Corps of Engineers. 1996. Risk Assessment Handbook Volume II: Environmental Evaluation. EM 200-1-4. Available at: http://www.usace.army.mil/inet/usacedocs/eng-manuals/em200-1-4vol2/.

Cura, J.J., Heiger-Bernays, W., Bridges, T.S., and D.W. Moore. 1999. Ecological and Human Health Risk Assessment Guidance for Aquatic Environments. Technical Report DOER-4, US Army Corps of Engineers, Engineer Research and Development Center, Dredging Operations and Environmental Research. Available at: http://el.erdc.usace.army.mil/dots/doer/pdf/trdoer4.pdf.

11.4 ELUTRIATE TESTING

Water quality effects caused by the introduction of sediment and sediment-associated contaminants into the water column must be considered at the point(s) of dredging and point(s) of disposal, as applicable. Laboratory elutriate tests, designed by the Corps' Waterways Experiment Station (see below), are used to predict water quality effects during dredging and disposal activities, particularly when CSs are being disturbed as part of the proposed activities.

Water column effects caused by dredging and related in-water construction activities (e.g., capping, disposal) are intermittent, discontinuous, and relatively short-lived. Therefore, water column effects associated with these activities, and simulated by elutriate tests, do not pose a long-term bioaccumulation concern (EPA/Corps 1998c). Dredging residuals, on the other hand, may contribute to long-term bioaccumulation risk if CSs are resuspended during dredging and redeposited on the surface of the project area where they may continue to be exposed to the aquatic community after the construction work is completed. Dredging residuals are discussed in Section 11.5.

Elutriate testing will generally be required for those chemicals that exceed SL2 guidelines in bulk sediment (see Section 7.8). Regional program experience, primarily at Superfund sites in which elutriate testing has been performed over a wide range of contaminant concentrations (e.g., Commencement Bay, Duwamish Waterway, Portland Harbor, and others), has shown that water quality effects are unlikely to occur at either the dredging or disposal sites if bulk sediment concentrations are below these criteria (or alternatively, below bulk sediment biological effects criteria; see Chapter 8).

Several types of elutriate tests are available to assess water quality effects, including:

- Dredging Elutriate Test (DRET) to assess water quality effects at the point of dredging (Di Giano et al. 1995),
- Standard Elutriate Test (SET) to assess open-water disposal of dredged material (EPA/Corps 1977),
- Modified Elutriate Test (MET) and Column Settling Test (CST) to assess discharges from a confined dredged material disposal facility (Palermo 1986, Palermo and Thackston 1988).

These tests are described in more detail in the Inland Testing Manual (EPA/Corps 1998c) and Upland Testing Manual (EPA/Corps 2003).

11.4.1 Mixing Zones

The guidelines at 40 CFR 230.10(b) state in part that “No discharge of dredged or fill material shall be permitted if it: (1) causes or contributes, after consideration of disposal site dilution and dispersion, to violations of any applicable State water quality standard.” This requirement applies at the edge of a state designated mixing zone (EPA/Corps 1998c).

Elutriate test results are intended to simulate water quality conditions at the point of discharge. For water quality CoCs, hydrodynamic modeling may be needed to characterize the degree of dilution and dispersion that occurs between the point of discharge and the mixing zone boundary, per the guidelines at 40 CFR 230.10(b).

Hydrodynamic modeling results are typically expressed in terms of a dilution factor, which describes the reduction in water column concentration that occurs during transport through the mixing zone. The ADDAMS modeling system (Automated Dredging and Disposal Alternatives Modeling System, Schroeder et al. 2004, www.wes.army.mil/el/elmodels), developed by the Corps’ Waterways Experiment Station, includes several computer modules to assist in the design and evaluation of dredging and disposal operations. In particular, the program modules DREDGE (Hayes and Je 2000) and STFATE (EPA/Corps 1998c, Appendix C) predict water quality effects associated with dredging and open-water disposal operations, respectively. Standard dilution models such as PLUMES (Frick et al. 2001) and CORMIX (Jirka et al. 1997) may be used to evaluate mixing and dilution of point-source discharges (e.g., outfalls conveying dredging elutriate return flows from upland or nearshore confined disposal facilities).

11.4.2 Receiving Water Impacts

The elutriate testing and hydrodynamic modeling results are used to estimate water column concentrations in the receiving water at the appropriate point of compliance, typically the authorized mixing zone boundary as specified in the Section 401 Water Quality Certification for the project. The estimated water column concentrations are compared to water quality standards or criteria that are based on exposure durations consistent with the duration of the construction activity. Because dredging and related in-water construction activities (e.g., capping, disposal) are intermittent and discontinuous in time and space, acute water quality criteria are generally considered appropriate for such evaluations (EPA/Corps 1998c). The agency responsible for issuing the Section 401 Water Quality Certification will establish the specific water quality standards and criteria that will be used to regulate the project.

If there is sufficient reason to believe based on bulk sediment enrichments that elutriate testing should be conducted on constituents that do not have state promulgated or nationally recommended water quality criteria, RSET will use best professional judgment to determine appropriate criteria to use in evaluating potential water quality effects. This may include consideration of standards or criteria in use in other EPA regions, states, or in the peer-reviewed scientific literature.

11.4.3 Elutriate Bioassay Tests

If water quality criteria are predicted to be exceeded at the mixing zone boundary based on elutriate test chemistry and predicted mixing zone dilution and dispersion, the project proponent may elect to perform serial-dilution bioassay tests on the elutriate water, as specified in the Inland Testing Manual (EPA/Corps 1998c, Sections 6.1 and 11.1). Such tests are designed to provide a more site-specific measurement of water column toxicity and contaminant bioavailability. If the receiving water of concern is freshwater and contains salmonid species, rainbow trout (*Oncorhynchus mykiss*) should be included as one of the test species for elutriate bioassay testing whenever possible.

If, after allowance for mixing, the predicted water column concentration does not exceed 0.01 of the toxic (LC_{50} or EC_{50}) concentration as determined from the elutriate bioassay tests, the dredged material is predicted not to be acutely toxic to aquatic organisms.

11.4.4 Contingency Water Quality Controls

If unacceptable toxic effects are predicted to occur outside the authorized mixing zone, the project proponent must consult with RSET to determine what additional controls or best management practices (BMPs) should be implemented to alleviate contaminant releases to the water column. These controls may include, but are not limited to, the following:

- Deployment of silt curtains, adsorbent booms, or other physical containment devices;
- Modification of operational procedures or equipment to minimize contaminant releases to the water column (e.g., use of environmental dredge buckets, slower dredging rates, etc.);
- Restriction of in-water construction activities to periods when more favorable mixing and dilution can be achieved; and
- Specifying a more rigorous water quality monitoring program during construction, potentially including “early warning” stations, contingency plans, and adaptive management of construction operations to anticipate and avoid the development of unacceptable water quality excursions.

11.5 EVALUATION OF DREDGING RESIDUALS

Dredging operations inevitably leave behind some residual contamination in the dredged area as well as in adjacent areas through dispersion and transport of the dredged sediments (EPA 2005). There are two distinct types of dredging residuals: (1) leftover CS below the dredge cutline that was never removed, and (2) sediment disturbed or resuspended during dredging that settles back to the sediment bed. The first type of undisturbed residual contamination, sometimes called "undredged inventory," may be minimized during the site characterization and remedial design process by developing an accurate conceptual site model (CSM) supported by adequate sampling density that describes the nature and extent of contamination, and faithfully captures the details of the contaminant distribution during the development of the engineered dredge plan. This section is focused on the second type of dredging residuals, sometimes called "generated dredge residuals," that may require adaptive management during and following the dredging action if accumulated residuals are found to contribute unacceptably to ongoing site risk.

A variety of processes contribute to generated dredge residuals, including:

- Sediment dislodged by the dredgehead that falls back to the bottom, such as sediment that falls from an overfilled bucket or from the outside of the bucket;
- Sediment resuspended during dredging that settles back to the bottom near the point of dredging or in down-current areas;
- Sediment that sloughs into the dredge cut from adjacent areas; and
- Sediment that spills back to the water during handling and transport (e.g., during barge filling or shore-to-land transfer).

A number of site-specific factors can affect the thickness and concentration of generated dredge residuals, including:

- Thickness and contaminant profile of the dredge prism;
- Dredging equipment and operations (i.e., type of bucket or cutterhead, production rate, lift thickness, sequencing, etc.);
- Local hydrodynamics (e.g. currents, tides);
- Steepness of dredge cuts and proximity to side slopes;
- Nature of underlying material, and feasibility of overdredging into less CS; and
- Extent of debris and obstructions.

Although not strictly “dredging” residuals, it should be noted that residual deposits of CSs can also be generated at certain types of disposal sites. When placing sediments through the water column into a confined aquatic disposal site, for example, care must be taken to minimize sediment waves, resuspension, and spillage during transport. Otherwise, residuals of CSs may be dispersed outside the disposal site boundaries.

11.5.1 Predicting Dredging Residuals

Responding to sediment contamination due to dredging residuals can cause unforeseen impacts to project schedules and budgets if the project design does not adequately anticipate and plan for the possibility of residuals. Currently, there is no commonly accepted method to accurately predict dredging residual concentrations, but research in this area is ongoing (Steering Committee for Dredging Resuspension, Release, Residual, and Risk 2006). Recent work by several groups has been focused on developing consistent assessment methods for use over a range of project conditions in efforts to develop a residuals management decision framework. Although there remains a need for additional post-construction monitoring data focused on characterizing residuals, a review of the growing database of empirical measurements collected over the last decade, including several projects in the Pacific Northwest, has allowed some generalizations to be made. Further data collection and evaluation is being performed by a number of parties at environmental dredging sites across the United States to improve our understanding of dredging residuals as well as our predictive capabilities.

Review of data from several environmental dredging case studies (including sites in Commencement Bay, Duwamish Waterway, and other sites throughout the country) indicate that contaminant concentrations in residuals are similar to the depth-averaged contaminant concentrations in the overlying dredge prism (Patmont and Palermo 2006). The empirical data from pilot and full-scale environmental dredging projects also suggest that the mass of generated residuals (both total solids and contaminants) remaining after completion of dredging has ranged from about 2 to 9 percent of the total mass in the dredge prism, averaging about 5 percent of the dredge prism mass (Patmont and Palermo 2006). However, total residuals (i.e., including undisturbed and generated fractions) have been measured up to 20 percent at sites with problematic field conditions. The available data suggest that site factors such as the presence of debris, hardpan/bedrock, and relatively high water content sediments (an inherent characteristic of generated residuals, and thus a concern for second-pass dredging) all contribute to increases in dredging residuals. To date, these existing case studies have not shown pronounced differences in levels of generated residuals between hydraulic and mechanical dredging methods.

Currently, mass balance calculations have been used to provide estimates of the thickness and concentration of generated residuals, considering the range of empirically determined mass release rates (averaging 5 percent, see above). Such calculations may need to account for changes in sediment density (i.e., generated residuals are low-density, high water content). In some cases, however, residuals may consolidate to near in situ sediment density values within days or weeks.

11.5.2 Post-Dredge Confirmation Sampling and Response Actions

The nature and extent of dredging residuals may be delineated using a post-dredge confirmation sampling program. Post-dredge confirmation sampling is routinely performed at sediment cleanup sites, and may also be required for some navigation dredging projects where thick sequences of CSs are being removed. Typically grab samples are collected and analyzed for CoCs at the newly exposed sediment surface. In some cases, however, short core samples may be needed to distinguish residuals caused by leftover undredged inventory from generated residuals caused by disturbance and resuspension of sediments during dredging.

The nature and thickness of the residuals will influence the selection of an appropriate response action if a response action is warranted. If residuals are found to contribute unacceptably to ongoing site risk, the following response actions may be considered (Steering Committee for Dredging Resuspension, Release, Residual, and Risk 2006, Patmont and Palermo 2006):

- Natural recovery, in areas with relatively thin and/or low-risk residual concentrations;
- Thin covers or engineered caps, in areas where water depths can accommodate additional shoaling (i.e., where navigation, habitat, or other depth-dependent uses will not be impacted), and/or where additional dredging is impracticable or ineffective; and
- Additional dredging passes in areas with thicker and higher concentration residuals where significant additional mass removal may be effectively accomplished.

In summary, dredging residuals are a reality of dredging technology. They should be anticipated and planned for during remedial alternative selection, design, and construction.

12. DATA SUBMITTALS

12.1 OVERVIEW

The multi-state sediment quality database in the Pacific Northwest is the Environmental Information Management (EIM) database managed by Ecology. It is a sediment quality management and analysis database that stores physical, chemical, and biological data, and has statistical and special tools for analyzing the data. The database contains both aquatic and upland data and has additional features for upland environmental cleanup projects. The merger of the former sediment quality (SEDQUAL) database with the EIM database will improve functionality and database maintenance. User agencies will still be responsible for the quality of the data in EIM and are recommended to review the transferred data fields from the former SEDQUAL database. Because of its multi-state applications and analytical tools, EIM was adopted as the official database for the SEF.

EIM is a web-based program. Data will be uploaded directly to the database using the web-based user interface. Data downloads or queries are also accomplished using the web-based users interface. Ecology warns there is a limitation of the physical size of the data query due to capacity of the servers. Special studies requiring extensive data studies should be requested via email at eim data coordinator@ecy.wa.gov or by telephone at (360) 407-6258.

Data obtained from a qualified sampling and testing effort should be submitted to RSET covering the following categories of information:

- A sediment characterization report, which includes the items listed below in Section 12.2. The report will be scanned or the file added to this SEF web site or a linked web site so that the data will be available publicly. The preferred method of sediment quality report publication is in digital Adobe® PDF (portable document format). CDs of the reports should be available on request, or downloaded from the author's agency's web site.
- QA1 and QA2 reports are preferred to be submitted to the regulating agencies on one or two CD disks.
- Other documents are extremely useful as part of the data submittal. These include, but are not limited to, the following:
  1. Sampling and Analysis Plans (SAPs),
  2. Habitat Protection Plans,

3. Clean Water Act (CWA) Section 404(b)1 evaluations, and
4. Contractor reports with QA data included.

12.2 SEDIMENT CHARACTERIZATION REPORT

The preferred format for the sediment characterization report is the standard 5 section scientific report. A good example is found in the following book:

> Ambrose, H.W, and Amborse, K.P. 1987. A Handbook of Biological Investigation, Fourth Edition, Hunter Books, Winston-Salem, North Carolina.

The sediment characterization report should include the following items:

- QA report documenting deviations from the SAP and the effects of QA deviations on the testing results;
- A plan view showing the actual sampling locations;
- The sampling coordinates in latitude and longitude, including the projection standard, units, and datum used;
- Methods used to locate the sampling positions within an accuracy of 2 meters;
- The compositing scheme;
- The type of sampling equipment used, the protocols used during sampling and compositing, and an explanation of any deviations from the sampling plan;
- Sampling logs with sediment descriptions;
- Chain-of-custody procedures used;
- An explanation of any deviations from the sampling plan;
- Chemical and biological testing results, including QA data (Chemical testing results shall be presented in the same order as the list of chemicals of concern (CoCs) presented in Table 7-1); and
- Explanation of any deviations from the analysis plan.

12.3 QUALITY ASSURANCE DATA REPORT

The term “quality assurance” describes the system of activities intended to provide evidence to the producer or user of a product or service that it meets predefined standards of quality with a stated level of confidence (Taylor 1987). To facilitate timely decision-making, the “Data Completeness” (QA1) must be submitted with the sediment evaluation report. Section 12.5 provides a QA1 Data Checklist to ensure data completeness.

Additional QA data are needed to fully validate the chemical and biological testing data. These data are used in the data quality comparison, and are referred to as “QA2.” These include such information as chromatograms, calibration curves, etc. Requirements for QA2 data have also been compiled are in Section 12.6.

The QA2 data may be submitted up to 3 months following sampling, and should be sent directly to Ecology with a copy of the transmittal letter provided to the DMMO.

12.4 INFORMATION ABOUT EIM

EIM is a web-based program available to interface from the Ecology web site at http://www.ecy.wa.gov/eim/. Users will need to establish an account and use the import module located at https://fortress.wa.gov/ecy/eimimport/submit.htm. Users will need to access the data using the Microsoft© Internet Explorer 6.0 or above. Other browser clients or versions will be supported by the EIM import module. Users are encouraged to download the EIM submittal guidelines manual and the EIM data dictionary.

12.5 FIELD DATA COLLECTION QUALITY ASSURANCE/QUALITY CONTROL

Chapter 6 provides the minimum sampling protocols. The sampling process is but one component to the overall program of obtaining quality data. Collecting a representative sample can be difficult, but it is the most crucial in the process of obtaining valid data (ODEQ 1997). Proper planning and development of data quality objectives (DQOs) (EPA 2006) are an integral component to obtaining quality field data (see Figure 12-1) (EPA 2000c). During this process, specific quality acceptance criteria should be documented. Data packages, QA/QC reports, and the sediment quality report should contain evaluations of the field DQOs to provide a full picture of QA. Special attention should be paid towards study error control (EPA 2006).

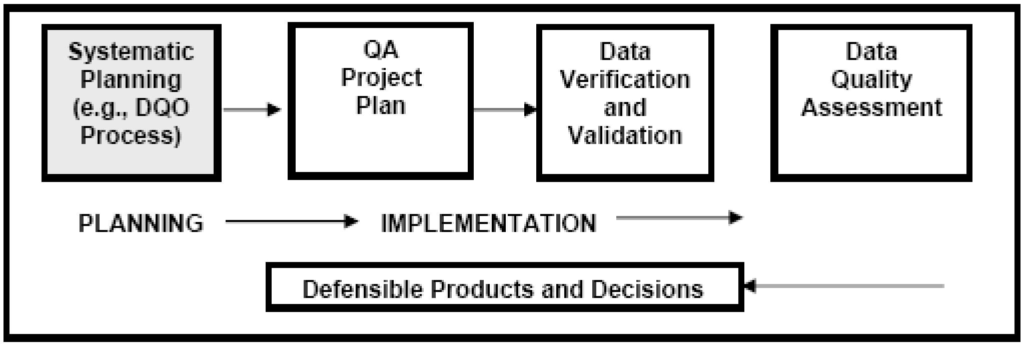

Figure 12-1. Project Life Cycle Components

12.6 QA1 DATA REPORT CHECKLIST

The following checklist can be used to ensure the data to be submitted are complete.

	Test Sediment	Reference Sediment	Control Sediment	Water Control
Sample Locations and Compositing				
Latitude and Longitude (to nearest 0.1 second)	✓		✓	✓
NAD 1983 HARN (requirement for SEDQUAL)	✓		✓	✓
Station name (e.g. Carr Inlet)	✓	✓	✓	✓
Water depth (corrected to MLLW)	✓	✓		
Drawing showing sampling locations and ID numbers	✓	✓	✓	✓
Compositing scheme (sampling locations/depths for composites)	✓	✓	✓	✓
Sampling method	✓		✓	✓
Sampling dates	✓			
Estimated volume of dredged material represented by each DMMU		✓	✓	✓
Positioning method	✓		✓	✓
Sediment Conventionals				
Preparation and analysis methods	✓		✓	✓
Sediment conventional data and QA/QC qualifiers	✓		✓	✓
QA qualifier code definitions	✓		✓	✓
Units (dry weight except total solids)	✓		✓	✓
Method blank data (sulfides, ammonia, TOC)	✓	✓	✓	✓
Method blank units (dry weight)	✓	✓	✓	✓
Analysis dates (sediment conventionals, blanks, TOC CRM)	✓	✓	✓	✓
TOC CRM ID	✓	✓	✓	✓
TOC CRM analysis data	✓	✓	✓	✓
TOC CRM target values	✓	✓	✓	✓
Grain Size Analysis				
Fine grain analysis method			✓	✓
Analysis dates			✓	✓
Triplicate for each batch		✓	✓	✓
Grain size data (complete sieve and phi size distribution)			✓	✓

Note: Shaded boxes indicate those type of data are not applicable for that column.

Figure 12-2. QA1 Data Checklist for Locations, Physical, and Conventional Analyses

Chemicals of Concern Analysis Data				
	Metals	**Semivol.**	**Pest./PCBs**	**Volatiles**
Extraction/digestion method				✓
Extraction/digestion dates (test sediment, blanks, matrix spike, reference material)	✓	✓	✓	✓
Analysis method	✓	✓	✓	✓
Data and QA qualifier included for:	✓	✓	✓	✓
Test sediments				
Reference materials including 95% confidence interval (each batch)				✓
Method blanks (each batch)				
Matrix spikes (each batch)				
Matrix spike added (dry weight basis)				
Replicates (each batch)				
Units (dry weight)	✓	✓	✓	✓
Method blank units (dry weight)	✓	✓	✓	✓
QA/QC qualifier definitions				
Surrogate recovery for test sediment, blank, matrix spike, ref. material	✓			
Analysis dates (test sediment, blanks, matrix spike, reference material)				

Note: Shaded boxes indicate those type of data are not applicable for that column.

Figure 12-3. QA1 Data Checklist for Chemicals of Concern

These tables are the minimum requirements in the sediment quality report as required by the QA-1 data system. This checklist is to be used as a guide. For a complete explanation of the requirements to attain QA-1 level data, the user should consult the requirements in the PSDDA Guidance Manual. The reference is as follows:

> PTI Environmental Services. 1989a. Puget Sound Dredged Disposal Analysis Guidance Manual: Data Quality Evaluation of Proposed Material Disposal Projects (QA-1). Prepared for Department of Ecology Sediment Management Unit, Contract C0089018, Olympia, Washington.

12.7 QA2 DATA REPORT CHECKLIST

These tables are the minimum requirements in the sediment quality report as required by the QA-2 data system. This checklist is to be used as a guide. For a complete explanation of the requirements to attain QA-2 level data, the user shall consult the requirements in the following reference:

> PTI Environmental Services. 1989b. Puget Sound Dredged Disposal Analysis Guidance Manual: Data Quality Evaluation of Proposed Material Disposal Projects (QA-2). Prepared for Department of Ecology Sediment Management Unit, Contract C0089018, Olympia, Washington.

	Test Sediment	**Reference Sediment**	**Control Sediment**	**Water Control**
Sample Locations and Compositing				
Latitude and Longitude (to nearest 0.1 second)	✓		✓	✓
NAD 1983 HARN (requirement for SEDQUAL)	✓		✓	✓
Station name (e.g., Carr Inlet)	✓	✓	✓	✓
Water depth (corrected to MLLW)	✓	✓		
Drawing showing sampling locations and ID numbers	✓	✓	✓	✓
Compositing scheme (sampling locations/depths for composites)	✓	✓	✓	✓
Sampling method	✓		✓	✓
Sampling dates	✓			
Estimated volume of dredged material represented by each DMMU	✓	✓	✓	✓
Positioning method	✓		✓	✓
Sediment Conventionals				
Preparation and analysis methods	✓		✓	✓
Sediment conventional data and QA/QC qualifiers	✓		✓	✓
QA qualifier code definitions	✓		✓	✓
Units (dry weight except total solids)	✓		✓	✓
Method blank data (sulfides, ammonia, TOC)	✓	✓	✓	✓
Method blank units (dry weight)	✓	✓	✓	✓
Analysis dates (sediment conventionals, blanks, TOC CRM)	✓		✓	✓
TOC CRM ID	✓	✓	✓	✓
TOC CRM analysis data	✓	✓	✓	✓
TOC CRM target values	✓	✓	✓	✓
Grain Size Analysis				
Fine grain analysis method	✓		✓	✓
Analysis dates	✓		✓	✓
Triplicate for each batch		✓	✓	✓
Grain size data (complete sieve accurate to .1 units)	✓	✓	✓	✓

Note: Shaded boxes indicate those type of data are not applicable for that column.

Figure 12-4. QA2 Data Checklist for Locations, Physical, and Conventional Analyses

Chemicals of Concern Analysis Data				
	Metals	**Semivol.**	**Pest./PCBs**	**Volatiles**
Extraction/digestion method	✓	✓	✓	✓
Extraction/digestion dates (test sediment, blanks, matrix spike, reference material)				
Analysis method	✓	✓	✓	✓
Data and QA qualifier included for:	✓	✓	✓	✓
• Test sediments				
• Reference materials including 95% confidence interval (each batch)		✓	✓	✓
• Method blanks (each batch)	✓	✓	✓	✓
• Matrix spikes (each batch)	✓	✓	✓	✓
• Matrix spike added (dry weight basis)	✓	✓	✓	✓
• Replicates (each batch)	✓	✓	✓	✓
Units (dry weight)	✓	✓	✓	✓
Method blank units (dry weight)	✓	✓	✓	✓
QA/QC qualifier definitions	✓	✓	✓	✓
Surrogate recovery for test sediment, blank, matrix spike, ref. material	✓			
Analysis dates (test sediment, blanks, matrix spike, reference material)	✓	✓	✓	✓
Instrument calibration checks raw data	✓			
Duplicate analysis of samples at least 5%	✓			
ICP interference check samples and serial dilution analysis	✓			
Certified reference material verification	✓	✓		
Mass spectra chromatograms		✓		
Final sample volumes and dilution factors (include wet/dry ratios)		✓	✓	
Tentatively identified compounds		✓	✓	
PCBs analyzed as congeners and not Arochlors		✓	✓	
GC/MS tuning procedures in accordance with EPA CLP		✓	✓	
Ongoing calibration materials in analytical train		✓	✓	✓

Note: Shaded boxes indicate those type of data are not applicable for that column.

Figure 12-5. QA2 Data Checklist for Chemicals of Concern

12.8 QUALITY ASSURANCE/QUALITY CONTROL FOR BIOLOGICAL DATA

Chapter 8 covers the minimum requirements for biological testing. Standardization of data reporting is strongly recommended. To best facilitate the standardization of biological data, the Puget Sound Protocols (PSEP) procedures for data reporting will continue to be used. A PDF of the PSEP protocol references can be found at http://www.psat.wa.gov/Publications/protocols/protocol.html. Currently the SEDQUAL templates will be used until such time that EIM templates have been developed for bioassay data.

13. BENEFICIAL USES FOR SEDIMENT

13.1 BACKGROUND AND DEFINITION OF “BENEFICIAL USE”

The following is an introduction to beneficial use and its importance to overall sediment management in the Pacific Northwest. Coordinating dredging activities in the coastal zone for the purposes of retaining sand in the littoral system to foster more balanced, natural system processes, and potential reduced costs of disposal is important to regional sediment management.

The RSET agencies are responsible for sediment management in the Pacific Northwest. One management option is beneficial use. Beneficial use is defined as the use of dredged material as a resource for productive purposes (e.g., habitat creation, mitigation, beach nourishment, restoration, etc.). While the term beneficial indicates some benefit is gained by a particular use, the term has come to generally mean any use of dredged material other than deepwater disposal of the material. The descriptor “beneficial” depends on one’s perspective; therefore, in this manual the definition has been kept general to encourage a wide array of potential projects.

Natural sand movement and replenishment of the littoral cells along the coasts and in rivers has been greatly altered by dams and coastal developments in the Pacific Northwest. Dredged material can and should be considered a resource, and its use should be supported wherever possible. While dredged material disposal facilities will always be needed in some capacity for CSs, in the spirit of resource conservation, re-use, and recycling, it is imperative to evaluate and cultivate emerging beneficial use strategies to ensure a practical, productive and integrated long-term program for the management of dredged sediments.

Depending on its characteristics, particularly grain size and degree of contamination, dredged sediments may be suitable for beach nourishment projects, structural or non-structural fill, landfill cover(s), habitat development projects, wetland enhancement/ restoration projects, capping open water disposal areas, or a variety of other uses. The use of suitable dredged material in habitat and wetland creation, enhancement, and restoration offers a unique opportunity to use sediments as a resource and, at the same time, restore and improve degraded habitats in ocean, riverine, estuarine, and adjacent uplands. Degraded lands such as active and inactive landfills, brownfield sites, and quarry sites can offer another unique opportunity to combine the use of dredged material with the environmental and economic restoration of otherwise unproductive or contaminated properties. All of these sites have disturbed environments and limited natural resource value in their present condition. Many of these sites also generate leachate and surface water runoff that contaminate surrounding soils, aquifers, and surface water. The beneficial use of dredged sediment for land remediation under properly controlled conditions and in conjunction with engineering and institutional controls can provide a safe and economical way of remediating these sites.

Several technical manuals and guidance documents have been issued on both the federal and state levels on beneficial use of dredged material. In particular, the Corps Engineer Manual No. 1110-2-5026, Beneficial Uses of Dredged Material, provides guidance for planning, designing, developing, and managing dredged material for potential uses. Web sites that have useful information regarding beneficial use of dredged sediments include http://www.wes.army.mil/rsm http://www.el.erdc.usace.army.mil/dots/budm/ and http://www.glc.org/dredging.

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APPENDIX A

BIOACCUMULATIVE CONTAMINANTS OF CONCERN

APPENDIX A

BIOACCUMULATIVE CONTAMINANTS OF CONCERN

This appendix provides the definitions for each of the four classifications of bioaccumulative chemicals. It also provides the default lists of chemicals resulting from these decision rules. These lists are to be applied RSET-wide in the absence of local information to refine the bioaccumulative contaminants of concern (BCoCs). The definitions in this appendix are based on the work of a Dredged Material Management Program (DMMP) workgroup to refine BCoCs, which developed a document providing the technical basis for the lists and placement of chemicals on the lists. This technical appendix should be consulted for further detail on the derivation of the decision rules (EPA 2004).

List 1. Primary Bioaccumulative Contaminants of Concern

Definition 1:

- log $K_{ow} > 3.5$

  AND

- 95th percentile of detected tissue concentrations (or maximum concentrations) > Screening LOED

Definition 2:

- log $K_{ow} > 3.5$

  AND

- tissue detection frequency > 10 percent

  AND

- residue-effects LOED available

  AND

- known human and/or ecotoxicity

Chemicals are placed on List 1 because they are hydrophobic and tend to partition into the organic fraction (Log $K_{ow} > 3.5$), and because the higher concentrations that have been detected in regional tissue monitoring exceed values associated with adverse effects in aquatic organisms (95th percentile tissue concentrations > 5th percentile LOED). Alternatively, List 1 chemicals are hydrophobic, detected in regional tissue monitoring in at least 10 percent of the samples tested, and have residue-effects data available in the scientific literature. Furthermore, they are known to be toxic to human and/or aquatic receptors in that they meet one or more of the following three criteria for human and ecological toxicity:

- Have a final chronic value less than 0.1 milligrams per liter (mg/L),
- Have a cancer slope factor or Integrated Risk Information System (IRIS) weight of evidence (WOE) score of A or B, or
- Have a reference dose value less than 0.06 milligrams/kilograms per day (mg/kg/day).

Chemicals meeting either the first or second definitions discussed above have a weight-of-evidence indicating they are of concern for bioaccumulation. Note both List 1 definitions prioritize tissue data over sediment data. Theoretically, a chemical does not need to be detected in sediments in order to be placed on List 1, although this is rarely the case. Typically, most chemicals detected in tissues are also detected in sediments while the reverse is not always true. It is for this reason that sediment detection is not a component of either List 1 definitions. List 1 chemicals are presented in Table A-1.

The WOE evaluation placed polychlorodibenzodioxins (PCDD) and polychlorodibenzofurans (PCDF) on Lists 2 and 3, respectively, while 2,3,7,8-TCDD was placed on List 1 based on definition 2. The tissue data sets that were queried for this effort did not include studies that analyzed for PCDD/PCDF. Studies that analyze for dioxins and furans do so because of site-specific need, and typically report results as 2,3,7,8-TCDD TEQ. Thus, the DMMP made the decision to put dioxins and furans on List 1 based on the results for 2,3,7,8-TCDD as well as best professional judgment. Dioxins and furans have a special status on List 1 in that they are only required for evaluation on an as-needed basis depending on site-specific conditions.

While the lists and the WOE analysis addressed the isomers of DDT (e.g., 2,4’ and 4,4’ DDD, DDE, and DDT) separately from total DDT, they were lumped together for purposes of list placement. Both 4,4’-DDE and 4,4’-DDT meet List 1 definition 2 and thus total DDT was placed on List 1.

In the absence of K_{oc} values, best professional judgment was used to select metals that may bioaccumulate for List 1. The remaining metals that are standard analytes have been placed on List 4.

Based on the summary and survey performed by D.M.D. Inc., standard methods for all List 1 chemicals are available and currently performed by regional laboratories (see Table 3 in EPA 2004).

List 2. Candidate Bioaccumulative Contaminants

Definition 1:

- log $K_{ow} > 3.5$
  AND
- no tissue data available[9]
  AND
- sediment detection frequency > 50 percent
  AND
- median of detected sediment samples exceeds 10x MDL (10x reference area concentrations for trace metals) OR sediment detection frequency > 10 percent AND median of detected samples exceed 50x MDL (50x reference area concentrations for trace metals)
  AND
- known human and/or ecotoxicity

Definition 2:

- log $K_{ow} > 3.5$
  AND
- no sediment or tissue data available
  AND
- known human and/or ecotoxicity

Chemicals are placed on List 2 because available information indicates that they may be of concern, but additional information (primarily from regional tissue and sediment monitoring) is needed in order to make a definitive placement on Lists 1 or 4. According to definition 1, List 2 chemicals are hydrophobic and either frequently detected in sediments at concentrations that are somewhat in excess of detection limits (or reference values or metals) or infrequently detected at concentrations that are well above detection limits/reference values. Furthermore, List 2 chemicals are known to be toxic to human and/or aquatic receptors in that they meet one or more of the following three criteria for human and ecological toxicity:

- Have a final chronic value less than 0.1 mg/L,
- Have a cancer slope factor or IRIS WOE score of A or B, or
- Have a reference dose value less than 0.06 mg/kg/day.

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[9] Chemicals for which only SEDQUAL tissue data is available must meet the DMMP's minimum criteria for data sufficiency (e.g., data must be from a minimum of two surveys, representing at least two taxa and the total number of samples must be greater than 30).

Chemicals that meet definition 2 have not been regionally monitored in tissues or sediments but are hydrophobic and documented to be toxic to human and/or aquatic receptors in the scientific literature. List 2 chemicals are presented in Table A-2.

List 3. Potentially Bioaccumulative Contaminants

- log $K_{ow} > 3.5$

  AND
- no sediment or tissue data available

  AND
- no information on human and/or ecotoxicity

Chemicals are placed on List 3 when they do not meet any of the definitions of the other three lists. Typically List 3 chemicals are just beginning to receive national attention due to their potential for persistence and/or being detected in monitoring programs. The critical distinction between List 2 (definition 2) chemicals and those on List 3 is that the former are known to be toxic to human or aquatic receptors while the latter are not. List 3 chemicals will be re-evaluated for list placement when/if additional toxicity and regional occurrence data become available. List 3 chemicals are presented in Table A-3.

List 4. Not Currently Considered Bioaccumulative

Definition 1:

- log $K_{ow} < 3.5$

Definition 2:

- log $K_{ow} > 3.5$

  AND
- tissue detection frequency < 10 percent

  AND
- 95th percentile of detected tissue concentrations (or maximum concentrations) < Screening LOED **OR** No Screening LOED available **OR** 95th percentile of nondetected concentrations (when all are NDs) < Screening LOED

  AND
- marine sediment detection frequency < 10 percent[10]

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[10] For trace metals which are expected to be detected in nearly all cases, the criterion is "< 10% elevated over reference area concentrations." Reference area concentrations from PSEP (1991).

AND

- freshwater sediment detection frequency < 10 percent[5]

Chemicals are placed on List 4 definition 1 because they are not sufficiently hydrophobic (log Kow < 3.5) to warrant prioritization under this approach. Alternatively, definition 2 chemicals are sufficiently hydrophobic, but regional tissue and sediment data indicate that they are rarely (if ever) detected and when detected are at concentrations that are less then tissue-residue effects levels (when available). Chemicals are always placed on List 4 based on positive information; the lack of information on a chemical is never justification for being on List 4. Thus, chemicals that otherwise satisfy the List 4 definitions but have no regional tissue data, would appear on either List 2 or 3 depending on what is known about their human/ecological toxicity. List 4 is presented in Table A-4.

Table A-1. List 1: Primary Bioaccumulative Contaminants of Concern

Definition 1

Arsenic
Cadmium
Chlordane
Lead
Pentachlorophenol
Total Aroclor PCB
Pyrene
Selenium
Tributyltin

Definition 2

Dioxins/Furans[11]
Fluoranthene
Hexachlorobenzene
Mercury
Total DDTs (ortho and para isomers of DDT, DDE, and DDD)

---

[11] Dioxins and furans are only required for analysis on an as-needed basis depending on site-specific conditions.

Table A-2. List 2: Candidate Bioaccumulative Contaminants

Definition 1
Benzo(e)pyrene
Biphenyl
Endosulfan
Mirex
Perylene

Definition 2
1,2,4,5-Tetrachlorobenzene
4-Nonylphenol, branched
Chromium VI
Dacthal
Heptachloronaphthalene
Hexachloronaphthalene
Kelthane
Octachloronaphthalene
Oxadiazon
Parathion
pentabromodiphenyl ether
Pentachloronaphthalene
Tetrachloronaphthalene
Tetraethyltin
Trichloronaphthalene
Trifluralin

Table A-3. List 3: Potentially Bioaccumulative Contaminants

1,2,3,4-Tetrachlorobenzene
1,2,3,5-Tetrachlorobenzene
1,2,3-Trichlorobenzene
1,3,5-Trichlorobenzene
1-methylnaphthalene
1-methylphenanthrene
2,6-Dimethyl naphthalene
2-methylnaphthalene
4,4’-Dichlorobenzophenone
4-bromophenylphenyl ether
Acenaphthene
Acenaphthylene
Aldrin
Anthracene
Antimony
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(g,h,i)perylene
Bis(2-ethylhexyl) phthalate
Butyl benzyl phthalate
C1-chrysenes/benzo(a)anthracene
C1-dibenz(a,h)anthracene
C1-fluoranthene/pyrene
C1-fluorenes
C1-naphthalenes
C1-phenanthrene/anthracene
C2-chrysenes/benzo(a)anthracene
C2-dibenz(a,h)anthracene
C2-fluorenes
C2-naphthalenes
C2-phenanthrene/anthracene
C3-chrysenes/benzo(a)anthracene
C3-dibenz(a,h)anthracene
C3-fluorenes
C3-naphthalenes
C3-phenanthrene/anthracene
C4-chrysenes/benzo(a)anthracene
C4-naphthalenes
C4-phenanthrene/anthracene
Chrysene
Dibenzo(a,h)anthracene
Dibenzothiophene
Dieldrin
Di-n-butyl phthalate
Di-n-octyl phthalate
Endosulfan sulfate
Ethoxylated nonylphenol phosphate
Fluorene
Gamma-BHC/Gamma-hexachlorocyclohexane
Heptachlor epoxide
Hexachlorobutadiene
Indeno(1,2,3-c,d)pyrene
Methoxychlor

Table A-3. List 3: Potentially Bioaccumulative Contaminants (continued)

Nonylphenol
Pentachloroanisole
Phenanthrene
Polybrominated terphenyls
Polychlorinated alkenes
Polychlorinated terphenyls
Pronamide
Tetradifon
Toxaphene

Table A-4. List 4: Not Currently Considered Bioaccumulative Contaminants

Definition 1

1,4-Dichlorobenzene
Bromoxynil
Chromium
Copper
Dicamba
Dichlobenil
Dimethyl phthalate
Diuron
Ethylbenzene
Fenitrothion
Guthion
Methyl parathion
Methyltin trichloride
Naphthalene
Nickel
N-nitroso diphenylamine
Phenol
Silver
Tetrachloroethene
Toxaphene
Trichloroethene
Triphenyltin chloride
Zinc

Definition 2

1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
Endrin
Heptachlor
Hexachloroethane

REFERENCES

EPA (U.S. Environmental Protection Agency). 2004. The Technical Basis for Revisions to the Dredged Material Management Program's Bioaccumulative Contaminants of Concern List. Draft Report. Prepared for the DMMP Agencies by U.S.EPA Region 10, Seattle, WA. http://www.nws.usace.army.mil/publicmenu/DOCUMENTS/BCoC_Technical_Appendix_090804.pdf.

APPENDIX B

SAMPLE HANDLING PROCEDURES

APPENDIX B

SAMPLE HANDLING PROCEDURES

Listed below are details concerning the sample handling procedures outlined in Chapter 7. All sample handling procedures should be specified in the sampling and analysis plan.

Decontamination Procedures

It is recommended that all sampling equipment and utensils, such as spoons, mixing bowls, extrusion devices, sampling tubes, cutter heads, etc., be made of noncontaminating materials and thoroughly cleaned prior to use. The intention is to avoid contaminating the sediments to be tested, because dredged material could possibly be found unacceptable when it otherwise would be found acceptable for open-water disposal. While not strictly required, an adequate decontamination procedure is highly recommended. The dredging proponent assumes a higher risk of sample contamination by not following an established protocol. The following procedure has been used successfully for other dredging projects:

- Wash with brush and Alconox soap,
- Double rinse with distilled water,
- Rinse with nitric acid,
- Rinse with metal-free water, and
- Rinse with methanol.

While methylene chloride has been used extensively in the past as an organic solvent, and is recommended by PSEP, its use is discouraged by the dredging regulatory agencies because of its status as a potential carcinogen and its impact on the ozone layer.

After decontamination, sampling equipment should be protected from recontamination. Any sampling equipment suspected of contamination should be decontaminated again or rejected. If core sampling is being conducted, extra sampling tubes should be available on site to prevent interruption of operations should a sampling tube become contaminated. Sampling utensils should be decontaminated again after all sampling has been conducted for a dredged material management unit (DMMU) to prevent cross-contamination. Disposable gloves are typically used and decontaminated or disposed of between DMMUs.

Volatiles and Sulfides Subsampling

The volatiles and sulfides subsamples should be taken immediately upon extrusion of cores or immediately after accepting a grab sample for use. For composited samples, one core section or grab sample should be selected for the volatiles and sulfides sampling. Sediments that are directly in contact with core liners or the sides of the grab sampler should not be used.

Two separate 4-ounce containers should be completely filled with sample sediment for volatiles. No headspace should be allowed to remain in either container. Two samples are collected to ensure an acceptable sample with no headspace is submitted to the laboratory for analysis. The containers, screw caps, and cap septa (silicone vapor barriers) should be washed with detergent, rinsed once with tap water, rinsed at least twice with distilled water, and dried at greater than 105 degrees Celsius (°C). A solvent rinse should not be used because it may interfere with the analysis.

To avoid leaving headspace in the containers, sample containers can be filled in one of two ways. If there is adequate water in the sediment, the vial should be filled to overflowing so that a convex meniscus forms at the top. Once sealed, the bottle should be inverted to verify the seal by demonstrating the absence of air bubbles. If there is little or no water in the sediment, jars should be filled as tightly as possible, eliminating obvious air pockets. With the cap liner's PTFE side down, the cap should be carefully placed on the opening of the vial, displacing any excess material.

For sulfides sampling, 5 mLs of two normal zinc acetate per 30 grams of sediment should be placed in a 4-ounce sampling jar. The sulfides sample should be placed in the jar, covered, and shaken vigorously to completely expose the sediment to the zinc acetate.

The volatiles and sulfides sampling jars should be clearly labeled with the project name, sample/composite identification, type of analysis to be performed, date and time, and initials of person(s) preparing the sample, and referenced by entry into the log book. The sulfides sampling jars should indicate that zinc acetate has been added as a preservative.

Sampling Logs

As samples are collected, and after the volatiles and sulfides subsamples have been taken, logs and field notes of all samples should be taken and correlated to the sampling location map. The following should be included in this log:

- Date and time of collection of each sediment sample;
- Names of field supervisors and person(s) collecting and logging in the sample;

- The sample station number and individual designation numbers assigned for individual core sections;
- Quantitative notation of apparent resistance of sediment column to coring;
- The water depth at each sampling station (this depth should then be referenced to mean lower low water [MLLW NAD 83] through the use of an on-site tide gage);
- Length, depth interval (referenced to the sediment/water interface), and percent recovery of core sections;
- Weather conditions;
- Physical sediment description, including type, density, color, consistency, odor, stratification, vegetation, debris, biological activity, presence of an oil sheen, or any other distinguishing characteristics or features; and
- Any deviation from the approved sampling plan.

Extrusion, Compositing, and Sub-sampling

Depending on the sampling methodology and procedure proposed, sample extrusion, compositing, and subsampling may take place at different times and locations. If core sampling is conducted, these activities can either occur at the sampling site (e.g., on board the sampling vessel) or at a remote facility. Grab samples will be processed immediately upon sampling. If cores are to be transported to a remote facility for processing, they should be stored at 4°C on board the sampling vessel and during transport. The cores should be sealed in such a way as to prevent leakage and/or contamination. If the cores will be sectioned at a later time, thought needs to be given to core integrity during transport and storage to prevent loss of stratification. For cores or split-spoon sampling, the extrusion method should include procedures to prevent contamination.

For composited samples, representative volumes of sediment should be removed from each core section or grab sample comprising a composite. The composited sediment should be mixed until homogenized to a uniform color and consistency, and should continue to be stirred while individual samples are taken of the homogenate. This will ensure the mixture remains homogenous and settling of coarse-grained sediments does not occur.

At least 6 liters of homogenized sample needs to be prepared to provide adequate volume for physical, chemical, and biological laboratory analyses. Bioassays require approximately 4 liters of sediment, while chemical testing requires approximately 1 liter of sediment. Both chemistry and bioassay samples should be taken from the same homogenate. Portions of each composite sample will be placed in appropriate containers obtained from the chemical and biological laboratories. See Table 7-1 of the main text for container and sample size information. In high ranked areas, the sample taken from the foot beyond the dredging overdepth should be placed in a 250 milliliter (mL) glass jar and frozen for possible future analysis.

After compositing and subsampling are performed, the sample containers should be refrigerated or stored on ice until delivered to the analytical laboratory. The samples reserved for bioassays should be stored at 4°C in a nitrogen atmosphere, i.e., nitrogen gas in the container headspace, for up to 56 days pending initiation of any required biological testing. Each sample container should be clearly labeled with the project name, sample/ composite identification, type of analysis to be performed, date and time, and initials of person(s) preparing the sample, and referenced by entry into the log book.

Sample Transport and Chain-of-Custody Procedures

Sample transport and chain-of-custody procedures should follow the PSEP protocols, which include the guidelines described below.

If sediment cores are taken in the field and transported to a remote site for extrusion and compositing, chain-of-custody procedures should commence in the field for the core sections, and track the compositing and subsequent transfer of composited samples to the analytical laboratory. If compositing occurs in the field, chain-of-custody procedures should commence in the field for the composites, and track transfer of the composited samples to the analytical laboratory.

- Samples should be packaged and shipped in accordance with U.S. Department of Transportation regulations as specified at 49 Code of Federal Regulations (CFR) 173.6 and 49 CFR 173.24.
- Individual sample containers should be packed to prevent breakage and transported in a sealed ice chest or other suitable container.
- Ice should be placed in separate plastic bags and sealed, or blue ice used.
- Each cooler or container containing sediment samples for analysis should be delivered to the laboratory within 24 hours of being sealed.
- A sealed envelope containing chain-of-custody forms should be enclosed in a plastic bag and taped to the inside lid of the cooler.
- Signed and dated chain-of-custody seals should be placed on all coolers prior to shipping.

- The shipping containers should be clearly labeled with sufficient information (name of project, time and date container was sealed, person sealing the container and consultant's office name and address) to enable positive identification.
- Upon transfer of sample possession to the analytical laboratory, the chain-of-custody form should be signed by the persons transferring custody of the sample containers. The shipping container seal should be broken and the condition of the samples should be recorded by the receiver.
- Chain-of-custody forms should be used internally in the lab to track sample handling and final disposition.

APPENDIX C

RSET ISSUE PAPERS

APPENDIX C

RSET ISSUE PAPERS

These Issue Papers are early work products that were used to begin to address issues. Some have been substantially revised or expanded. Please see the main body text for the most current presentation of the issues. All Issue Papers included as Appendix C can also be downloaded from the Corps' web site.

List of RSET Issue Papers

1 – Establishment and Use of Detection and Reporting Limits
2 – Development of Sediment Quality Guidelines for Petroleum Hydrocarbons
3 – Chemical Summation Techniques
4 – Evaluation of Modern Pesticides in Sediments
5 – TEF Methods for Wildlife
6 – PCB Analysis
8 – PCB Analytical Methods
9 – SQG Cost Effectiveness/Reliability
10 – Develop Regional Data Compilation/Database Structure
11 – Evaluate Ecology's Guideline Development/Reliability
16 – Framework for Assessing Bioaccumulation under RSET
17 – Tissue Bioaccumulation Triggers and Proposed Methods of Protection of Fish/ESA Species
18 – Development of Tissue Trigger Levels for Aquatic-Dependent Wildlife
19 – Testing Protocols Available For Laboratory Based Freshwater Bioaccumulation Testing Under RSET
20 – Testing Protocols for In-situ Freshwater Bioaccumulation Testing
21 – Framework for Deriving Tissue Concentrations to be Protective of People Consuming Fish and Shellfish
25 – Integrating Range of Disposal Options into SEF
26 – Grain Size, Analysis, and Exclusion Criteria
27 – Disposal Site Issues
28 – Programmatic Consultation on SEF
29 – Frequency of Dredging Guideline
30 – Effect Level Question
31 – New Surface Material Exposed by Dredging
32 – Minor Text Changes and Clarifications

RSET ISSUE PAPER #1 – Establishment and Use of Detection and Reporting Limits

CHEMICAL ANALYTE LIST SUBCOMMITTEE: T. Thornburg, Chair (tthornburg@anchorenv.com); August 2, 2004

QUESTION/ISSUE: There are a diversity of reporting limits (RLs) being used in sediment management programs. Best available science has progressed adequately to lower the method detection levels and reporting limits for routine sediment metals and organic contaminants of concern. May one set of method detection limits and reporting limits be identified for all sediment quality programs? May a consistent set of qualifier code definitions be developed and applied (e.g., "U" applied to RLs) for use in all sediment management programs?

DISCUSSION: In the state of Washington, the SMS, PSDDA and PSAMP, CERCLA, and NRDA sediment programs have each identified individual programmatic RLs (i.e., practical quantitation limits). These programmatic limits are identified in Table C-14 of the Puget Sound Estuary Program's (PSEP) Recommended Quality Assurance and Quality Control Guidelines For the Collection of Environmental Data in Puget Sound (April 1997). Additionally, this PSEP protocol identifies different sediment programmatic data qualifiers in Tables D-1 through D-6.

Key considerations in identification of programmatic RLs are to identify 1) sediment chemical guidelines and/or criteria against which sediment data will be compared, 2) laboratory and analytical method capabilities, and 3) associated costs. Some regional scientists have suggested that reduction of RLs is possible and necessary to adequately support development of sediment quality criteria, especially for freshwater sediments.

There is also considerable confusion regarding consistent identification and application of appropriate data qualifiers. Different sets of qualifiers and definitions exist, which are generated and applied in various sediment program studies. These data are often later consolidated into SEDQUAL. The "U" qualifier for undetected can be often reported at or near the method detection limit (e.g., for metals or at the RL, e.g., for organics). Recently, EPA Superfund developed a new, modified EPA CLP data qualifier list for work at the Duwamish sediment cleanup site. Finally, application of appropriate data qualifiers is necessary to support sediment quality criteria development (e.g., use of "J" or "E" estimated data).

REFERENCES: PSEP QA/QC Protocol (see attachments)

RECOMMENDATION: Convene a cross-program panel with RSET staff, and agency and commercial laboratory representatives to discuss development of consolidated recommendations for sediment chemistry analytical methods, reporting limits, and data qualifiers.

PROPOSED LANGUAGE: None yet.

LIST OF PREPARERS: Brett Betts/Tom Gries, Washington Department of Ecology

RSET ISSUE PAPER #2 – Development of Sediment Quality Guidelines (SQGs) for Petroleum Hydrocarbons

CHEMICAL ANALYTE LIST SUBCOMMITTEE: T. Thornburg, Chair (tthornburg@anchorenv.com); August 6, 2004

QUESTION/ISSUE: What analytes and associated SQGs should be used for bulk petroleum hydrocarbons and/or their constituents, such as polynuclear aromatic hydrocarbons (PAHs)?

DISCUSSION:

Background

Most existing SQG sets include guidelines for individual PAHs. To date, screening levels for bulk petroleum hydrocarbons in sediment have not been developed due to the widely varying mix of compounds that make up this group and the sense that toxicity was adequately accounted for by considering typical constituents of petroleum products (e.g., PAHs). However, there are situations where bulk petroleum hydrocarbons are present in sediment at elevated levels, and individual listed constituents either are absent or are present at levels that would not indicate toxicity. There has been limited analysis of whether these sediments pose a toxicity threat and in many cases the analysis for petroleum products is not performed. For cleanup sites in Oregon and some sites in Washington with heavy petroleum contamination, the policy has been to require bioassays to assess toxicity of petroleum-contaminated sediment; however, a consistent concentration above which bioassays would be required has not been established. Dredging programs in Washington and along the Columbia River have relied on SQGs for individual PAHs and sums of PAHs.

Recent work developing SQGs for a variety of areas along the west coast has identified issues with the predictiveness of individual PAH criteria. Specifically, PAHs do not appear to be associated with substantial toxicity on an individual basis, and in some cases can be dropped entirely from a data set without affecting the reliability of the resulting SQGs (Ecology 2003, Bay et al. 2004, Germano Assts. 2003). When added together on a dry weight basis, it is possible to see a relationship between the PAHs as a group and toxicity within the data set. However, this relationship is still prone to substantial error and is not a strong one. Taken together, these studies suggest the following conclusions:

- PAHs exhibit behavior that does not support a toxicity model in which these chemicals act independently of one another; rather some form of sum appears to better model their potential for toxicity.

- Dry weight sums of individual PAHs alone may not accurately reflect the manner in which petroleum hydrocarbons express their additive toxicity and may introduce error into SQG calculations.

These conclusions are consistent with what is known about petroleum toxicity to invertebrates, as discussed below. Furthermore, they suggest that existing individual PAH-based guidelines may be underprotective, especially in situations where substantial bulk petroleum exists.

Historically, regulation of bulk petroleum has largely occurred through total petroleum hydrocarbon (TPH) measurements, which are difficult to relate directly to toxicity. More recent theories for assessing the toxicity of petroleum and its constituents to benthic organisms have focused on a narcosis-based approach. Narcosis is a form of toxicity resulting from the presence of foreign molecules in hydrophobic or lipid tissues, which depresses and disrupts various cellular functions (Abernathy et al. 1988, Franks and Lieb 1978). It is a well-studied phenomenon, as it is the basis for anesthesiology in medicine. Because narcosis represents a general disruption of basic cellular functions, which are essentially the same in all living organisms (microorganisms, invertebrates, fish, mammals, humans), the narcosis endpoint is applicable to any freshwater or marine aquatic receptor. Researchers have found that narcotic effects occur at similar tissue concentrations in a wide variety of aquatic receptors (Abernathy et al. 1988, McCarty and Mackay 1993, McCarty 1991, EPA 1988).

In aquatic receptors, narcosis is manifested in various ways, including immobility, loss of equilibrium in fish, and mortality (McCarty et al. 1992, Rogerson et al. 1983, Bobra et al. 1985, Mackay and Hughes 1984). These different manifestations are not really different endpoints, but rather can be thought of as a continuum of increasing responses to cellular dysfunction and shutdown. These effects are clearly related to population-level impacts, as they affect the ability of the organism to perform day-to-day functions, such as foraging, predator avoidance, and reproduction, and may finally result in mortality. Moreover, onset of narcosis effects would be expected at similar exposure concentrations for any member of an exposed assemblage of organisms, regardless of its taxonomic or community status.

In addition, the narcotic effect is not dependent on the specific lipophilic chemical or chemicals present (Call et al. 1985). Various studies (Ferguson 1939, McGowan 1952, Hermens et al. 1984, Hermens et al. 1985a, b, Deneer et al. 1988) have demonstrated that the narcotic effect is instead related to the total number of foreign molecules present, and therefore effects in tissue can be predicted from the total molar concentration of contaminants in the tissue. Thus, it is not necessary to know the identity or toxicity of each individual chemical, just the molar concentration of all the chemicals in tissue combined. This property makes the narcosis endpoint particularly well-suited to the evaluation of toxic effects of petroleum (and other) mixtures in the environment, as a single sediment or tissue concentration can be selected that will be protective of aquatic receptors for a wide variety of lipophilic organic chemicals, assuming these chemicals do not have other, more specific interactions with the receptor causing toxicity.

Two methods could be employed to make use of this model in regulating petroleum constituents in sediments or tissues. First, individual PAH concentrations could be added together, normalized to a molar concentration, or to a reference K_{ow} rather than using a dry weight sum (as is currently employed in the dredging program). K_{ow}-normalization is the basis of EPA's approach to regulating PAHs in sediments, authored by DiToro et al. (2000). Ecology recently compared the reliability of molar concentration sums vs. dry weight sums vs. individual PAHs during the development of the freshwater sediment quality guidelines

(Ecology 2003). This comparison indicated that dry weight sums showed greater association with toxicity in the data set than did the use of individual PAHs, and molar concentration sums showed greater association with toxicity in the data set than did dry weight sums. However, the overall reliability of the three data sets was approximately the same, indicating that there are errors associated with all three approaches. Most likely this is due to the use of individual PAHs to represent the entirety of the bulk petroleum present, when in fact all of the petroleum present contributes to narcosis toxicity.

Alternatively, bulk petroleum in the environment could be measured in molecular weight fractions, which would then be added together on a molar concentration basis to obtain a total petroleum concentration in molar units (μmol/kg). This approach is similar to methods adopted under the MTCA in Washington (WAC 173-340-740) and Massachusetts (MADEP 2002) to regulate petroleum hydrocarbons in soils. There is not currently enough VPH/EPH or TPH data in SEDQUAL to test whether this approach has better reliability than those that rely on individual PAHs.

Discussion

The following options are available for regulating individual PAHs and/or bulk petroleum products in sediments and tissues:

- Individual PAHs
- Dry weight sums of PAHs
- Molar or K_{oc}-normalized sums of PAHs
- Dry weight bulk measurements (e.g., TPH)
- Molar sum bulk measurements (e.g., VPH, EPH)

The individual PAHs and dry weight sums/bulk measurements have the advantage of being familiar, consistent with past practices, and consistent with current analytical techniques in widespread use. However, both in practice and in theory, these approaches do not appear to accurately model petroleum toxicity. The molar or K_{oc} normalized approaches, particularly those addressing bulk petroleum fractions, have the advantage of being consistent with toxicological theory and reflect the emerging scientific consensus with respect to petroleum toxicity and regulation. However, they rely on analytical techniques and calculation methods that are not currently in widespread use (though the methods do exist at a commercial level). Data would need to be collected using these analytical methods before the reliability of this approach could be definitively determined, as these measurements have not typically been done in sediments in the past.

It is worth noting that narcosis theory applies not only to bulk petroleum hydrocarbons, but also to any lipophilic compound that does not have a specific mode of action. Toxicologically speaking, narcosis effects would manifest as the sum of all such compounds. Narcosis-based water quality guidelines have been derived for pulp mill effluents as well as petroleum products in the Netherlands, for example. However, determining the molar concentrations of such complex mixtures requires monitoring and analytical techniques that are not currently in use in the United States. Nevertheless, it may be reasonable to add certain chemicals that are already being measured and are expected to have narcotic effects, such as phthalates and dibenzofuran, to the sum.

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RECOMMENDATION:

Proposed Next Steps

- Policy committee and broader RSET discussion of these issues in September 2004 with comments forwarded to the SQG and Analyte subcommittees.

- Analyte subcommittee to evaluate "doability" of VPH/EPH approaches in the region with respect to laboratories and costs, types of information obtained, and how well it matches the needs of the toxicity models available; one question of particular interest is whether the majority of sediment-related bulk petroleum would be found in the EPH fraction, thus reducing the cost of the analysis.

- SQG subcommittee to look at policy implications of changing from PAH to any bulk approach with respect to use of older data and development of new guidelines (it may be possible to develop them based on narcosis information already in the literature, followed by field-verification over time).

SQG subcommittee also to eventually decide whether bulk measurements should 1) not be used, 2) replace PAHs, 3) be added to PAHs as SQGs, and in what form (e.g., dry weight vs. molar sums).

Interim Recommendations:

- Continue to evaluate petroleum at marine sites based on existing PAH criteria, and at freshwater sites based on criteria as recommended by the SQG subcommittee (currently under review).

- Consider bulk petroleum as a "Chemical of Special Occurrence" (per Section 8.4.2 of DMEF) at sites where petroleum is potentially a major issue (e.g., crude oil or fuel spills, waterfront tank, or pipeline leaks). EPH/VPH is the recommended analytical method as it provides differentiation of aliphatic and aromatic carbon ranges. Traditional bulk TPH analysis may be used as a screening tool to help map the distribution of bulk petroleum, but provides little value in predicting sediment toxicity.

PROPOSED LANGUAGE: None yet available.

LIST OF PREPARERS: Teresa Michelsen, Avocet Consulting and Jennifer Sutter, Oregon Department of Environmental Quality

RSET ISSUE PAPER #3 - Chemical Summation Techniques

CHEMICAL ANALYTE LIST SUBCOMMITTEE: T. Thornburg, Chair (tthornburg@anchorenv.com); August 2, 2004

QUESTION/ISSUE: Is the current chemical summation method used by Washington State Sediment Management Standards (SMS) and Corps Puget Sound Dredged Disposal Analysis (PSDDA) program for total PCBs (Aroclors), total PAHs, and total DDTs appropriate for inclusion as the default method in the new SEF?

DISCUSSION:

Standard procedure for Washington State SMS and Corps PSDDA process is to sum detected concentrations only. If all results are non-detected, the total is the highest individual detection limit.

If the summation procedure is changed, it may affect current screening criteria (AETs, etc). Originally, Ecology's summation procedure was different from the Corps'; therefore, screening criteria had to be recalculated.

SEDQUAL is currently using the Corps/ SMS procedure for summation. Qualified values, i.e. <PQL (J) are included in the total.

We need to be aware of unintended consequences of summation procedures so we don't have the case where all analytes are undetected but the calculated sum is above screening criteria. By adopting current summation practices (for the benthic direct contact screening levels) we would avoid this situation.

REFERENCES: WAC 173-204-320 (2)(b)(i) and (ii)

RECOMMENDATION: Current method works best for the inclusion in SEF and should be recommended for SEF.

PROPOSED LANGUAGE: Add to Current DMEF Section 8.4.1:

1. Where chemical analyses identify an undetected value for every individual compound/isomer, the single highest detection limit shall represent the sum of the respective compounds/isomers.
2. Where chemical analyses detect one or more individual compounds/isomers, only the detected concentrations will be added to represent the group sum.

LIST OF PREPARERS: Taku Fuji, Ph.D., Kennedy/Jenks Consultants

RSET ISSUE PAPER #4 – Evaluation of Modern Pesticides in Sediments

CHEMICAL ANALYTE SUBCOMMITTEE: T. Thornburg, Chair (tthornburg@anchorenv.com); August 2, 2004

QUESTION/ISSUE: Are modern pesticides (e.g., organophosphorus, carbamates, triazines, etc.) accumulating in sediments at potentially toxic levels? Should certain modern pesticides be listed as "chemicals of special occurrence" to be considered for evaluation in areas affected by agricultural runoff?

DISCUSSION: The persistence of modern pesticides, and their ability to accumulate in sediments at potentially toxic levels, is not well studied. Sediment sampling for modern pesticides in areas affected by agricultural runoff is rare; recent sediment sampling of the Lower Snake River by the U.S. Army Corps of Engineers (Corps) Walla Walla District has shown common detections of only one modern pesticide, linuron, which is a phenyl urea compound. This issue paper provides a review of agricultural usage rates, environmental occurrence, and chemical properties that may be used to prioritize modern pesticides on a project-specific basis for further evaluation. Because no sediment quality guidelines are available for these chemicals, they would be classified as "chemicals of special occurrence," and would be analyzed during agency investigations or monitoring programs and where there is a "reason to believe" they are present, primarily in areas affected by agricultural runoff. After sufficient data have been collected (including synoptic chemistry and bioassay data), these chemicals may be evaluated to determine whether they contribute to sediment toxicity, and if so, whether the observed effects are predictable enough to support the development of screening levels.

The modern pesticides database is compiled in Table 1. This table contains chemical properties, usage data, environmental occurrence, and other parameters that are used to help prioritize the need for further study of these chemicals.

Chemicals of Interest:
Based on research conducted by the U.S. Geological Survey (USGS 1997, 2002) in Willamette and Yakima Valleys, the following types of pesticides are in common use in the Pacific Northwest:

- Organophosphorus
- Carbamates
- Thiocarbamates
- Phenyl Urea
- Triazine Compounds
- Others

Methods of Analysis:
Numerous methods are available for analysis of modern pesticides. Because of the diversity of types of modern pesticides, no one method provides comprehensive coverage. Also, certain pesticides may be analyzed by customization of existing EPA methods (e.g. 8081 or 8270), whereas others are not clearly associated with any EPA method.

Approximate costs and practical quantitation limits (PQLs) for commercial analysis of sediment by the various pesticide methods is provided below:

- EPA 8081 (OC Pests): $160 [PQL ~ 1 to 5 ppb]
- EPA 8141 (OP Pests): $190 [PQL ~ 10 to 50 ppb]
- EPA 8151 (OC Herbicides): $200 [PQL ~ 10 to 50 ppb]
- EPA 8270 (Semivolatiles): $400 [PQL ~ 50 to 100 ppb]
- EPA 8318 (Carbamates): $170 [PQL ~ 100 ppb]
- EPA 8321 (Phenyl Urea): $250 [PQL ~ 25 ppb]

Although each analysis alone is not particularly expensive, to run all possible pesticide methods could run well over $1,000. The Walla Walla District has successfully analyzed a fairly broad suite of pesticides (organochlorine, organophosphorus, and organonitrogen) using a customized 8270 analysis. This may have some application as a fairly inexpensive reconnaissance method, because 8270 analysis is already required for many sediment characterization projects to quantify PAHs, phenols, and other organic compounds. However, there may be some loss of sensitivity with 8270 compared to other methods such as 8141.

Evaluation Criteria:
Pesticide evaluation criteria are summarized in Table 1 and described briefly below.

Agricultural Application Rates. Application rates (pounds applied per year to the Yakima or Willamette basin study areas) have been estimated by the USGS. Because the climate, crop types, and cropping practices are different on the east and west sides of the Cascades, the two areas are characterized by different pesticide usage rates and preferences.

Detection in River Water. Detection frequencies of modern pesticides in rivers and streams in the Willamette and Yakima basins are summarized in Table 1. Water quality statistics (50th and 90th percentiles, and maximum concentrations) are also presented. Similar to the geographic differences in pesticide usage, the river waters in the eastern and western study areas are characterized by different suites of detected pesticides.

Detection in River Sediment. Some of the most comprehensive studies of modern pesticides in Pacific Northwest sediments have been performed by the USACE Walla Walla District (2003). At sites on the Lower Snake River and near the Clearwater River confluence, linuron was the only modern pesticide detected, at concentrations ranging from 28 to 77 ug/kg. Using equilibrium partitioning theory, based on an interim Environment Canada (1999) aquatic life criterion of 7 ug/L, and an average sediment organic carbon content of 2 percent, an estimated sediment screening value for linuron is 210 ug/kg. Thus, the observed linuron concentrations do not appear to be high enough to cause adverse biological effects.

Exceedence of Water Quality Criteria. EPA water quality criteria are only available for some organophosphorus pesticides (EPA 2002). Water quality criteria for certain other modern pesticides have been developed by Environment Canada (2002). A thorough review of the basis and applicability of the Canadian values is beyond the scope of this paper. The maximum detected concentrations for a few pesticides exceeded their aquatic life criteria; however, in all but one instance, the 90th percentile concentrations did not exceed the criteria. The one exception is azinphos-methyl (guthion), an organophosphorus pesticide; in the Yakima basin, the 50th and 90th percentile concentrations of this pesticide exceeded the EPA chronic criterion. Aside from this one constituent in Yakima, this evaluation suggests occasional water quality excursions are possible, probably close to the area of application, but exceedences are not ubiquitous or routine, and are likely short-lived.

Hydrophobicity. The organic-carbon partitioning coefficient (K_{oc}) is a measure of the hydrophobicity of modern pesticides. Log K_{oc} values are low to moderately low, ranging from 1.24 to 3.63. By comparison, the log K_{oc} value for DDE is about 100 to 10,000 times higher (5.44). In general, modern pesticides are not strongly hydrophobic, and will exhibit a weak tendency to adsorb to sediments.

Environmental Persistence. Environmental persistence is expressed in terms of half life, based primarily on empirical lab or field experiments (SRC 2004). The half lives of modern pesticides are relatively short, ranging from a few days or a few months, to a maximum of about 1.5 years. By comparison, the half life of DDE is about 10 to 100 times longer—15 to 25 years. Based on these data, modern pesticides will degrade relatively quickly in the environment, through biodegradation, hydrolysis, and other processes.

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RECOMMENDATION: Modern pesticides appear to pose a relatively low risk of sediment toxicity, but may deserve further study in areas dominated by agricultural land use and runoff. In general, modern pesticides are short lived in the environment and exhibit a weak tendency to adsorb to sediments. In river and stream samples, exceedences of water quality criteria are uncommon. Sediment samples collected by the Walla Walla District to date have detected only linuron, at concentrations below those likely to cause adverse effects.

Organophosphorus pesticides have the highest ranking for further evaluation, because 1) these chemicals are in common use in both Willamette and Yakima basins; 2) these chemicals have somewhat higher partitioning coefficients (2.67 to 3.63) compared to many other modern pesticides; 3) these chemicals have some of the more stringent aquatic life criteria, and the only domestic (i.e., EPA derived) aquatic life criteria; and 4) azinphos-methyl (guthion) was the one pesticide that exceeded aquatic life criteria in a large percentage of samples from the Yakima basin. Triazine compounds are a secondary priority for study, because these are among the compounds most frequently detected in agricultural river water on both sides of the Cascades. Organophosphorus and triazine compounds may be analyzed using either EPA Method 8141 or a customized Method 8270. Method 8141 is recommended because it appears to provide better sensitivity.

The need to analyze other types of modern pesticides may be determined on a case-by-case basis. For example, the Walla Walla District may continue to monitor linuron in sediments of the Lower Snake River, based on detections in previous sampling events.

PROPOSED LANGUAGE:

8.4.2. Chemicals of Special Occurrence.

<Add the following paragraph:>

Organophosphorus Pesticides. Testing for organophosphorus-based and potentially other types of modern pesticides (e.g., triazines) may be required in areas dominated by agricultural land use and in sediments affected by agricultural runoff. Analysis by EPA Method 8141 is recommended.

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RSET ISSUE PAPER #5 – TEF Methods for Wildlife

CHEMICAL ANALYTE LIST SUBCOMMITTEE: T. Thornburg, Chair (tthornburg@anchorenv.com); August 6, 2004

QUESTION/ISSUE: Summarize existing information and recommendations for use of dioxin-like toxicity equivalency factors (TEFs) for assessing risks to humans and wildlife from exposure to polychlorinated biphenyls (PCBs), PCDDs, and PCDFs. Are TEFs for wildlife ready for prime time?

DISCUSSION: A procedure for assessing the toxicity to humans of a mixture of dioxins and furans has been developed. This method utilizes TEFs for adjusting the potency values of individual dioxin/furan isomers and PCB congeners relative to 2,3,7,8-TCDD and derives a “summed” 2,3,7,8-TCDD equivalent concentration of these compounds. These compounds comprise a class of chemicals that include several hundred compounds in closely related families; the chlorinated dibenzo-p-dioxins (CDDs), chlorinated dibenzofurans (CDFs), and certain PCBs.

For the SEF, depending on the need for analyzing for dioxins/furans, the TEF methodology can be used for analytical data for these compounds collected in either bulk sediment or fish tissue to estimate exposure. The SEF will only recommend PCB Congener analysis for fish tissue, and the discussion of PCB Congener TEFs is limited to this application.

Central to the use of the TEF methodology is that all the compounds that are summed to derive the 2,3,7,8-TCDD Equivalence must have the same mechanism of toxicity. For PCBs, dioxins, and furans, the common toxic mechanism of action is that all these compounds require the presence of a cytosolic aryl hydrocarbon receptor (Ah-R). All these compounds act as ligands to the Ah-R, and this binding to the Ah-R is a necessary first step in initiating any dioxin-like toxic effects. Also central to the TEF approach is the concept of additivity. Not only does there need to be a clear understanding of the relative potencies of individual isomers/congeners relative to 2,3,7,8-TCDD, but it MUST be assumed that they all work through an additive model of toxicity to exert their dioxin-like effects (i.e., all toxicity is Ah-R mediated).

For human health, the TEFs that have been developed by the World Health Organization are currently being used to assess human health impacts from exposure to “dioxin-like” compounds (EPA 1994). These TEFs currently are available for CDD and CDF isomers.

For wildlife, EPA has reviewed the use of TEFs and has proposed a draft set of TEFs for mammals, birds, and fish that include TEFs for CDDs, CDFs, and twelve dioxin-like PCB congeners (EPA 1993, 2003). The greatest challenge in the evaluating whether these TEFs are scientifically justified for use is the uncertainty associated with the derivation of these TEFs relative to the uncertainty associated with other aspects of the ecological risk assessment process (EPA 2003).

It should be noted that the relative sensitivity to dioxin-like toxicity among species that posses the Ah-R varies greatly, even within taxonomic class (Eisler 2000). For example, the sensitivity of bird species tested to date to TCDD-induced embryo mortality varies by about 200-fold, with domestic chickens generally more sensitive than wildlife species (EPA 2003). Similar differences have been observed amongst mammals and fish. Therefore, there are relative potency issues within a particular species and inter-species differences in sensitivity to dioxin-like toxicity.

The relative sensitivity of animal classes is not constant across chemical class either. For example, while fish are generally more sensitive to PCDDs and PCDFs relative to birds and mammals, they are much less sensitive to mono-ortho-substituted PCBs (EPA 2003). Amphibians, reptiles, and primitive fish are relatively insensitive to dioxin-like chemicals. Although Ah-R homologs have been identified in amphibians and primitive fish, their toxicological significance is unknown. It has also been demonstrated that a wide variety of invertebrates, including amphipods, cladocerans, midges, mosquito larvae, sandworms, oligochaete worms, snails, clams, and grass shrimp, are insensitive to 2,3,7,8-TCDD induced toxicity (EPA 2003).

Therefore, the application of TEFs for wildlife species presents additional complexities that were not encountered in the development of TEFs for a single species (Humans). In addition, the two fundamental assumptions in the use of TEFs have not been verified as being true for all wildlife species being considered; the assumption that all toxicity associated with the CDD, CDF, and PCBs are related to Ah-R interactions (there is some evidence of reproductive and other toxic endpoints that may be derived from other toxic mechanisms); and the assumption that the individual potencies of isomers/congers are additive.

The potential development of appropriate TEFs for wildlife is an exciting opportunity for addressing potential risks from this complex class of persistent compounds. Additional data in the form of laboratory and field verification of some of the assumptions in the proposed EPA methodology over the next few years should help RSET assess the technical defensibility of this approach and whether it is ready for recommendation for use in the Pacific Northwest.

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Tillit, D.E. 1999. The Toxic Equivalents Approach for Fish and Wildlife. Human and Ecological Risk Assessment: Vol. 5 (1). Pp. 25-32.

RECOMMENDATION: Use of TEFs for assessing human health risks from CDDs and CDFs that interact with the cytosolic aryl hydrocarbon receptor (Ah-R) are well established and accepted. The EPA draft wildlife TEFs have only been recently developed and there are still considerable uncertainties in their application in ecological risk assessments. RSET can possibly present these approaches in an appendix with a discussion of uncertainties, but wildlife TEFs are still a few years from being ready for general use. Additional field and laboratory validation studies need to be completed to ensure that the assumptions inherent in the Wildlife TEFs are acceptable and correct.

PROPOSED LANGUAGE: For risk assessment purposes, the use of TEFs for addressing human health impacts from exposure to “dioxin-like” compounds is relatively well established and has been approved by EPA, as well as international organizations (e.g., World Health Organization). Recently, there have been attempts to develop similar TEFs for addressing ecological risks and draft TEFs for CDDs, CDFs, and twelve PCB congeners have been developed for mammals, birds, and fish (EPA 2003). Because these are still draft values and uncertainty in the underlying toxicological principles for their use exists, it is recommended that they not be adopted by RSET at this time. These TEFs can be used a part of a weight-of-evidence approach for estimating ecological risk, but they should not be relied upon alone to make ecological risk decisions. There should be more information coming out with the review of this draft EPA document that may help address the uncertainties and provide a more technically defensible methodology for addressing ecological risks from these compounds. Additional field and laboratory validation studies need to be completed to ensure the assumptions inherent in the wildlife TEFs are acceptable and correct.

LIST OF PREPARERS: Taku Fuji, Ph.D., Kennedy/Jenks Consultants

RSET ISSUE PAPER #6 – PCB Analysis

CHEMICAL ANALYTE LIST SUBCOMMITTEE: T. Thornburg, Chair (tthornburg@anchorenv.com); August 10, 2004

QUESTION/ISSUE: PCB Analysis.

DISCUSSION:

Background: Currently, the DMEF contains screening levels (Screening Levels [SLs], Maximum Levels [MLs], and Bioaccumulation Triggers [BTs]) for polychlorinated biphenyls (PCBs) in sediments based on total PCBs. Recent advances in risk assessment for PCBs have indicated that risk to humans and wildlife associated with PCBs may not be well-represented by a total PCB value. In particular, it may only be possible to accurately assess dioxin-like cancer risk using PCB congener data. This may require analyzing for all or a subset of the 209 congeners that are considered PCBs. On the other hand, risks to benthic invertebrates may be well-characterized by a total PCB value, because it is expected to occur through a narcosis mechanism rather than through the Ah receptor, which is absent in invertebrates.

Issue: The science associated with evaluating bioaccumulative risks from PCBs has advanced considerably since the development of the marine AETs and the original PSDDA BTs, both of which are currently included in the DMEF manual. At this time, there is a consensus among the Analyte Subcommittee that it is time to begin incorporating this new knowledge base into our regulatory framework. Specifically, the committee has discussed whether sediments and/or tissue should be analyzed for PCB congeners, considering the value of the information this would provide us, the practical implications of doing so, and the cost associated with congener analyses.

The cost to analyze for PCB congeners is significantly greater than the cost for standard PCB arochlor or homologue analysis (Table 1). However, this information, particularly in tissues, is considered necessary in order to conduct risk assessments for the bioaccumulative pathways. On the other hand, the committee does not consider it necessary to obtain congener data for sediments, because risks to the benthic community are better modeled through a total PCB (or narcosis-based) pathway. These recommendations affect the SQG and Bioaccumulation Subcommittees' work, who would then need to formulate sediment and/or tissue standards accordingly.

There will be issues related to calculation of site-specific cleanup or dredging criteria based on analysis of tissues and calculation of bioaccumulative risks associated with tissues, if sediments and tissues are analyzed in different ways. However, these issues are unavoidable to some extent even if congeners are analyzed in both sediments and tissues, because the pattern of congeners present in each is affected by disproportionate accumulation of congeners with varying molecular weights. As an alternative, the committee recommends using methods recently developed (Nedoff et al. 2004, NOAA 1989) to estimate total PCBs in tissues from congener data, and back-calculate to sediment concentrations based on these estimates (Table 2). Alternatively, GIS-based methods can be used to evaluate the areas and extent to which PCBs in sediments need to be lowered to reduce overall exposure concentrations within a species' home range to levels that should reduce tissue concentrations to acceptable risk levels.

Because of the higher costs associated with congener analysis and the more time-consuming procedures associated with collecting tissue data, the determination of the need to evaluate this contaminant becomes more critical. Before PCB tissue congener analysis is determined to be necessary, there should be a "reason to believe" that PCBs may pose an unacceptable bioaccumulation risk. In addition, any existing tissue data for the watershed should be considered in determining whether PCBs may present an unacceptable bioaccumulation risk. These issues are currently being evaluated in the Bioaccumulation Subcommittee (see Issue Paper #16: *Framework for Assessing Bioaccumulation Under RSET*).

Proposal:

1. Sediments would continue to be analyzed for total PCBs. This is the best determinant of direct toxicity to benthos.

2. Tissue would be analyzed for PCB congeners for assessment of risks to fish and bioaccumulative risks. Options include laboratory bioaccumulation tests, *in situ* testing using caged bivalves/fish, and collection of resident species from the area.

3. Recent research would be used to correlate total PCB values in sediments to an equivalent total PCB value based on congener results in tissue, should it be necessary to do so to establish site-specific cleanup levels in sediment based on bioaccumulation pathways.

Next Steps:

1. Sediment Guideline Subcommittee and Bioaccumulation Subcommittee to develop appropriate screening levels for total PCBs in sediment and PCB congeners in tissue, as well as criteria for establishing "reason to believe" that PCBs may pose an unacceptable bioaccumulation risk.

2. With input from the Bioaccumulation Subcommittee on target tissue levels for PCB congeners, the Chemical Analyte Subcommittee will recommend an analytical method which provides an appropriate level of sensitivity (see White Paper #8, PCB Analytical Methods).

3. Efforts should be made to document existing tissue and sediment data on PCB concentrations for watersheds in the Northwest. In particular, congener analysis should be compiled in a database and made easily accessible to parties who may be involved in dredging or environmental investigations.

4. An outreach effort to the Department of Health should be initiated to determine how they plan to evaluate PCBs in tissue and the levels they will use to establish fish advisories.

REFERENCES:

Nedoff J.A., Kennedy LJ, Williams BA. 2004. How Many PCB Congeners are Really Needed to Estimate Totals? Platform presentation at the Pacific Northwest SETAC Conference, Port Townsend, Washington. April 14-16, 2004. Kennedy/Jenks Consultants, San Francisco, California.

NOAA (National Oceanic Atmospheric Administration). 1989. Standard Analytical Procedures of the NOAA National Analytical Facility. 2nd ed. NOAA Tech. Memo. NMFS F/NWC-92, 1985-86. Contact: National
Status and Trends Program, National Oceanic and Atmospheric Administration,
NOAA N/OMA32, 11400 Rockville Pike, Rockville, MD 20852.

PROPOSED LANGUAGE:

Section 8.4.1.

<<Add the following paragraph>>

Different analytical methods are required for analysis of PCBs in bulk sediment and tissue matrices. Bulk sediment will be analyzed for Aroclor composition using EPA Method 8082. If bioaccumulation testing is required, tissue samples will be analyzed for individual congeners (or a subset of congeners) using EPA Method [8082 or 1668, to be determined].

Table 8-2.

Revise Table 8-2 to add PCB congener method for tissue analysis and add footnote explaining different methods will be used for bulk sediment and tissue analysis.

Table 1. PCB Analytical Methods and Costs

Method	Detector	Detection limits	Cost	Analytes detected**	Comments
EPA 8082	ECD, Dual column for confirmation	~0.1-0.3 ug/kg	$225-350	~62 congeners with one injection (dual column), All 19 Coplanars	Possible interference include chlorinated pesticides, phthalates, polychlorinated terphenyls
EPA 680	Mass Spec	~0.2 ug/kg	$400-600		Some problems with identification due to co-elutions and presence of PCTs or other similar analytes

EPA 1668	Hi Res MS	~0.002-0.050 ug/kg	$750-1150	All 209 congeners, All 19 Coplanars	Most comprehensive based on detection selectivity
Krahn et al, 1994	HPLC/ Photodiode array	~1-4 ug/kg	$425-560	16 congeners, 12 Coplanars 77, 105, 118, 126, 128, 138, 156, 157, 169, 170, 180, and 189	Limited availability, Possible interference by PCTs, and PCNaphthalenes

*Typically dependent on the number of congeners requested.
**All methods include some co-elutions.
The 19 PCB co-planar congeners are:
Co-planars: Nos. 77, 81, 126, 169,
Mono-ortho coplanars: Nos. 60, 105, 114, 118, 123, 156, 157, 167, 189
Di-ortho co-planars: Nos. 128, 138, 158, 166, 170, 180

PCB Congener co-elution is not a static condition, and will vary between laboratories based on GC operating conditions, column conditions, etc., while still adhereing to the guidance put forth by the EPA methodology.

Table 2. PCB Congener Lists that Account for 80 Percent and 50 Percent of Total Congeners in Seven Sample Types* Collected from Portland Harbor

80% List	50% List	Congener on list from only one matrix	NOAA List (18)	12 Dioxin-like (coplanar)
1		crayfish		
4		crayfish		
18/30**			18	
20/28			20	
31				
40/41/71				
44/47/65	44/47/65	sculpin	44	
49/69				
52	52		52	
56				
61/70/74/76	61/70/74/76			
64				
66	66		66	
83/99	83/99			
84		sediment		
85/116/117				
86/87/97/108/119/125	86/87/97/108/119/125	sediment		
90/101/113	90/101/113		90	
92				
93/95/98/100/102	93/95/98/100/102	sediment		
105			105	105
110/115	110/115			
118	118		118	118

128/166		sediment	128	
129/138/160/163	129/138/160/163		129	
132				
135/151/154	135/151/154	carp		
136		carp		
141				
146				
147/149	147/149			
153/168	153/168		153	
156	156	crayfish		156
158		bullhead		
170	170		170	
171/173				
174	174	carp		
177				
178		bullhead		
179		carp		
180/193	180/193		180	
183/185				
187	187		187	
194				
196				
198/199				
83 congeners not including coplanars not in 80% list	45 congeners not including coplanars not in 50% list			
			8	
77	77		77	77
81	81			81
114	114			114
123	123			123
126	126		126	126
157	157			157
167	167			167
169	169		169	169
189	189			189
92 including coplanars not in top 80% list	54 including coplanars not in 50% list		18 total	12 total

* Seven sample types for which PCB Congener data were available in Round 1:
Sediment, Crayfish, Sculpin, Smallmouth Bass, Black Crappie, Brown Bullhead, and Carp (tissues were whole body)

** X/X/X Indicates group of coeluting congeners.

Highlighted cells indicate dioxin-like congeners.

Congener counts include coeluting congeners.

Methods:

1. Averaged the detected concentrations of each congener in each sample type
2. Totaled the average concentrations for each sample type (total PCB value)
3. Normalized the concentration against the total for each detected congener (% of total)

4. Ranked the congeners from highest to lowest normalized concentration (%)
5. Determined which congeners accounted for 80% and 50% of total for each sample type
6. Compiled list of all congeners in top 80% and top 50% for each sample type

Notes:

A. If apply 80% list to averaged, normalized list (in step 4), result is 86 - 89% of total for each sample type
Multiply total from 80% list by 1.2 to get total PCBs as congeners

B. If apply 50% list to averaged, normalized list (in step 4), result is 65 - 70% of total for each sample type
Multiply total from 50% list by 1.5 to get total PCBs as congeners

LIST OF PREPARERS: Jennifer Sutter, Oregon Department of Environmental Quality and Teresa Michelsen, Avocet Consulting

RSET ISSUE PAPER #8 – PCB Analytical Methods

CHEMICAL ANALYTE LIST SUBCOMMITTEE: T. Thornburg, Chair (tthornburg@anchorenv.com); August 15, 2004

QUESTION/ISSUE: What methods should be used to evaluate polychlorinated biphenyl (PCB) concentrations in sediments and tissues, and should the concentration determinations include Aroclor and/or Congener concentrations?

DISCUSSION: Although some degree of PCB Aroclor degradation can occur in sediments, in most instances the Aroclor can be identified based upon its analytical pattern. In tissues, PCB Aroclors undergo a much more significant degradation due to biological processes, making identification and quantification of parent Aroclors difficult. It is recommended that sediments are analyzed for PCB Aroclors, and tissue samples be analyzed for PCB Congeners to determine the extent of PCB contamination (see paper by Sutter and Michelsen for additional technical rationale regarding aroclor versus congener analysis). EPA Method 8082 (GC/ECD) will be used to analyze for Aroclors in sediment and may also be used to analyze congers in tissue. In instances where toxicological evaluation requires lower detection limits, EPA Method 1668 (Hi Res GC/MS) can be used. The selection of Method 8082 versus Method 1668 for PCB congener analysis will need to consider detection limits, cost, and commercial availability. Therefore, a final decision on method selection awaits the development of target tissue levels for PCB congeners by the Bioaccumulation Subcommittee.

REFERENCES: None.

RECOMMENDATION: Text and table revisions to specify methods of analysis for PCB congeners in tissue, pending development of target tissue levels for PCB congeners by the Bioaccumulation Subcommittee.

PROPOSED LANGUAGE:

Method	Detector	Detection limits	Cost	Analytes detected**	Comments
EPA 8082	ECD, Dual column for confirmation	~0.1-0.3 ug/kg	$225-350	~62 congeners with one injection (dual column), All 19 Coplanars	Possible interference include chlorinated pesticides, phthalates, polychlorinated terphenyls
EPA 680	Mass Spec	~0.2 ug/kg	$400-600		Some problems with

					identification due to co-elutions and presence of PCTs or other similar analytes
EPA 1668	Hi Res MS	~0.002-0.050 ug/kg	$750-1150	All 209 congeners, All 19 Coplanars	Most comprehensive based on detection selectivity
Krahn et al, 1994	HPLC/ Photodiode array	~1-4 ug/kg	$425-560	16 congeners, 12 Coplanars 77, 105, 118, 126, 128, 138, 156, 157, 169, 170, 180, and 189	Limited availability, Possible interference by PCTs, and PCNaphthalenes

*Typically dependent on the number of congeners requested.
**All methods include some co-elutions.
The 19 PCB co-planar congeners are:
Co-planars: Nos. 77, 81, 126, 169,
Mono-ortho coplanars: Nos. 60, 105, 114, 118, 123, 156, 157, 167, 189
Di-ortho co-planars: Nos. 128, 138, 158, 166, 170, 180

PCB Congener co-elution is not a static condition, and will vary between laboratories based on GC operating conditions, column conditions, etc., while still adhereing to the guidance put forth by the EPA methodology.

LIST OF PREPARERS: Gregory Salata, CAS; Roger McGinnis, Hart Crowser; Lyndel Johnson, NOAA

RSET ISSUE PAPER #9 - SQG Cost Effectiveness / Reliability

SEDIMENT QUALITY GUIDELINES SUBCOMMITTEE: B.Betts , Chair (bbet461@ecy.wa.gov); August 2, 2004

QUESTION/ISSUE: How has cost-effectiveness and environmental reliability been evaluated in the development of sediment quality guidelines and a recommended routine analytes list? Has the most cost-effective and reliable set of guidelines been recommended?

DISCUSSION: Currently, the RSET Analyte Subcommittee is developing recommendations for key chemical analytes/groups for routine analysis. These recommendations will not encompass all chemicals of concern, but rather specific chemicals or groups of particular concern (e.g., PCBs, PAHs and pesticides).

Regionally, Ecology completed development of freshwater sediment quality guidelines in September 2003. Ecology's report identifies recommended routine analytes for freshwater sediment analysis/evaluation based on thorough reliability analyses (i.e., ability of specific chemical guidelines to accurately predict regional biological effects).

REFERENCES:

Author??. Phase II Report: Development and Recommendation of SQVs for Freshwater Sediments in Washington State, September 2003, Publication No. 03-09-088.

RECOMMENDATION: The two RSET development efforts will be combined in the short-term future to evaluate cost-effectiveness and reliability. Cost-effectiveness may be evaluated using primary and alternative lists of recommended chemicals of concern for routine analyses. Cost-effectiveness recommendations may be based in-part on consideration of chemical detection frequency, chemical relationship to regional/national bio-effects, persistence, bioaccumulation, and other considerations.

Regionally, reliability analyses have been completed for regionally available, synoptic sediment chemical, and bioassay data. The reliability analyte lists may be independently evaluated for cost-effectiveness.

Because two lists may soon be available (i.e., recommended analytes and recommended guidelines), evaluation of cost-effectiveness should address the relationship between these two lists.

PROPOSED LANGUAGE: None yet available.

LIST OF PREPARERS: Brett Betts, Washington Department of Ecology

RSET ISSUE PAPER #10 - Develop Regional Data Compilation/Database Structure

SEDIMENT QUALITY GUIDELINES SUBCOMMITTEE: B.Betts , Chair (bbet461@ecy.wa.gov); August 2, 2004

QUESTION/ISSUE: How should a regional sediment quality data compilation be stored? What is the recommended sediment quality data structure for regional sediment data?

DISCUSSION: Three regional sediment data systems currently exist in the Northwest: DAIS, Query Manager and SEDQUAL. DAIS is a USACE, Seattle District application that includes dredged material data for Seattle District only. Query Manager is a NOAA data system that is primarily national in scope and uses a watershed approach to compile and review data. Sedqual is an Ecology application that has compiled multi-program sediment data since 1989. Sedqual contains data from multiple west coast states, primarily Washington and Oregon. Sedqual's relational data structure has remained essentially the same since 1995. The Sedqual data file, application, and data submittal templates are publicly available online at Ecology's website Web address???.

REFERENCES:

NEED FULL REFERENCE

http://www.ecy.wa.gov/programs/tcp/smu/sedqualfirst.htm

RECOMMENDATION: The SQG Subcommittee recommended use of Sedqual to the RSET Policy Committee in September 2003. Sedqual is still recommended to compile regional sediment quality data from all regulatory, investigation, status and trend, and academic sampling efforts. It is the most complete Portland Division sediment compilation. It also is the primary sediment data system for Ecology and Oregon Department of Environmental Quality.

PROPOSED LANGUAGE: None yet available.

LIST OF PREPARERS: Brett Betts, Washington Department of Ecology

RSET ISSUE PAPER #11 - Evaluate Ecology's Guideline Development /Reliability

SEDIMENT QUALITY GUIDELINES SUBCOMMITTEE: B.Betts , Chair (bbet461@ecy.wa.gov); August 2, 2004

QUESTION/ISSUE: What methods were used by Washington Department of Ecology to evaluate alternative marine and freshwater sediment quality guidelines and their respective reliability?

DISCUSSION: Ecology adopted marine sediment quality standards in April 1991. Development of marine sediment quality criteria dated back to Puget Sound investigations in 1986. Ecology's evaluation and selection of marine sediment quality criteria are based on several reports available to the public. Significant reports include the 1990 Environmental Impact and Economic Impact Statements, and the 1988 and 1994 criteria technical development documents. Reliability analyses are included in the technical reports.

Ecology conducted two significant rounds of freshwater sediment guideline technical development in 1997 and again in 2003. Technical reports for both efforts are available from Ecology's website. The 2003 Phase II technical effort re-developed apparent effects threshold (AET) values from 1997, but also developed guidelines using the floating percentile method. Ecology does not recommend one set of guidelines in the 2003 report, but instead provides reliability results for a number of AET and floating percentile guidelines. Ecology plans to issue separate public guidance recommending a preferred set of freshwater sediment guidelines and sediment evaluation methods in the near future.

Currently, no other west coast state has issued final reports on development of marine or freshwater sediment guidelines. The state of Oregon has enough synoptic, chemical, and biological data to separately evaluate one or more of Washington's freshwater guidelines using methods from the Phase II report.

REFERENCES: http://www.ecy.wa.gov/programs/tcp/smu/sed_pubs.htm, Phase II Report: Development and Recommendation of SQVs for Freshwater Sediments in Washington State, September 2003, Publication No. 03-09-088.

RECOMMENDATION: Complete Oregon freshwater reliability analyses using methods and guidelines from the Phase II Ecology report. Evaluate sediment quality data availability from the state of Idaho for potential reliability analyses. Re-visit development of consensus agreement on SQG guidelines after the Oregon reliability analyses.

PROPOSED LANGUAGE CHANGES: None yet available.

LIST OF PREPARERS: Brett Betts, Washington Department of Ecology

RSET ISSUE PAPER #16 – Framework For Assessing Bioaccumulation Under RSET

BIOACCUMULATION SUBCOMMITTEE: D. Kendall (david.r.kendall@usace.army.mil) and T. Michelsen (teresa@avocetconsulting.com), Co-Chairs; August 2, 2004

QUESTION/ISSUE: How should potential toxicity associated with bioaccumulation be addressed as part of the Pacific Northwest Region Sediment Evaluation Framework?

DISCUSSION:

Background: The current Dredged Material Evaluation Framework (DMEF) for the Lower Columbia River Management Area contains guidance for assessing bioaccumulation in Section 9.4 of the manual (Corps et al. 1998). This manual is in the process of being updated and consolidated with other dredging manuals in the Pacific Northwest Region, and will apply to both marine and freshwater areas in Washington, Oregon, and Idaho. While primarily focused on dredging projects, it is also intended to provide a framework consistent with cleanup and habitat restoration projects in the region. The text included in the existing DMEF is to be used until the RSET is able to develop a more comprehensive and up-to-date approach to addressing potential risks associated with bioaccumulation.

In the DMEF manual, bioaccumulation testing is a Tier III requirement when there is reason to believe that specific chemicals of concern may be accumulating in target tissues at levels of concern. Reason to believe is established by comparing sediment concentrations to bioaccumulation triggers (BTs) listed in Appendix C. However, most of these bioaccumulation trigger values are based on the Screening Levels (SLs) and Maximum Levels (MLs), which are themselves derived from sediment toxicity tests rather than bioaccumulation tests or bioaccumulation-based risk assessments. Therefore, there has been a recognized need to update the bioaccumulation triggers to be directly reflective of toxicity through the bioaccumulation pathway.

In the existing process, once the bioaccumulation tests are triggered, the results are first compared to tissue concentrations from the reference samples. If concentrations are not statistically greater than in the reference tissues, the DMEF manual states that sediments are assumed to be associated with no adverse effects (which may or may not be the case). If test sample concentrations exceed reference sample concentrations, they are compared to human health and ecological levels of concern.

Human health comparisons are currently based on Food and Drug Administration (FDA) action levels, above which tissue concentrations would be considered to be of concern. For chemical concentrations lower than or without FDA action levels, risk assessment techniques are to be used. For ecological effects, a simple exceedance of reference conditions is enough to trigger a determination of unsuitability. However, the text also references the Environmental Residue Effects Database (ERED) as information that could be used in assessing potential ecological risks. These tissue levels need to be updated and expanded to be more reflective of actual risks to humans and wildlife associated with bioaccumulation.

In addition, the SEF is attempting to expand its scope to include not only dredged material management projects, but also sediment cleanup projects. A more holistic approach to bioaccumulation issues is needed that allows both types of projects to be integrated on a watershed-wide scale to meet common risk-based goals, and which also incorporates regional monitoring. Ideally, a cost-effective approach could be developed to assess and integrate tissue concentrations, sediment concentrations, and effects endpoints.

Discussion: The Bioaccumulation Subcommittee identified a number of areas where the bioaccumulation approach needs to be clarified and/or updated:

- Methods for establishing "reason to believe" that bioaccumulation is a concern for a particular project
- Identification of bioaccumulative chemicals of concern for freshwater and marine areas
- Determining what type of tiered approach is appropriate for assessing bioaccumulation and whether there are differences between dredging and cleanup projects in this respect
- Methods for establishing sediment and/or tissue guidelines based on risks associated with bioaccumulative chemicals
- Bioaccumulation testing protocols, especially for freshwater
- Identification of appropriate freshwater reference areas (this issue is being addressed by the SQG subcommittee)

Of these issues, one of the most difficult is establishing a link between tissue concentrations, which have the most direct association with risks from bioaccumulative chemicals, and sediments. This consideration led to spirited discussion of the use of a "top-down" approach – i.e., assessing bioaccumulative risks on a watershed-wide basis in tissues and only then moving to sources in sediments – vs. a "bottom-up" approach more traditional in dredging programs, with chemical triggers in sediments and bioaccumulation testing in a subsequent tier. The most significant obstacle in pursuing the traditional dredging program approach is establishing sediment bioaccumulation triggers that are scientifically defensible. Nevertheless, the committee recognizes this as a clear goal of the dredging program, to simplify the decision process for applicants and reduce the cost of testing. The recommended framework outlined below blends the two approaches.

Regardless of which approach is pursued, it was agreed that the first step is to establish scientifically defensible tissue triggers based on protection of human health, fish and aquatic ESA species, and higher trophic levels such as birds and mammals. Each of these three receptor groups will be addressed more specifically in a follow-up paper to this overall bioaccumulation framework issue paper. Before any of this work can be done, bioaccumulative chemicals of concern need to be identified. Recommendations for this process are also discussed in more detail in a forthcoming paper.

REFERENCES:

USACE-PNW, EPA Region 10, WDOE, ODEQ, WDNR. 1998. Dredged Material Evaluation Framework Lower Columbia River Management Area. U.S. Army Corps of Engineers, Pacific Northwest Division, Portland, OR.

RECOMMENDATION:

1. Identify Bioaccumulative Contaminants of Concern (BCOCs). The committee has reviewed the approach established by the previous BCOC committee under the Dredged Material Management Program (DMMP), and most likely will adopt it after further discussion. The approach relies on a review of the occurrence of contaminants in sediments and tissue, chemical properties of contaminants such as K_{ow}, known toxicity of the contaminants to human and ecological receptors, and comparison of tissue levels to available action levels. Contaminants are placed on one of several lists depending on the amount of information available and the weight-of-evidence indicating their potential to be bioaccumulative chemicals of concern.

Upon adoption of this approach (with or without modifications as determined necessary), the committee will then review whether it can adopt the DMMP BCOC list without modification, either as an interim or a permanent list. If most of the data that went into developing that list are marine data, then the committee may adopt that list as a marine list and work on developing a separate freshwater list. To that end, the committee is currently compiling a database of existing freshwater tissue data in the region.

2. More Clearly Define "Reason to Believe." Because of the cost of bioaccumulation testing and the potential lack of defensible sediment triggers for some time to come, the committee believes it is important to have a strong "reason to believe" prior to requiring bioaccumulation testing. This reason to believe may include both "top-down" and "bottom-up" types of information.

As soon as reasonably possible following the establishment of a regional BCOC list, tissue data should be reviewed by watershed to identify a subset of BCOC chemicals of concern in tissues for each watershed. This will only be possible in areas where sufficient tissue data have been collected; however, this may include the most contaminated areas where tissue assessments are currently or have previously been conducted. In this manner, the BCOC list can be narrowed down for each area to include only those chemicals that are currently detected in tissues (assuming that detection limits are appropriate). Once tissue triggers are available, the list can be narrowed further to those chemicals that exceed tissue triggers.

Chemical testing conducted in Tier 1 can be used to identify whether any chemicals on the watershed BCOC list are present in project or site sediments. In the absence of scientifically defensible sediment triggers, if such chemicals are present, then laboratory bioaccumulation testing, *in situ* bioaccumulation testing, and/or tissue collection from the site or dredging area would need to be conducted in Tier 2, along with any bioassays being completed. Such testing could be limited to the BCOCs present to save analytical costs. The Bioaccumulation committee strongly recommends consideration of tests that combine measures of effects and exposure with tissue concentrations.

It is not recommended that the SEF continue to use the existing BTs to establish reason to believe, particularly those based on the SLs and MLs, as these are not likely to be protective for all BCOCs and are not defensible based on the best available science. Clearly it will be important to move ahead with all possible speed to establish tissue and sediment triggers, and there are some interim steps that can be taken (see below).

3. Establish Tissue Triggers. Tissue triggers are expected to be used by both dredging and cleanup programs to identify target levels that may be applied region-wide. Developing tissue triggers is the first step toward establishing sediment triggers and/or a watershed-wide approach to source reduction, and would also serve as the criteria to which the results of bioaccumulation testing would be compared. The subcommittee identified several groups of receptors for which tissue triggers need to be established:

- Human consumption of fish and shellfish
- Wildlife consumption of fish and invertebrates
- Fish
- ESA species (fish, mussels, snails, birds, etc.)

Tissue levels for the first two sets of receptors would be based on back-calculation using established risk assessment techniques and receptors common in the Pacific Northwest. Tissue levels for protection of fish would be based on tissue-residue-effects data contained in databases such as ERED. Three companion papers discuss each of these methods in greater detail. Member agencies involved in RSET are currently discussing whether separate levels need to be established to protect ESA species.

Note that this approach will not protect fish against contaminants that do not appreciably bioaccumulate in tissues, or which are rapidly transformed to other compounds, such as PAHs. SQGs for such contaminants will need to be developed separately by the SQG subcommittee or the Bioaccumulation subcommittee, and this will be a follow-up task for one of the two committees.

Since each of these receptor groups is protected under all of the regulatory programs addressing sediments, it is assumed that generally, the lowest of the applicable levels will be used as the target tissue level. However, the approaches and input values used to derive each of the levels must be transparent and readily available for review, as some aspects may vary on a site-specific basis. For example, consumption rates may vary by region, disposal site, or watershed, as may the wildlife and ESA receptors present. Cleanup site managers, and to some degree dredging agencies, should be provided the opportunity to modify the values based on good science and site-specific factors, as long as the modifications are recorded in an appropriate document such as a suitability determination or record of decision.

4. Establish Bioaccumulation Triggers for Sediments. Experience to date in the scientific and regulatory community is that it is difficult to back-calculate generally applicable sediment triggers from tissue levels using literature-derived BSAFs or other modeling approaches, due to significant uncertainties in BSAFs for the same chemical derived from different data sets. This may be due to differences in study design, sediment geochemistry, bioavailability of contaminants, and food webs from one data set to the next. However, BSAFs can be developed on a site-specific or watershed basis using tissue data paired with sediment data from the home range of the species being evaluated. Please see Attachment A for further discussion of methods for deriving sediment BTs from tissue BTs.

For the purposes of the dredging program, the most relevant BSAF would be that at the disposal site. It may be possible to use past monitoring data to develop disposal site-specific BSAFs that can be applied to derive BTs for each disposal site (or for a set of disposal sites that are similar in nature and receptors, such as ocean disposal sites along the coast of Oregon or those in Puget Sound). In deriving and applying such BSAFs, it will be important to consider whether sediment characteristics affecting bioavailability are similar at the disposal site and in the dredged material being disposed there.

Similarly, BSAFs may be developed for certain chemicals and watersheds as part of large Superfund sites currently in progress, and under source control (e.g., TMDL) and NRDA processes. In these cases, it may be more productive to use a GIS-based approach to determine which areas of sediment in the site or watershed need to be cleaned up to reduce overall loading to a level that would, in turn, reduce tissue concentrations to acceptable levels. This may be accomplished by identifying the factor by which tissue concentrations need to be reduced (e.g., to 50% of current levels), and then using GIS tools to identify areas that if cleaned up, would reduce the area-weighted average sediment concentration within that organism's home range to 50% or less of its previous value.

Because of both environmental and programmatic differences, it is not necessary or even possible to use the same approach or have the same criteria for bioaccumulation in sediments. What is important is that the programs and agencies are all using consistent target tissue criteria and are working toward meeting those criteria in whichever way best meets their project needs.

5. Collection of Missing Data. For areas where not enough data exist to establish watershed BCOCs, determine reason to believe, or develop BSAFs, it is recommended that the agencies and the regulated community share the burden of data collection. For example, the agencies should have the primary responsibility for collecting data to determine tissue concentrations and BSAFs at the disposal sites. The agencies should also establish a priority list of chemicals and areas to be monitored to fill key data gaps, and develop a plan for incorporating this monitoring into their budgets and programs. As part of this plan, it should be determined specifically how much and what types of data are enough for the purposes of the program needs. When projects and sites come up that involve lower-priority chemicals or which wish to proceed on a faster track than the agency monitoring programs can accommodate, the project proponent should then bear the cost of providing the necessary data, as an alternative to proceeding to the next tier of testing.

Similar to the process recently completed in the SQG subcommittee, the Bioaccumulation subcommittee identified a need to develop data management and review procedures. Specifically, a single database needs to be identified to maintain bioaccumulation data, and an agency needs to be identified to manage the database. For consistency with the sediment data management system, SEDQUAL was selected since it has the capability of maintaining tissue as well as sediment data. In addition, some areas of bioaccumulation science are rapidly evolving, such as wildlife toxicity and the availability of tissue residue effects data. These areas need to reviewed and updated frequently, and a mechanism needs to be established within RSET to accomplish this.

6. Testing Procedures. Although this topic is somewhat outside the scope of this paper, laboratory and *in situ* bioaccumulation testing procedures, particularly for freshwater organisms, need to be reviewed and updated. The committee especially recommends that the agencies evaluate the use of procedures that allow bioassay and bioaccumulation testing to be conducted simultaneously, as well as new analytical methods developed by the Waterways Experiment Station that can reduce the tissue volume required for chemical analysis. Both of these areas of research may substantially reduce the cost burden of bioaccumulation testing, as well as allowing us to more directly link observed effects with tissue concentrations. Two companion papers have been developed reviewing emerging laboratory and in-situ testing procedures for freshwater.

7. Revise SEF. Once the framework outlined in this paper has been fully reviewed and approved by RSET, the Bioaccumulation subcommittee will develop specific language to replace the current Section 9.4 of the DMEF manual and several appendices to provide further information on topics such as testing procedures, methods for calculating BSAFs, and derivation of tissue and sediment BTs.

PROPOSED LANGUAGE: None yet available.

LIST OF PREPARERS: Teresa Michelsen, Avocet Consulting

Attachment A. Converting Target Tissue Levels to Sediment Quality Guidelines

Jim Meador, NOAA Fisheries, National Fisheries Science Center

Once a protective tissue residue has been selected, a protective sediment concentration may also be generated from the target tissue level (TTL). Sediment guidelines may be generated for benthic and epibenthic fish (but not for pelagic fish) if reliable site-specific BSAFs can be determined or a distribution of BSAFs can be generated that would be used to determine a range in sediment concentrations that would lead to the selected TTL.

There are two ways to convert the TTL to a SQG using bioaccumulation factors. One uses the bioconcentration factor coupled with the sediment water partition coefficient. The other uses the BSAF to convert a TTL to an equivalent SQG. For each method, the best approach is to consider the distribution of all bioaccumulation factors, which can be used to generate a probability distribution of SQGs.

Bioconcentration approach

The first step is to compile all available bioconcentration factors. The organic-carbon normalized sediment-water partition coefficient (K_{oc}) for a compound needs to be obtained from empirical measurements or modeled.

Water-sediment partition coefficients for many neutral hydrophobic compounds can be predicted with the octanol-water partition coefficient (K_{ow}), a good predictor of K_{oc}. Several authors have developed equations that predict K_{oc} values from the K_{ow} for various hydrophobic compounds (Karickhoff et al. 1979, Means et al. 1980, Karickhoff 1981, Di Toro et al. 1991). These studies show the K_{oc} to range from $0.4*K_{ow}$ to $1.0*K_{ow}$.

For each TTL, the following equation would be used to generate the SQG:

$$[\mathrm{SQG}_{oc}] = \mathrm{Koc} * \frac{\mathrm{TTL}}{\mathrm{BCF}}$$

BSAF approach

The BSAF approach has some advantages over the BCF approach because BSAFs generally exhibits much less variability than do BCFs. Because tissue concentrations are normalized to lipid and sediment concentrations are normalized to organic carbon, BSAFs for organic compounds will achieve a theoretical maximum value between 1 and 4, based on equilibrium partitioning between all phases (Di Toro, Boese, xxx). Metabolism or transformation of the toxicant, insufficient time to steady state for partitioning between phases will lead to BSAF values less than the theoretical maximum. For many compounds, a cumulative distribution function is the best way to select the highest BSAF for determining an SQG. If no BSAF data are available and the organic compound is known to behave according to equilibrium partitioning (EqP), the default value of 4 can be selected to represent the worst case bioaccumulation.

Ideally, representative bioaccumulation values from several species should be obtained to generate a cumulative density function. From this CDF, a percentile value, such as the 95th, can be selected to ensure that the most sensitive species are protected. Because the bioaccumulation factor is controlled by the uptake and elimination kinetics and these are variable among species and conditions, a high percentile value is desirable to account for this variability and to be protective of most species.

The sediment quality guideline can be determined by:

$$[\mathrm{SQG}_{\mathrm{oc}}] = \frac{[\mathrm{TTL}]}{\mathrm{BSAF} * \mathrm{f}_{\mathrm{lip}}}$$

For those organic compounds and metals that do not behave according to EqP, a standard bioaccumulation factor that is selected from a high percentile (e.g., 95th) of all BAF values should be used to convert the TTL to a SQG:

$$\frac{[\mathrm{TTL}]}{\mathrm{BAF}} = \mathrm{SQG}$$

RSET ISSUE PAPER #17 – Tissue Bioaccumulation Triggers and Proposed Methods of Protection of Fish/ESA Species

BIOACCUMULATION SUBCOMMITTEE: D. Kendall (david.r.kendall@usace.army.mil) and T. Michelsen (teresa@avocetconsulting.com), Co-Chairs; September 19, 2004

QUESTION/ISSUE: How should tissue bioaccumulation triggers (BTs) be developed to protect fish and Endangered Species Act (ESA)-listed species from exposure to contaminants that bioaccumulate?

DISCUSSION:

Background: Bioaccumulation studies are an element of Tier 3 evaluations of dredged material under existing regional and national dredging evaluation guidance. Unfortunately, there are no generally applicable tissue residue guidelines currently available that can be used to interpret the ecological implications of bioaccumulation study results with aquatic species. The Regional Sediment Evaluation Team (RSET) has identified development of tissue residue guidelines, termed tissue BTs in this paper, for protection of fish species as a high priority during its development of a regional sediment evaluation framework. The toxicity of bioaccumulated chemicals to aquatic biota can be evaluated with a tissue residue approach (TRA) toxicity assessment. The results of this assessment can be used to generate tissue BTs. This issue paper addresses the following questions:

- Is it feasible to develop tissue BTs for protection of aquatic life?
- For what chemicals can tissue BTs be developed?
- What are the appropriate toxicological endpoints to evaluate during tissue BT development?
- How can tissue BTs be developed?
- Are separate tissue BTs required for ESA-listed species?

Summary of Issue Paper Conclusions

The conclusions of this issue paper are:

- Yes, it is feasible to develop tissue BTs. Identified technical concerns and issues that will have to be resolved before tissue BTs can be developed include limited residue-effects data availability, the computational methodology to be used to derive tissue BTs, the data quality required of information used to derive BTs, the quantity of data needed before BTs can be developed for individual chemicals, and the toxicological endpoints to be incorporated into the BTs
- Tissue BTs can be developed for most chemicals. Exceptions exist for compounds that do not appreciably bioaccumulate in tissues but are nevertheless toxic; whose mode of action do not require bioaccumulation to elicit toxicity, such as contact herbicides; and

compounds rapidly metabolized to other chemicals that are either substantially more or less toxic than the parent compound, such as many polynuclear aromatic hydrocarbon (PAH) compounds.

- At a minimum, tissue BTs should be generally applicable to all fish species, and protective from adverse effects on survival, reproduction and growth. Other sublethal endpoints that may be considered during tissue BT development include contaminant effects on populations, behavior, immunosuppression, physiology, morphology and biochemistry. Additionally, the same BTs derived for fish will generally be applicable to all aquatic invertebrate species as well.
- Two primary methods exist for developing tissue BTs: Species sensitivity distributions and bioaccumulation modeling, with several variations and computational methodologies available for each of the two primary methods. While using measured residue-effects literature to develop tissue BTs is preferred, it must be recognized that sufficient literature to develop species sensitive distributions (SSDs) is available for only a limited number of chemicals. For chemicals without sufficient residue-effects literature, tissue BT development will have to be accomplished using bioaccumulation models.
- Available data to date indicate that separate tissue BTs are not required for ESA-listed species, because as a group, ESA-listed species appear to be neither more nor less sensitive to contaminants than non-ESA-listed species. Exceptions undoubtedly exist for some species-chemical combinations

Introduction

A fundamental principle of toxicology is the dose-response relationship: the proportionality of the chemical concentration in tissue at the site of toxic action (the dose) to the toxic response. The chemical concentrations in exposure media (water, sediment, diet) commonly used as surrogates for the actual dose of toxic chemical have many limitations when used during toxicity assessments with aquatic biota, some of which are listed below.

- The bioavailable and toxicologically active fraction of the total exposure media chemical concentration may not be known.
- It does not consider multiple uptake routes of chemicals.
- Intermittent, pulsed or variable exposures cannot be readily assessed.
- Chemical mixture toxicity cannot be easily assessed.
- Exposure duration (i.e. bioaccumulation kinetics) effects on toxicity may not be well defined.
- Metabolic transformations, which reduce or enhance parent compound toxicity, are not considered.
- Animal behavior such as seasonal migration or toxicant avoidance is not considered.
- Acclimation to toxicants can yield differential sensitivity to exposure media concentrations under different exposure regimes.
- Analytical chemistry limitations (e.g., non-detectable concentrations in water) mean that the exposure concentration is often unknown.

By associating the toxic response of aquatic biota with the tissue concentration of the chemical causing the effect, the above complicating factors can largely be eliminated. Toxic effects can then be directly expressed as a function of tissue residues. Elimination or minimization of the above confounding factors is the great advantage of using tissue residues to evaluate toxicity of environmental contaminants compared to evaluating toxicity using chemical concentrations in water, sediment or diet.

The main precept of the TRA is that it generates critical body residues (CBRs), such as LR_{50}s, LR_{10}s, or lowest observed effect residues (LOERs) for a given toxicant that exhibit relatively low variability among species. The advantages of a CBR statistic used as a tissue BT to interpret bioaccumulation test results are obvious, but worth explanation. First and foremost, the reduced variability in the biological response compared to exposure media concentrations associated with toxicity (e.g. LC_{50}) is highly desirable for generating tissue BTs that are protective of all species. Additionally, CBRs are based on causal relationships between the whole body tissue concentrations and the biological response, which allows the approach to be highly technically defensible. Other advantages of a TRA approach in deriving tissue BTs are given in the bulleted list presented in the introduction to this issue paper.

In many cases the BT value developed for fish will also be applicable to aquatic invertebrates. For many contaminants, the CBRs will be the same for fish and invertebrates and data from a number of taxa will be used to generate the BTs. Not all CBRs will have broad taxonomic application and exceptions will occur (e.g., dioxins). Each compound or class of compounds will be evaluated for its ability to represent toxicity for a wide range of species.

Protocols for the Development of Tissue Bioaccumulation Triggers (BTs)

At least two methods by which tissue BTs can be developed have been identified.

1. SSDs of existing tissue residue - effects literature
2. Bioaccumulation modeling using existing water quality criteria as an input into the model

Tissue BTs can be developed for some chemicals using existing residue-effects information in the technical literature. For chemicals without sufficient residue-effects information in the literature, a bioaccumulation model would need to be used to develop tissue BTs, with a higher level of uncertainty of the usefulness of the guidelines. However, there are data quality, data availability, and computational issues that need to be addressed before a decision can be made regarding how to go forward with the development of tissue BTs.

One issue of concern that applies to both the bioaccumulation modeling and SSD generation approaches is selection of the toxicological endpoints to incorporate into BT derivation. Consistency with EPA's current methodology for deriving ambient water quality criteria (Stephan et al. 1985) would dictate consideration of only contaminant effects on survival, reproduction, and growth. The RSET may wish to consider other endpoints when developing tissue BTs. Possible examples of additional endpoints to consider include contaminant effects on behavior, physiology, morphology, and biochemistry. Evaluation of these non-traditional endpoints in BT development may be of particular importance for fish species such as salmonids, where contaminant impacts on swimming behavior or olfactory ability may have significant adverse effects on the ability of the fish to return to their natal streams to spawn.

The strengths and limitations of each of the two primary tissue BT development methods are described below, as are some of the available options within the two approaches.

Species Sensitivity Distribution Approach

The species sensitivity distribution approach uses existing toxicological literature in a manner that is very similar to the existing EPA methodology (Stephan et al. 1985) used to develop ambient water quality criteria. It is the approach used in Europe to derive water quality criteria, and has also been used to derive sediment quality criteria such as the Long and Morgan (1991) effects range-low (ER-L) values and Washington's sediment management standards. As used in water quality criteria development, the SSD is generated from laboratory toxicity data. The Environmental Residue Effects Database (ERED) (Bridges and Lutz 1999) and Jarvinen and Ankley (1999) are the two primary sources of residue-effects information that could be used to develop SSDs. Given its consistency with other criteria development methodologies, use of the SSD approach during tissue BT development is preferred if the toxicological data are available.

The toxicity datasets used to develop water quality criteria generally employ a statistically derived description of the concentration-response curve, such as an LC_{50} or EC_{20}. By contrast, much of the available tissue residue literature contains no description of the magnitude of the observed effect, or of the proportion of species responding to a given tissue residue. These endpoints, termed the lowest unquantified effect dose (LUED) may be of limited utility in the derivation of tissue BTs. If it is assumed that LUED values are analogous to lowest observed effect residues (LOERs), a species sensitivity distribution could be generated with both tissue-based LUED and LOER data, providing a sizable increase in the amount of literature available for use in developing SSDs. It is unlikely that enough statistically reduced residue-effect concentrations are available in the literature to permit development of more than a few tissue BTs using only statistically reduced data to generate the SSD.

If an SSD is to be used to derive tissue BTs, the RSET would have to decide at what level of effect (or the proportion of species to be protected) the tissue BT should be set. Consistency with EPA's Ambient Water Quality Criteria (AWQC) derivation methodology would call for using the 5th percentile of the adverse effects data for survival, reproduction and growth as the selected BT. This is not the only possible level of protection or combination of toxicological endpoints available. A tissue BT could be set at any percentile agreed upon by the RSET. Examples of endpoints historically used with SSDs include the highest no effect concentration, the lowest adverse effect concentration, the 10th, 20th, or 50th percentile of the adverse effects concentration, or the concentration above which adverse effects are always observed (apparent effects thresholds approach).

Another potential difficulty with using measured residue - effects data to derive tissue BTs is data availability. There is simply less information available in the literature on tissue residues associated with toxicity than there is on water column or sediment concentrations associated with toxicity. The EPA aquatic toxicity information retrieval (AQUIRE) database, the repository of toxicity data for chemicals in water contains over 180,000 records. In contrast, the ERED database contains approximately 4,000 records. This does not preclude the use of literature data to derive tissue BTs, but the limited available information for many chemicals could in turn limit both the number and reliability of tissue BTs derived from the literature.

Bioaccumulation Modeling Approach

At its simplest, a tissue BT could be derived from the product of a water quality criterion and a bioconcentration factor (or bioaccumulation factor). As many water quality criteria and bioconcentration factors are already available, this approach could be used to quickly generate tissue BTs for a number of chemicals. The simpler bioaccumulation models are not data intensive, a potentially large advantage during the development of tissue BTs.

Through a review of the existing residue-effects literature, Shephard (2004) demonstrated that the product of existing EPA water quality criteria and a standardized set of bioconcentration factors resulted in tissue screening concentrations for aquatic life were lower than 94.5 percent of measured tissue residues associated with adverse effects on survival, reproduction and growth. This is excellent agreement with the intended 95 percent level of protection for aquatic genera that is the goal of the EPA water quality criteria (Stephan et al. 1985).

Another observation made by Shephard (2004) was that no statistically significant differences exist in tissue residues associated with toxicity in marine and freshwater biota. This leads to the possibility that generally applicable tissue BTs can be generated from bioaccumulation models, eliminating the need to derive separate sets of tissue BTs for marine and freshwater biota.

Tissue BTs derived from a bioaccumulation model have many uncertainties. These uncertainties include the accuracy of water quality criteria used as an input to the model, and the appropriateness of using a single bioconcentration factor (BCF) or bioaccumulation Attenuation Factor (BAF)to derive generally applicable tissue BTs. Addressing these uncertainties during tissue BT development may result in BTs with large safety factors relative to the safety factors of tissue BTs derived from SSDs.

Measured contaminant residues in field collected fish tissues that exceeded tissue guidelines generated by both a bioaccumulation model and a SSD were found to be statistically significantly correlated with fish community health in a statewide survey of fish in Ohio (Dyer et al. 2000). The Dyer et al. (2000) study is one of the few available that has simultaneously evaluated the predictive utility of tissue guidelines developed from both bioaccumulation models and species sensitivity distributions.

Mixture Toxicity

One of the strong advantages of using the TRA for toxicity assessment is the ability to address mixtures of contaminants. In general, the tissue residue approach is an excellent way to examine the toxicity of contaminants bioaccumulated by organisms in the field. Mixture toxicity studies based on tissue residues are less complicated than those with exposure concentrations because the variability observed among compounds in bioaccumulation and metabolic conversion is greatly reduced. Also, mixture toxicity from exposure concentrations can be confounded by differences in time to steady state from the various compounds in the mixture, whereas CBRs are generally time independent. The utility of mixture toxicity is supported by several studies demonstrating that multiple contaminants will produce toxicity at a small fraction of their individual effect concentration. Therefore, to generate the best available BT that will be protective of aquatic organisms, the combined effects from a complex mixture of compounds must be considered.

Chemicals for Which Tissue Quality Guidelines Can Be Derived

In theory, tissue BTs can be derived for any chemical or compound that is bioaccumulated into aquatic biota tissues. In practice, tissue residues associated with toxicity have seldom been measured for organic chemicals that are freely water soluble, or at least have a high water solubility. As shown by McCarty et al. (1991), for organic chemicals with a log K_{OW} < 1.5, the chemical concentration in the water phase of the organism dominates toxicity, and total body residues associated with toxicity should be similar to the respective threshold LC_{50} in water.

Tissue BTs should not be derived for chemicals that fall into three rather broad categories:

1. Chemicals that do not appreciably bioaccumulate but which nevertheless are toxic.
2. External toxicants such as contact herbicides.
3. Chemicals that are rapidly biotransformed into more (or less) toxic metabolites relative to toxicity of the parent compound.

Some chemicals are quite toxic without appreciable bioaccumulation. Cyanide is one example of a highly toxic chemical with a low bioaccumulation potential. This should not be confused with implying that a chemical can cause toxicity without bioaccumulating at all. Most chemicals in this group have high water solubilities and may not preferentially partition from water to tissues, resulting in low tissue residues associated with toxicity. These chemicals are unlikely to be on lists of bioaccumulative chemicals, reducing the need for tissue BTs for this group.

External toxicants do not need to enter the body of an organism to elicit toxicity. In addition to contact herbicides that act by destroying the cell wall of the plant, a few other chemicals can act as external toxicants under some circumstances. Iron and aluminum are two chemicals which, under certain conditions of water quality, form flocculent materials that coat the gills of aquatic species, causing death by suffocation without entering the body of the organism.

The toxicity of some compounds is enhanced by biotransformation (biological, chemical, or physical) after they have been bioaccumulated. Under these conditions, the concentration of the parent compound in tissue may have little or no relationship to the toxicity of the transformation product. The largest group of chemicals to which this applies are PAH compounds. Some PAH compounds are metabolically transformed into more toxic PAH epoxides, the chemical form often responsible for the carcinogenic effects of some PAHs. Other PAHs are photochemically activated, which enhances the toxicity of bioaccumulated parent PAH compounds. Available tissue residue-effects literature for PAHs shows substantial variations among body residues associated with the same toxic endpoint. These variations cut across taxonomic classes (e.g., some benthic invertebrate species rapidly transform PAHs, resulting in low body burdens associated with toxicity, whereas some fish species do not rapidly transform PAHs, and are substantially more tolerant of elevated body burdens. This variability makes it difficult to develop a single PAH tissue BT that is protective of all species.

Existing data do not currently permit development of generally applicable tissue guidelines for either individual PAH compounds or mixtures of PAHs. We recommend that the RSET not attempt to develop tissue BTs for either individual PAH compounds or PAH mixtures at this time. For PAHs, it may be possible to use bioindicators of exposure, such as fluorescent aromatic compounds (FACs) in bile to assess bioaccumulation. Ongoing work at the Northwest Fisheries Science Center has found a high correlation between bile FACs and dietary intake of PAHs in salmon. PAH toxicity to aquatic species can also be evaluated by comparing their concentration in water or sediment to existing environmental guidelines, standards, or criteria.

Sensitivity of Endangered Species to Chemicals

Not surprisingly, relatively few toxicity studies have been performed with endangered species, or at least with the specific ESAlisted stocks, strains or subspecies of species that are more common elsewhere in their range. EPA, US Fish and Wildlife Service (USFWS), and U.S. Geological Survey (USGS) have combined to fund several studies of the contaminant tolerance of several ESA-listed aquatic species, primarily fish, in recent years (Besser et al. 2001, Dwyer et al. 1999). The findings of these studies have provided support for the belief that most water quality criteria are protective of ESA-listed aquatic species.

On a body residue basis, additional support for this belief is available from studies with the ESA-listed bull trout (*Salvelinus confluentus*). Studies with cadmium (Hansen et al. 2002) and copper have found that while whole body residues associated with toxicity are low, they are not as low as residues associated with toxicity in other aquatic species. It is highly recommended, however, that residue-effects data for an appropriate surrogate species for an ESA-listed species (e.g., rainbow trout for listed salmonids) be considered during any tissue BT development.

Summary

Tissue BTs are a promising approach for evaluating the effects of contaminants in aquatic systems. At least two methods are available for developing tissue BTs, both of which have a demonstrated relationship with adverse effects observed in field populations of aquatic species. Use of species sensitivity distributions of toxicity data from the literature to derive tissue BTs would be computationally very similar to approaches currently used to derive ambient water quality criteria, and is the preferred method for chemicals where sufficient data are available to permit development of SSDs. The amount of data available and its quality are limiting factors for deriving tissue BTs. It should be recognized that useable tissue BTs should not be developed for some chemicals such as PAH compounds. However, with recognition of the limitations of the TRA, development of tissue BTs is a feasible approach for evaluating the toxicity of chemicals bioaccumulated in both laboratory exposed and field collected aquatic biota.

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RECOMMENDATION: None.

PROPOSED LANGUAGE: None yet available.

LIST OF PREPARERS: Burt Shephard, U.S. EPA; James Meador, NOAA Fisheries; Lyndal Johnson, NOAA Fisheries

RSET ISSUE PAPER #18 – Development of Tissue Trigger Levels for Aquatic-Dependent Wildlife

BIOACCUMULATION SUBCOMMITTEE: D. Kendall (david.r.kendall@usace.army.mil) and T. Michelsen (teresa@avocetconsulting.com), Co-Chairs; September 19, 2004

QUESTION/ISSUE: How should tissue levels be developed to protect higher trophic level wildlife from exposure to contaminants that bioaccumulate?

DISCUSSION:

Background: Aquatic organisms in both freshwater and marine environments can be exposed to bioaccumulative contaminants as a result of dredging or disposal of dredged materials. During the dredging or disposal process, sediment is re-suspended into the water column and resettles in or downstream from the dredge cut or disposal site. At the site of the dredge cut, a new sediment surface layer is exposed and new materials can slough into the dredge cut area during side-slope adjustment. If sediment at these sites contains bioaccumulative contaminants at any concentration, aquatic organisms can be exposed to the contaminants through contact with re-suspended materials during dredging or disposal, re-colonization of areas where contaminated sediment has been exposed in the dredge cut, or through resettlement of contaminated suspended materials on surface areas in or near the dredge or disposal site. The degree of contaminant exposure in aquatic organisms would be determined by the duration of time an organism is exposed to contaminated materials, the bioavailability of the contaminant to specific organisms, and the ability of organisms to metabolize, eliminate, and accumulate a contaminant. These variables make quantifying an organism's exposure during the relatively short dredging timeframe difficult, and insufficient data exists to support a relationship between concentrations of bioaccumulative contaminants in sediment and their absolute bioavailability to aquatic organisms (i.e., it is difficult to predict if bioaccumulation will occur based on sediment concentrations alone).

Because aquatic organisms such as sediment-dwelling invertebrates and fish can be exposed to bioaccumulative contaminants during dredging and disposal operations, it is important to understand how the accumulation of contaminants into the tissues of these organisms can adversely affect higher trophic animals, such as birds and mammals, when consumed. In this paper, we describe a process to use "tissue trigger levels" in wildlife prey items as a first step in developing sediment cleanup levels that are protective of higher trophic species exposed to bioaccumulative contaminants at sediment dredge and disposal sites. These tissue trigger levels are appropriate for both freshwater and marine dredge and disposal sites.

This paper provides a general set of concepts that should be considered in developing tissue trigger levels for contaminants that bioaccumulate[1] and biomagnify[2] in food chains. A tissue trigger level is defined as the concentration or target level of a bioaccumulative contaminant in a prey item that is considered protective of aquatic-dependent wildlife (birds and mammals that prey on aquatic species). Thus, contaminants present in prey items at or below the trigger level will not harm the most sensitive life stage of bird or mammal predators. Because it can be difficult and costly to directly measure tissue concentrations in higher order receptors, we consider prey items as sentinels, which can be monitored on a site-specific basis to determine if action is warranted to protect aquatic-dependent wildlife from bioaccumulative chemicals in a watershed. Though sediment ingestion is another pathway by which chemicals can enter aquatic dependant wildlife, the dietary pathway tends to be the dominant source for bioaccumulative chemicals (Bridges et al. 1996).

It is important to note that tissue trigger levels are not toxicity reference values (TRVs) and therefore may not be protective of the prey species themselves. Rather, tissue trigger levels are derived based on TRVs previously established and reported for the protection of sensitive life stages of higher trophic level species. Therefore, TRVs for the receptors identified in a watershed must be available prior to identifying a trigger level. Although contaminants can bioaccumulate and harm species lower in the food chain such as invertebrates and fish, the focus of this paper is solely on protecting avian and mammalian species. Companion papers from other RSET subcommittees will address the protection of lower trophic level aquatic species such as fish and invertebrates.

The tissue trigger levels outlined in this paper can be used with chemical-specific biota-sediment accumulation factors (BSAFs) to develop Sediment Quality Values (SQVs) protective of higher trophic level dietary exposure pathways. The process and conditions that may warrant development of sediment-based protective values is addressed in other companion RSET papers.

Chemicals of Concern to Aquatic-dependent Wildlife:

Organic and inorganic chemicals commonly taken up in aquatic food chains can be accumulated or magnified over time to concentrations that are potentially harmful to higher trophic level species even when these concentrations may not be harmful to their prey organisms (U.S. Environmental Protection Agency [EPA] 1998). Researchers have a reasonably good handle on the types of chemicals that are typically of concern to aquatic dependant wildlife through dietary bioaccumulation (Bridges et al. 1996, Froese et al. 1998, EPA 2003). The first step in understanding the potential risk to aquatic-dependent wildlife

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[1] Bioaccumulation is a process reflecting the net accumulation of a chemical by an organism as a result of uptake from all environmental sources. A bioaccumulative chemical accumulates in an organism faster that can be eliminated, resulting in higher concentrations in the organism compared to the organism's surroundings.

[2] Biomagnification is the process by which a chemical is transferred through the foodchain (i.e., trophic transfer) and concentrates in higher order receptors at levels that are many times higher than in receptors at lower trophic levels. The concentrations that reside in predators such as fish-eating birds and mammals can be high enough to affect reproduction or result in other chronic toxic effects, even though the concentrations in their prey items at lower trophic levels may be below threshold effect levels.

from trophic transfer is to conduct a site-specific review of the chemicals occurring in the sediment and/or tissue in the watershed of interest, or refer to companion RSET papers identifying bioaccumulative chemicals of concern (BCoCs). If no BCoCs occur in site sediment (or tissue) based on a review of sufficient data with adequate detection limits, then a further evaluation of the potential for trophic transfer (bioaccumulation into wildlife) would not be required.

Defining Aquatic-dependent Wildlife Receptors

Recognizing the difficulties on developing tissue trigger levels on a site-specific basis, guidance is provided in this paper to developing tissue trigger levels in wildlife prey items that are more broadly applicable to a wide range of sites. If the wildlife sentinel species discussed herein are for some reason less appropriate for a particular site, then the same general approach may be used to develop other tissue trigger concentrations in the prey items of additional wildlife species. However, it is likely that the concepts presented in this paper will be applicable to most if not all sites where BCoCs are present that could impact higher trophic wildlife.

Certain avian and mammalian receptors are frequently considered as “representative” or sentinel wildlife receptors as shown in Table 1. These include the great blue heron, belted kingfisher, osprey and bald eagle, which consume large amounts of fish in their diets. Most of these receptors are found in both freshwater and marine environments. Depending on the type of water body under consideration, shorebirds (such as the stilt, avocet, or sandpiper) may also serve as representative receptors since these birds typically consume aquatic invertebrates including insects and crustaceans, which may bioaccumulate metals/metalloids to a higher degree than fish consumed by predominantly fish-eating birds. Mammals that commonly feed on crustaceans and fish in watersheds include river otter, sea otter and mink.

The following sentinel wildlife species are representative for wildlife occurring in many freshwater and marine environments.

Table 1. Common Aquatic-dependent Wildlife Receptors in Freshwater and Marine Systems

Candidate Wildlife Receptors	Scientific Name	Present in RSET Region?	Dominant Food Items
Birds			
Great Blue Heron	*Ardea herodias*	Yes	Fish, crustaceans, small mammals
Belted Kingfisher	*Ceryle alcyon*	Yes	Fish and crayfish
Black-Necked Stilt	*Himantopus mexicanus*	Yes (summer)	Aquatic (including emergent) insects, small fish
American Avocet	*Recurvirostra Americana*	Yes (summer)	Mostly crustaceans and insects (including emergent)
Spotted Sandpiper or Western Sandpiper	*Actitis macularia or Calidris mauri*	Yes	Aquatic insects, mollusks, worms, crustaceans
Bald Eagle	*Haliaeetus leucocephalus*	Yes	Fish, fish-eating and non-fish eating birds, some mammals
Osprey	*Pandion haliaetus*	Yes	Fish
Mammals			
North American River Otter**	*Lutra canadensis*	Yes	Fish predominantly. Also crustaceans (crayfish)
Northern Sea Otter*	*Enhydra lutris lutris*	Yes	Marine fish, shellfish and invertebrates
American Mink**	*Mustela vision*	Yes	Crustaceans (crayfish), fish

* Predominantly a marine species
** Predominantly a freshwater species

Development of Tissue Trigger Levels

Tissue trigger values should be derived after selecting the receptor species used to represent a site and identifying TRVs from the literature that are protective of the receptors. The TRVs selected from the literature should address information about the likelihood of biological effects to aquatic-dependent wildlife (for example, reduced survival, growth, and reproduction) and address what level of bioaccumulation constitutes an "unacceptable adverse effect." Once the TRV is selected, empirical data collected from the watershed or data from literature reviews can be used to derive a tissue trigger. Key parameters identified for use in modeling should come from the literature and be based on studies specific to the receptor. Additional site-specific parameters can be added at any time to fine-tune the model and potentially adjust the tissue trigger level in an area if warranted.

TRVs from the scientific literature or other noted data sources will be the primary focus when developing the generic prey tissue trigger levels for RSET. Tissue trigger levels are developed based on toxicity studies for wildlife species as closely related to the species of interest at a site as possible. Two types of TRV studies are of greatest relevance to setting wildlife prey item tissue trigger levels: dietary TRV and egg-based TRV studies. The approach for establishing tissue trigger levels using each type of TRV study is presented below.

Establishing Prey Tissue Trigger Levels Using Dietary TRV Studies

The most straightforward way to determine if concentrations of BCoCs are of concern in wildlife prey items is to compare concentrations measured in these organisms at a site to the dietary test concentrations from a well-conducted TRV study for the wildlife species of interest. The TRV ideally should represent a no-observed-adverse effect level (NOAEL). Where a NOAEL is not available, a low-observed-adverse effect level (LOAEL) can be considered, although LOAELs may not be protective of listed species and safety factors may need to be incorporated in the assessment. The use of dietary studies for establishing TRVs makes the implicit assumption that the dietary exposure pathway is of greater importance than other exposure pathways such as incidental sediment ingestion. This is generally the case for most receptors, although the sediment ingestion pathway can be of high importance for receptors such as shorebirds.

TRV studies should be based on sensitive toxicity endpoints such as reproduction as a matter of priority. Also, the dietary TRV selected should be protective of the most sensitive life stage of a receptor for a particular test chemical (i.e., if a test chemical exerts toxicity at lower concentrations to developing embryos or juveniles compared to adults, then a TRV protecting these more sensitive life stages should be used in the assessment). TRV studies with toxicity endpoints relative to impacts on growth and survival may also be considered when more sensitive reproductive endpoint TRV studies are not available. The studies should be dietary to have maximum relevance to establishing tissue trigger levels for use at dredging and disposal sites. For the dietary approach, injection or other non-dietary based studies have less relevance in establishing tissue trigger levels since the goal in establishing tissue trigger levels is to determine *what levels in wildlife food* could cause them harm and be easily monitored[3]. Fortunately, many dietary studies are available for BCoCs in the scientific literature and can be used for establishing tissue trigger levels for wildlife protection.

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[3] Gavage studies can be considered if well-conducted dietary studies are not available for a BCoC. Gavage represents forced oral administration to the stomach using oil, water or capsule. Resulting tissue trigger levels established from this type of study should be interpreted with greater caution. As a matter of priority well-conducted dietary studies are always the preferred type of TRV study.

Commonly used databases containing wildlife TRV studies include EPA's Soil Screening Levels (EPA 2003), Oak Ridge National Laboratories (ORNL), EPA's ECOTOX database (ECOTOX 2003), and the Environmental Residue-Effects Database (ERED) 2003. The scientific literature should be consulted in cases where TRV studies are not available from these sources.

The tissue trigger level is established using the NOAEL (or LOAEL with adjustment) dietary test concentration from a well-conducted TRV study. As an example, the selenium NOAEL for mallards is 4 mg/kg in the diet (Heinz et al. 1989). Therefore, if selenium concentrations greater than 4 mg/kg in aquatic invertebrates or fish at a given site are measured it could be concluded that there is a potential risk to aquatic-dependent birds feeding on these organisms. Ideally, an adjustment for the difference in food ingestion rate to bodyweight ratios between the test wildlife species in the TRV study and the species of interest at the site should be made. This adjustment is made as follows:

$$\textbf{Tissue Trigger Level} = \mathbf{C}_{\mathbf{tissue}} \cdot \frac{\mathbf{FIR}_{\mathbf{test}}}{\mathbf{BW}_{\mathbf{test}}} \cdot \frac{\mathbf{BW}_{\mathbf{site}}}{\mathbf{FIR}_{\mathbf{site}}}$$

Where:

Tis. Trig. Level = Allowable prey concentration for wildlife (mg/kg)
C_{tissue} = Chemical concentration in TRV test diet (food item)
FIR_{test} = Food ingestion rate of TRV test species (kg/day)
BW_{test} = Body weight of TRV test species (kg)
BW_{site} = Body weight of site species (kg)
FIR_{site} = Food ingestion rate of site species (kg/day)

Food ingestion rates and bodyweights of site-specific wildlife species of interest can be determined from many literature sources including EPA's Wildlife Exposure Factor Handbook (EPA 1993). Site-specific species with a higher food ingestion rate to body weight ratio than that of the test species would have a lower tissue-based guideline and vice versa.

Establishing Prey Tissue Trigger Levels Using Egg-Based TRV Studies

The dietary model above can be used for establishing tissue trigger concentrations protective of wildlife for many organic and inorganic compounds. However, some types of chemicals such as DDE, polychlorinated biphenyls (PCBs), "dioxin-like[4]" compounds (EPA 2003) and selenium (Fairbrother et al. 1999, Adams et al. 2003) have demonstrated effects on avian development at the level of the egg. In these cases, developing tissue trigger levels based on eggs is more appropriate than the dietary pathway because the reproductive effects and corresponding TRVs are based on concentrations in bird eggs rather than in the diet, as the dietary pathway model above may not result in tissue levels that are sufficiently protective.

Estimated egg-based TRVs (NOAELs or LOAELs) are available for fish-eating birds for PCBs (calculated as total PCBs) and DDE (Custer et al. 1999, Elliott et al. 1994, Wiemeyer

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[4] Compounds that demonstrate "dioxin-like" effects include dioxins, furans and some PCB congeners (EPA 2003).

et. al 1984, 1988, 1994; Yamashita et. al 1993), and an egg-based approach would be the preferred method for assessing these particular chemicals. Examples and explanations of using the egg-based approach can be found in EPA (2003) and other references (Giesy et al 1995, U.S. Fish and Wildlife Service [USFWS] 1994).

A simple egg-based model for developing tissue trigger levels follows below.

$$\textbf{Tissue Trigger Level} = \textbf{TRVegg} / \textbf{BMF}_{\textbf{egg}}$$

Where:

Tissue Trigger Level (mg/kg) = Tissue concentration in prey protective of avian predators
TRV_{egg} = Egg-based Toxicity Reference Value (mg/kg)
BMF_{egg} = Biomagnification factor from prey to egg (unitless)

The BMF_{egg} value can be derived from site-specific data (if available) or from the literature. Examples of site-specific derivation of BMFs can be found in Henny et al. (2003), USFWS (2004), and Braune and Norstrom (1989). Other methods to estimate BMFs can be found in USFWS (1994).

Conclusion

Trigger levels can be useful to screen measured fish and invertebrate tissue data for their potential to result in bioaccumulative effects in upper trophic avian and mammalian wildlife or used to establish general sediment quality values to guide cleanup (i.e., at sites where sediment contamination is understood to be the dominant contaminant source for uptake into biological tissue). Trigger levels should be developed based on data specific to a watershed, or based on literature values when site-specific data is unavailable. Exceedance of tissue trigger levels would not automatically constitute a requirement for cleanup but would indicate a need for further evaluation of the bioaccumulation pathway for fish- and invertebrate eating birds at a given location, or require actions to minimize exposure of aquatic-dependent wildlife to contaminants at the site. Minimizing exposure could include such actions as installing silt fences to minimize re-suspended sediment from leaving the site during dredging and disposal, and using close-lipped clamshell bucket to reduce disturbance of sediment while dredging.

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RECOMMENDATION: None.

PROPOSED LANGUAGE: None yet available.

LIST OF PREPARERS: Sue Robinson, Parametrix, Inc., Jeremy Buck, U.S, Fish and Wildlife Service

RSET ISSUE PAPER #19 – Testing Protocols Available For Laboratory Based Freshwater Bioaccumulation Testing Under RSET

BIOACCUMULATION SUBCOMMITTEE: D. Kendall (david.r.kendall@usace.army.mil) and T. Michelsen (teresa@avocetconsulting.com), Co-Chairs; September 19, 2004

QUESTION/ISSUE: What are the available laboratory-based freshwater bioaccumulation testing protocols available and what are the known advantages and disadvantages of these protocols?

DISCUSSION:

Background: The current Dredged Material Evaluation Framework (DMEF) for the Lower Columbia River Management Area (EPA/Corps 1998a) contains guidance for laboratory based freshwater bioaccumulation testing in section 9.4 of the manual. Bioaccumulation testing is currently a Tier III requirement when there is reason to believe that specific chemicals of concern (CoCs) may be accumulating in target tissues at levels of concern.

The DMEF and the Inland Testing Manual (EPA/Corps 1998b), recommends a 28-day laboratory bioaccumulation tests for assessing the potential for constituents to bioaccumulate. The Inland Testing Manual recommends the use of two bioaccumulation test species where possible representing two different trophic niches such as a suspension-feeding/filter-feeding and a burrowing deposit feeding organism. For marine/estuarine systems, the DMEF has established a set of two species to be tested; an adult bivalve (*Macoma nasuta*) and an adult polychaete (*Nereis virens*, *Nepthys*, or *Arenicola marina*). For freshwater systems, the DMEF recommends the use of the oligochaete *Lumbriculus variegatus* but does not specifically recommend a second freshwater bioaccumulation test species. The Inland Testing Manual (Table 12-1) presents a list of candidate laboratory bioaccumulation test species, however, there are only three listed as appropriate for freshwater sediments; *Lumbriculus variegatus*, the mayfly *Hexagenia limbata,* and the amphipod *Diporeia sp.* Of these three, only *Lumbriculus variegatus*, is commonly used for 28-day solid phase bioaccumulation testing for freshwater sediments. Ingersoll et. al. (EPA 1998) has stated that one of the disadvantages for the use of mayflies and the amphipod *Diporeia sp.* as a laboratory test species is the difficulty in culturing these organisms. It should be noted that the recently published "Regional Implementation Manual for the evaluation of dredged Material Proposed for Disposal in New England Waters" (EPA/Corps 2004) states that only one freshwater bioaccumulation test species is required for dredge material testing.

Discussion: The Bioaccumulation Subcommittee identified the need to summarize the current status of freshwater bioaccumulation testing protocols and also discuss the need and options available for the development of new freshwater test protocols and species.

Lumbriculus variegatus is the standard freshwater bioaccumulation testing organism recommended by the DMEF and Inland Testing manual but has limited tissue biomass available for analytical chemistry testing of tissues, which limits the types of chemical analysis that can be conducted on tissues at the conclusion of the standard 28-day laboratory bioaccumulation test.

In general, using existing EPA/ASTM protocols, the mean wet weight mass of tissue that can be collected from the replicate exposure chambers is approximately 8 to 9 grams. Depending on the nature and chemicals of interest in the test sediment, this tissue mass may be insufficient to be able to run complete analytical chemistry testing on more than one or two classes of compounds. For example, testing for PCBs/Pesticides, or semivolatile compounds, or metals each requires about four to six grams wet weight of tissue to provide an adequate amount of mass for chemical analyses. By reducing the available amount of tissue for chemical testing, the consequence can be that not all required analytes can be tested for, detection limits may become elevated due to insufficient tissue mass, and no extra tissue is available for secondary extraction and analysis if any)quality assurance/quality control QA/QC) problems arise during the initial analysis.

There have been efforts to develop analytical methods that do not require as much tissue for analysis, but at this point in time, these methods are not provided by commercial analytical laboratories and it is unclear whether all the appropriate method development activities have been completed.

One alternative that has been explored in the freshwater systems of the Pacific Northwest (and in other areas) is the use of the bivalve *Corbicula fluminea* as a second laboratory bioassay species. The bivalve *Corbicula fluminea* is also a recommended species by this subcommittee for *in-situ* bioaccumulation testing (Salazar 2004). The advantage for the use of this species is that the available tissue mass at the end of the laboratory exposure is much greater than that for *Lumbriculus*, about thirty to forty grams wet weight per replicate. *Corbicula fluminea* is a bivalve found throughout the freshwater systems in the Pacific Northwest (as well as the united states in general), therefore, there is an ecological relevance to its use in bioaccumulation testing. Hart Crowser (2002) conducted side-by-side testing of these two species in 28-day bioaccumulation tests from potential reference sediments collected in the Willamette River in Oregon (Hart Crowser 2002).

While this study focused on sediments that contained very limited concentrations of bioaccumulative compounds, the study did come to the conclusion that *Corbicula* is a promising candidate for use as a second freshwater laboratory bioassay species and survived and were healthy after 28-days of exposure using standard EPA/ASTM protocols in fine-grained and medium-grained sediment. Corps (2001) provides a list of publications that have also evaluated the use of *Corbicula* as a bioaccumulation test species under a variety of test protocols.

One of the concerns that has been expressed with the use of *Corbicula fluminea* is whether the uptake kinetics of this species is similar to *Lumbriculus variegatus*. Bivalves are able to conduct avoidance behavior in unsuitable habitats/situations by reducing their respiration and filter feeding which would consequently reduce exposure to sediment-associated contaminants. It has yet to be determined whether this is a real phenomenon and if it is, whether this difference would have any significance in regulatory decision-making.

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RECOMMENDATION:

1. Compile and Evaluate Existing Data on Bioaccumulation of Various Classes of Bioaccumulative Compounds by *Corbicula fluminea* and Compare with Results from *Lumbriculus variegatus* tests. This evaluation will be helpful to determine any differences in bioaccumulation kinetics between the oligochaete and the bivalve and the magnitude of the difference if such a difference exists. This information can be used as the basis for determining whether any discovered differences between these two test species are significant or not for regulatory decision-making.

2. Conduct Additional Bioaccumulation Testing Using *Corbicula* as Projects Allow. By increasing the amount of data available on these two species, we should be able to have greater certainty to any decision RSET makes as to recommendations for their use.

3. Follow-up on Methods Development for Analytical Techniques that Utilize Reduced Tissue Volumes. This exercise will help RSET determine the advantages and trade-offs present with the current methods available to conduct tissue analysis using low tissue volumes.

4. Coordinate with Other Researchers that are Exploring Related Issues. Scientist at the Corps Waterways Experiment Station and other research institutions have completed studies using *Corbicula* as a test bioaccumulation species. Speaking and coordinating with these researchers may provide additional insight on the appropriate use of *Corbicula* in freshwater bioaccumulation testing.

5. Recommend that Two Species be Used for Freshwater Bioaccumulation Testing. Once sufficient method development has taken place for *Corbicula fluminea*, it is recommended, where possible, that two species be used for bioaccumulation testing. This is consistent with the Inland Testing Manual recommendations (EPA/Corps 1998b) that two species be tested to cover the range of accumulation rates amongst test species and to be environmentally protective.

PROPOSED LANGUAGE: None yet available.

LIST OF PREPARERS: Taku Fuji, Ph.D., Kennedy/Jenks Consultants and Jim Meador, NOAA Fisheries

RSET ISSUE PAPER #20 – Testing Protocols For In-Situ Freshwater Bioaccumulation Testing

BIOACCUMULATION SUBCOMMITTEE: D. Kendall (david.r.kendall@usace.army.mil) and T. Michelsen (teresa@avocetconsulting.com), Co-Chairs; September 19, 2004

QUESTION/ISSUE: What are the available in-situ freshwater bioaccumulation testing protocols and what are the known advantages and disadvantages of these protocols?

DISCUSSION:

Background: Consensus-based American Society for Testing and Materials (ASTM) protocols have been developed for in-situ caged bivalves that can be used to assess bioaccumulation potential and associated biological effects from contaminated sediments in marine, estuarine and freshwater species (ASTM 2001). Over 30 freshwater studies have been conducted in freshwater environments using these methods and 7 different species. These studies include five Superfund sites; three marine and two freshwater. The main advantage of this approach is the ability to characterize exposure and effects over space and time and under environmentally realistic test conditions. The main disadvantage is the cost, although costs do not increase incrementally with time as in laboratory toxicity or bioaccumulation tests because daily maintenance is not required. Other advantages and disadvantages are summarized in Table 1 (Salazar & Salazar 1998).

Protocols have also been developed for freshwater toxicity tests using species other than bivalves that may be adaptable for in-situ bioaccumulation testing (Burton 2002). The most promising candidate among those protocols is the oligochaete *Lumbriculus variegatus,* although questions have been raised regarding the small tissue mass and this species was not reported in a recent survey of the Lower Columbia River (Waldeck et al. 2003). The main advantage of *Lumbriculus* is that methods exist for in-situ testing and it has been used routinely in the laboratory for toxicity testing across the country for many years. The analogous disadvantage in the marine environment would be the polychaete worms *Neanthes arenaceodentata* and *Armandia brevis*. While they too have been used extensively for toxicity testing, they have been used less for bioaccumulation testing because of their relatively small tissue mass. Nevertheless, these species have been used effectively for both toxicity and bioaccumulation testing.

In-situ testing is needed as part of RSET to bridge the gap between traditional laboratory testing and field monitoring and help establish links between bioaccumulation data collected using those methods. Because effects endpoints such as survival, growth, and reproduction have been developed for some bioaccumulation test species, in-situ testing can also help integrate toxicity and bioaccumulation testing. Other advantages include validation of results from laboratory bioaccumulation testing and integration of results from field monitoring, assessment of long-term exposures and associated effects, and the ability to characterize benthic exposure pathways under environmentally realistic conditions. While there are no perfect monitoring tools, bivalves satisfy many of the criteria identified for being a practical in-situ testing organism for bioaccumulation potential and associated biological effects.

Discussion: The Bioaccumulation Subcommittee identified the need to summarize the current state of in-situ freshwater bioaccumulation protocols and options available for the development of new freshwater test protocols and species. The need for using two species for assessing bioaccumulation potential was also discussed. A list of criteria for selecting appropriate species for in-situ bioaccumulation tests was compared with a list of species found in the Lower Columbia River in a recent survey to help develop a candidate list of indicator organisms. In the context of RSET, criteria used for selecting organisms to assess bioaccumulation potential and protect higher trophic level wildlife should be similar to those used for selecting toxicity test organisms. Criteria for selecting candidate freshwater species for testing should be similar to those used for selecting marine species. The selection of a suitable organism is one of the first steps in the preparing a monitoring strategy once the decision to conduct bioaccumulation testing has been made. The importance of this step cannot be overemphasized. Several attributes of both the organism and the study area must be considered. Furthermore, no one organism is best suited for all aquatic ecosystems (Burton 2002, Phillips 1980). This is another reason for using two bioaccumulation test species instead of only one.

Species Selection Criteria

The following criteria for selecting candidate species for in-situ bioaccumulation testing were synthesized from several different sources which included different perspectives (Burton 2002, Phillips 1980, Widdows & Donkin 1992). A test organism should:

a) Accumulate chemicals at concentrations in test sediment without being killed,
b) Be sedentary, to represent the study area and minimize caging effects,
c) Be abundant, with stable populations in the area for ecological relevance,
d) Be sufficiently long-lived to allow the sampling of more than 1-year class,
e) Be of reasonable size, giving adequate tissue for analysis,
f) Be easy to sample and robust enough to survive in the laboratory,
g) Be easy to collect, cage, and make bioaccumulation measurements on,
h) Have a large toxicological database for pairing exposure and effects endpoints,
I) Be easily identified,
j) Have standardized protocols available,
k) Allow integration of laboratory testing, field monitoring, and in-situ experiments, and
l) Have a relatively low ability to metabolize accumulated chemicals.

Candidate Test Species

Based on the criteria identified above, three groups of organisms were selected as satisfying the criteria and being in the Lower Columbia River. In order of preference these were 1) bivalves; 2) gastropods; and 3) decapods (crayfish).

Bivalves

Fourteen to 15 species of freshwater bivalves are found in the Lower Columbia River. These include the invasive species *Corbicula fluminea* and four native unionids in the genus *Anodonta*. Although *Anodonta* satisfy many of the criteria and may be more sensitive than Corbicula, they are not recommended for large-scale monitoring and testing because of their declining numbers and uncertain taxonomy. The dichotomy is that while native unionids need to be studied to preserve them, their numbers may be too small to collect in large numbers to support extensive monitoring and assessment. Many more studies have been conducted on *Corbicula* throughout the world, including laboratory bioaccumulation and toxicity tests, field monitoring, and transplant experiments, and they have been found in almost every previous survey conducted on the Lower Columbia River. In addition, a laboratory bioaccumulation test is being proposed for this species as part of RSET.

Corbicula fluminea is an introduced freshwater bivalve found throughout freshwater environments in the Pacific Northwest in large numbers and therefore is ecologically relevant. Side-by-side bioaccumulation tests have been conducted using *Corbicula fluminea* and *Lumbriculus variegatus* using 28-day laboratory exposures to candidate reference sediments collected in the Willamette River in Oregon (Hart Crowser 2002). While one of the concerns regarding the use of *Corbicula fluminea* has been the uptake kinetics of this species relative to *Lumbriculus variegatus* and valve closure to avoid exposure in a short-term 28-d exposure, this is not an issue in standard in-situ testing protocols that suggest an exposure period of 60 to 90 days for most species and most chemicals. Bivalves are able to close their valves to avoid exposure in short-term tests and reduce their respiration and filtration rates, which would consequently reduce exposure to sediment-associated contaminants. However, in longer term tests, effects would be manifested in reduced survival and growth rates. This is another reason for pairing exposure and effects endpoints in toxicity and bioaccumulation tests.

Also included in this list are seven species of fingernail clams. The main advantage of fingernail clams is their small size. This makes them very suitable for laboratory and field testing but their small size is also a disadvantage for bioaccumulation potential for the same reason that *Lumbriculus* has a disadvantage. Nevertheless, they should be considered for bioaccumulation and toxicity testing. Fingernail clams have been shown to be extremely sensitive to ammonia, among other chemicals, and have been used in a number of in-situ toxicity tests. While ammonia is not easily measured in bivalve tissues, fingernail clams should be placed in the category of candidate species for in-situ bioaccumulation testing and laboratory toxicity testing.

Gastropods

Gastropods also have a good potential for freshwater monitoring because they also satisfy many of the criteria for selecting candidate test species. Many species related to those found on the Lower Columbia River have been used in laboratory bioaccumulation and toxicity tests, field monitoring and even transplant experiments. However, they have not been used as extensively as bivalves. Although 35 different species have been reported in the literature, only 14 of those were found in the most recent surveys. Perhaps more importantly, these gastropods are classified as deposit feeders and potentially in more direct contact with sediment. In a weight-of-evidence approach with multiple species they would be a good second choice for laboratory testing, field monitoring, and transplant experiments.

Crayfish

Only one species of freshwater crayfish has been reported in the LCR and it was also found in the most recent Lower Columbia River surveys. *Pacifastacus leniusculus leniusculus* has the potential to be an important species for laboratory testing, field monitoring and transplant experiments. However, since only one species was found and it has been used far less than either bivalves or gastropods we ranked it third in terms of recommended species but as with the gastropods, remains potentially useful, particularly in a weight of evidence approach. Additionally, it represents a different pathway of exposure in that the dietary exposure pathway should dominate, particularly for hydrophobic organic chemicals.

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RECOMMENDATION:

The Bioaccumulation Subcommittee recommends *Corbicula fluminea* as the first choice for in-situ assessments of bioaccumulation potential because it has been used extensively in laboratory testing, field monitoring, and in-situ assessments of both toxicity and bioaccumulation potential. The Bioaccumulation Subcommittee recommends the following tasks to be completed:

1. Compile and evaluate existing data on bioaccumulation by *Corbicula* fluminea and another species to be selected.

2. Conduct additional bioaccumulation testing in the lab and the field using *Corbicula* as projects allow.

3. Conduct additional bioaccumulation testing for other candidate species.

4. Conduct synoptic bioaccumulation tests in the laboratory and in-situ using *Corbicula* and the second candidate test species.

PROPOSED LANGUAGE: None yet available.

LIST OF PREPARERS: Mike Salazaar, Applied Biomonitoring

Table 1. Advantages and disadvantages of the in-situ field bioassay by category: transplants, bivalves, bioaccumulation, and growth.

	Transplants	**Bivalves**	**Bioaccumulation**	**Growth — Whole Animal/Tissue**
Advantages	Experimental control Environmental realism Defined exposure period Infinite sampling matrix Repetitive, non-destructive sampling Monitoring individuals Field validation Exposure system Captive biochemical sampling Hypothesis testing Low maintenance	Integrate bioavailable contaminants Bioconcentrate contaminants Easy to collect, cage, measure Large database from field monitoring and lab bioassays Survive sub-optimal conditions Any biochemical measurements possible Sedentary No feeding required Standardized protocols	Concentrations above ambient Integration of contaminants, natural factors, man-made non-toxics Assessments for sediment, overlying water, or porewater Link between exposure and response Link between lab and field Link between bioassays and community structure Long-term exposures ~1 yr	Integration of internal biological processes Environmentally significant response Link to population effects Quantifiable dose-response Related to environmental exposures Repetitive, non-destructive measurements Easy for the public to understand No special equipment No specialized training More sensitive than survival Long-term exposures ~1 yr
Disadvantages	Effects of transplanting Loss of cages from acts of nature, inadvertent capture by moving vessels, vandalism Cost of collection, sorting, deployment Possible caging effects	Not found in all areas May not be representative of assessment area May not be the most sensitive species May not directly assess community effects May close to avoid exposure in short-term tests	Affected by chemical and natural factors Not all contaminants are accumulated equally Some contaminants may be purged May not always accurately represent effective dose	Affected by chemical and natural factors May not be the most sensitive bioeffect Tissue and shell growth occur at different rates and are affected by different factors May not directly assess community effects

RSET ISSUE PAPER #21 – Framework for Deriving Tissue Concentrations to be Protective of People Consuming Fish and Shellfish

BIOACCUMULATION SUBCOMMITTEE: D. Kendall (david.r.kendall@usace.army.mil) and T. Michelsen (teresa@avocetconsulting.com), Co-Chairs; September 19, 2004

QUESTION/ISSUE: How should target tissue concentrations (TTCs) be derived to protect people who consume fish and shellfish?

DISCUSSION:

Background: The RSET bioaccumulation subcommittee was organized to propose methods to derive trigger concentrations for chemicals in sediments based on bioaccumulation into tissues. Current sediment guidelines and criteria are based on toxicity testing and do not directly address the potential for bioaccumulation into fish and shellfish and the resulting potential for risks to wildlife and human consumers, and to fish and shellfish themselves as receptors (Cite Teresa's Framework Paper here). This technical memorandum provides a proposed approach to deriving bioaccumulation trigger levels in tissues that would be protective of human health, which is a necessary step prior to developing bioaccumulation trigger levels in sediments. A separate paper discusses approaches for the back-calculation of sediment trigger levels from fish or shellfish tissue trigger levels. For the purposes of this assessment, only human health risks associated with consumption of bioaccumulative chemicals in fish or shellfish are considered. At some sediment sites, it may be necessary to also consider other potential pathways (e.g., direct human contact with sediments). However, where fish and shellfish consumption is one of the potential exposure pathways, the food-related pathway typically is a more substantial contributor to site risks than direct contact with sediments. Thus, initial focus on fish and shellfish consumption is appropriate.

The TTCs are intended to be tissue concentrations that would be applicable at all sites. The TTCs will be used to derive bioaccumulation trigger levels for sediments, which will be used in decision-making for: 1) screening at potential sediment cleanup sites; and 2) evaluating whether open-water disposal is acceptable for dredged material. In site screening, site-specific sediment data can be compared with bioaccumulation trigger levels or, if tissue data are available, tissue concentrations can be compared with TTCs. Because the intended uses for the sediment bioaccumulation trigger levels involve a wide variety of site-specific conditions, some flexibility is desirable in applying the TTCs to derive sediment bioaccumulation trigger levels. Specifically, the size and nature of the sediment source (i.e., the degree of contamination, the area and distribution of contamination) and the relative presence and abundance of fish and shellfish resources in the area with affected sediments may also be considered as part of regulatory risk management decision-making. In deriving the bioaccumulation trigger levels for sediments from the TTCs, it may be reasonable to apply a reduction factor to account for the degree to which sediments at a specific site could contribute to fish and shellfish concentrations as considered in the TTC.

The first section of this paper provides an overview of the background and applicability of this methodology. Following this is a general algorithm for calculation of tissue levels to be protective of human health risks and a discussion of considerations in deriving such levels.

Proposed methodology for calculating target tissue concentrations to be protective of people consuming fish and shellfish: As described in the framework document, the initial list of bioaccumulative chemicals of concern (BCoCs) will be developed through consideration of numerous lines of evidence, including the potential for bioaccumulation and the presence of the chemical at concentrations greater than reference (or background) concentrations in sediments. It is proposed here that TTCs for fish and shellfish should not be lower than tissue concentrations observed at reference (or background) locations. This will serve to limit the amount of resources spent on addressing chemicals with widespread anthropogenic (or in some cases naturally occurring) sources where exposure within a relatively small area of contaminated sediments may have little or no influence on resulting tissue concentrations.

In order to accomplish this objective, it is proposed that TTCs first be calculated for all BCoCs and then compared with appropriate reference or background concentrations, taking into account the need to balance the objective of reducing overall environmental concentrations with the potentially limited benefit associated with reducing concentrations below those in adjacent sediments, particularly where ongoing sources are present. For example, in evaluating a cleanup site within an urban area, TTCs might best be compared with urban reference concentrations so that TTCs in these areas would not be set lower than urban reference conditions. In contrast, evaluation of TTCs for relatively pristine open-water dredged material disposal sites should not be set lower than background concentrations. This comparison will be most relevant for metals, particularly arsenic and mercury, but may also be relevant for ubiquitous organic compounds such as DDT, PCBs and PCDD/Fs. Identification of appropriate background (e.g., relatively pristine) and reference (e.g., urban sites with no known sources) is presently not well defined and will be a task to be addressed by the RSET bioaccumulation subcommittee through consideration of available regional data on tissue concentrations.

Toxicity values: TTCs will need to address both carcinogenic and non-carcinogenic effects of BCoCs through application of a carcinogenic slope factor (CSF) for carcinogenic effects and a reference dose (RfD) for non-carcinogenic effects. EPA-approved toxicity values are described on the EPA Integrated Risk Information System web site[1] and EPA's Provisional Peer Reviewed Toxicity Values for Superfund (PPRTV)[2]. Additional interim toxicity values

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[1] http://www.epa.gov/iris/search.htm

[2] http://hhpprtv.ornl.gov/..

can be obtained by contacting EPA Region 10 or the EPA's National Center for Environmental Assessment (NCEA)[3].

Algorithm for calculating TTCs for carcinogenic effects of BCoCs: TTCs for carcinogenic effects of BCoCs can be calculated using the following general algorithm:

$$TTC\ (mg/kg) = \frac{TR \times AT_c \times BW}{EF \times ED \times FI \times CL \times IR \times 0.001\ kg/g \times CSF}$$

TTC = target tissue concentration in fish or shellfish tissue (mg/kg wet weight)
TR = target risk of 10^{-6} proposed for individual carcinogens
AT_c = averaging time (25,550 days)
BW = body weight (kg adult or child; varies with receptor population)
0.001 = conversion of grams fish to kg
EF = exposure frequency (365 days/year)
ED = exposure duration (years; varies with receptor population)
FI = fraction of intake assumed from site—(variable up to 100 percent; see text)
CL = cooking loss (none assumed; see text)
IR = ingestion rate for fish or shellfish (g/day; see text)
CSF = carcinogenic slope factor $(mg/kg\text{-}day)^{-1}$

Algorithm for calculating TTCs for non-carcinogenic effects of BCoCs: For non-carcinogenic effects, the following algorithm can be used to derive TTCs for fish and shellfish tissue:

$$TTC\ (mg/kg) = \frac{THQ \times BW \times AT_n \times RfD}{EF \times ED \times FI \times CL \times IR \times 0.001\ kg/g}$$

TTC = target tissue concentration in fish or shellfish tissue (mg/kg wet weight)
THQ = target hazard quotient (0.1)
AT_n = averaging time (exposure duration (years) × 365 days/year)
BW = body weight (kg adult or child; varies with receptor population)
0.001 = conversion of grams to kg
EF = exposure frequency (365 days/year)
ED = exposure duration (years; varies with receptor population)
FI = fraction of intake assumed from site (variable, up to 100 percent; see text)
CL = cooking loss (none assumed; see text)
IR = ingestion rate for fish or shellfish (see text)
RfD = reference dose for non-cancer effects (mg/kg-day)

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[3] http://cfpub2.epa.gov/ncea/cfm/aboutncea.cfm?ActType=AboutNCEA

Selection of a target risk and hazard index: For carcinogenic effects of BCoCs, a total cumulative target risk level of 10^{-5} (upper-end) is proposed, which is consistent with regulatory requirements set out by the Oregon Department of Environmental Quality. This risk level represents the middle of the risk range (10^{-4} to 10^{-6}) typically identified as acceptable by EPA and allows for exposure to multiple carcinogenic BCoCs. In order to achieve this risk level, TTCs for individual BCoCs will be set at risk levels of 10^{-6}. Site managers may determine appropriate adjustments where fewer than 10 BCoCs are present at a site.

In deriving TTCs for non-cancer endpoints, a cumulative hazard index of 1 is proposed. In order to not exceed this cumulative level, initial TTCs for individual BCoCs will be derived through application of a hazard index of 0.1 for screening. Where multiple BCoCs are present at concentrations greater than the non-cancer TTC, site managers may consider additional evaluation to determine whether the BCoCs identified at the site could affect the same target organs at the concentrations present. If this is not the case, it may be appropriate to adjust the resulting sediment bioaccumulation target levels to result in a cumulative hazard index of 1.0.

Selection of receptor population and endpoint: It is desirable to have a single TTC to address all human health considerations. However, the TTC will need to be protective of both adults and children consuming fish and shellfish and protective of both the carcinogenic and non-carcinogenic effects of BCoCs. Where EPA has both a CSF and an RfD available for a BCoC, the carcinogenic effect will typically provide the lowest risk-based concentration for various reasons, including the assumption that there is no threshold for carcinogenic effects. However, in some contexts, there may be some BCoCs for which the TTC calculated based on non-cancer endpoints is lower (more health-protective) than that derived based on the CSF. In addition, depending on the consumption rates assumed for adults and children, the TTC for non-carcinogenic effects may be lower for children consuming fish than for adults, particularly at the 10^{-5} cancer risk level. Thus, once the target risk level and the consumption rates are selected for use in deriving TTCs, these considerations will need to be evaluated to derive a TTC protective of all receptors and endpoints.

Exposure assumptions – fish consumption, fractional intake, and cooking loss: As described above, the TTCs will be derived to be protective of all populations and endpoints. To meet this objective, fish consumption rates for various populations present in the region will need to be reviewed to determine the most representative rates for adults and children. Because consumption rates are highly variable among various populations, it may be beneficial to derive more than one set of rates (e.g., a recreational and a high-end or tribal rate) depending on the specific situation. Where site-specific consumption rate studies have been conducted, risk managers may determine whether they should be applied on a case-by-case basis.

Although studies of tribal consumption rates have estimated fish and shellfish consumption rates for children, most studies of recreational fish and shellfish consumption have focused on adults only, and therefore some rates may need to be developed based on adults, with some consideration of their likely applicability to children. Because recreational rates are much lower than those identified for subsistence populations and because not all sites are locations for subsistence fishing, it may be appropriate to calculate separate TTCs for recreational and subsistence populations and determine on a site-by-site basis which is most appropriate as the basis for a TTC. An additional consideration is the fraction that the affected area represents of the overall subsistence or recreational fishing and gathering area (i.e. FI, or the fractional intake from the site). It is proposed that the TTCs be developed based on a default fractional intake of 100 percent, but then allow for consideration of site-specific characteristics as appropriate (e.g., limited resources within the site, small site size) in linking the TTCs to a given sediment evaluation.

Cooking reduces the concentrations of some organic BCoCs in fish and shellfish. However, given the variability in cooking methods applied by various populations in the region, cooking loss factors are not proposed for the generic TTCs. It may be appropriate to consider this factor on a case-by-case basis in more detailed evaluations at sites where warranted.

REFERENCES: None.

RECOMMENDATION: None.

PROPOSED LANGUAGE: None yet available.

LIST OF PREPARERS: Lisa Yost, Exponent Environmental Group

RSET ISSUE PAPER #25 - Integrating Range of Disposal Options into SEF

POLICY SUBCOMMITTEE: S. Stirling, Chair (Stephanie.K.Stirling@NWS02.usace.army.mil); February 17, 2004

QUESTION/ISSUE: Integrating Range of Disposal Options into SEF.

DISCUSSION: Currently the Dredged Material Evaluation Framework (DMEF) provides a process for evaluating whether dredge material is suitable for open water placement. RSET consensus is that the Sediment Evaluations Framework (SEF) should be expanded to include procedures, or references to existing guidelines, for evaluating the suitability of dredge material for other disposal/management options. The SEF will also identify, or reference appropriate guidelines for, any associated long-term monitoring/management requirements associated with particular disposal options and indicate the appropriate regulatory authority for overseeing these requirements. It would also be helpful if the SEF included discussion of how unconfined or confined aquatic disposal sites are established or how suitable upland disposal sites are identified.

REFERENCES: None.

RECOMMENDATION: Specific text and table revision to appropriate sections of DMEF.

PROPOSED LANGUAGE CHANGES: **Chapter 1** - Introduction

- Revise introduction to reflect that manual will address all five basic dredge material disposal options: unconfined aquatic, unconfined upland, confined aquatic, confined nearshore, and confined upland.
- Expand discussion of unconfined aquatic disposal to describe types of available sites (e.g., flow-lane, near shore,??) and indicate that particular locations may have site-specific criteria for determining suitability.
- Include general discussion of how sampling requirements may differ for different disposal options and what efficiencies may be gained by considering these sampling needs during the initial characterization of the material to be dredged.
- Reference appendix that lists and includes location maps for unconfined aquatic disposal sites.

Chapter 2 – Dredged Material Management Regulation

- Revise discussion of federal regulations to include an overview of Resource Conservation and Recovery Act (RCRA) as it pertains to upland disposal. Careful with this one. The HW folks just promulgated HWIR, which exempts sediment from a consideration as an HW.
- Revise discussion of state regulations to include an overview of pertinent state authority/requirements for management of solid waste (only pertinent to Oregon?). If we can get Washington to talk too, we might all learn something…

Chapter 4 – Overview of Regulatory Processes

- Expand flow charts and discussion to include approval and, as necessary, permitting by state solid waste program where upland disposal at a non-permitted site is proposed.
- Indicate that disposal at a permitted landfill will require approval by the landfill owner/operator.
- Expand flow charts and discussion to include approval by appropriate authority (likely state agency) where CAD or CDF disposal or disposal in a particular unconfined disposal site is proposed. Reference appendix with list of particular available facilities, identified contacts, and maps with disposal site locations.

Chapter 5 – Tiered Evaluation Process and Tier I

- Include discussion that material meeting exclusion ranking under Tier I or IIa is generally suitable for unconfined or confined aquatic disposal. Potential issue: need for additional evaluation at specific disposal sites – may be resolved with establishment of new protocols regarding application of exclusion ranking.
- Add note that material meeting exclusion ranking under Tier I or IIa may still be considered solid waste in Oregon if placed upland and may require associated solid waste permitting. Suggested changes based on some work I am doing with DSL to clarify this issue.
- Expand Tiered testing flow chart and discussion of transition to subsequent tiers to more specifically identify other dredge material management options and associated evaluation frameworks – refer to appendix.

Chapter 6 – Sampling and Analysis Plan

- Identify aspects of the Sampling and Analysis Plan (SAP) that may differ depending on the disposal option. This could include sampling intensity, analytes, and analytical techniques.
- Include example of a SAP for upland disposal in appendix.

Chapter 7 – Sampling Protocols

- Include sampling approach that would assess other disposal options concurrent with the assessment of unconfined aquatic disposal.
- Include discussion of additional sample collection/handling procedures and criteria pertinent to confined disposal options or upland disposal options (e.g., leachate tests).

Chapter 8 – Tier II Physical and Chemical Testing

- At some point, may want to include screening levels for unconfined upland disposal. At this time, in Oregon, upland disposal may still require a SW determination. Screening levels in Washington and Idaho may be available.
- At some point, may want to include screening levels or dredge material characteristics that would make the material unsuitable for confined in-water disposal (CAD, CDF).
- At some point, may want to include screening levels or testing protocols that would

indicate the material is hazardous waste.

Chapter 9 – Tier III Biological Testing

- May want to add a note that this testing does not apply to disposal other than unconfined in-water (or beach nourishment?).

Chapter 9.5? – Tier III Testing for Disposal Options Other than Unconfined In-Water

- One option – to have a focused section on the testing protocols for upland or confined in-water disposal options – primarily would reference other guidance but an overview of likely evaluation might be nice.

Chapter 10 – Tier IV Evaluations

- Expand to include discussion of the scenarios where this might be warranted for upland or confined in-water disposal options and the likely testing and evaluations that would be conducted.

Chapter 11 – Submittal of Sampling and Testing Data

- Include requirement that proposed disposal site be described.

Chapter 12 – Disposal Site Identification

- Add a chapter that describes the process for establishing a dredge material disposal site.
- Include sections on flow lane disposal, ocean disposal, confined aquatic, upland sites, and beach nourishment sites.
- For confined disposal, sites would include identifying appropriate cap characteristics and long-term management and monitoring protocols. Agencies in each state with regulatory authority for these sites would be identified.
- Reference appendix that identifies existing sites and shows locations on map.

LIST OF PREPARERS: Jennifer Sutter, Oregon Department of Environmental Quality

RSET ISSUE PAPER #26 – Grain Size, Analysis, and Exclusion Criteria

POLICY COMMITTEE: S. Stirling, Chair (Stephanie.K.Stirling@NWS02.usace.army.mil); February 17, 2004

QUESTION/ISSUE: Grain Size, Analysis and Exclusion Criteria.

Question #1: To what degree are organochlorine compounds only associated with the fine-grained sediments, and is the grain size rule of 80 percent sufficient to represent contaminant associations in the lower Columbia River (LCR)? Should other techniques be used to evaluate the potential for larger grain sized materials to also contain contaminants?

Question #2: Should organic carbon content of bed sediment be characterized or evaluated differently? For a single whole bed sediment sample, should only the fine-grained fractions from bed sediment for contaminants be analyzed to minimize the "dilution" effect of including larger-grained components from bed sediment?

DISCUSSION: The Dredged Material Evaluation Framework (DMEF) states that if the results of grain size analysis are at least 80 percent sand, total volatile solids is less than 5 percent, and no active sources of contamination are determined to be present, then the proposed dredged material qualifies for unconfined aquatic disposal (without further chemical characterization) (DMEF 1998).

During evaluation of sediment proposed for dredging, the volume of dredged material partly determines the minimum number of sediment samples and analyses required for full characterization of a dredging project. The majority of sediments dredged in the LCR are considered homogenous, as described in the DMEF. Table 6-1 determines the size of a dredged material management unit (DMMU) based on the ranking of sediment as Exclusionary, Low-Low-Moderate, Moderate, and High. A low ranking DMMU containing up to 100,000 cubic yards (cy) of homogenous material can be characterized by a minimum of one sample. Small projects can be excluded from testing based on volume and ranking (Table 6-2). For example, no samples are required for a low ranking project when less than 10,000 cy are proposed for dredging.

REFERENCES: Included in attachment (see below)

RECOMMENDATION: Specific text and table revision to appropriate sections of DMEF.

PROPOSED LANGUAGE CHANGES: None yet.

LIST OF PREPARERS: Jeremy Buck, U.S. Fish and Wildlife Service

Technical/Policy Problem Statements

Jeremy Buck
April 18, 2002
Draft Issue Paper

Topic: Grain size, analysis and exclusion criteria

Background:

Few studies have specifically evaluated sediment contaminant concentrations in the lower Columbia River (LCR); most sediment samples from the area have been collected to specifically evaluate sediment quality for proposed dredging projects. Sediment collected to evaluate material for dredging in the LCR is often excluded from further chemical analysis because the grain size evaluations show the sediment to be primarily sandy materials, and most contaminants of concern are associated with the organic carbon fractions within finer-grained materials (e.g., silts and clays). Sediment from the LCR navigation channel is sandy with generally less than 1% fine materials, and therefore considered very unlikely to contain contaminants. Even in depositional and backwater areas where finer-grained materials are encountered, organic contaminants such as DDT and PCBs are infrequently found or are below the Dredged Material Evaluation Framework (DMEF) screening values (Tetra Tech 1993, 1994). However, nearly all samples of fish and other wildlife within in the LCR contain contaminants such as DDT and PCBs (Tetra Tech 1993, 1994; U.S. Fish and Wildlife Service 2002). Therefore, a source for organochlorine contaminants exists, and other studies have suggested that bed sediment is a primary source for uptake of hydrophobic contaminants in biota (Zaranko et al. 1997, Maruya and Lee 1998). However, it remains unclear as to whether LCR bed sediment serves as a source for this contaminant pathway, or whether the number of samples collected to characterize a dredged material management unit (DMMU) as identified in the DMEF sufficiently addresses site specific conditions and contaminant associations in the LCR.

The lower Columbia River system is also characterized as carbon limited. It has been proposed that whatever carbon is available moves quickly into tissue along with any associated contaminants, and therefore even small concentrations of contaminants would be readily available and incorporated into tissue (Tetra Tech 1993,1994; U.S. Fish and Wildlife Service 2002). Given the site specific conditions in the lower Colombia River system, a key question is whether or not the thresholds currently used in the DMEF for excluding sediment for further chemical analysis based on grain size characteristics is a good representation of the contaminant content of the material, or if changes in the threshold levels should be made.

How is this issue currently addressed:

The DMEF states that if the results of grain size analysis are at least 80% sand, total volatile solids is less than 5%, and no active sources of contamination are determined to be present, then the proposed dredged material qualifies for unconfined aquatic disposal (without further chemical characterization) (DMEF 1998).

During evaluation of sediment proposed for dredging, the volume of dredged material partly determines the minimum number of sediment samples and analyses required for full characterization of a dredging project. The majority of sediments dredged in the LCR are considered homogenous, as described in the DMEF. Table 6-1 determines the size of a dredged material management unit (DMMU) based on the ranking of sediment as Exclusionary, Low-Low-Moderate, Moderate, and High. A low ranking DMMU containing up to 100,000 cyds of homogenous material can be characterized by a minimum of one sample. Small projects can be excluded from testing based on volume and ranking (Table 6-2). For example, no samples are required for a low ranking project when less than 10,000 cyds are proposed for dredging.

What are the issues/questions? Any examples, case studies?

Questions:
To what degree are organochlorine compounds only associated with the fine-grained sediments, and is the grain size rule of 80% sufficient to represent contaminant associations in the LCR? Should other techniques be used to evaluate the potential for larger grain sized materials to also contain contaminants?

Case study/examples: Total PCBs were detected in the LCR at Bradford Island, apparently within sandy sediments. High river flows often limit the amount of fines in this area, yet high concentrations were observed in sediments and extremely high concentrations were observed in crayfish. Presumably, the PCB oils may have coated the sands and even the crayfish due to the proximity of leaking PCB-containing materials in the area, and this type of contamination may be site specific. However, in a carbon-limited system, it may not take much of a concentration of an organic contaminant to be readily available, especially if the contaminant is associated with sandy material and not more firmly attached to the organic materials within fine particulates.

Question: Should organic carbon content of bed sediment be characterized or evaluated differently? For a single whole bed sediment sample, should only the fine-grained fractions from bed sediment for contaminants be analyzed to minimize the "dilution" effect of including larger-grained components from bed sediment?

Concern/example: The results of Tetra Tech (1993) and U.S. Fish and Wildlife Service (2002) indicated that further characterization of contaminant concentrations and the organic carbon content, specifically within various grain-sized fractions of depositional sediment in the LCR, would be worthwhile to help determine the true availability of sediment-borne contaminants to organisms, and the degree to which bed sediment acts as a source of organochlorine compounds.

Information Need/Discussion Points - brainstorming, what information is needed? What do we know now?

Additional background information supporting the 80% rule would be helpful. For the site specific conditions in the LCR described in the background section above, does the 80% rule still hold? What about samples that are 14% fine materials (silts or clays), would these samples be suspect? The DMEF states that: "*The adoption of exclusion category is based upon numerous studies and sampling efforts done on the LCR verifying that coarser-grained sediments are characterized by very low to negligible levels of chemical contamination*." Having access to these studies or having these studies available for review or discussion would be helpful.

Would it be helpful to further characterize sediment for organic carbon, fine materials, or contaminants? For instance, rather than sampling whole sediment, it may be helpful to sieve and sample only the fine materials for organic carbon and contaminants in some locations, thereby obtaining a larger sample size of only fines and minimizing the "dilution" affect that could arise when analyzing whole samples with lots of sand. These methods have been used and recommended by USGS in past studies.

What is the value of elutriate studies to determine sediment quality? What data is available on the LCR for sediment elutriate samples? What are the benefits and problems associated with elutriate sample interpretation?

Is there as similar concern for metal or PAH concentrations as there is for organochlorine compounds?

other ideas??

Timeframe/Budget

1) Gather and review existing data on site specific studies that support the exclusion criteria for the LCR. Estimated time: 3-4 weeks, depending on availability of data??

2) Evaluate any existing studies regarding total organic carbon, fine particulates, and contaminant relations within the LCR (or even similar areas if available). Estimated time: 3-4 weeks.

3) Identify bed sediment samples collected outside the main navigation channel which were collected for the purpose of dredge evaluation and for nondredge-related reasons and review results for patterns in contaminant/particulate associations. Estimated time: 8 weeks.

4) Explore the need to gather additional bed sediment samples in the LCR to further investigate contaminant and grain size relationships specific to the LCR. Estimated time: 4 weeks to 1 year.

REFERENCES

DMEF. 1998. Dredged Material Evaluation Framework-Lower Columbia River Management Area. U.S. Environmental Protection Agency Region 10, U.S. Army Corps of Engineers Northwestern Division (Portland and Seattle District), Washington State Department of Ecology, Oregon Department of Environmental Quality, and Washington State Department of Natural Resources.

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Tetra Tech. 1994. Lower Columbia River backwater reconnaissance survey. Reconnaissance report. Volume 1: Reconnaissance report. Final report (TC 9497-06) prepared for Lower Columbia River Bi-State Committee, May 26. Tetra Tech, Inc., Redmond, Washington. 422 pp.

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Zuranko, D.T., R.W. Griffiths, and N.K. Kaushik. 1997. Biomagnification of polychlorinated biphenyls through a riverine food wed. Environ. Toxicol. Chem. 16:1463-1471.

RSET ISSUE PAPER #27 – Disposal Site Issues

POLICY SUBCOMMITTEE: S. Stirling, Chair (Stephanie.K.Stirling@NWS02.usace.army.mil); February 17, 2004

QUESTION/ISSUE: Disposal Site Issues. How do sampling requirements differ for different disposal options? Are there efficiencies to be gained by identifying additional sampling that might be conducted in conjunction with the sampling for evaluating unconfined disposal to assess these other options concurrently? How do parties needing to dredge identify likely disposal sites? What are the currently available unconfined sites, confined sites?

DISCUSSION: If dredged material does not meet the criteria for unconfined aquatic disposal, the procedures for assessing other disposal options are not currently specified in the Dredged Material Evaluation Framework (DMEF). It is unclear how unconfined or confined aquatic disposal sites are established or how suitable upland disposal sites are identified.

The DMEF provides a process for evaluating if dredge material can be disposed of in an unconfined aquatic disposal site. It does not describe how unconfined aquatic disposal sites are identified. It does not provide sampling requirements for determining if other disposal options are appropriate or what engineering and institutional controls may be warranted for these other options.

REFERENCES: DMEF 1998, Upland Testing manual.

RECOMMENDATION: Specific text and table revision to appropriate sections of DMEF.

PROPOSED LANGUAGE CHANGES: None yet.

LIST OF PREPARERS: Jennifer Sutter, Oregon Department of Environmental Quality

RSET ISSUE PAPER #28 – Programmatic Consultation on SEF

POLICY SUBCOMMITTEE, Stephanie Stirling, Chair.
(stephanie.k.stirling@nws02.usace.army.mil); March 5, 2004

QUESTION/ISSUE: Programmatic Consultation on SEF. 1. Is a programmatic consultation appropriate for all or part of the revised Dredged Material Evaluation Framework (DMEF) manual? 2. Are the action agencies the whole of the Regional Dredging Team (RDT) (i.e., all Federal agencies) or just the Corps and U.S. Environmental Protection Agency (EPA) as leads? 3. If a programmatic consultation is to be done, how does it fit into the existing timeline for the Sediment Evaluations Framework (SEF) and any National Environmental Policy Act (NEPA) action that needs to occur? 4. What happens regarding the Endangered Species Act (ESA) consultation and essential fish habitat consultations if a programmatic consultation is not pursued?

DISCUSSION: A programmatic consultation under (ESA) allows the action agency to receive coverage for incidental take of ESA-listed salmon and steelhead for routine actions with predictable effects. The use of a programmatic consultation can save time and resources because the expectations regarding what the action is required to do to meet ESA requirements are identified well in advance of future actions. Action and activities to be included as part of a programmatic consultation must clearly be non-jeopardy in nature. The biological opinion for a programmatic consultation includes an incidental take statement, re-initiation requirements, non-discretionary terms and conditions, and may include discretionary conservation recommendations.

REFERENCES: None

RECOMMENDATION: Review consultation procedures for EPA and the Corps, review SEF timeline, pursue programmatic approach, and integrate with NEPA process.

PROPOSED LANGUAGE CHANGES: None

LIST OF PREPARERS: Cathy Tortorici, NOAA Fisheries, Northwest Region and John Malek, EPA Region 10

RSET ISSUE PAPER #29 – Frequency of Dredging Guideline

POLICY SUBCOMMITTEE, S. Stirling, Chair
(Stephanie.K.Stirling@NWS02.usace.army.mil); February 23, 2004

QUESTION/ISSUE: Frequency of Dredging Guideline. Is exclusion of routine, annual dredging projects from sediment sampling and testing still an acceptable practice? If modifications should be made, what are they? How frequently are site rankings evaluated and can revisions of projects rankings be made. Should our efforts at gathering information and evaluating sediment quality be placed on those projects most likely to impact the environment?

DISCUSSION: Dredging projects that occur on an annual basis (or at most every 2 to 3 years) may be eligible for multiple dredgings between testing events. These projects generally occur in areas of rapid shoaling with relatively homogeneous sediments. The quality of the sediment on these projects tends to remain the same, barring any significant change upstream or up-current of the site.

In order to be considered under the frequency of dredging guideline, a project must undergo two full sediment characterizations. The sediment must be found suitable for unconfined aquatic disposal in both sediment characterizations. Once a dredging project has met this standard, it can be considered for multiple dredgings between testing under the frequency guideline. This consideration is time-limited, and additional testing will be required at the end of the designated time period (based on project ranking – see below).

REFERENCES: DMEF 1998, Section 5.3.4

RECOMMENDATION: Specific text and table revision to appropriate sections of SEF.

PROPOSED LANGUAGE CHANGES: Insert the following table in the SEF to clarify the frequency guideline.

Project Ranking	Frequency Guideline (Number of years between testing events)
High	2 years
Moderate	5 years
Low-moderate	6 years
Low	7 years

LIST OF PREPARERS: Stephanie Stirling, USACE, NWS

RSET ISSUE PAPER #30 – Effect Level Question

POLICY COMMITTEE: S. Stirling, Chair (Stephanie.K.Stirling@NWS02.usace.army.mil); February 17, 2004

QUESTION/ISSUE: Request for RSET Policy Committee Review and Response: submitted by RSET Sediment Quality Guidelines Subcommittee.

1. Shall the RSET Sediment Quality Guidelines (SQG) Subcommittee assume Site Condition 2 Minor Adverse Effects as the “standard site management condition” for development and recommendation of SL/ML chemical guidelines?

2. If the answer to question 1 is no, should the SQG Subcommittee begin a deliberative process for defining the recommended site biological condition for Lower Columbia unconfined in-water dredged material management?

DISCUSSION: The SQG Subcommittee provided a presentation and recommendations to the RSET at the last meeting, September 24, 2003. The SQG Subcommittee presented initial recommendations to revise the Lower Columbia (LC) Dredged Material Evaluation Framework (DMEF) screening levels (SLs) and maximum levels (MLs) based on recent freshwater sediment quality guideline work completed by the Washington Department of Ecology. Prior to ruling on the adoption of the SQG Subcommittee specific SL and ML recommendations, the RSET asked the SQG Subcommittee for submittal of key “policy” questions related to the definition of the SL and ML for the LC DMEF. The questions below represent the SQG Subcommittee’s response to this RSET request.

The LC DMEF SL/MLs are conceptually based on the Puget Sound Dredged Disposal Analysis (PSDDA) Evaluation Procedures Technical Appendix (EPTA) (EPTA1988). The EPTA provides a substantial discussion in chapter 2 on 5 alternative site management conditions for unconfined, in-water disposal. Importantly, paired biological and chemical guidelines are proposed for three alternative site management conditions from which Site Condition 2 was selected. The identified PSDDA SL/MLs are based on selection of Site Condition 2, Minor Adverse Effects on Biological Resources Due to Sediment Chemicals.

The November 1998 LC DMEF specifically defines the SL and ML (see pages 8-9 and 9-5 and Table 8-1) and explains how these are used in a DMEF. In short, the SL and ML are used to avoid “unacceptable adverse effects due to toxicity measured by sediment bioassays.” **However, the LC DMEF does not define unacceptable adverse effects in the context of an overall disposal site biological management condition. Unlike EPTA, no discussion of alternative site management conditions for unconfined, in-water disposal of dredged material is provided.**

REFERENCES: EPTA, 1988, DMEF 1998.

RECOMMENDATION: Specific text and table revision to appropriate sections of DMEF.

PROPOSED LANGUAGE CHANGES: None yet.
LIST OF PREPARERS: Brett Betts, Ecology (Chair) Lyndal Johnson, NOAA Fisheries Teresa Michelsen, Avocet Consulting Taku Fuji, Kennedy/Jenks Consultants Russ Heaton, Corps Walla Walla Donna Ebner Corps Portland District

RSET ISSUE PAPER #31 – New Surface Material (NSM) Exposed by Dredging

POLICY COMMITTEE: S. Stirling, Chair (Stephanie.K.Stirling@NWS02.usace.army.mil); February 17, 2004

QUESTION/ISSUE: New Surface Material (NSM) Exposed by Dredging, Section 6.6.5. What is the policy towards NSM evaluation when in-water biological testing is inappropriate for the material being removed?

Discussion: Present Dredged Material Evaluation Frameworks (DMEF) requires testing of NSM if "sediment immediately above the NSM has concentrations of chemicals-of-concern exceeding screening levels and fails the applicable biological tests…" The DMEF tests are for unconfined in-water disposal. What is to be done if the material is not slated for in-water disposal and therefore no applicable biological tests are conducted on the material to be removed? These biological tests are also discussed in the last sentence of second paragraph and bullet one.

REFERENCES: DMEF 1998, Upland Testing manual, Section 6.6.5.

RECOMMENDATION: Edit text to include appropriate evaluation of the exposed surface or provide a management option such as capping.

PROPOSED LANGUAGE CHANGES: Change in paragraph 2 "levels and fails" to "levels and/or fails;" delete last sentence in the second paragraph; add to last sentence in bullet 1 "…of the exposed new surface material." Also review second bullet language.

LIST OF PREPARERS: Mark Siipola, Portland District Corps

RSET ISSUE PAPER #32 – Minor Text Changes and Clarifications

POLICY COMMITTEE: S. Stirling, Chair (Stephanie.K.Stirling@NWS02.usace.army.mil); February 17, 2004

QUESTION/ISSUE: Minor text changes and clarifications.

DISCUSSION:

Acronyms; Review and edit, add OTM, UTM, MDL, MRL, PQL,…?
Section 7 Sampling Approach; Add “physical” to “chemical…biological analysis”
Section 8.3 Tier IIA Testing; Change “…are <u>greater</u> than 20 percent…” to “…are less than 20 percent…”
Table 8-1; Add units to all bold headings such as Phthalates, Phenol, etc.
Table 8-1: Add SEDQUAL chemical codes to table.
Section 8.5.3 The Role of Detection Limits in Interpretation; Edit to discuss how total DDT, PCBs, etc. for non-detects are to be handled. Table 8-2 list DDT MDLs as 2.3, 3.3, and 6.7 which adds up to 12.3 which is > the 6.9 SL.
Section 11.1; Update to include SEDQUAL format for data submission for physical, chemical, and biological data.

<u>Policy Questions:</u>

REFERENCES: DMEF 1998.

RECOMMENDATION: Edit text to include appropriate changes and updates. For Total DDT adopt PSDDA protocols for non-detect. Non-detects are not summed, individual non-detects must be below 6.9 SL but not their sum.

PROPOSED LANGUAGE CHANGES: See above.

LIST OF PREPARERS: Mark Siipola