Sediment Evaluation Framework for the Pacific Northwest

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Idaho Department of Environmental Quality

State of Oregon Department of Environmental Quality

Washington State Department of Natural Resources

Department of Ecology State of Washington

US Army Corps of Engineers

United States Environmental Protection Agency Region 10

U.S. Fish & Wildlife Service

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

SEDIMENT EVALUATION FRAMEWORK FOR THE PACIFIC NORTHWEST

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NATIONAL MARINE FISHERIES SERVICE

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ACRONYMS AND ABBREVIATIONS

ADDAMS	Automated Dredging and Disposal Alternatives Modeling System
AET	apparent effects threshold
ARAR	Applicable or Relevant and Appropriate Requirement(s)
ASTM	American Society for Testing and Materials
BA	Biological Assessment
BCF	bioaccumulation factor
BCoC	bioaccumulative chemical of concern
BiOp	Biological Opinion
BMF	biomagnification factor
BMP	best management practice
BSAF	biota-sediment accumulation factor
BT	bioaccumulation trigger
BW	body weight
°C	degrees Celsius
CAD	confined aquatic disposal
CAS	Chemical Abstract Service
CBR	critical body residue
CD	compact disc
CDF	confined disposal facility
CDFB	chlorinated dioxins/furans and polychlorinated biphenyls
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CoC	chemical of concern
Corps	U.S. Army Corps of Engineers
CSF	carcinogenic slope factor
CSL	cleanup screening level
CSM	conceptual site model
CST	column settling test
CWA	Clean Water Act
CWHRS	California Wildlife Habitat Relationship System
cy	cubic yard(s)
CZMA	Coastal Zone Management Act
DMEF	Dredged Material Evaluation Framework
DMMP	Dredged Material Management Program (state of Washington)
DMMU	dredged material management unit
DOTS	Dredging Operations and Technical Support Program
DPS	distinct population segment
DQO	data quality objective
DRET	dredging elutriate test
DSL	Oregon Department of State Lands
dw	dry weight

ACRONYMS AND ABBREVIATIONS (continued)

EA	Environmental Assessment
EC_{20}	effects concentration (affecting 20% of test organisms)
Ecology	Washington State Department of Ecology (also WDOE)
EDL	estimated detection limit
EFH	essential fish habitat
EIM	Environmental Information Management
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
EPH	extractable petroleum hydrocarbon
ER_{10}	effective residue (10% mortality based on tissue residue)
ERDC	Environmental Laboratory at the Engineering Research and Development Center
ERED	Environmental Residue Effects Database
ESA	Endangered Species Act
ESC	Executive Steering Committee
ESU	evolutionarily significant unit(s)
FAC	fluorescent aromatic compounds
FCWA	Fish and Wildlife Coordination Act
FIR	food ingestion rate
FONSI	Finding of No Significant Impact
FPM	floating percentile method
g	gram(s)
GC/MS	gas chromatography/mass spectrometry
GIS	geographic information system
HCp	hazardous concentration percentile (p = percentile)
HPAH	high-molecular weight polynuclear aromatic hydrocarbon (PAH)
IDAPA	Idaho Administrative Procedures Act
IDEQ	Idaho Department of Environmental Quality
IDWR	Idaho Department of Water Resources
K_{ow}	octanol-water partition coefficient
kg	kilogram(s)
K-S	Kolmogorov-Smirnoff goodness-of-fit test
LC_{50}	lethal concentration (affecting 50% of test organisms)
LCI	lower 95% confidence interval
LOAEL	lowest-observable-effect level
LPAH	low-molecular weight polynuclear aromatic hydrocarbon (PAH)
LR_{50}	lethal residue (50% mortality based on tissue residue)
MDL	method detection limit(s)
MET	modified elutriate test
mg/kg	milligrams per kilogram
ML	maximum level
mL	milliliter(s)

ACRONYMS AND ABBREVIATIONS (continued)

MMPA	Marine Mammal Protection Act
MPRSA	Marine Protection Research and Sanctuaries Act
MSA	Magnuson Stevens Fishery Conservation and Management Act
MTCA	Model Toxics Control Act (state of Washington)
N/A	not applicable
NAD	North American Datum
NCMA	normalized combined mortality and abnormality
NDIR	non-dispersive infrared detection
NEPA	National Environmental Policy Act
ng/kg	nanograms per kilogram
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAEL	no-observed-adverse-effect level
NRSC	Navigation/Steering Committee
OAR	Oregon Administrative Rule
ODEQ	Oregon Department of Environmental Quality
ORNL	Oak Ridge National Laboratory
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzodioxins
PCDF	polychlorinated dibenzofurans
PDF	portable document format
PIANC	Permanent International Association of Navigation Congresses
PL	public law
PM	project manager
poly	high-density polyethylene
ppt	parts per thousand
PRG	Project Review Group (states of Oregon and Idaho)
PSDDA	Puget Sound Dredged Disposal Analysis
PSEP	Puget Sound Estuary Program
PSWQAT	Puget Sound Water Quality Action Team
PTFE	poly(tetrafluoroethene) or poly(tetrafluoroethylene)
QA	quality assurance
QA/QC	quality assurance/quality control
QSAR	quantitative structure activity relationship
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RDT	Regional Dredging Team
RfD	reference dose
RPA	reasonable and prudent alternative
RPM	reasonable and prudent measure

ACRONYMS AND ABBREVIATIONS (continued)

RSET	Regional Sediment Evaluation Team
SAP	Sampling and Analysis Plan
SEF	Sediment Evaluation Framework
SEPA	State Environmental Policy Act (state of Washington)
SET	standard elutriate test
SETAC	Society of Environmental Toxicity and Chemistry
SL	screening level
SMARM	Sediment Management Annual Review Meeting
SMS	Sediment Management Standard (state of Washington)
SOF	Statement of Findings
SOP	standard operating procedure
SQG	sediment quality guideline(s)
SQL	sample quantitation limit(s)
SQS	sediment quality standard(s)
SSD	species sensitivity distribution
SSL	soil screening level
SVOC	semivolatile organic compound
TBT	tributyltin
TCDD	2,3,7,8-tetrachlorodibenzo-p-doxin
TEF	toxic equivalency factor
TEF	toxicity equivalency factor
TEQ	toxicity equivalent
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TRA	tissue residue approach
TRV	toxicity reference value
TSS	total suspended solids
TTL	target tissue level
TVS	total volatile solids
μg/kg	micrograms per kilogram
μg/L	micrograms per liter
USFWS	U.S. Fish and Wildlife Service
UTL	upper tolerance limit
VPH	volatile petroleum hydrocarbon
ww	wet weight
WAC	Washington Administrative Code
WDFW	Washington State Department of Fish and Wildlife
WDNR	Washington State Department of Natural Resources
WDOE	Washington State Department of Ecology (also Ecology)
WHO	World Health Organization
WQC	water quality criteria

SEDIMENT EVALUATION FRAMEWORK PREAMBLE

What does this SEF do?

The assessment of sediments and dredged material is a critical component of all dredging and dredged material disposal/management activities. The primary purpose of this SEF is to determine the suitability of sediment for in-water disposal (or beneficial reuse). This SEF provides a framework for the assessment and characterization, that is helpful in considering management (disposal) options for sediments in Washington, Oregon, and Idaho (defined in this document as the Pacific Northwest). This SEF can also be used to evaluate the *need* for cleanup activities. However, the development of cleanup criteria is outside of the purview of this manual, and the states of Washington, Oregon, and Idaho will exercise their regulatory authority via their cleanup statutes.

This framework is consistent with federal and state regulations and the national manuals prepared by the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers for evaluation of dredged material (Ocean Testing Manual and Inland Testing Manual), and it provides a "toolbox" of methods that can be utilized for sediment and dredged material characterizations. It is intended only as guidance, and best professional judgment should be exercised in determining the uses of this SEF. Nothing in this SEF alters or limits agency responsibilities, or imposes mandatory requirements beyond existing statute or regulation. Agencies may request additional sampling and/or analyses to clarify site conditions or to meet specific regulatory requirements.

Why is the SEF being prepared?

The SEF is being prepared to provide a regionally consistent framework for evaluating the suitability of dredged material for in-water disposal. This SEF was derived in large part from the Puget Sound Dredged Disposal Analysis (PSDDA) program in the state of Washington and the national manuals, and it is being prepared to replace and expand the existing Dredged Material Evaluation Framework (DMEF) and the 2006 Interim Final SEF. It also provides useful guidelines in accordance with applicable state and federal regulatory programs that address sediment characterization and disposal issues.

History of the SEF

To determine the need for the SEF, the Regional Sediment Evaluation Team (RSET) conducted a 3-day technical scoping workshop from September 11 to 13, 2002, which included RSET members and other interested parties from federal and state agencies and regional Port authorities. The 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. The purpose of the workshop was to develop the scope for preparing an overall plan and process for updating the existing DMEF. The workshop was also used to gauge the level of agency support for replacing the existing DMEF and expanding the DMEF to include evaluation of sediments throughout the entire Pacific Northwest under a variety of regulatory programs. Since the 2002 meeting, the RSET plus technical experts, regulators, and policy makers from the federal and state resource agencies, as well as the private sector, worked to develop the Interim 2006 SEF.

During this time period, the RSET met frequently to coordinate subcommittee activities and prepare the SEF. Participation by affected users was sought via participation in technical subcommittees, attendance at RSET meetings and conference calls, and review of the SEF by representatives of the ports, maritime industries, tribes, and other interested parties. Some of these representatives are listed below.

- Corps of Engineers – Portland, Seattle, and Walla Walla Districts and Northwestern Division;
- U.S. Environmental Protection Agency, Region 10;
- Washington State Department of Ecology;
- 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;
- People for Puget Sound; and
- Private consulting firms including Anchor Environmental, Applied Biomonitoring, Avocet Consulting, Battelle Pacific Northwest Laboratories, Columbia Analytical Services, Ecology & Environment, Exponent, Hart Crowser, Integral, Kennedy/Jenks Consultants, MEC Analytical Services, Newfields, Northwestern Aquatic Sciences, Parametrix, QA/QC Solutions, TestAmerica, Tetra Tech EC Inc., URS Corporation, and Windward.

Current RSET Subcommittees

Much of the work by RSET is performed by subcommittees that prepare white papers providing recommendations, technical information, and/or requesting policy guidance. White papers provide the basis for RSET's deliberations. The white papers can be found on the Corps of Engineers' RSET website (located at https://www.nwp.usace.army.mil/pm/e/rset.asp). Changes to the SEF will require concurrence of the full RSET, as well as public review. The current RSET subcommittees and their membership are shown below.

- **Policy Committee**: Corps of Engineers – Portland, Seattle and Walla Walla Districts and Northwestern Division, National Marine Fisheries Service, U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency Region 10, Anchor Environmental, Avocet Consulting, Kennedy/Jenks Consultants, Idaho Department of Environmental Quality, Oregon Department of Environmental Quality, and Washington Department of Ecology.
- **Biological Testing Subcommittee**: Kennedy/Jenks Consultants (Chair), Newfields Northwest (Co-Chair), Battelle Pacific Northwest Laboratories, Northwestern Aquatic Sciences, Parametrix, Windward, Corps of Engineers – Seattle and Walla Walla Districts, National Marine Fisheries Service, and U.S. Fish and Wildlife Service.
- **Bioaccumulation Subcommittee**: Avocet Consulting (Chair), Washington Department of Ecology, Oregon Department of Environmental Quality, Anchor Environmental, Applied Biomonitoring, Exponent, Integral, Kennedy/Jenks Consultants, Newfields Northwest, Parametrix, People for Puget Sound, Test America, Tetra Tech EC Inc., URS Corporation, Corps of Engineers – Portland, Seattle and Walla Walla Districts, National Marine Fisheries Service, U.S. Fish and Wildlife Service, and U.S. Environmental Protection Agency Region 10.

- **Chemical and Analyte Subcommittee**: Anchor Environmental (Chair), Washington Department of Ecology, Oregon Department of Environmental Quality, Analytical Resources Inc., Avocet Consulting, Columbia Analytical Services, Hart Crowser, Kennedy/Jenks Consultants, TestAmerica, Corps of Engineers – Portland, Seattle, and Walla Walla Districts, National Marine Fisheries Service, and U.S. Fish and Wildlife Service.
- **Sediment Quality Guidelines Subcommittee**: This subcommittee is working on freshwater values and is funded by the Oregon Department of Environmental Quality.

Who should use the SEF?

The SEF is designed to help users who want to better understand and work with methodologies for assessing and characterizing sediments. The RSET prepared the SEF to assist regulators, permittees, stakeholders, trustees, and the public.

How will the SEF help me?

If you are a regulator, the 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, state regulatory or proprietary authorities) may have specific requirements other than those specified in the SEF. Therefore, if there is a chance the project could fall into another regulatory program, early coordination with RSET may be beneficial.

If you are seeking a dredging permit, the SEF provides sampling, testing, and analysis guidance that can reduce uncertainties about the actions a regulator may require. Reducing uncertainties can help with project scheduling, financial planning, and project management decisions.

If you are a member of the public, the SEF can help determine what information regulators require in sediment management decisions. Within the context set by the SEF and the open and transparent continuous improvement process, you, as a member of the public, will have enhanced access to the process behind regulatory decision making regarding sediments.

For the state of Washington, this manual will be utilized as guidance for dredged material management only. In Washington, the Sediment Management Standards (Washington Administrative Code, Chapters 173-204) and the Model Toxics Control Act (Washington Administrative Code, Chapters 173-340) will continue to be used as the regulatory tools for sediment management and cleanup decisions.

How does the SEF become final?

The RSET expects the SEF to always be a living document with a process available to update and incorporate advances in scientific, engineering, and regulatory fields (see Section 1.6.3 for more information). Public comments were accepted when the draft Interim 2006 SEF was made public in the summer of 2005 and 2006. Comments were reviewed by representatives from each of the participating agencies, and changes were made.

In February 2009, a draft of this "Final" SEF was made available for public review and comment. All commenst received were considered, leading to changes and clarifications in this final document. A complete list of comments with RSET agency resposnses is available on the RSET website, located at https://www.nwp.usace.army.mil/pm/e/rset.asp.

In the future, major revisions will be presented annually by the RSET to agency staff and the interested public for review and comment. Any necessary revisions will be posted on the SEF website (https://www.nwp.usace.army.mil/pm/e/rset.asp) and will be provided as supplements to this SEF.

What are the differences between this SEF and the Interim 2006 SEF?

While the 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 in this SEF.

- A consistent approach for characterizing in-place sediments and proposed dredged material;
- Draft freshwater sediment screening levels added;
- Updated information on the chemical analyte lists that will need to be evaluated in different parts of the Pacific Northwest;
- Updated information on the analysis of polychlorinated biphenyls in sediment and tissue;
- A framework for addressing bioaccumulation, including a process for deriving scientifically defensible bioaccumulation triggers for tissues and sediments;
- A two-level process, as opposed to the historical four-tier assessment process, consistent with emerging national guidance (described in Chapter 4);
- Elutriate test triggers added (described in Chapter 10); and
- Editorial changes and clarifications.

How is the SEF organized?

The authors of the SEF organized the report to address the overall implementation strategy for the assessment and characterization of proposed dredged material. The initial chapter presents the goals and structure of the SEF. Additional chapters place the SEF within the context of federal and state sediment management regulations, and discuss regulatory processes where the SEF can be applied. Subsequent chapters and appendices present the specific chemical and biological tests that are recommended with interpretation criteria.

CHAPTER 1. GOALS, DESCRIPTIONS, AND ORGANIZATION

1.1. INTRODUCTION

This Sediment Evaluation Framework (SEF) manual provides a regional framework for the assessment, characterization, and management (disposal) of sediments in the Pacific Northwest (defined in this document as the states of Washington, Oregon, and Idaho) to determine suitability for unconfined in-water disposal. This document addresses the development of a comprehensive evaluation framework governing sediment sampling, testing, and test interpretation for determining the potential risk of dredged material (freshwater and marine sediments), as well as evaluating the suitability of alternative management options.

The goal of this manual is to provide the technical and regulatory basis 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. For cleanup activities, the states of Washington, Oregon, and Idaho will exercise their regulatory authority via their cleanup statutes (see Chapter 2). The SEF guidelines ensure consistency in evaluation among the various programs that regulate sediment.

Reliable and cost-effective sampling and analysis procedures for characterizing sediments, which are also protective of the ecosystem, are incorporated into the SEF for application in the Pacific Northwest. Application of the chemical/biological tests and interpretation guidelines found in the SEF provides suitable information to determine management options, such as no action, unconfined aquatic, unconfined upland, confined aquatic, confined nearshore, and confined upland. Some tests may also be useful in evaluating the chemical/biological effects of dredging activities.

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/WDOE), Washington State Department of Natural Resources (WDNR), Oregon Department of Environmental Quality (ODEQ), and the 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).

The SEF ensures adequate regulatory controls and public accountability for the assessment, characterization, and management of sediments. The procedures used to develop this manual were derived from similar regional programs including the successful Puget Sound Dredged Disposal Analysis (PSDDA) program in the state of Washington, the Grays Harbor/Willapa Bay Dredged Material Evaluation Procedures Manual, the Corps Portland District Dredged Material Tiered Testing Procedures, and the Regional 1998 Dredged Material Evaluation Framework (DMEF). Documents containing justification for the guidelines and procedures in the SEF are contained in Chapters 2 and 13. Full consideration was made of all pertinent state and federal laws, regulations, and guidance, including other regional sediment management programs. In addition, the SEF is consistent with the guidelines of the national-level sediment assessment manuals.

1.3. How to Use This Manual

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

This first chapter presents the goals and structure of the SEF and gives an overview of agency laws, regulations, and authorities as they relate to the assessment and characterization of sediment and the dredging and disposal of sediments. Chapter 2 summarizes 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 the SEF manual. Not all process steps are described in detail and additional information from the regulating agency may be necessary.

The risk-based framework is discussed in Chapter 4. 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 contaminated sediment 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 methods in a systematic manner will help ensure more accurate sediment quality data and facilitate comparisons among sediment studies. Chapters 4 through 6 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 for dredging activities. Chapter 4 describes in detail the necessary information required in a SAP. Chapter 5 discusses the recommended procedures for sample acquisition and handling, and Chapter 6 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 guideline values. Chapters 7 and 8 discuss recommended biological and bioaccumulation tests, test species, the quality control requirements for each test, and the guidelines used for decision-making. Chapter 9 provides an overview of the factors to be considered when selecting sediment disposal options. Chapter 10 describes the process to follow in those rare cases when standard sediment assessment techniques are insufficient to reach a management decision.

Chapter 11 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 were conducted 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 12 is an introduction to the beneficial use and its importance to the overall sediment management in the Pacific Northwest. References are provided in Chapter 13.

The appendices provide additional technical support to the chapters. White papers, contributed by the RSET subcommittees, can be found on the RSET website (located at https://www.nwp.usace.army.mil/pm/e/rset.asp) and allow the reader to better understand how the SEF was developed.

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

The SEF was prepared to satisfy the following five objectives:

(1) It establishes a marine and freshwater sediment characterization framework in coordination with the public, stakeholders, and regulatory resource agencies.

The regional SEF manual establishes a sediment sampling, testing, and interpretation framework in coordination with 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.

Project actions in one state may affect another state. Because sediment management activities 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 most efficiently under this regulation, it would be ideal to have uniform water quality requirements in a bi-state waterway. 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, the SEF does not govern CERCLA response actions. However, the "tools" described in the SEF may be useful to the CERCLA program.

(4) It establishes databases to track the long-term trends in sediment quality for specific dredging projects/locations and for the region.

Sediment management programs require the collection and maintenance of data about projects and their characteristics. This objective includes the establishment of databases that will track sediment quality trends over time at specific locations and for the region. 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 focuses on determining suitability of sediment for in-water disposal. The manual also recognizes 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 dredged material management. A regulatory decision on acceptability of material for remediation or disposal is determined from the test results. This manual defines the minimum requirements for evaluation of dredged material for regulatory decision-making under the CWA, National Environmental Policy Act (NEPA), Endangered Species Act (ESA), Fish and Wildlife Coordination Act (FWCA), Magnuson Stevens Fishery Conservation and Management Act (MSA), and Marine Protection Research and Sanctuaries Act (MPRSA).

One of the underlying principles in the preparation of the 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 August 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 presented in this manual. This workshop was held in Fairmont, Montana, and brought together 55 experts in the field of sediment assessment and management from the United States, Australia, Canada, France, Germany, Great Britain, Italy, and the Netherlands 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 levels (tiers) recommended. Previously, dredged material evaluations were conducted based on a four-tier testing framework as presented in historical Pacific Northwest regional manuals. The two-level testing process, 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 SEF as for the historical Pacific Northwest regional manuals, the two-level testing process summarized below will be more consistent with national guidance and an understanding of the ecosystem function provided at the site. The two-level testing process is described fully in Chapter 4.

- Level 1 includes defining the scope of the project, collecting historically available data, developing a CSM, and providing the information used for ranking a project. If existing Level 1 data satisfies parameters in the CSM and indicate risk to receptors is minimal, then there is no need to collect further data and management decisions can be made at the end of Level 1. The transition from Level 1 to Level 2 occurs when data are insufficient for making a decision with only Level 1 information and additional information is needed.
- Level 2 involves development of a SAP in order to collect new data to support a management decision. Level 2 has two parts. Level 2A consists of analysis of sediment chemical and physical characteristics. Data from Level 2A can either support a decision, or lead to Level 2B biological testing, bioaccumulation testing, or other special evaluations. Level 2A and Level 2B may be conducted concurrently to speed up project evaluations.

1.5.1. Characteristics of the Sediment Evaluation Framework

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 and use best available science. 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 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. 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 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.

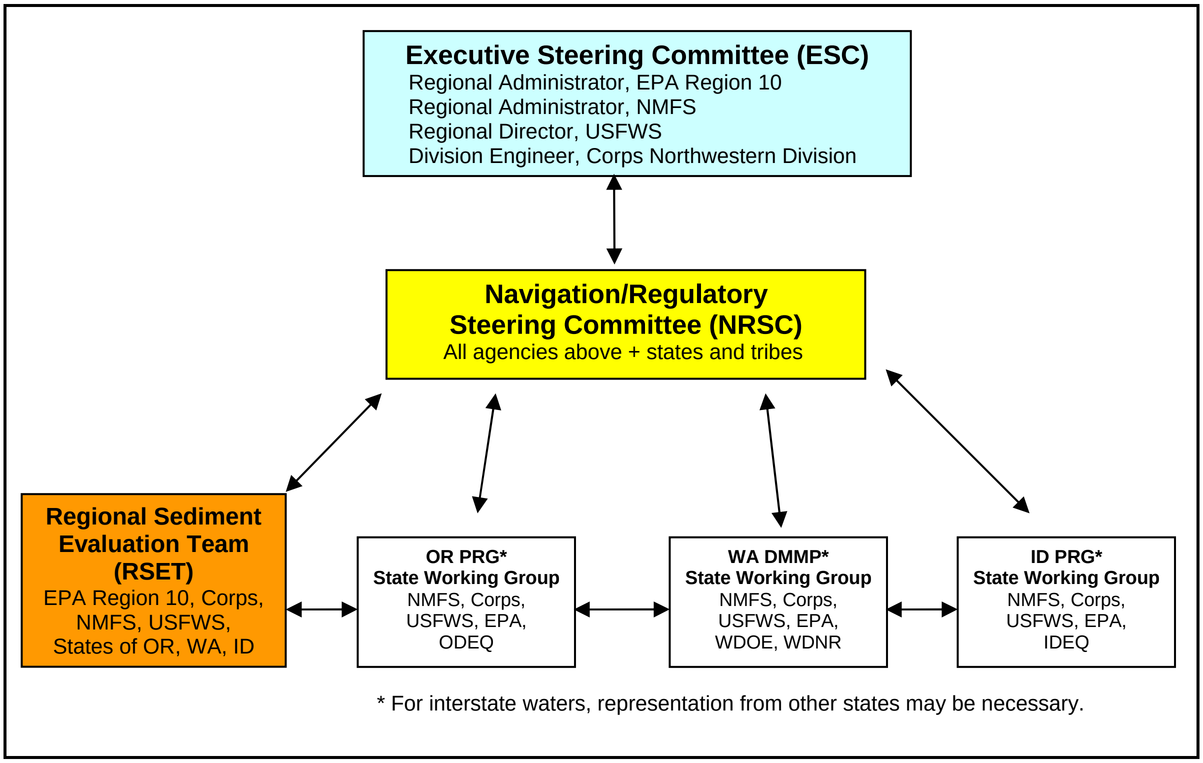
1.6. RSET STRUCTURE AND PROCESS

The RSET requires a high level of knowledge concerning the 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 scientific advice combined with practicable knowledge about the administrative use of the SEF to ensure science-based recommendations. The structure and processes outlined below support the functions of RSET: continuous improvement of methods for sediment sampling, testing, and analysis to support regulatory management decisions at a regional 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 needed.

1.6.1. Roles, Relationships, and Representation

The structure of the Regional Dredging Team (RDT) is shown in Figure 1-1. The Executive Steering Committee (ESC) is composed of upper-level management at EPA Region 10, the Corps Northwestern Division, NMFS, and USFWS.

Figure 1-1. Structure of the Regional Dredging Team



The RSET reports to the Navigation/Regulatory Steering Committee (NRSC). The NRSC provides both technical and policy guidance and feedback to RSET. Issues that cannot be resolved by the RSET membership will be taken to the NRSC. As issues are elevated from local dredging teams to the NRSC, it will often be appropriate for the RSET to advise these groups. The RSET operates by consensus to amend the SEF and to provide guidance about the implementation of the SEF (both the technical aspects and the interface with regulatory). The RSET also provides region-wide analysis of sampling results to make regulatory management decisions regarding sediment characterization. To meet these responsibilities, the 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 Project Review Groups (PRGs) for Oregon and Idaho, and the Dredged Material Management Program (DMMP) for the state of Washington work cooperatively with RSET by raising issues and concerns to address. The PRGs/DMMP and applicants can raise issues of concern to the NRSC for review and resolution, if necessary.

The ESC, NRSC, and RSET are each co-chaired by the Corps and EPA.

1.6.2. Current RSET Subcommittees

Much of the work by RSET is performed by subcommittees that prepare white papers providing recommendations, technical information, and/or requesting policy guidance. White papers provide the basis for RSET's deliberations. The white papers can be found on the RSET website (located at https://www.nwp.usace.army.mil/pm/e/rset.asp). Once a white paper is prepared by a subcommittee, it is forwarded to the policy subcommittee. The policy subcommittee's role at that point is to ensure the recommendations and supporting information are clear, and necessary coordination has occurred with other subcommittees. Changes to the SEF will require concurrence of the full RSET, as well as public review. The current RSET subcommittees are shown below. The Policy Subcommittee may form other subcommittees to critically evaluate emerging issues.

- Policy
- Biological Testing
- Bioaccumulation
- Chemical Analyte
- Sediment Quality Guidelines

1.6.3. RSET Continuous Improvement/Adaptive Management

A very important aspect of the SEF is its ability to continuously evolve. Fundamentally, RSET members share a strong commitment to making the SEF a "living document." As new information becomes available, the RSET agencies will need to revise and refine all aspects of the program, which must take place in a publicly accessible forum. The first mechanism for ensuring this is regular meetings similar to or concurrent with the Sediment Management Annual Review Meeting (SMARM). The RSET shall meet at least yearly. If these meetings fail to occur, any RSET member may request, in writing to the NRCS, that such a meeting be held.

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

1.6.4. Regulatory/Technical Sediment Interface

The interface between regulatory agencies and technical sediment issues is described in Chapter 3. The 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 one exception is EPA Region 10's responsibility for Alaska. The EPA has suggested that the SEF be considered for use in Alaska at a future date; this will require a similar review process for this manual to determine its suitability for Alaska.

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. The RSET will work together assessing and interpreting sediment-related projects. For the near term, there will be case-by-case interpretations necessary until the SEF is fully developed. The 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

The RSET management and the decision-making process regarding the sediment database are discussed in Chapter 11.

1.6.7. Public Involvement/National Environmental Policy Act

The SEF is a continuation of a sediment evaluation process started in the Pacific Northwest more than 20 years ago with the advent of the PSDDA. Updates and improvements to this process over the years have had full public involvement and state and federal environmental compliance, either in the form of 103 MPRSA or 401/404 CWA public notices and/or NEPA documentation. All comments received prior to or during the public notice process were fully considered in the final version of this manual. All of the RSET agencies are committed to using the guidelines developed in this collaborative effort.

CHAPTER 2. SEDIMENT MANAGEMENT REGULATIONS

2.1. INTRODUCTION

Several state and federal entities have regulatory authority governing the management of dredged material and contaminated sediment in the Pacific Northwest. At the federal level, the Corps and EPA share responsibility for the regulation of dredged material within waters of the United States under Section 404 of the Clean Water Act (CWA), and for the regulation of dredged material within ocean waters under Section 103 of the Marine Protection, Research, and Sanctuaries Act (MPRSA). In the state of Washington, regulation is shared by Ecology, Washington Department of Natural Resources (WDNR), and the Washington Department of Fish and Wildlife (WDFW). In Oregon, regulation is carried out by the ODEQ, Department of State Lands (DSL), and the Department of Land Conservation and Development. In Idaho, regulation is carried out by the IDEQ, Idaho Department of Lands, and the Idaho Department of Water Resources (IDWR).

For the assessment and management of contaminated sediment cleanup, the EPA has federal regulatory authority. The states of Washington, Oregon, and Idaho exercise their regulatory authority via their cleanup statutes. In Washington, this SEF will be used only as guidance for the evaluation of dredged sediments. Evaluation of sediments for cleanup actions shall be in compliance with the Model Toxics Control Act (MTCA) and Sediment Management Standards (SMS). If the SAP results from a dredged sediment evaluation show contamination above dredged material open-water disposal levels, then the site will be referred to Ecology for evaluation in compliance with the MTCA and SMS.

This chapter provides an overview of CWA and MPRSA regulatory responsibilities. Regulations governing the Corps regulatory program are found in Title 33 of the Code of Federal Regulations (CFR), Parts 320 to 332. Also, an overview is provided for Section 10 of the Rivers and Harbors Act that requires a Corps permit for certain structures or work in or affecting navigable waters of the United States.

Many other federal and state laws and regulations that apply to dredging and dredged material disposal are listed in this chapter. For example, dredged material disposal must comply with applicable requirements of the National Environmental Policy Act (NEPA). In some cases, disposal is subject to additional regulation by state governments through state water quality certification and coastal zone consistency under the federal Coastal Zone Management Act (CZMA). Table 2-1, located at the end of the chapter, summarizes some of the other applicable federal and state laws and regulations. Regulatory processes are discussed in Chapter 3.

2.2. OVERVIEW OF THE CLEAN WATER ACT (CWA)

2.2.1. Section 401 of the CWA

Section 404 of the CWA governs discharges of dredged material into "waters of the United States," which is defined as all waters landward of the baseline of the territorial sea. Section 401 of the CWA requires the states to certify that any federally permitted project discharging into waters of the United States will not violate state water quality standards, which are based on federal water quality criteria. For non-federal dredging, Section 401 certification is a precondition to compliance with the Section 404 guidelines, and is required before receiving a Corps Section 404 permit for the disposal of dredged or fill material. 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 water may affect waters of the United States.

Under Section 303 of the CWA, the states are required to develop and adopt a statewide anti-degradation policy and to identify the methods for implementing such policy in developing water quality standards, consistent with Section 303 (see 40 CFR 131).

2.2.2. Section 404 of the CWA

Section 404 of the CWA (33 U.S.C. 1344; see 33 CFR Part 323) governs the discharge of dredged or fill material into waters of the United States (inland of and including the territorial sea). The geographical limits of jurisdiction under the CWA include all waters of the United States as defined at 33 CFR 328.3. These include wetlands adjacent to jurisdictional waters and navigable waters of the United States. In tidal waters of the United States, the landward limit of jurisdiction extends to the high tide line. Additionally, the Corps/EPA CWA jurisdiction in non-tidal waters extends to the ordinary high water mark in the absence of adjacent wetlands, or when adjacent wetlands are present, the jurisdiction extends beyond the ordinary high water mark to the limit of the adjacent wetlands. If the waters of the United States consist only of wetlands, then the jurisdiction extends to the limit of the wetland, if that wetland meets certain legal tests.

Section 404(b)(1) requires the EPA, in conjunction with the Corps, to promulgate guidelines for the discharge of dredged or fill material to ensure that such proposed discharge will not result in unacceptable adverse environmental impacts either individually or in combination to waters of the United States. Section 404(b)(1) assigns to the Corps the responsibility for authorizing all such proposed discharges and requires application of the guidelines in assessing the environmental acceptability of the proposed action. The Corps is also required to examine the least environmentally damaging practicable alternative to the proposed discharge, including alternatives to disposal into waters of the United States.

A Section 404 permit is required when dredged material is disposed of in either an aquatic or nearshore environment, including some ocean discharges within the Territorial Sea (see Section 2.3). A Section 404 permit is also required when dredged material will be 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.

The Corps and EPA also have authority under the Section 404(b)(1) guidelines to identify, in advance, that sites that are either suitable or unsuitable for the discharge of dredged or fill material into waters of the United States. The EPA is responsible for environmental oversight under Section 404 and retains permit veto authority pursuant to Section 404(c). Section 401 of the CWA provides a certification role to the states as to project compliance with applicable state water quality standards.

2.3. Overview of Marine Protection, Research and Sanctuaries Act (MPRSA)

The MPRSA (also called the Ocean Dumping Act, 33 U.S.C. 1401 *et seq*.) governs the transportation of dredged material for the purpose of disposal into ocean waters (seaward of the baseline of the territorial sea). In accordance with Section 103 of the MPRSA, the Corps is the permitting authority for ocean disposal of dredged material, subject to EPA review and concurrence.

Section 103 specifies that all proposed operations involving the transportation and disposal of dredged material into ocean waters will be evaluated to determine the potential impact of such activities. This is performed by the Corps using criteria developed by EPA (see 40 CFR Parts 227-228). The Corps also is required to consider navigation, economic and industrial development, and foreign and domestic commerce, as well as the availability of alternatives to ocean disposal. Proposed ocean disposal of dredged material also must comply with the permitting and dredging criteria in the regulations in 33 CFR Parts 320-330 and 335-338. The EPA must determine the proposed disposal will comply with the criteria prior to disposal, and concur with the use of the site.

The EPA has a major environmental oversight role in reviewing the Corps determination of compliance with the ocean disposal criteria. If EPA determines the criteria are not met, disposal may not occur without a waiver of the criteria by EPA. In addition, the EPA has authority under Section 102 to designate ocean disposal sites. The Corps is required to use such ocean disposal sites to the extent feasible. Where not feasible, the Corps may, with the concurrence of EPA, select an alternate ocean disposal site using the EPA site selection criteria.

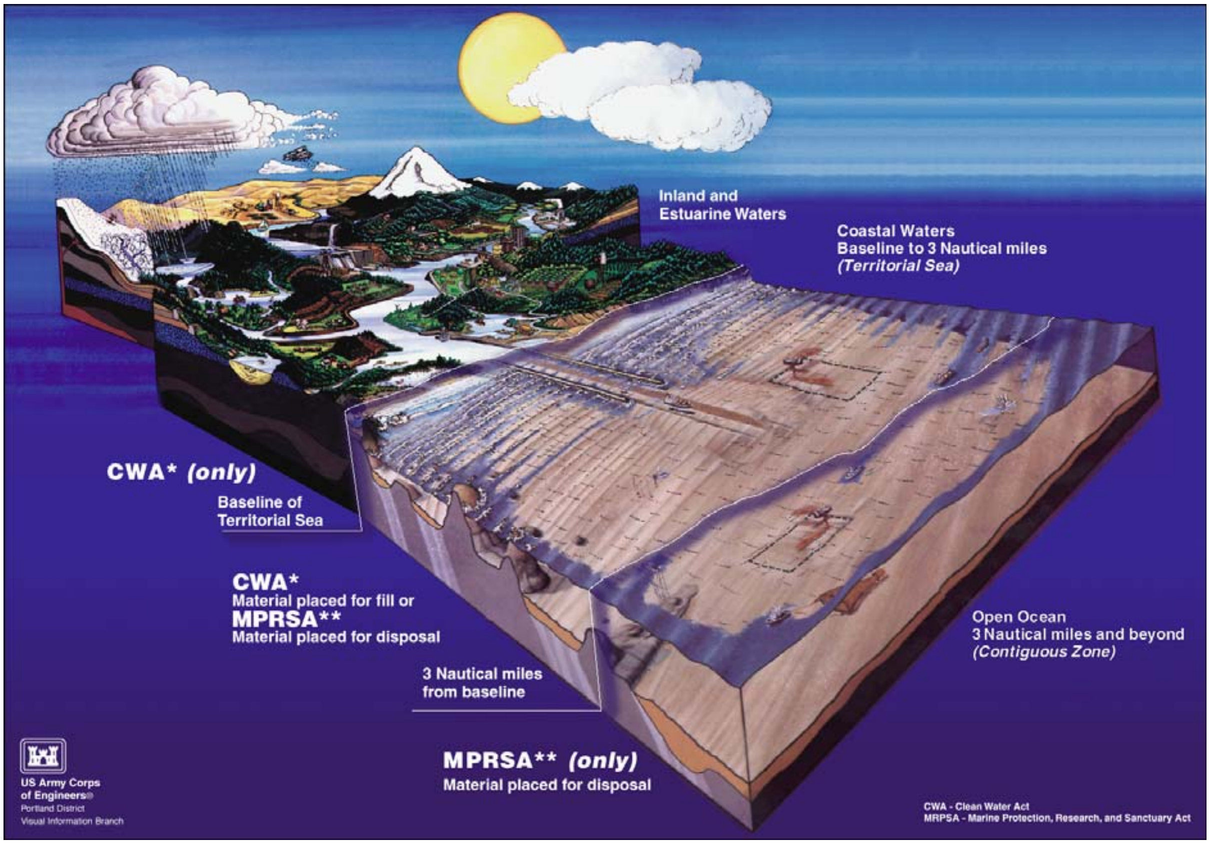
2.4. Overlapping Geographic Jurisdiction of CWA and MPRSA

In order to understand the geographic jurisdiction of the CWA and MPRSA, it is necessary to define the baseline of the territorial sea. For purposes of both international and domestic law, the baseline is the boundary line dividing the land from the ocean. In the United States, the baseline is the mean lower low water line along the coast as shown on official nautical charts. The baseline is drawn across river mouths, the opening of bays, and along the outer points of complex coastlines.

Section 404 of the CWA applies to the discharge of dredged or fill material into waters of the Untied States, which include waters inside the baseline of the territorial sea, as well as waters seaward of the baseline a distance of three nautical miles. The MPRSA applies to transportation of dredged material for the purpose of disposal into ocean waters outside the baseline from which the territorial sea is measured. Therefore, both statutes apply in the first three nautical miles seaward of the baseline (Figure 2-1).

The regulations of EPA and Corps [40 CFR 230.2(b) and 33 CFR 336.0(b), respectively] define which law applies in this three nautical mile belt of water seaward of the baseline. If dredged material is placed in this area for the purpose of disposal, it is evaluated under the MPRSA. If dredged material is discharged in the territorial sea as fill (e.g., beach nourishment, island creation, or underwater berms), it is evaluated under Section 404 of the CWA.

Figure 2-1. Geographic Jurisdictions of MPRSA and CWA



2.5. Overview of Section 10 of the Rivers and Harbors Act

Under Section 10 of the Rivers and Harbors Act of 1899 [33 United States Code (U.S.C.) 403; see 33 CFR Part 322], a Corps permit is required for certain structures or work in or affecting navigable waters of the United States. A dredging project in navigable waters, with no discharge of fill material or return flow back into the navigable waters, would require a Section 10 permit but not a Section 404 permit.

For navigable rivers and lakes, federal regulatory jurisdiction and powers of improvement for navigation extend laterally to the entire water surface and bed of a navigable water body, which includes all the land and waters below the ordinary high water mark. Jurisdiction thus extends to the edge (as determined above) of all such water bodies, even though portions of the water body may be extremely shallow, or obstructed by shoals, vegetation or other barriers. Marshlands and similar areas are thus considered navigable in law, but only so far as the area is subject to inundation by the ordinary high waters (33 CFR 329.11).

Navigable waters of the United States, over which the Corps Section 10 regulatory jurisdiction extends, includes all ocean and coastal waters within a zone that is three geographic (nautical) miles seaward from the baseline of the territorial sea (see Figure 2-1). Wider zones are recognized for special regulatory powers exercised over the outer continental shelf (33 CFR 329.12). The baseline is defined as the line where the shore directly contacts the open sea; specifically, the baseline is the line on the shore reached by the ordinary low tides.

2.6. LISTING OF RELEVANT FEDERAL AND STATE REGULATIONS

The following federal and state laws and regulations may be applicable to dredging and dredged material disposal activities in the Pacific Northwest. Table 2-1 summarizes the information for key laws and regulations.

2.6.1. Federal

- National Environmental Policy Act of 1969.
- Executive Order 11514, Protection and Enhancement of Environmental Quality.
- Environmental Quality Improvement Act of 1970.
- Executive Order 12088, Federal Compliance - Pollution Control Standards.
- Executive Order 11564, Transfer of Oceanographic Programs.
- Executive Order 11988, Floodplain Management.
- Executive Order 11990, Protection of Wetlands.
- Executive Order 12114, Environmental Effects Abroad of Major Federal Actions.
- Executive Order 12291, Federal Regulation.
- Executive Order 12301, Integrity and Efficiency in Federal Programs.
- Executive Order 12372, Intergovernmental Review of Federal Programs.
- Executive Order 12498, Regulatory Planning Process.
- Comprehensive Environmental Response, Compensation and Liability Act of 1980.
- Environmental Education Act of 1978.
- Environmental Programs Assistance Act of 1984.
- Clean Air Act of 1970: Section 309 (review of NEPA documents)
- Resource Conservation and Recovery Act of 1976.
- Federal Water Pollution Control Act of 1972 (amended and renamed Clean Water Act of 1977):
    - Section 301 - Effluent Limitations
    - Section 303 - Water Quality Standards and Implementation Plans
    - Section 313 - Federal Facilities Pollution Control
    - Section 401 - Water Quality Certification
    - Section 402 - National Pollutant Discharge Elimination System
    - Section 403 - Ocean Discharge Criteria
    - Section 404 - Permits for Dredged Material or Fill
    - Section 405 - Disposal of Sewage Sludge
- Water Quality Act of 1987.
- Rivers and Harbors Act of 1899 (the Refuse Act):
    - Section 10 - Permits for Structures and Activities in Navigable Waters
    - Section 13 - Refuse Act
- Water Resource Planning Act of 1965.
- Port and Tanker Safety Act of 1979.
- Oil Pollution Act of 1990.
- Marine Protection, Research, and Sanctuaries Act of 1972 (also called Ocean Dumping Act):
    - Title I - Ocean Dumping
        - Section 102 - EPA Permits
        - Section 103 - Corps Permits (provides authority to the Corps to select ocean dumping sites in the event that EPA-designated sites are not suitable for use).
        - Section 106 - Relationship to Other Laws
    - Title II - Comprehensive Research on Ocean Dumping
    - Title III - National Marine Sanctuaries

- Safe Drinking Water Act of 1974.
- Estuary Protection Act of 1968.
- National Ocean Pollution Act of 1978.
- Reservoir Salvage Act of 1968.
- River and Harbor and Flood Control Act of 1970.
- Water Resources Development Act of 1976:
  - Section 145 - Sand Fill
  - Section 148 - Disposal Areas
  - Section 150 - Wetlands
- Water Resources Development Act of 1986:
  - Section 924 - Office of Environmental Policy
  - Section 933 - Cost-sharing for Disposal of Material on Beaches
  - Section 1135 - Project Modification for Improvement of the Environment
  - Section 1146 - Acceptance of Certain Funds for Mitigation
- Water Resources Development Act of 1988:
  - Section 35 - State Funding for Section 933 Activities
- Water Resources Development Act of 1990:
  - Section 304 - Project Modification for Improvement of the Environment
  - Section 306 - Environmental Protection Mission
  - Section 307 - Wetlands
  - Section 312 - Environmental Dredging (additional information and requirements are provided on Section 312 in Policy Guidance Letter No. 35 dated 17 March 1992.)
- Water Resources Development Act of 1992:
  - Section 202- Projects for Improvements of the Environment
  - Section 204- Beneficial Uses of Dredged Material
  - Section 207- Cost-sharing for Disposal of Dredged Material on Beaches
  - Section 216- Dredged Material Disposal Areas
  - Section 333- Fish and Wildlife Mitigation
  - Section 345- Bank Stabilization and Marsh Creation
  - Section 405- Sediments Decontamination Technology
- Water Resources Development Act of 1996:
  - Section 205- Environmental Dredging
  - Section 207- Beneficial Uses of Dredged Material
  - Section 217- Dredged Material Disposal Facility Partnerships
  - Section 226- Sediments Decontamination Technology
  - Section 506- Periodic Beach Nourishment
  - Section 509- Maintenance of Navigation Channels
- Water Resources Development Act of 1999:
  - Section 204- Sediments Decontamination Technology
  - Section 209- Beneficial Uses of Dredged Material
  - Section 217- Disposal of Dredged Material on Beaches
  - Section 224- Environmental Dredging
  - Section 503- Contaminated Sediment Dredging Technology
  - Section 512- Beneficial Uses of Dredged Material
- Federal Environmental Pesticide Control Act of 1972
- Outer Continental Shelf Lands Act of 1953.
- Coastal Zone Management Act of 1972:
  - Section 303 - Declaration of Policy
  - Section 307 - Coordination and Cooperation
- Marine Mammal Protection Act of 1972.

- Endangered Species Act of 1973: Section 7 - Interagency Cooperation.
- Coastal Barrier Resource Act of 1982.
- Fish and Wildlife Coordination Acts of 1934, 1956, and 1958.
- Fish and Wildlife Conservation Act of 1980.
- Wild and Scenic Rivers Act of 1968.
- Soil and Water Resources Conservation Act of 1977.
- Water Resources Research Act of 1984.
- Toxic Substances Control Act of 1976.
- Antiquities Act of 1906.
- American Indian Religious Freedom Act of 1978.
- Archeological Resources Act of 1979.
- Historic Sites Act of 1935.
- National Historic Preservation Acts of 1966 and 1980.
- Abandoned Shipwreck Act of 1987 [Public Law (PL) 100-298].
- American Folklife Preservation Act, PL 94-201.
- Farmlands Protection Policy Act of 1981.
- Federal Land Policy and Management Act of 1976, 40 U.S.C.
- Federal Insecticide, Fungicide and Rodenticide Act as amended by the Federal Environmental Pesticide Control Act, 7 U.S.C.
- Federal Water Project Recreation Act, PL 89-72, 16 U.S.C.
- Land and Water Conservation Fund Act of 1965, PL 88-578, 16 U.S.C.
- Marine Mammal Protection Act of 1972, PL 92-522, 16 U.S.C.
- Migratory Bird Conservation Act of 1928, 16 U.S.C.
- Migratory Bird Treaty Act of 1918, 18 U.S.C.
- Native American Graves Protection and Repatriation Act of 1990, PL 101-601.
- Native American Religious Freedom Act, PL 95-341, 42 U.S.C.
- Noise Control Act, 42 U.S.C.
- Safe Drinking Water Act, 42 U.S.C.
- Submerged Lands Act of 1953, PL 82-3167, 43 U.S.C.
- Surface Mining Control and Reclamation Act of 1977, PL 95-89, 30 U.S.C.
- Executive Order 11593, Protection and Enhancement of the Cultural Environment.
- Executive Order 12580, Superfund Implementation.
- Magnuson-Stevens Act, 16 U.S.C. 1801 *et seq*. as reauthorized by the Sustainable Fisheries Act of 1996.

2.6.2. State of Washington

- Section 401 Certification Program (located at http://apps.ecy.wa.gov/permithandbook/permitdetail.asp?id=43).
- State Environmental Policy Act [Revised Code of Washington (RCW) Chapter 43.21C].
- Hydraulic Project Approval (RCW Chapter 77.5).
- Aquatic Lands Act (RCW Chapter 79.105).
- Model Toxics Control Act (RCW Chapter 70.105D).
- Shoreline Management Act (RCW Chapter 90.58).
- Washington Coastal Zone Management Program (located at http://www.ecy.wa.gov/programs/sea/czm/).

2.6.3. State of Oregon

- Section 401 Certification Program (located at http://www.deq.state.or.us/WQ/sec401cert/sec401cert.htm).
- Oregon Coastal Zone Management Program (located at http://www.oregon.gov/LCD/OCMP/).
- Removal/Fill Law (located at http://www.oregon.gov/DSL/PERMITS/r-fintro.shtml).
- Permit for any activity on state beaches (includes placement of dredged material).
- Oregon Solid and Hazardous Waste Rules [Oregon Administrative Rule (OAR) 340-100-0001].
- Cleanup Authority (OAR 340-122-0115).

2.6.4. State of Idaho

- Idaho Section 401 Certification Program (located at http://www.deq.state.id.us/water/permits_forms/permitting/401_certification.cfm).
- Idaho Stream Channel Protection Act (Title 42, Chapter 38, Idaho Code).
- Idaho Lake Protection Act (Section 58-142 et. seq., Idaho Code).
- Environmental Protection and Health Act (Idaho Code Title 39 Chapter 1).
- Hazardous Waste Management Act (Idaho Code Title 39 Chapter 44).
- Idaho Water Quality Standards [Idaho Administrative Procedures Act (IDAPA) 58.01.02].

Table 2-1. Summary of Federal and State Regulations

AUTHORITY (ADMINISTERING AGENCY)	ACTIVITIES/ACTIONS REGULATED	JURISDICTION
FEDERAL GOVERNMENT		
National Environmental Policy Act (federal action agency)	• federal actions	• all federal actions, including applications for federal permits or other forms of authorization that are not otherwise exempted from NEPA.
Section 10 Rivers and Harbors Act (Corps)	• construction of structures in or over navigable waters of the United States • the excavation from or depositing of material in navigable waters • other work affecting the course, location, condition, or capacity of navigable waters	• navigable rivers and lakes: extends laterally to the entire water surface and bed of a navigable water body, which includes all the land and waters below the ordinary high water mark • ocean and coastal waters within a zone three geographic (nautical) miles seaward from the baseline (i.e., the Territorial Seas) • wider zones are recognized for special regulatory powers exercised over the outer continental shelf
Section 404 Clean Water Act (EPA/Corps)	• discharge of dredged or fill material into waters of the U.S.	• navigable waters of the U.S. • in tidal waters of the U.S., the landward limits of jurisdiction in tidal waters extend to the high tide line • in non-tidal waters extends to the ordinary high water mark in the absence of adjacent wetlands • in adjacent wetlands, jurisdiction extends beyond the ordinary high water mark to the limit of the adjacent wetlands • if only of wetlands, then jurisdiction extends to the limit of the wetland, if that wetland meets certain tests resulting from Supreme Court case law
Section 103 Marine Protection, Research and Sanctuaries Act (EPA/Corps)	• transportation of dredged material for the purpose of disposal in the ocean	• extends seaward from the baseline into the territorial sea as provided for in the Convention on the Territorial Sea and Contiguous Zone
Public Law 92-583 Coastal Zone Management Act (NMFS/state CZM agencies)	• effective management, beneficial use, protection, and development of coastal zone • federal agency activities that affect the coastal zone must be carried out in a manner consistent to the maximum extent practicable with the enforceable policies of the approved state management program	• WA – the 15 coastal counties that front saltwater • OR – inland to the crest of the coastal range, except for the following: along the Umpqua River where it extends upstream to Scottsburg; along the Rogue River where it extends upstream to Agness; and except in the Columbia River Basin where it extends upstream to the downstream end of Puget Island • federal agency activities affecting the coastal zone
Fish and Wildlife Coordination Act (federal agencies/ state wildlife resources agencies)	• land, water and interests may be acquired by federal construction agencies for wildlife conservation and development	• where waters or channel of a body of water are modified by a department or agency of the United States

AUTHORITY (ADMINISTERING AGENCY)	ACTIVITIES/ACTIONS REGULATED	JURISDICTION
	• real property under federal agency jurisdiction or control, and no longer required by that agency, can be utilized for wildlife conservation by the state agency exercising administration over wildlife resources on that property	
Endangered Species Act (NMFS/USFWS)	• actions affecting listed species and/or their designated critical habitat	• species that are endangered or threatened with extinction throughout all or a significant portion of their range • designated critical habitat on which they depend
Marine Mammal Protection Act (NMFS)	• actions resulting in the lethal take, non-lethal take, or incidental harassment of marine mammals	• all species of whales, dolphins, porpoises, seals, and sea lions • marine mammal habitat
Magnuson-Stevens Fishery Conservation and Management Act (NMFS)	• actions affecting commercial fisheries	• federally managed species with designated essential fish habitat (EFH)
Section 106 National Historic Preservation Act (State Historic and Tribal Preservation Offices)	• federal actions affecting cultural resources; federal actions affecting tribal cultural resources, treaty fishing access sites, usual and accustomed areas, traditional cultural properties, and/or other resources important to the respective tribes	• cultural and tribal resources • federal action agency coordinates with State Historic and Tribal Preservation Offices, and attempts to avoid or minimize impacts to cultural and/or tribal resources, and mitigate unavoidable impacts. • federal action agency makes final determination of project effect.
STATE OF WASHINGTON		
State Environmental Policy Act (state agencies, counties, cities, ports, and special districts)	• state actions	• issuing permits for private projects • construction of public facilities • adopting regulations, policies or plans
Section 401 Clean Water Act (Ecology)	• any federally permitted project discharging into waters of the U.S. will not violate state water quality standards	• see Section 404 jurisdiction, above • discharges in Washington or in interstate waters (e.g. Columbia River)
Hydraulic Project Approval (WDFW)	• actions that affect the natural flow of state waters	• waters under the state's jurisdiction
Aquatic Lands Act (WDNR)	• discharge of dredged material on state aquatic lands	• 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

AUTHORITY (ADMINISTERING AGENCY)	ACTIVITIES/ACTIONS REGULATED	JURISDICTION
Model Toxics Control Act (Ecology)	• governs remedial actions in the state	• state remedial actions, including sediment cleanup under state Sediment Management Standards
Washington Shoreline Management Act (Ecology)	• actions that may affect shoreline use, shoreline natural resources, access to public areas, and preservation of recreational opportunities	• shorelines of the state - all marine waters, streams > 20 cubic feet per second mean annual flow, lakes 20 acres or larger • upland areas extending 200 feet landward from the edge of these waters • biological wetlands and river deltas, and some or all of the 100-year floodplain when associated with one of the above waters.
STATE OF OREGON		
Oregon Coastal Management Program	• see Coastal Zone Management Act, above	• see Coastal Zone Management Act, above
Section 401 Clean Water Act (ODEQ)	• any federally permitted project discharging into waters of the U.S. will not violate state water quality standards	• see Section 404 jurisdiction, above • discharges in Oregon or in interstate waters (e.g. Columbia River)
Removal/Fill Law (DSL)	• removal, fill, or alterations equal to or exceeding 50 cubic yards of material within beds or banks of waters in Oregon	• waters in Oregon, including wetlands
State Beaches (Oregon State Parks)	• placement of dredged material on state beaches	• beaches of the state
Oregon Solid and Hazardous Waste Rules	• upland disposal of dredged material	• all lands within Oregon, including the territorial sea.
Oregon State Cleanup Authority	• remedial actions within the state	• contaminated sites in the state
STATE OF IDAHO		
Section 401 Clean Water Act (IDEQ)	• any federally permitted project discharging into waters of the U.S. will not violate state water quality standards	• see Section 404 jurisdiction, above • discharges in Idaho or in interstate waters (e.g. Snake River)
Idaho State Contaminated Sediments and Hazardous Waste Authorities	• disposal of some dredged materials and any remedial actions within the state	• all lands in the state
Lake Protection Act (Idaho Dept. of Lands)	• projects affecting lakes and reservoirs in the state	• lakes and reservoirs in the state
Stream Channel Protection Act (IDWR)	• projects affecting streams in the state	• perennial waters of the state

*Note that this table is not all inclusive.

CHAPTER 3. REGULATORY PROCESS AND SEDIMENT EVALUATION

3.1. INTRODUCTION

As discussed in Chapter 2, there are many federal and state regulations that govern the management of both uncontaminated and contaminated sediments. This chapter focuses on the regulatory processes involved in sediment evaluation and project approval. This chapter also attempts to clarify some of the key consultation and coordination procedures between the Corps and other state and federal regulatory agencies.

Sediment evaluation is a critical component to all dredging and site investigation sediment-impacting activities (e.g., navigation-related dredging or disposal activities, habitat restoration efforts, and others). As such, the PRGs/DMMP provide 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. The PRGs/DMMP will be responsible for providing comment on and review for dredging project permit applications evaluated under one or more of the Corps regulatory authorities. Additionally, the PRGs/DMMP will provide review for and comments on Corps Civil Works projects.

3.2. CONSISTENT APPLICATION OF THE SEF

One of the goals of the SEF is the consistent and predictable application of sediment evaluation procedures across projects and across Corps District boundaries. Consistent application of the SEF through the Corps District PRGs/DMMP will allow for greater predictability in the SEF and permit review processes, improved project planning, and reduced delays caused by changes in project scope due to sediment management issues. In addition, the application of consistent guidelines and processes is intended to speed the regulatory review process and ultimately result in more timely and efficient review of projects and permit applications. The process to be used by the Corps Districts is described in Sections 3.3.1 and 3.7.

3.3. REGULATORY PERMITS AND PROCESSES

The permit review process consists of a series of progressive steps applicable to most dredging projects, as summarized below and in Figure 3-1. This process integrates several sub-processes, including the ESA consultation process (Figure 3-2) and the sediment evaluation process (Figure 3-3) described below. Other regulatory processes may have equally complex consultation or coordination requirements, but the illustration of all of these processes is beyond the scope of this chapter. Since the SEF process and the ESA consultation process are particularly relevant to nearly all dredging projects, they have been included as well.

Figure 3-1. Federal - State Regulatory Process

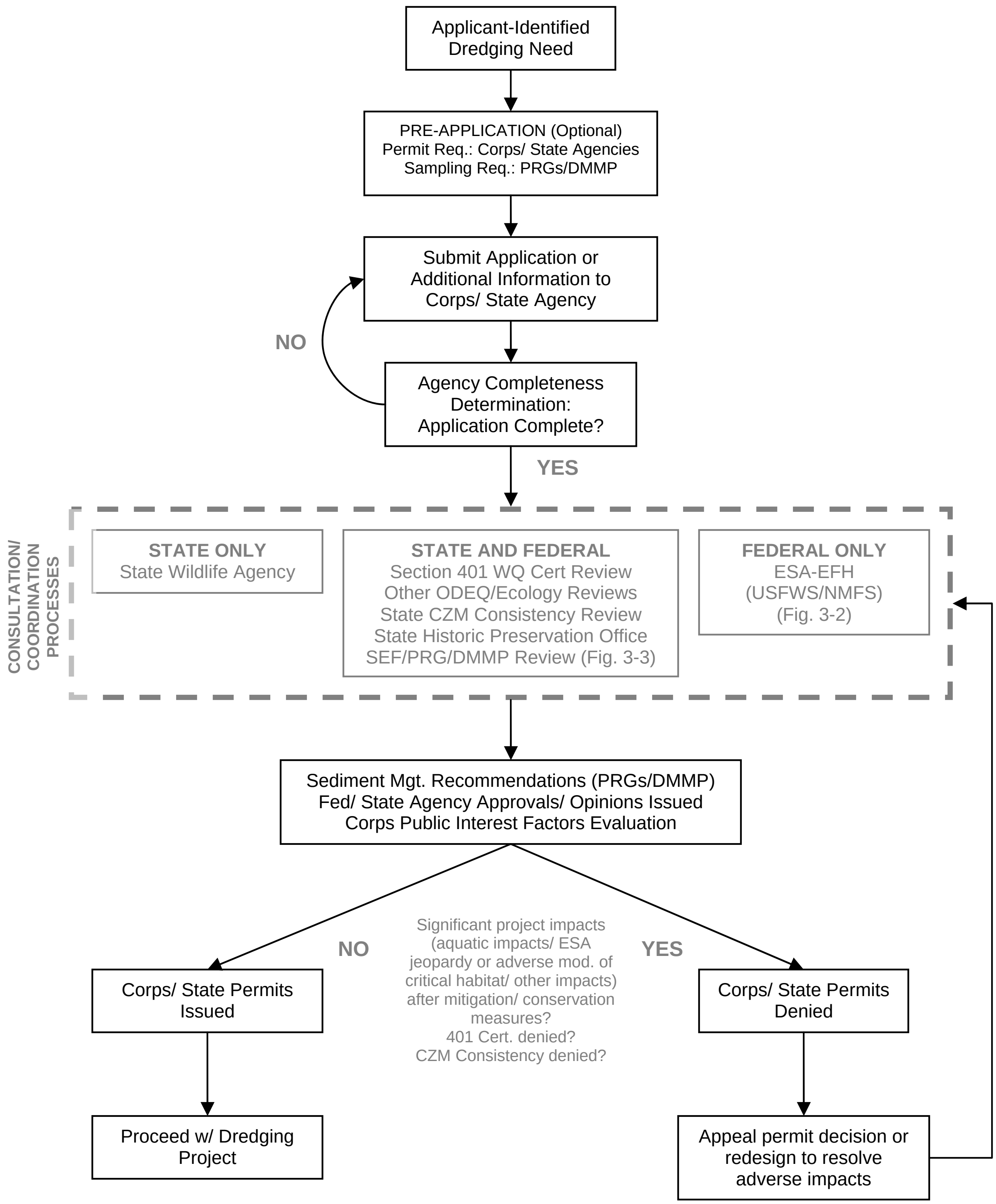


Figure 3-2. Endangered Species Act Consultation

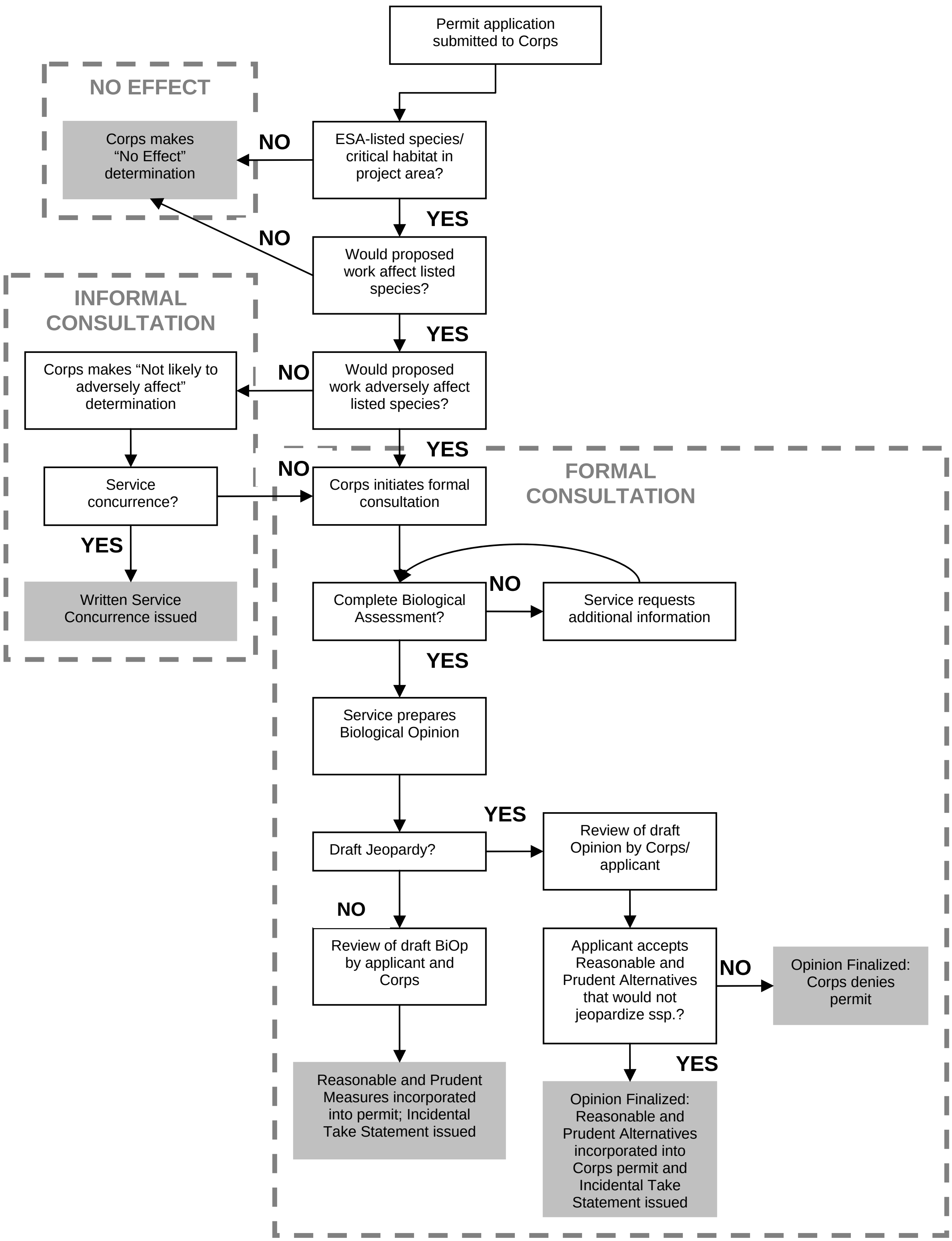
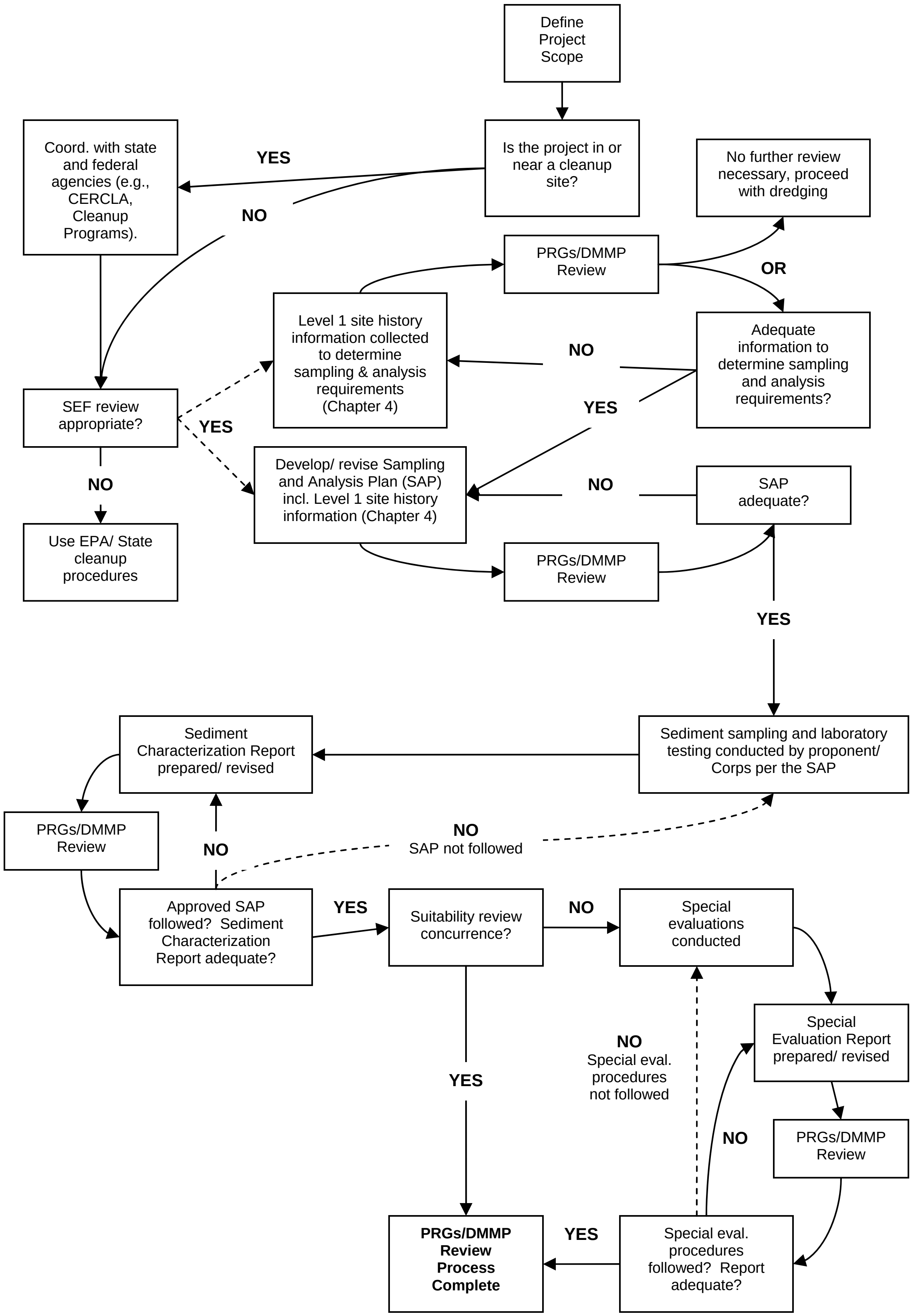


Figure 3-3. Sediment Evaluation Process



3.3.1. Corps of Engineers Permitting Processes

- The applicant may request that the Corps conduct a pre-application meeting to discuss the dredging project and outline regulatory issues and processes, data requirements for the submittal, and preliminary permitting time frames (optional).
- The Corps receives the proponent's application packet and determines if the Corps has regulatory authority over the waterway and over the proposed activity.
  - Dredging projects in navigable waters that have a discharge of dredged or fill material (including return water) require both a Section 10 of the Rivers and Harbors Act and Section 404 of the CWA authorization.
  - Dredging projects in navigable waters where there is no return water or in-water disposal require Section 10 authorization only.
  - Dredging projects where ocean disposal is proposed in the territorial seas below the low tide line require Section 103 authorization in addition to the requisite Section 10 and/or Section 404 authorization(s).
  - Dredging in a Section 404 water body is not regulated by the Corps, as long as there is no discharge of dredged or fill material.
- The Corps determines what type of permit (Regional General Permit, Nationwide Permit, Letter of Permission, or Standard Permit) and level of analysis are appropriate for the project. In general, Regional General Permits require the least amount of environmental analysis, since impacts are typically minor, and the analysis has been done up front. Typically, Standard Permits require the greatest amount of analysis, and the Corps must submit a public notice for the project and prepare an environmental assessment once all comments are received.
- Within 15 days of receipt, the Corps reviews the application for completeness per 33 CFR 325.1(d)(1-9), and if the application is incomplete, the Corps requests additional information.
  - To be complete, applications must include: a description of the project, including necessary drawings, sketches, or plans sufficient for public notice; the location, purpose and need for the proposed activity; scheduling of the activity; the names and addresses of adjoining property owners; the location and dimensions of adjacent structures; and a list of authorizations required by other federal, interstate, state, or local agencies for the work, including all approvals received or denials already made.
  - The proposed project must be a single and complete, stand-alone project. If the project is part of a larger plan of development, then the applicant must apply for a permit for the entire plan of development.
  - The application must be signed by the applicant and designated agent (consultant) if any.
  - Applications for dredging must also include a description of the type, composition, and quantity of the material to be dredged, the method of dredging, and the site and plans for disposal of the dredged material.
  - If the proposed activity would result in the discharge of dredged or fill material into the waters of the United States or the transportation of dredged material for the purpose of disposing of it in ocean waters, then the application must include the source of the material; the purpose of the discharge, a description of the type, composition and quantity of the material; the method of transportation and disposal of the material; and the location of the disposal site. Certification under Section 401 is required for such discharges into waters of the United States.
- Once the application has been determined complete, the Corps may be required to consult/coordinate with one or more of the following agencies/groups to comply with other federal laws.

- The Corps Regulatory Project Manager (PM) must initiate consultation with USFWS and/or NMFS if there are federally listed species or their designated or proposed critical habitat in the project area and the proposed project may affect the species or habitat. This process is described in Section 3.3.2 and illustrated in Figure 3-2 (similarly for a state permit, the permitting agency must coordinate with the relevant state wildlife and fisheries management agency). The NMFS will also include a consultation under the MSA as part of their Biological Opinion (BiOp) for the project being reviewed.
- Most dredging projects will require that the Corps PM coordinate with the PRGs/DMMP in order to evaluate site history data, determine sampling requirements to adequately characterize the dredging project area, and develop sediment/contaminant management recommendations based on characterization data and special evaluations. This process is described in Section 3.4 and illustrated in Figure 3-3.
- ODEQ/Ecology/IDEQ for Section 401 Water Quality Certification if there is a discharge of dredged or fill material.
- If the project occurs in the coastal zone of Oregon or Washington, then the Department of Land Conservation and Development or Ecology, respectively, must review for project consistency with the state coastal zone management planning and regulations.
- The Corps PM must coordinate with the relevant State Historic Preservation Office and tribe(s) if there are cultural resources or tribal issues associated with the project area.
- For dredging projects at or near a federal cleanup site, the Corps PM may coordinate through EPA cleanup programs.

- Additionally, once the application has been determined complete, within 15 days, the Corps must issue a notice to state and federal agencies and adjacent landowners if the project is eligible for authorization under a letter of permission. If the project requires a standard permit authorization, then the Corps must issue a public notice.
- Once the public notice comment period has ended (typically 15 days for notice of letters of permission and 30 days for a standard permit public notice), and all coordination, consultation, and certifications have been concluded/issued, the Corps factors all public comments and resulting approvals into its decision document. The Corps will typically ask the applicant to help address public comments. The decision document is the Corps Environmental Assessment (EA) and Statement of Findings (SOF) regarding the project's effect on public interest factors which include, but are not limited to:

• Substrate • Currents, circulation or drainage patterns • Suspended particulates and turbidity • Water quality (temperature, salinity patterns) • Flood control, storm, wave and erosion buffers • Erosion and accretion patterns • Aquifer recharge • Baseflow • Mixing zone • Habitat for fish and other aquatic organisms	• Threatened and endangered species • Special aquatic sites • Biological availability of possible contaminants in dredged or fill material • Existing and potential water supplies • Recreational and commercial fisheries • Other water related recreation • Aesthetics of aquatic ecosystem • Parks, national seashores, wild and scenic rivers, etc. • Traffic/transportation patterns • Energy consumption or generation	• Navigation • Safety • Air quality • Noise • Historic properties (National Historic Preservation Act) • Land use classification • Economics • Prime and unique farmland (7 CFR Part 658) • Food and fiber production • Mineral needs • Consideration of private property rights

- After consideration of these public interest factors, agency and tribal comments and/or requirements, and generally within 60 days of receipt of a complete application for a nationwide permit, the Corps makes a permit decision to either verify or not verify the project meets the terms of a nationwide permit. Similarly, generally within 120 days of receipt of a complete application for a standard permit, the Corps makes a permit decision to either issue or deny the permit. However, other consultations (e.g., ESA, cultural resources) and the Section 401 Water Quality Certification review may take significantly longer depending upon project location, complexity, timing, and other factors.
- If the Corps issues a permit for the project, the conditions of the Section 401 Water Quality Certification, the BiOp, and other agency conditions are incorporated as special conditions of the permit.
- If the Corps denies the permit, or if the applicant disagrees with the conditions of the initially proffered permit, the applicant may appeal the permit denial or any of the conditions of the permit. The Corps appeals process is described in 33 CFR 331.

3.3.2. ESA Consultation Process

Section 7 of the ESA (16 U.S.C. 1531 *et seq.*) outlines the procedures for federal interagency cooperation to conserve federally listed species and designated or proposed critical habitats. Section 7(a)(2) states that each federal agency shall, in consultation with USFWS and/or NMFS, ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of designated or proposed critical habitat. In fulfilling these requirements, each agency must use the best scientific and commercial data available.

Under the ESA, two forms of consultation are possible: informal or formal. Due to the listing of salmonids and other listed fish and marine mammals throughout the Pacific Northwest, dredging project proponents should expect to go through one of these consultation processes. These consultation processes and the “No Effect” determination are summarized below and in Figure 3-2.

The data generated through the SEF process is particularly relevant to ESA consultation because contaminants in dredged material can have adverse and long-term effects on aquatic life, including ESA-listed species. The PRGs/DMMP review process (see Section 3.4) is often used by the USFWS and NMFS to evaluate the effects of the proposed action on ESA species and their critical habitat. The guidance outlined in this SEF, however, does not provide all the monitoring measures or conservation measures that may be required when a project is implemented in a water body with ESA-listed species.

3.3.2.1. No Effect Determination

It is up to the Corps to determine whether the project would have “No Effect” on ESA-listed species. This determination can only be made if there are no ESA-listed species and/or critical habitat in the project area, or if the proposed work would not affect ESA-listed species and/or critical habitat. If a “No Effect” determination is made, it is incumbent upon the Corps to document the project administrative record with the assistance of the applicant, if necessary.

3.3.2.2. Informal Consultation

If the proposed work occurs in or directly abutting designated or proposed critical habitat, then the proposed work would likely affect listed species. It is then up to the Corps to determine whether or not the proposed action would adversely affect listed species or their critical habitat. If the Corps believes the proposed action would not result in adverse effects, then informal consultation is appropriate. Carried to its end, informal consultation will have one of three outcomes:

1. The USFWS and/or NMFS concur with the Corps determination and issue a "May Affect, Not Likely to Adversely Affect" determination, with additional conservation recommendations to be incorporated into the Corps permit authorization.
2. The USFWS and/or NMFS disagree with the Corps determination on project effects for ESA-listed species and/or their designated or proposed critical habitat, requiring the Corps to initiate formal consultation.
3. The USFWS and/or NMFS (rarely) determine that the project as proposed would not affect listed species or their designated or proposed critical habitat.

3.3.2.3. Formal Consultation

Formal consultation is necessary when a project may adversely affect ESA species and/or designated/proposed critical habitat. The applicant will assist the Corps by preparing a Biological Assessment (BA) for the project. The Corps receives the BA, reviews it for content, and forwards the document to USFWS and/or NMFS for review. If the document is incomplete, then the USFWS and/or NMFS will require additional information. Once the BA is complete, the USFWS and/or NMFS will use that information, along with the best available best scientific and commercial data, to prepare a BiOp. Carried to its end, formal consultation will have one of three outcomes:

1. The USFWS and/or NMFS determine that proposed action will not jeopardize the continued existence of the species through that portion of its range and/or adversely modify its designated or proposed critical habitats.
   - The USFWS and/or NMFS will issue reasonable and prudent measures (RPMs) in their BiOp that the applicant must implement to ensure that the proposed action has the least impact to ESA species possible.
   - The RPMs are incorporated as special conditions into the Corps-issued permit.
   - The USFWS and/or NMFS will also issue an Incidental Take Statement, which identifies the amount or extent of take to ESA-listed species and/or their critical habitats. Take is defined as "to harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in such conduct."

2. The USFWS and/or NMFS determine that the proposed action will jeopardize an ESA-listed species through all or part of its range and/or adversely modify their designated or proposed critical habitats. The USFWS and/or NMFS will work with the Corps and the applicant to develop a Reasonable and Prudent Alternative (RPA) to the proposed action that will minimize impacts so the species is not jeopardized.
   - An Incidental Take Statement will also be issued with the BiOp.
   - Assuming the applicant agrees to implement the RPA, the Corps will issue the permit.

3. If the USFWS and/or NMFS determine that the proposed action will jeopardize an ESA-listed species through all or part of its range, and the applicant is unable to or refuses to implement the RPA, then the Corps will deny the permit.

3.3.3. State Permitting Processes

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:

- Shoreline Permits,
- Hydraulic Project Approval Permit,
- Section 401 Water Quality Certification; and
- Disposal site use authorization from WDNR if at an approved open-water site or if disposal affects state-owned lands.

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;
- Stream Alteration Permit; and
- Lake Encroachment Permit

3.4. PRGs/DMMP Process

The sediment evaluation process presented herein is not a regulatory requirement in itself. Rather, it is a process through which the Corps Regulatory offices can evaluate the public interest factors associated with the dredging project. The sediment evaluation process is carried out by the applicant with guidance from the Corps regulatory office and the PRGs/DMMP. It is important to recognize that the PRGs/DMMP have no regulatory authority for projects, but the Corps and other participating agencies do have regulatory authority. Also, the use of the PRGs/DMMP for actions not requiring a Corps permit is discretionary for the agency or program. An information/request will be submitted to the PRGs/DMMP either by the applicant or the Corps regulatory PM. In addition, the PRGs/DMMP will review and comment on Corps Civil Works projects.

Each member agency of PRGs/DMMP is responsible for internal coordination and for bringing issues and concerns regarding sediment assessment to the appropriate PRGs/DMMP team. For Corp's permit actions, the PRGs/DMMP are organized into three teams that correspond to the Corps regulatory offices, with the Corps assuming coordination activities as part of its regulatory and navigation responsibilities (Table 3-1). In addition to these state teams, a regional RSET meets 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 the SEF.

The sediment evaluation process is integrated into both the overall permit process and the verification of existing permits (see Figure 3-3).

Table 3-1. Corps of Engineers Regulatory Offices

State and Applicable Corps Regulatory Office	Corps Regulatory Contact	State Working Group
State of Washington Corps Seattle District	U.S. Army Corps of Engineers Seattle District CENWS-OD-RG P.O. Box 3755 Seattle, WA 98124-3755 Phone: (206) 764-3495 http://www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=REG&pagename=Home_Page	Washington DMMP* Corps, NMFS, USFWS, EPA WDOE, WDNR
State of Oregon Corps Portland District	U.S. Army Corps of Engineers Portland District CENWP-OD-GP 333 SW First Avenue, P.O. Box 2946 Portland, OR 97208-2946 Phone: (503)808-4373 https://www.nwp.usace.army.mil/OP/g/home.asp	Oregon PRG* Corps, NMFS, USFWS, EPA, ODEQ
State of Idaho Corps Walla Walla District	U.S. Army Corps of Engineers Walla Walla District Regulatory Division 201 North 3rd Avenue Walla Walla, WA 99362 Phone: 509-527-7154 http://www.nww.usace.army.mil/html/offices/op/rf/rfhome.htm	Idaho PRG* Corps, NMFS, USFWS, EPA, IDEQ

*Note: For interstate waters, PRGs/DMMP representation from other states may be necessary.

3.4.1. Historical Information Review

Some projects will require an initial screening (i.e., nationwide permits, minor actions) to determine if no further testing or evaluation necessary. If PRGs/DMMP can make a favorable suitability determination based upon the existing information, a memo will be prepared and signed by the PRGs/DMMP. This initial PRGs/DMMP evaluation will be completed within 30 days of receiving complete information from the applicant. No further sediment evaluation will be required.

3.4.2. Draft Sampling and Analysis Plan (SAP) Review

If the PRGs/DMMP 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 SAP to acquire additional information (see Section 4.3). The SAP must be approved by the PRGs/DMMP prior to sampling. The PRGs/DMMP 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.

3.4.3. Sediment Characterization Report

Once sampling is complete, the applicant prepares and submits a report of the results of the sampling and analysis effort to the PRGs/DMMP. The PRGs/DMMP reviews the adequacy of the information and prepares a decision documents and distributes it for review and concurrence by the PRGs/DMMP. The PRGs/DMMP may take up to 30 days for this review, with an additional 15 days for resolution of any existing issues and completion of documentation. Those projects involving large and complex data sets may require additional time for review and documentation.

3.5. Conflict Resolution Process

In instances where a permit applicant or one of the agencies disagrees with a decision made by the PRGs/DMMP, the applicant (or agency) should first try to resolve the issue with the PRGs/DMMP. In the event that the issue cannot be resolved, the applicant may elevate the issue, first to the Regulatory Chief at the Corps District. If the issue cannot be resolved at the Corps District, then the applicant may elevate it to the RSET. If the RSET is unable to resolve the issue, then the RSET may choose to elevate it to the Navigation/Regulatory Steering Committee (NRSC). If the NRSC is unable to resolve the issue, then it may be elevated to the Executive Steering Committee (ESC; see Figure 1-1).

3.6. Verification of Multi-Year Maintenance Dredging Permits

Permits by the Corps may authorize maintenance dredging for a period of up to 10 years. During this time, no additional Corps permitting activity may be required. However, the state water quality certification is not issued for 10 years and the project may need recertification. In addition, endangered species consultation will need to be reinitiated within the 10-year period for any activity that was not considered in the original consultation or to account for any new listed species not covered in the original consultation. 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 4. Holders of permits for maintenance dredging will have to continue to coordinate with the PRGs/DMMP to determine if additional sampling and analysis is necessary. Each dredging event will be evaluated based on the state of the science, and new information may change evaluation requirements.

3.7. Process for Corps of Engineers 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*. The coordination process for Civil Works dredging projects mirrors the regulatory program, with a few procedural exceptions. The conflict resolution process is similar, except Civil Works projects are not coordinated through the Regulatory Chiefs. Corps dredging is subject to requirements under NEPA, CWA and amendments, MPRSA, MSA, 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. The Corps assesses a project by preparing an EA and determines whether an Environmental Impact Statement (EIS) is warranted. If not, then a "Finding of No Significant Impact" (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, a Record of Decision document is prepared to record the Corps decision to exercise its authority. A SOF, which considers all

effects and benefits and determines if the project should proceed, is completed at the end of the public coordination period.

3. For coastal zone projects, a determination of consistency with the enforceable provisions of the state coastal zone program is prepared and submitted to the relevant state agency along with the public notice. The federal CZMA consistency concurrence will be requested from the state.
4. If threatened or endangered species are known or suspected in the project area, 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.

3.8. CONTAMINATED SEDIMENT EVALUATION

This SEF stemmed from the PSDDA program and the DMEF for the lower Columbia River; therefore, it still holds an emphasis on dredged material evaluation to determine suitability for in-water disposal. At this time, the SEF is not intended to be used for cleanup activities. For cleanup activities, the EPA and the states of Washington, Oregon, and Idaho will exercise their regulatory authority via their cleanup statutes (see Chapter 2). However, the premise of this SEF is a risk-based evaluation and, as such, is an approach that could prove useful to other regulatory programs.

CHAPTER 4. EVALUATION FRAMEWORK/SAMPLING AND ANALYSIS PLAN

4.1. INTRODUCTION

This chapter describes the process for sediment characterization for all routine dredging projects (as regulated under Section 10 of the Rivers and Harbors Act, Section 404 of the CWA, and/or Section 103 of the MPRSA), and for determining suitability for unconfined in-water placement or the need for managing sediments with other disposal options. Projects containing materials unacceptable for open, in-water disposal will continue to follow SEF guidance for sediment management. Note that other state or federal guidance and requirements may also apply (see Section 4.4).

The process for sediment characterization is shown in Figure 4-1. Level 1 (see Section 4.2) includes defining the scope of the project, collecting historically available data, developing a conceptual site model (CSM), providing information used for ranking a project, and a discussion for the number of dredged material management units (DMMUs) to be delineated per project (see Section 4.3.1). If existing Level 1 data satisfy parameters in the CSM and indicate risk to receptors is minimal, then there is no need to collect further data and management decisions can be made at the end of Level 1. The transition from Level 1 to Level 2 occurs when data are insufficient for making a decision with only Level 1 information and additional information is needed.

Level 2 (see Section 4.3) involves development of a Sampling and Analysis Plan (SAP) in order to collect new data to support a management decision to include discussion and decision criteria for the number of management units to be delineated per project. Level 2 contains two parts. Level 2A consists of analysis of sediment chemical and physical characteristics. Data from Level 2A can either support a decision or lead to Level 2B biological testing, bioaccumulation testing, or other special evaluations. Levels 2A and 2B may be conducted concurrently to speed up project evaluations.

4.2. LEVEL 1

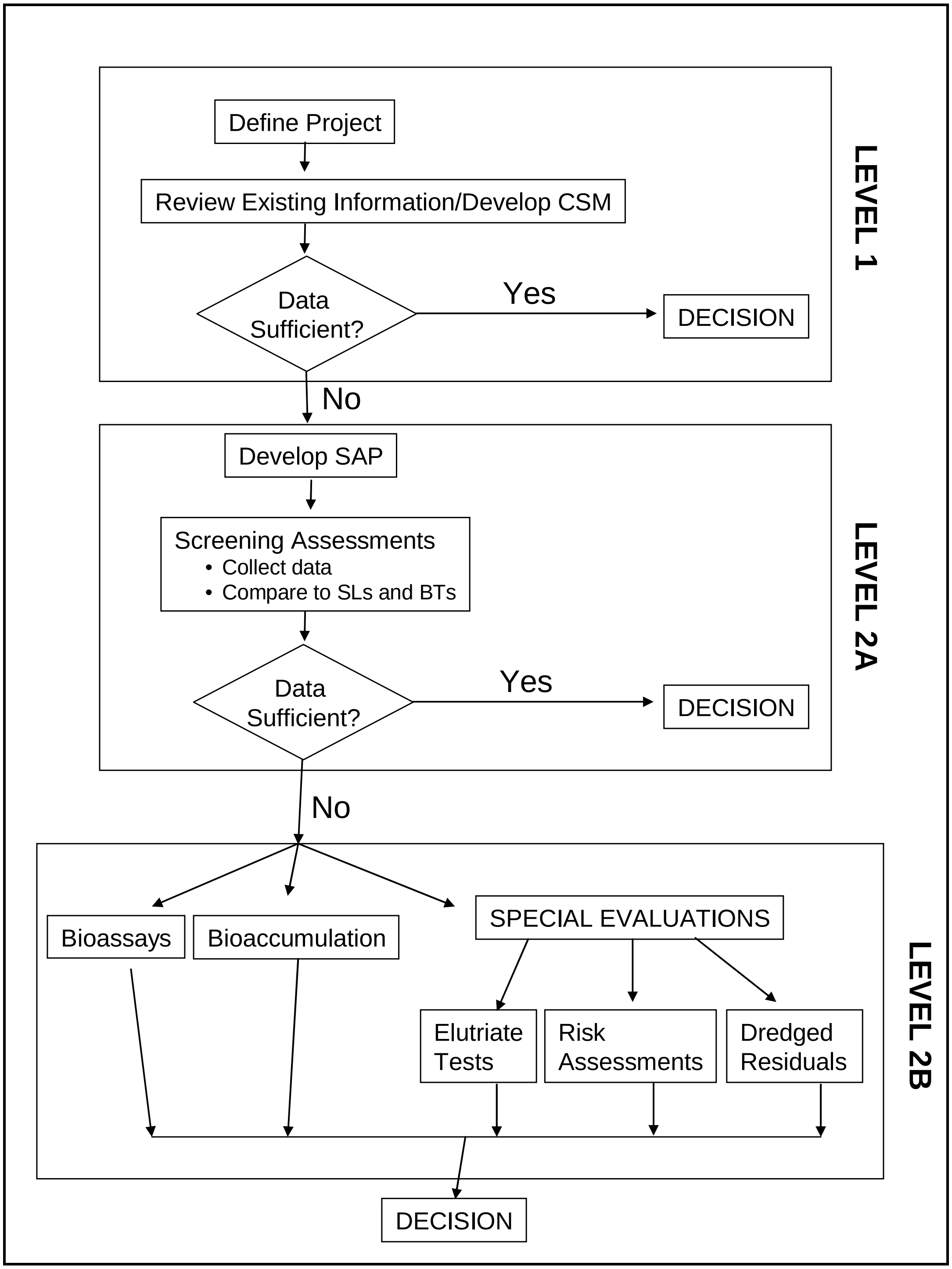
The Level 1 assessment includes defining the project, collecting existing information, developing a CSM, and establishing or reviewing a project's rank. These requirements are discussed in the following sections.

4.2.1. Defining the Project

The Level 1 report to the PRGs/DMMP must define the goals of the project and identify potential contaminants of concern. The information provided will be used to determine what additional information, if any, is required to further characterize sediment for final placement.

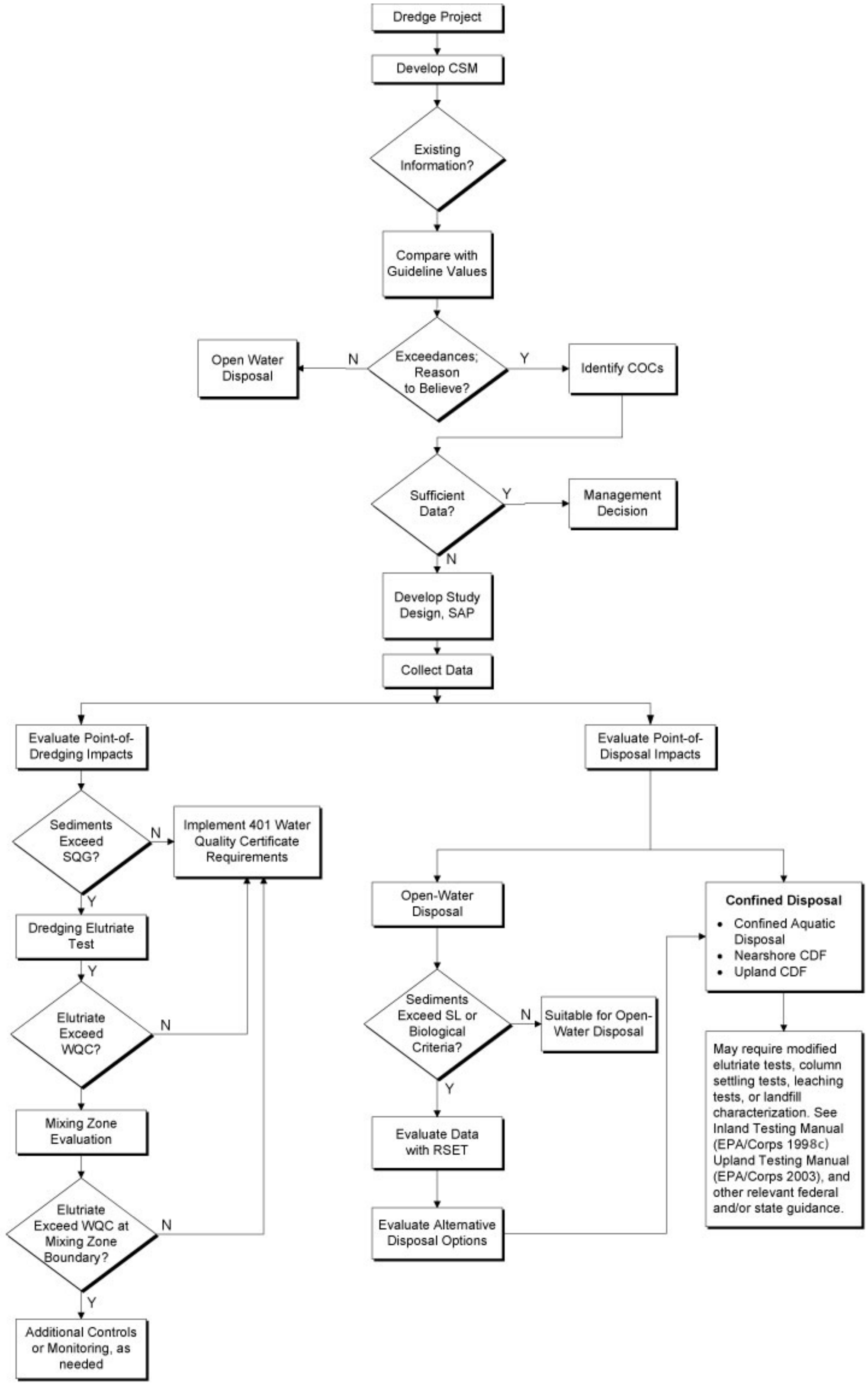
The results from the Level 1 report will be used to determine how the material, once removed from the site, will be managed, or if the proposed approach poses unacceptable risks. The management alternatives range broadly from unrestricted open water disposal or beneficial uses (e.g., beach nourishment or habitat creation) for materials posing no or minimal risk, to confined in-water or upland disposal for sediments where risks are elevated (EPA/Corps 2004). Data are needed to evaluate both point of dredging impacts and point of disposal impacts. A generic dredging flow chart of this process is shown in Figure 4-2.

Figure 4-1. Sediment Evaluation Framework



SLs = screening levels; BTs = bioaccumulation triggers

Figure 4-2. Generalized Dredging Project Flow Chart



CoCs = chemicals of concern; CDF = confined disposal facility; SQGs = sediment quality guidelines; WQC = water quality criteria

Level 1 report submissions to the PRGs/DMMP should be accompanied by project details containing sufficient information to define the goals of the project and identify potential contaminants of concern that, in turn, will drive and structure what important information is required to facilitate the decision-making process. This submission should include:

- The specific location of the site;
- The objective of the project;
- The action intended;
- A plan view of the site;
- The depth and physical nature of the material to be dredged;
- The volume to be dredged, including advanced maintenance, side slope, and overdepth dredging;
- Lengths, widths and depths of dredging;
- Proposed dredging methods;
- Proposed disposal methods and locations (e.g., unconfined or confined in-water or upland);
- Information regarding the rank of the site or area and supporting CSM development, including a description of historical and current site activities, current and historical activities at adjacent properties (particularly upstream properties), any available data on sediment quality adjacent to the site, and information on location of stormwater outfalls and associated drainage basins;
- The presence of ESA-listed species and critical habitat in the area; and
- Quality and configuration of the newly exposed sediment surface.

4.2.2. Collect Existing Information

Gathering existing information and data is an important part of establishing the project goals and developing an adequate CSM (see Section 4.2.3). Existing information can include sediment and tissue analytical data from previous characterizations at the project site, adjacent sites, or from monitoring programs. The value of historical data is controlled by its reliability, which in turn depends upon the quality, timeliness (see Section 4.2.4 for recency and frequency guidelines), and completeness of the data. The following types of information are required to use existing data for suitability determinations:

- Sampling and analytical methods for any chemistry or biological tests performed;
- Chemical detection limits (see Table 6-2);
- Biological test control sediment for any biological tests conducted; and
- Quality control measures for any chemistry or biological tests performed.

The agencies involved in the review and approval of dredging projects in the region (e.g., PRGs/DMMP) serve as a source of historical information about sediments and proposed dredging locations. The agencies share a common responsibility to make this information available. However, 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. Accurate compilation and reporting of historical data could yield substantial cost savings. For example, historical data of good quality may eliminate or reduce the need for testing, limit the number of contaminants tested, and reduce the amount of dredged material to be tested.

4.2.3. Developing a Conceptual Site Model

The CSM provides the structure, organization, and flow to address dredging project risk and guide sediment management decisions. Factors to evaluate as part of determining what management is required include consideration of the water column (both during dredging and in the event of return water from upland or nearshore placement), dredging prism material, disposal process, disposal site, and the newly exposed sediment surface.

Based on available information, the CSM identifies the processes linking contaminant sources and the physical, chemical, and biological processes occurring within the sediment that enhance chemical release (the transfer or repartitioning of contaminants from sediment pore water and sediment particles into the water column or air) and affect exposure. The processes for releasing contaminants at the dredging or disposal site are primarily related to resuspension (the dislodging bedded sediment particles and dispersal into the water column), redeposition (the resettling of suspended particulates on the surface of the sediment after disturbance), and from creation of residuals (contaminated sediment found at the post-dredging surface of the sediment profile, either within or adjacent to the dredging footprint; Bridges et al., 2008).

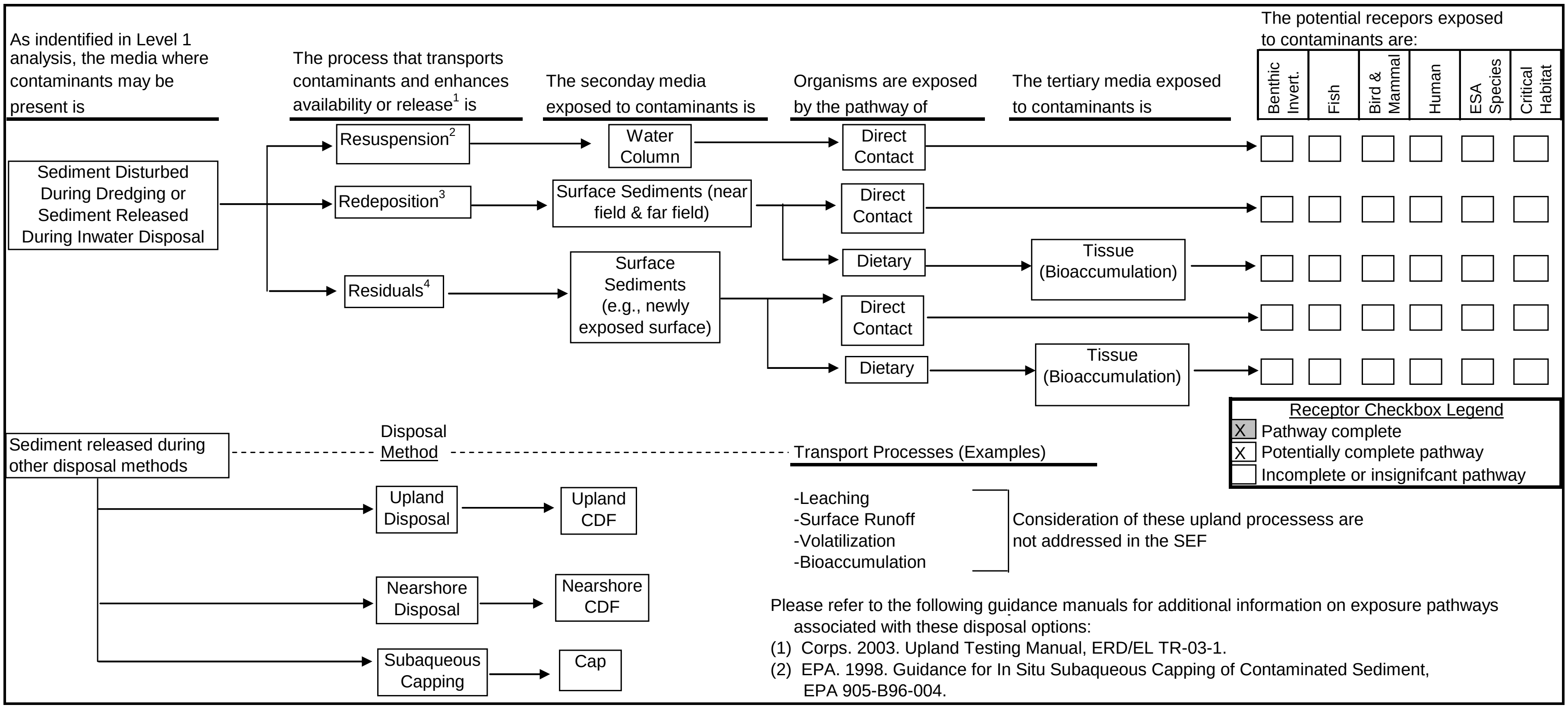
The CSM further defines the receptors of concern, and describes how the receptors are exposed to the contaminants associated with the sediment. A CSM provides a graphical and/or narrative representation of the relationships between receptors and resources in the environment and the stressors to which they may be exposed. A CSM is not necessarily derived from a computer model and does not need to be complex. It can be a narrative and/or graphical representation of the known information. A graphical CSM for a dredging project is presented in Figure 4-3; this CSM could be modified for specific projects, especially when a disposal method has already been proposed.

The CSM can provide an avenue for beginning to address uncertainties in the relationships and exposure pathways and the presence or absence of important receptors at a particular project site or disposal location. For example, these receptors can be eliminated for many pathways if a project will not be conducted when threatened or endangered species are known to occur or where work area isolation or timing would limit species exposure. Another example is that bioaccumulation may not always be of concern to upper trophic level receptors if historical information indicates contaminants of concern are not on the bioaccumulative chemicals of concern list (bioaccumulation testing is discussed in detail in Chapter 8). 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.

The process to develop the CSM includes gathering and documenting existing information, including but not limited to the following:

- Site history.
- Current site use.
- Adjacent lands, especially known chemicals of concern, or hazardous waste or cleanup sites.
- Potential sources of contamination: 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 or boat traffic.
- Source control measures at the site.

Figure 4-3. Conceptual Site Model (CSM) for Dredging Activities



[1] Release: The process by which the dredging operation results in the transfer of contaminants from sediment pore water and sediment particles into the water column or air (i.e., repartitioning). Contaminants in near-surface sediments (e.g., transported from redeposited sediment or residuals) may be released into water column by densification, diffusion, and bioturbation (Bridges et al., 2008).

[2] Resuspension: The process by which dredging and attended operations dislodge bedded sediment particles and disperse them into the water column. Resuspension rates range from <0.1% to over 5% (Bridges et al., 2008).

[3] Redeposition: The process by which suspended particulates resettle on the surface of the sediment after disturbance. Redeposition can occur in the near field (the plume area dominated by rapid settling velocities, changes in sediment total suspended concentration, and load with distance from the dredging operation) or the far field (the area where the total load in the plume is slowly varying and where advective diffusion and settling are of the same order of magnitude).

[4] Residuals: Contaminated sediment found at the post-dredging surface of sediment profile, either within or adjacent to the dredging footprint (Bridges et al., 2008). Examples include contaminated surface sediments uncovered by dredging but not fully removed (e.g., newly exposed surface) or contaminated sediment dislodged from nearby slopes during dredging or slope failures. Although in-water disposal does not create undisturbed residuals, resuspended sediment particles settling at a site become part of the generated dredging residuals.

- Recency of data and frequency of dredging (Section 4.2.4).
- Past permitting history.
- An overview of previous evaluations at the site, including:
  - Sediment chemistry. The potential for direct sediment toxicity to benthos may be assessed using sediment quality guidelines (SQGs). Sediment quality guidelines are intended to provide insight as to whether or not benthic toxicity is expected from exposure to contaminants present in sediments or as a result of disturbance and disposal. 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. Sediment quality guidelines 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 Level 1 assessment from the CSM. The use of SQGs must also be guided by a clear understanding of how the SQGs were derived, what type and level of effects they address, their predictive ability, the assumptions behind their use, and their 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 receptors of concern beyond the benthos (e.g., fish, aquatic wildlife, humans) 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. Contaminant problems previously documented in the watershed can also be used to reach conclusions (i.e., water quality limited status, receptors with contaminant concentrations exceeding guidelines).
- Grain-size distribution of sediment. If sediment is associated with highly erosional areas and largely composed of coarse-grained material, the sediment is unlikely to contain contaminants.
- Hydrogeologic processes. The accumulation of materials and the erosion processes in the vicinity may also be relevant. This will allow the assumption, to be substantiated or disputed, that sediments far removed from sources of pollution are less likely to contain contaminants. This includes:
  - Aggradation (accumulation of materials) and erosion tendencies at the site; and
  - Hydrology (river flow, currents, and other dynamics that relate to dredging activities).
- Site information in relation to sediment movement and potential for contaminating ecological and human receptors of concern.
- How receptors of concern are exposed to the contaminants associated with the sediment.
- How physical, chemical, and biological processes in the sediment could affect exposure.
- Any site bioaccumulation concerns based on “reason to believe” information (see Chapter 8).
- Other lines of evidence as posted on the RSET website. As the RSET matures, new or revised guidance will appear on the RSET website (https://www.nwp.usace.army.mil/pm/e/rset.asp).

Information gathered for the CSM will be the primary evidence relied upon for decisions made during the Level 1 assessment. 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 to guide in the decision making process.

4.2.4. Frequency and Recency Guidelines

Level 1 involves the review of all available historical information, and provides a description of the information within the CSM, in order to assess if significant contamination may be present at a proposed dredging site or if more information is needed. Included in the Level 1 evaluation is the determination of whether the sediments to be dredged fall under "frequency and recency guidelines." The frequency guideline relates to material that is deposited and removed on a frequent basis. For projects with sediment characterization data, recency guidelines have a bearing on the longevity of the information for decision purposes. The recency clause places a limit on how long a suitability determination is valid for the sediment in a given project prior to dredging. As new guidelines are developed (e.g., updated BTs, new SQGs, new contaminants of concern, and others), existing data may need to be subjected to review to ensure sediments still meet the new guidelines (i.e., when a dredging proponent collects testing data but does not remove the material until sometime thereafter).

4.2.4.1. Qualifying for the Frequency Guideline

The frequency of dredging guideline pertains to dredging projects that occur on a frequent basis. The frequency guideline provides a line of evidence based on historical data that can be used to determine if a dredging project may need no further testing for specific periods of time. Such dredging commonly reflects a situation of routine and rapid buildup of shoals with relatively homogeneous sediments. The quality of the sediment at sites that frequently require dredging tends to stay the same for successive years (barring any significantly changing condition at or upstream of the site) because the material is expected to originate from the same source.

To qualify for consideration under the frequency guideline, a project typically requires full characterization of sediments for two successive dredging events (see Section 6.1). 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.

The frequency guideline specifies a period of time in which a qualified dredging project does not need additional testing (Table 4-1). The time durations provided by the frequency guideline are the same as for the "recency of data" and confirmation testing guidelines (PSDDA 1988).

Table 4-1. Frequency of Dredging, Recency of Data, and Confirmation Testing

Ranking	Years
Very Low	10
Low	7
Low-Moderate	6
Moderate	5
High	2

4.2.4.2. Qualifying for Recency of Data Guideline

The recency of data guideline refers to the duration of time for which 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. The recency guidelines for the various ranks are in Table 4-1. The recency or frequency guidelines do not apply when a known "changed" condition, both physical and chemical and regulatory, 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.

4.2.4.3. Analysis of 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 during review of the SAP. The testing of newly exposed surface material may be required in high, moderate, and in some cases, low ranked areas.

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

- If dredging results in the exposure of new surface material having higher chemical concentrations than the sediment that was dredged and exceeds screening levels, then 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 tests.
- If dredging results in the exposure of new surface material as clean as, or cleaner than, the overlying sediments, then no additional requirements are triggered under this manual. There may be additional requirements under the cleanup process.
- If surface sediments with elevated concentrations of CoCs are present adjacent to the dredging site, but not in the site proposed to be dredged, then these sediments and the potential for side-slope sloughing and spreading of contaminated material will be considered on a case-by-case basis, depending on the regulatory context.

4.2.4.4. Confirmation Testing

The credibility of established rankings must be tested and maintained by confirmation sampling. Confirmation sampling and analysis is primarily intended for application to frequently dredged projects ranked very low or low, and should be completed as described under the frequency guidelines. The main purpose of confirmation sampling is to re-affirm the historical record and show that no significant environmentally unacceptable changes have occurred to the project sediments. Confirmation 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. Confirmation sampling shall duplicate earlier sediment testing as much as possible, thereby providing spatial and analytical consistency between testing periods. If the results of confirmation sampling and analysis indicate the project or shoal sediments have changed significantly for the worse, project re-ranking to a higher level and further sampling may be necessary.

4.2.5. Project Ranking

The process of ranking incorporates the lines of evidence from the project description, existing data, and CSM information and allows judgments to be made on the level of risk for the site. Ranking is used to determine the need and level of testing required to evaluate the site when future dredging needs are identified. More than one rank could be assigned to a single project depending upon the size of the proposed dredging area, volume proposed for dredging, and the distribution of potential contaminant sources. After the Level 1 information is gathered, an initial ranking determination is made for the site by the applicant and submitted to the PRGs/DMMP along with the Level 1 information (see Section 4.2.6). This initial ranking is evaluated by the PRGs/DMMP and given a final rank, which may differ from the initial ranking. The final rank is used to evaluate the sufficiency of data to meet the Level 1 evaluation or, if not sufficient, to develop requirements of a SAP. Typically at least two rounds of sampling are required to confirm a final rank for a site for on-going projects and to carry that rank forward for each dredging event (see Section 4.2.6). The PRGs/DMMP can use the initial ranking information, CSM, and data generated from the SAP to establish an on-going project ranking without two rounds of sampling. Rankings will be reviewed and updated based upon the results of new sediment testing or events such as oil or hazardous waste spills and addition of new chemicals of concern within a watershed.

Reaches or sites where sufficient information has been gathered are ranked as one of five possible levels: very low, low, low-moderate, moderate, or high. In that order, these ranking levels represent a scale of increasing potential for concentrations of contaminants of concern and/or adverse biological effects (PSDDA 1988, DMMP 2008). The primary lines of evidence used for ranking include:

1. The availability of historic or current information on the physical, chemical, and/or biological response characteristics of the sediments from a reach or site, including the frequency of dredging and recency of data history (see Section 4.2.4);
2. The number, kinds, and proximity of chemical sources (existing and historical) known or suspected to occur in or near a particular reach or site;
3. The hydrological information of the reach or site in relation to the erosional or depositional tendency within the area; and
4. The prevalence (presence and level of concern) of bioaccumulative contaminants in the watershed.

Projects with ranks above the level of “very low” may be required to undergo additional evaluation in Level 2. Table 4-2 further identifies the lines of evidence to better define these rankings.

Table 4-2. Management Area Ranking Definitions

Ranking Level	Lines of Evidence to Establish Rank
Very Low	Level 1 information indicates locations sufficiently removed from potential sources of sediment contamination based on historical information and review of known or suspected contaminated sites near the project area, or there is a limited pathway for contaminants to reach ecological receptors of concern based on the CSM. Bioaccumulation is not at a level of concern.[1] Areas characterized as highly active or erosional (i.e., energetic) systems, and aggregating materials do not originate near contaminated areas and typically consist of coarse-grained sediment with at least 80 percent sand retained in a No. 230 sieve and total organic carbon content of less than 0.5 percent.[2] Typical locations include gravel bars, mainstem channels such as the lower Columbia River or coastal inlets.
Low	Level 1 site data indicate low concentrations of contaminants of concern (at or below SL values) and/or no significant response in biological tests. Sites have higher percentage of finer grained sediments (and associated organic material) but few sources of potential contamination exist. Bioaccumulation is not a concern.[1] Depositional materials do not originate from or near contaminated areas. Typical locations include areas adjacent to entrance channels, rural marinas, navigable side sloughs, and small community berthing facilities.
Low-Moderate	Level 1 available data indicate a "low" rank may be warranted, but data are not sufficient to validate the low ranking.
Moderate	Level 1 available data indicate moderate concentrations of contaminants of concern in sediments in a range known to cause adverse response in biological tests. Locations where sediments are subject to sources of contamination, where existing or historical use of the site has the potential to cause sediment contamination, or bioaccumulation has been identified as a potential problem for higher level receptors.[1] Areas characterized with aggregating materials that could have originated near contaminated areas. 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	Level 1 available data indicate one or more of the following conditions: high concentrations of contaminants of concern 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, past releases, and stormwater outfalls, or where existing or historical use of the site has the potential to cause sediment contamination; bioaccumulation has been identified as a problem for higher level receptors[1] in areas characterized with aggregating materials that originate near contaminated areas. Typical locations include large urban areas and shoreline areas with major industrial development.

[1] The CSM process will identify the potential for contaminants to reach ecological receptors at a site and identify the pathways as complete or incomplete (e.g., a receptor that is not present at a site at the project or disposal site would have an incomplete pathway). The bioaccumulative line of evidence described here only applies to sites in watersheds that have sufficient bioaccumulation information as identified in Chapter 8. Some sites ranked very low or low may have a bioaccumulation problem identified in the watershed but still have an incomplete or unlikely pathway for contaminants to reach receptors (justifications for incomplete or unlikely pathways should be described in the CSM).

[2] It should be noted that the reliability of using SQGs to predict toxicity for sediment containing mostly coarse-grained materials has not been evaluated regionally, and SQGs are not considered appropriate for characterizing sediments in non-depositional and erosional habitats due to lack of fine grain sediments and longitudinal variations in particle size (Wenning and Ingersoll 2002). In these cases, the PRGs/DMMP may rely primarily on Level 1 information (i.e., distance from known sources) or recommend other testing to sufficiently characterize sediments.

4.2.6. Use of Guidelines and Level 1 Conclusions

The Level 1 evaluation concludes with a determination of rank and a comparison of existing or preliminary data to applicable physical, chemical, and/or biological guidelines. There is merit in using sediment and tissue guidelines, in combination with other sources of information, to identify sediments that require no additional consideration because they pose little potential for risk, or to identify sediments that require additional evaluation because they pose a higher potential for risk.

When assessment questions can be satisfactorily addressed using Level 1 information and chemicals of concern can be managed sufficiently, sediment and tissue guidelines may be used to determine that no further testing is required. For instance, if the applicant believes there is sufficient existing information to support a decision, then Level 1 information (project description, historical and site information, CSM, and rank) can be submitted to the PRGs/DMMP. If the sediment chemistry data are sufficient (see Section 4.2.4 for recency and frequency guidance) and pass guidance for the chemicals of concern (see Section 6.5), then the PRGs/DMMP may agree that no new data are required for a decision. If there is insufficient information for a regulatory decision or data are ambiguous, then the applicant must enter the Level 2 assessment and a SAP must be developed to obtain data to adequately characterize contaminant exposure and effects.

4.3. LEVEL 2

Level 2 assessments must be undertaken when the information presented as part of Level 1 is insufficient to support a decision, or as an option if the applicant wishes to refine the existing rank of a site. The Level 2 process contains two parts:

<u>Level 2A</u> testing involves developing a SAP that will guide the acquisition of additional chemical and physical data of sediment for the project that can be used to support a decision. Depending on the details of the SAP, or the subsequent analytical results obtained, the applicant may wish to transition into Level 2B.

<u>Level 2B</u> testing consists of biological testing (bioassays or tissue analyses) or other special evaluations that are completed to provide more empirical evidence (beyond simple comparisons to regional or national screening levels) regarding the potential for sediment contamination in the project area to have adverse effects on receptors. These evaluations are often undertaken when available screening levels are exceeded, excessive uncertainty of data quality exists, or if other analytical results that indicate a need for more detailed assessment of the sediment or water column. Tests involving whole sediment identify potential contamination that could affect bottom-dwelling (benthic) organisms. Tests using suspension/elutriates of dredged material are used to assess the potential effects to the water column and associated receptors.

Biological effects testing may be necessary if 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 screening level guideline values listed in Chapter 6 and the applicant still desires in-water disposal, or if the newly exposed sediment surface is contaminated.

A SAP addendum should be prepared to outline what special Level 2 evaluations (Level 2B evaluations) will be conducted and how they will assist in supporting a ranking decision. Both the SAP and addendum will be reviewed by the PRGs/DMMP prior to sampling and/or conducting tests to ensure that the tests will address the regulatory needs of the involved agencies. Failure to coordinate with the PRGs/DMMP could result in expensive re-sampling, re-testing, and/or re-analysis if the collected data is insufficient or of unacceptable quality to allow a regulatory decision.

Upon completion of Level 2B testing, the CSM may need to be modified and refined to reflect any new data. Such modifications allow the CSM to become more refined and relevant as the ranking process proceeds.

4.3.1. Sampling and Analysis Plan Preparation

The basic sampling and analysis structure described in this section is patterned after those used to evaluate environmental concerns related to dredging actions, disposal of dredged material, or contaminated sediment projects in the Pacific Northwest. Field sampling and laboratory testing can be the most expensive part of the sediment characterization process and should follow established protocols. This is why a thorough, detailed, and approved SAP is essential prior to field work. The SAP must be designed to characterize all of the material proposed to be dredged and impacts of the dredging action itself. This includes sediments in the dredge prism, any sediments associated with advanced maintenance dredging, and anticipated overdepth or side-slope dredging. The newly exposed sediment surface also must be sampled.

A draft SAP must be submitted for review by the PRGs/DMMP (see Chapter 4). Note that if the SAP requires extensive corrections and changes, re-submittal and review by the PRGs/DMMP may be necessary prior to proceeding with sampling. The PRGs/DMMP will prepare a decision document allowing sampling and analysis to proceed as written or with recommended corrections or changes to the draft SAP. Such corrections and changes if needed must be reflected in the final SAP that is submitted to the PRGs/DMMP with the report containing the results of the sampling and analysis effort. A SAP should contain the following information:

Level 1 information (see Section 4.2). The project purpose and objectives, history of the project site, project description, and CSM submitted in the Level 1 assessment should be updated or modified, as needed.

DMMU information. 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. 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.

In the SAP, include the identification of DMMUs and allocation of field samples, as well as bathymetry, maps and one or more cross-sections of the dredging prism, proposed core locations, the type and volume of sediment to be dredged, and the process to analyze new surface material. Applicants should always check with their PRGs/DMMP in order to confirm the number of DMMUs needed for their project.

The applicant can propose or the PRGs/DMMP can require more or less sampling based on the Level 1 or other site specific or historical information. Within each DMMU, composite sampling (consisting of three samples for one analysis) is preferred over discrete sampling.

Sampling procedures. Include information describing the field-sampling schedule, sampling technology, positioning methodology, decontamination of equipment, sample collection and handling protocols, core logging, sample extrusion, sample compositing and sub-sampling, sample transport, and chain-of-custody.

This second transition into special evaluations can be triggered by exceedances of 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.

Chemical/physical testing (Level 2A). Testing requirements and methods are presented in Chapter 6. Although there is a standard list of chemicals of concern, applicants should check their Corps District for guidance about special chemicals of concern that should be included in sediment investigations for their region.

Biological testing (Level 2B). Biological testing requirements are presented in Chapters 7 and 8. Biological effects tests may be necessary if 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 screening level guideline values listed in Chapter 7 and the applicant still desires in-water disposal or the newly exposed sediment surface is contaminated. A 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 detail in Chapter 8.

Include holding time requirements, proposed testing sequence, bioassay protocols (type of media and species), and quality assurance requirements to conduct toxicity testing (see Chapter 7) and bioaccumulation testing, if needed (see Chapter 8).

4.3.2. Testing Requirements for Special Cases

Small Projects. Some applicants, after completion of a CSM and ranking determination for the site, may request an exemption from testing requirements based on small dredge volumes (typically less than 5,000 cubic yards, which represents a typical barge load). Sediment chemistry analysis for small volumes of sediment may be determined unnecessary due to the potentially lower risk of adverse effects at the dredging and disposal site. Because there is significant uncertainty in evaluating risk of potentially contaminated materials without sediment testing, the PRGs/DMMP will need to make a decision on a case-by-case for these projects. This decision will be primarily based on the management rank and information provided in the Level 1 report.

Furthermore, there is no exemption from testing within high ranked areas, or in areas where threatened and endangered species are present, unless the CSM clearly demonstrates that no reasonable pathways for contamination exist. For example, a site where the material to be removed was from a high current or wave energy environment, predominantly composed of sand, gravel, or other naturally occurring inert material (an unlikely carrier of contaminants) and with no nearby contaminant sources would have an incomplete pathway to receptors in the CSM and may not be subject to additional testing requirements. Small volume projects will need to follow the guidelines provided in Section 4.2.4 for establishing that there is no need for testing.

In defining what constitutes a small project, there are two key qualifiers:

1. Intentional partitioning of a dredging project to reduce or avoid testing requirements is not acceptable.
2. Project volumes are cumulative for a site. For example, the recurring maintenance dredging of a small marina where "project volume" will be the projected dredging volume over a 5-year period (i.e., dredging 1,000 cy per year for 5 years would equal a project volume of 5,000 cy). Or, a multiple-project dredging contract where a single dredging contractor conducts dredging for several projects under a single contract or contract effort.

Large Projects. For projects proposing to dredge very large volumes of materials, lower sampling requirements may be requested after submission of a Level 1 evaluation. These projects would be ranked very low or low and have no local sources of contaminants. Project volumes between 300,000 and 1 million cy may request a minimum of four samples; project volumes over 1 million cy may request a minimum of five samples. Recency and frequency guidelines should inform this decision.

4.3.3. Other Special Evaluations

These special evaluations are non-routine evaluations that require coordination with the PRGs/DMMP to determine the specific testing required. Evaluations such as elutriate tests and dredge residuals may be necessary based on the contaminant and considerations covered in the conceptual site model. 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 contaminated sediment investigations or proposed dredged material. The 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 10).

Special evaluations can be triggered by circumstances such as:

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

If special evaluations are determined necessary by the PRGs/DMMP, specific tests or evaluations and interpretive criteria will be specified in coordination with the applicant and the PRGs/DMMP.

4.4. Special Considerations for Sediments Under Cleanup Actions

The guidance outlined in the SEF is meant to be applied to projects once the decision to dredge has been made, regardless of whether the project is maintenance dredging or part of a cleanup action. The guidance regarding sample handling, storage, analysis, and various biological testing are consistent with those used within the various states' cleanup programs, which ensures consistent data quality across the programs. However, this manual does not provide guidance for characterizing a contaminated site in order to make decisions regarding how the site will be managed. Sediment evaluations for cleanup actions are not presented in this manual primarily due to the different existing regulations between participating states. Additionally, sediment evaluations for cleanup actions are to be coordinated through the cleanup programs of each state agency and EPA Region 10.

In the state of Washington, the evaluation of sediments for cleanup actions shall be in compliance with the MTCA and SMS. If the results from a dredged sediment evaluation show contamination above dredge spoil open-water disposal levels, then the site will be referred to Ecology for evaluation in compliance with the MTCA and SMS.

CHAPTER 5. SAMPLING PROTOCOL

5.1. INTRODUCTION

When required, sampling and testing must be coordinated far enough in advance of dredging to allow time for chemical testing, possible biological testing, and data review. An accurate assessment of the physical, chemical, and biological characteristics of proposed dredged sediment 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 dredged. 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. A number of regional programs have developed standard sampling protocols. This chapter provides an overview of these widely accepted practices.

5.2. 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. Pre-sampling bathymetric surveys should be conducted to provide information on current shoaling patterns and volumes of sediment present at the time of sampling. The timing of sampling should be coordinated with the PRGs/DMMP.

The recommended volume needed for each type of analysis is listed in Table 5-1. There are four sampling approaches which the dredging proponent may take:

1. Alternative 1: Collect enough sediment for physical characterization only.
2. Alternative 2: Collect only enough sediment to conduct the physical and chemical analyses. If biological testing is necessary, resampling will be required.
3. Alternative 3: Collect sufficient sediment for all physical, chemical, and biological tests. Archive adequate sediment for biological testing pending the results of the chemical analysis.
4. Alternative 4. Collect sufficient sediment for all chemical and biological tests. Run these tests concurrently.

The sampling approach should be clearly documented in the Sampling and Analysis Plan (SAP). The selection of either Alternative 3 or 4 is encouraged if biological analysis is anticipated, because these alternatives provide chemical and biological data on sub-samples of a single, homogenized sediment sample. These alternatives are also advantageous because they both eliminate 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 5-1). For Alternative 2, biological analysis can proceed without reanalysis of sediment chemistry. Biological samples must be taken from the same stations as the sediment chemistry samples.

Table 5-1. Sample Storage Criteria

Sample Type	Hold Time (4°C)	Hold Time (-18°C)	Minimum Sample Size (wet weight)	Container[1]
Archive[2]	N/A	(see below)	N/A	500 mL (16 oz.) glass
Particle Size	6 months	Do not freeze	100-200 g	500 mL (16 oz.) poly
Total Solids	6 months	6 months	50 g	(combined with TOC)
Total Organic Carbon (TOC)	14 days	6 months	25 g	125 mL (4 oz.) glass
Metals (except Mercury)	6 months	2 years	50 g	125 mL (4 oz.) glass
Total Mercury	2 months[3]	2 months[3]	5 g	(combined with metals)
Semivolatiles (SVOCs), Pesticides, PCBs	14 days until extraction; 40 days after extraction	1 year until extraction; 40 days after extraction	200 g	500 mL (16 oz.) glass
Tributyltin[4] (marine)	Same as SVOCs	Same as SVOCs	Pore-water extraction	2x 1 liter (2x 32 oz.) glass or poly
Tributyltin[4] (freshwater)	Same as SVOCs	Same as SVOCs	20 g	(combined with SVOCs)
TPH-Dx[4]	Same as SVOCs	Same as SVOCs	20 g	(combined with SVOCs)
Volatile Organics[4] [5]	14 days	Do not freeze	50 g	2x 40 mL (2x 2 oz.) glass w/septa
Ammonia[6]	7 days	Do not freeze	25 g	(combined with TOC)
Total Sulfides[6] [7]	7 days	Do not freeze	50 g	125 mL (4 oz.) glass or poly
Bioassay Testing[8]	8 weeks	Do not freeze	5 liters	5x 1 liter (5x 32 oz.) glass or poly
Bioaccumulation Testing[8]	8 weeks	Do not freeze	10-20 liters	10-20x 1 liter (10-20x 32 oz.) glass or poly

1/ Recommended minimum field sample sizes for one laboratory analysis. All containers should have wide-mouth Teflon® lined lids. Containers should be laboratory-provided, pre-cleaned, and certified. The analytical laboratory should be consulted as they may request different sample sizes than those specified in this table.
2/ For every test sediment or DMMU, an extra container will be filled and archived (frozen upon receipt at the lab) to allow re-testing of metals or semivolatile organic compounds if quality control or other issues are identified.
3/ The PRGs/DMMP may allow longer holding times for mercury on a project-specific basis.
4/ Tributyltin, TPH, and volatile organics are chemicals of special occurrence; analysis of these chemicals will be determined by the PRGs/DMMP on a project-specific basis.
5/ The volatile organics jars should be filled with zero head space.
6/ Ammonia and sulfides should be analyzed if contingent biological testing is planned.
7/ The sulfides sample will be preserved with 5 mL of normal zinc acetate for every 30 g of sediment.
8/ Headspace for biological testing samples is purged with nitrogen.

Acronyms and abbreviations: g = grams; mL = milliliter; °C = degrees Celsius; TOC = total organic carbon; PCBs = polychlorinated biphenyls; SVOCs = semivolatile organic compounds; TPH-Dx = total petroleum hydrocarbons, diesel-range extended; poly = high-density polyethylene; N/A = not applicable.

5.3. 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. If sampling locations are referenced to a local coordinate grid, the local grid should be tied to the North American Datum of 1983 (NAD83) to allow conversion to latitudes and longitudes. The use of a standard horizontal datum will allow dredging data to be accurately mapped, including display and analysis using geographic information system (GIS) software.

5.4. SAMPLING METHODS

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) that will be representative of the DMMU. The agencies have established minimum sampling requirements based on volumetric measurements. The type of sampling required, however, depends on the type of project. The sampling methodology to be used should be presented in the SAP along with the rationale for its use.

Core Sampling. For projects in heterogeneous areas and for most new work dredging, the proponent will be required to take core samples from the sediment/water interface down to the newly exposed sediment surface. There are numerous methods available for obtaining core samples including impact corers, hydraulic push corers, Gus samplers, augers with split spoons or Shelby tubes, jet samplers, and others. The methodology chosen will depend on availability, cost, efficacy, and anticipated sediment recoveries.

Grab Sampling. It is anticipated that sediments in frequently dredged areas or in areas of high energy will be relatively homogeneous. In these locations, grab samples will be considered adequate to represent the dredged material, even if shoaling results in sediment accumulation greater than 4 feet. A number of factors need to be considered in the selection of a grab sampler, including type of sediment, volume needed and ease of deployment.

5.5. 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, sample transport, chain of custody, archiving and storage, all of which need to be treated in the SAP. Guidance can be found in the *Recommended Protocols for Measuring Selected Environmental Variables in Puget Sound Estuary Program* (PSEP 1996), which contains detailed information on sample handling procedures. Project proponents are urged to contact the PRGs/DMMP for the latest protocols. General guidance is summarized below and discussed in more detail in Appendix A.

Decontamination Procedures. Sampling containers should be decontaminated by the laboratory or manufacturer 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 aquatic disposal.

Sample Collection. Sampling procedures and protocols will vary depending on the sampling methodology chosen. Whatever sampling method is used, measures should be taken to prevent contamination from contact with sources of contamination such as the sampling platform, grease from winches, engine exhaust, and others. Core sampling methodology should include the means for determining when the core sampler has penetrated to the required depth. 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.

Volatiles and Sulfides Sub-sampling. The volatiles and sulfides sub-samples should be taken immediately upon extrusion of cores or immediately after accepting a grab sample for use. For composited samples, one discrete core section or grab sample for each DMMU should be selected for the volatiles and sulfides sampling. For heterogeneous sediments, the discrete sub-sample should be collected from the expected worst-case location based on proximity to known or suspected sources in the site vicinity. For homogeneous sediments with no expectation of chemical gradients, the discrete sub-sample should be collected from a central location in the DMMU. The location proposed for discrete sub-sampling should be identified in the SAP but may be modified in the field based on field evidence of contamination, or to account for sample recovery limitations. Any such modifications should be documented in the Sediment Characterization Report.

Sampling Logs. As samples are collected, and after the volatiles and sulfides sub-samples have been taken, logs and field notes of all samples should be taken and correlated to the sampling location map. Information to be included in the log is provided in Appendix A.

Extrusion, Compositing and Sub-sampling. Depending on the sampling methodology and procedure proposed, sample extrusion, compositing, and sub-sampling may take place at different times and locations. More information is provided in Appendix A.

Sample Transport and Chain-of-Custody Procedures. Sample transport and chain-of-custody procedures are discussed in Appendix A.

Sample Storage and Holding Times. Proper sample storage is critical to accurate assessment of sediment toxicity. Table 5-1 outlines the storage and holding time requirements for each type of analysis.

5.6. ARCHIVING ADDITIONAL SEDIMENT

In areas where the exposed sediment is anticipated to be contaminated above the in situ sediment, a sample from the first foot below the dredging overdepth will be collected and archived. This will allow possible future analysis to evaluate chemical concentrations in the newly exposed sediment if this is deemed necessary by the Regional Dredging Team (RDT). 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 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.

5.7. DATA SUBMITTAL

A key component of the sampling effort is the completeness of the data package submitted for regulatory review. Chapter 11 contains information regarding submittal requirements.

CHAPTER 6. PHYSICAL AND CHEMICAL TESTING

6.1. INTRODUCTION

The physical and chemical characterization of sediments is designed to provide a reliable screening evaluation of the potential for adverse biological effects from dredged material or in-place contaminated sediments. The pathways of concern for biological effects are through the bulk sediment itself, through the water column during sediment removal or disposal activities, and through the tissues of biological organisms. This chapter focuses on requirements and procedures for testing and interpreting chemical analytical results of bulk sediment. Recommended chemical analytical methods for testing biological tissue samples are also provided in this chapter; however, the details of designing and interpreting bioaccumulation tests are provided in Chapter 8. Guidelines for evaluating water column effects during dredging and disposal are provided in Chapter 10.

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

- Updated sediment screening levels (SLs) for characterizing dredged material or in-place sediments, including apparent effects threshold (AET) guidelines for marine sediments and floating percentile method (FPM) guidelines for freshwater sediments; in addition, bioaccumulation triggers (BTs) are in the process of being replaced with a more rigorous process for evaluating bioaccumulation potential, as described in Chapter 8;
- Updated chemical analytical methods and quantitation limits for sediment testing (Table 6-1);
- Development of recommended chemical analytical methods and quantitation limits for tissue testing (Table 6-2);
- Revision of the physical screening criterion for determining chemical testing requirements, which is now based on total organic carbon (TOC) content rather than total volatile solids (TVS; Section 6.4);
- Inclusion of new chemicals of special occurrence [e.g., total petroleum hydrocarbons (TPH), organophosphorus pesticides; Section 6.5.2], and development of procedures for evaluating and nominating emerging chemicals for inclusion in the SEF (Section 6.5.3); and
- More information for data quality requirements (Section 6.7 and Chapter 11).

Sediment quality guidelines for evaluating chemical analytical results consist of chemical SLs and bioaccumulation guidelines. Screening levels have been developed for the standard list of chemicals of concern (CoCs) and two chemicals of special occurrence, as shown in Table 6-3. The SLs are designed to be protective of direct biological effects to benthic and aquatic organisms. The derivation and regulatory application of SL values is described in Section 6.8.

The standard list of CoCs should normally be analyzed as part of the sediment characterization process for dredging projects. Exceedance(s) of SLs may trigger the need for bioassay testing, as discussed in Chapter 7. In addition, the presence of contaminants or other deleterious substances not addressed during the development of marine or freshwater SLs may also trigger bioassay testing.

Table 6-1. Recommended Sediment Analytical Methods and Sample Quantitation Limits

Parameter	Prep Method	Analysis Method	Sample Quantitation Limit (SQL) [1/]
STANDARD CHEMICALS OF CONCERN			
Conventionals:			
Total Solids (%)	---	EPA 2450-G	0.1
Total Organic Carbon (%)	PSEP 1997 and Bragdon-Cook 1993	EPA 5310B mod or EPA 9060	0.1
Total Sulfides (mg/kg)	---	PSEP 1997	1.0
Ammonia (mg/kg)	---	Plumb 1981	0.1
Grain Size (%)	---	PSEP 1986 or 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 (PAHs; µg/kg):			
Low-molecular weight PAHs			
Naphthalene	EPA 3550-mod[3/]	EPA 8270	20
Acenaphthylene	EPA 3550-mod[3/]	EPA 8270	20
Acenaphthene	EPA 3550-mod[3/]	EPA 8270	20
Fluorene	EPA 3550-mod[3/]	EPA 8270	20
Phenanthrene	EPA 3550-mod[3/]	EPA 8270	20
Anthracene	EPA 3550-mod[3/]	EPA 8270	20
2-Methylnaphthalene	EPA 3550-mod[3/]	EPA 8270	20
High-molecular weight PAHs			
Fluoranthene	EPA 3550-mod[3/]	EPA 8270	20
Pyrene	EPA 3550-mod[3/]	EPA 8270	20
Benzo(a)anthracene	EPA 3550-mod[3/]	EPA 8270	20
Chrysene	EPA 3550-mod[3/]	EPA 8270	20
Benzofluoranthenes	EPA 3550-mod[3/]	EPA 8270	20
Benzo(a)pyrene	EPA 3550-mod[3/]	EPA 8270	20
Indeno(1,2,3-c,d)pyrene	EPA 3550-mod[3/]	EPA 8270	20
Dibenzo(a,h)anthracene	EPA 3550-mod[3/]	EPA 8270	20
Benzo(g,h,i)perylene	EPA 3550-mod[3/]	EPA 8270	20
Chlorinated Hydrocarbons (µg/kg):			
1,4-Dichlorobenzene	EPA 3550-mod[3/]	EPA 8270	20
1,2-Dichlorobenzene	EPA 3550-mod[3/]	EPA 8270	20
1,2,4-Trichlorobenzene	EPA 3550-mod[3/]	EPA 8270	20
Hexachlorobenzene	EPA 3550[3/]/3540	EPA 8270/8081	10

Table 6-1 (continued). Recommended Sediment Analytical Methods and Sample Quantitation Limits

Parameter	Prep Method	Analysis Method	Sample Quantitation Limit (SQL) [1/]
Phthalates (µg/kg):			
Dimethyl phthalate	EPA 3550-mod[3/]	EPA 8270	20
Diethyl phthalate	EPA 3550-mod[3/]	EPA 8270	20
Di-n-butyl phthalate	EPA 3550-mod[3/]	EPA 8270	20
Butyl benzyl phthalate	EPA 3550-mod[3/]	EPA 8270	20
Bis(2-ethylhexyl)phthalate	EPA 3550-mod[3/]	EPA 8270	100
Di-n-octyl phthalate	EPA 3550-mod[3/]	EPA 8270	20
Phenols (µg/kg):			
Phenol	EPA 3550-mod[3/]	EPA 8270	20
2 Methylphenol	EPA 3550-mod[3/]	EPA 8270	20
4 Methylphenol	EPA 3550-mod[3/]	EPA 8270	20
2,4-Dimethylphenol	EPA 3550-mod[3/]	EPA 8270	20
Pentachlorophenol	EPA 3550-mod[3/]	EPA 8270	100
Miscellaneous Extractables (µg/kg):			
Benzyl alcohol	EPA 3550-mod[3/]	EPA 8270	50
Benzoic acid	EPA 3550-mod[3/]	EPA 8270	100
Dibenzofuran	EPA 3550-mod[3/]	EPA 8270	20
Hexachloroethane	EPA 3550-mod[3/]	EPA 8270	20
Hexachlorobutadiene	EPA 3550[3/]/3540	EPA 8270/8081	10
N-Nitrosodiphenylamine	EPA 3550-mod[3/]	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 compounds[4/]	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
CHEMICALS OF SPECIAL OCCURRENCE			
Tributyltin (ppb):			
TBT in pore water (µg/L ion)	NMFS/Hoffman	Krone 1989	0.03
TBT in sediment (µg/kg ion)	NMFS	Krone 1989	5
Total Petroleum Hydrocarbons (mg/kg):			
TPH-diesel	EPA 3630/ 3665	NWTPH-Dx	25
TPH-residual	EPA 3630/ 3665	NWTPH-Dx	50
Dioxins/ Furans (ng/kg):			
2378-TCDD	EPA 8290/ 1613	EPA 8290/ 1613	1
Dioxins/Furans (other)	EPA 8290/ 1613	EPA 8290/ 1613	1 - 10

[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/] EPA Method 3550 is modified to add matrix spikes before the dehydration step, not after.
[4/] Chlordane compounds include cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, and oxychlordane. In samples with interference from PCBs, the SQLs for cis- and trans-nonachlor and oxychlordane may be elevated.
mg/kg= milligrams per kilogram; ng/kg = nanograms per kilogram; µg/kg = micrograms per kilogram.

Table 6-2. Recommended Tissue Analytical Methods and Sample Quantitation Limits

Parameter	Prep Method	Analysis Method	Sample Quantitation Limit (SQL) (1)(2)
Conventionals (%)			
Lipids	Bligh/Dyer	Bligh/Dyer	0.01
Metals (mg/kg)			
Arsenic	EPA 3050B/ PSEP	EPA 6010/6020/7010	0.05 – 0.2
Cadmium	EPA 3050B/ PSEP	EPA 6010/6020/7010	0.05 – 0.2
Lead	EPA 3050B/ PSEP	EPA 6010/6020/7010	0.05 – 0.2
Mercury	EPA 7471	EPA 7471	0.01 – 0.02
Selenium	EPA 3050B/ PSEP	EPA 6010/6020/7010	0.05 – 0.2
Polynuclear Aromatic Hydrocarbons (µg/kg)			
Fluoranthene	3540C, 3541 or 3550B	EPA 8270-SIM/8270	1 - 5
Pyrene	3540C, 3541 or 3550B	EPA 8270-SIM/8270	1 - 5
Miscellaneous Semivolatiles (µg/kg)			
Hexachlorobenzene	3540C, 3541 or 3550B	EPA 8081	1
Pentachlorophenol	3540C, 3541 or 3550B	EPA 8270-SIM/8270	25
Pentachlorophenol	3540C, 3541 or 3550B	EPA 8151	5
Chlorinated 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 compounds (3)	3540C, 3541 or 3550B	EPA 8081	2
Dieldrin	3540C, 3541 or 3550B	EPA 8081	2
Endosulfans	3540C, 3541 or 3550B	EPA 8081	2
Lindane	3540C, 3541 or 3550B	EPA 8081	2
Methoxychlor	3540C, 3541 or 3550B	EPA 8081	10
Polychlorinated Biphenyls (µg/kg) (4)			
PCB Aroclors	3540C, 3541 or 3550B	EPA 8082	5 - 10
PCB Congeners	3540C, 3541 or 3550B	EPA 8082	0.5 – 2
PCB Congeners (Low Level)	EPA 1668A	EPA 1668A	0.01 - 0.1
Dioxins/Furans (ng/kg) (5)			
2378-TCDD	EPA 8290/ 1613	EPA 8290/ 1613	1
Dioxins/Furans (other)	EPA 8290/ 1613	EPA 8290/ 1613	1 – 10
Organotins (µg/kg) (5)			
Tributyltin	EPA 3550B or NMFS	Krone	10

(1) All sample quantitation limits are expressed on a wet-weight basis.
(2) SQLs are highly dependent on sample size. Details should be confirmed with the laboratory.
(3) Chlordane compounds include cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, and oxychlordane; in samples with interference from PCBs, the SQLs for cis- and trans-nonachlor and oxychlordane may be elevated.
(4) Selection of PCB analytical method will be determined on a project-specific basis.
(5) Dioxins/furans and tributyltin are chemicals of special occurrence; 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.

Note: this is the updated table. DFox

Table 6-3. Bulk Sediment Screening Levels for Chemicals of Concern

** Note that freshwater SLs are being finalized and will be presented to the public when they are complete. In the interim, the freshwater SL1s from the 2006 SEF will be used for dredged material evaluations in freshwater systems. Also note that the marine screening levels (SL1s) for pesticides will be used for both marine and freshwater sediment evaluation.*

Chemical	CAS (1) Number	Marine SL (dry weight)	Freshwater SL (dry weight)
STANDARD CHEMICALS OF CONCERN			
Metals (mg/kg)			
Antimony	7440-36-0	150	
Arsenic	7440-38-2	57	
Cadmium	7440-43-9	5.1	
Chromium	7440-47-3	260	
Copper	7440-50-8	390	
Lead	7439-92-1	450	
Mercury	7439-97-6	0.41	
Nickel	7440-02-0	---	
Silver	7440-22-4	6.1	
Zinc	7440-66-6	410	
Polynuclear Aromatic Hydrocarbons (µg/kg)			
Total LPAH	---	5,200	
Naphthalene	91-20-3	2,100	
Acenaphthylene	208-96-8	560	
Acenaphthene	83-32-9	500	
Fluorene	86-73-7	540	
Phenanthrene	85-01-8	1,500	
Anthracene	120-12-7	960	
2-Methylnaphthalene	91-57-6	670	
Total HPAH	---	12,000	
Fluoranthene	206-44-0	1,700	
Pyrene	129-00-0	2,600	
Benz(a)anthracene	56-55-3	1,300	
Chrysene	218-01-9	1,400	
Benzofluoranthenes (b+k)	205-99-2	3,200	
	207-08-9		
Benzo(a)pyrene	50-32-8	1,600	
Indeno(1,2,3-c,d)pyrene	193-39-5	600	
Dibenz(a,h)anthracene	53-70-3	230	
Benzo(g,h,i)perylene	191-24-2	670	
Chlorinated Hydrocarbons (µg/kg)			
1,4-Dichlorobenzene	106-46-7	110	

Chemical	CAS (1) Number	Marine	Freshwater
		SL (dry weight)	SL (dry weight)
1,2-Dichlorobenzene	95-50-1	35	
1,2,4-Trichlorobenzene	120-82-1	31	
Hexachlorobenzene	118-74-1	22	
Phthalates (µg/kg)			
Dimethyl phthalate	131-11-3	71	
Diethyl phthalate	84-66-2	200	
Di-n-butyl phthalate	84-74-2	1,400	
Butyl benzyl phthalate	85-68-7	63	
Bis(2-ethylhexyl) phthalate	117-81-7	1,300	
Di-n-octyl phthalate	117-84-0	6,200	
Phenols (µg/kg)			
Phenol	108-95-2	420	
2-Methylphenol	95-48-7	63	
4-Methylphenol	106-44-5	670	
2,4-Dimethylphenol	105-67-9	29	
Pentachlorophenol	87-86-5	400	
Miscellaneous Extractables (µg/kg)			
Benzyl alcohol	100-51-6	57	
Benzoic acid	65-85-0	650	
Dibenzofuran	132-64-9	540	
Hexachlorobutadiene	87-68-3	11	
N-Nitrosodiphenylamine	86-30-6	28	
Pesticides/PCBs (µg/kg)			
p,p'-DDD	72-54-8	16	
p,p'-DDE	72-55-9	9	
p,p'-DDT	50-29-3	12	
Aldrin	309-00-2	9.5	
Chlordane	12789-03-6	2.8	
Dieldrin	60-57-1	1.9	
Heptachlor	76-44-8	1.5	
gamma-BHC (Lindane)	58-89-9		
Total PCBs	---	130	
Tributyltin			
TBT pore water (µg/L)	56573-85-4	0.15	
TBT dry weight (µg/kg ion)		---	
Total Petroleum Hydrocarbons (mg/kg)			
TPH-Diesel	N/A		
TPH-Residual	N/A		

(1) Chemical Abstract Service Registry Number

Sediment bioaccumulation guidelines are currently under development for bioaccumulative chemicals of concern (BCoCs). Exceedances of sediment bioaccumulation guidelines where they exist (e.g., the DMMP) or in the interim, elevations above background, may trigger the need for bioaccumulation testing, as described in Chapter 8. Target tissue levels are also provided in Chapter 8 for interpretation of bioaccumulation tests.

The marine SLs have been in use since 1988, with a few minor updates, and have been validated through environmental studies of dredging, disposal, and cleanup sites. Freshwater SLs are being developed in 2009 through a collaborative, multi-agency workgroup process. While the freshwater SLs have not been as extensively validated, due to their recent development, they are being subjected to reliability tests to assess false positive and false negative error rates. It should be noted that agencies may require bioassay testing to be conducted in areas where there are few existing data, to assess the potential toxicity of chemicals not represented in the regional database, or to better evaluate chronic or sublethal endpoints. It is expected that these additional studies would be focused on larger and more complex dredging projects so as not to present an undue burden on small applicants.

6.2. General Testing Protocols

Recommended chemical analytical methods and sample quantitation limits (or reporting limits) for sediment testing are presented in Table 6-1. These testing and analytical protocols follow the latest version of the *Recommended Protocols for Measuring Selected Environmental Variables in Puget Sound* (PSEP 1986, 1996), *Methods for Collection, Storage, and Manipulation of Sediments for Chemical and Toxicological Analyses* (EPA 2001), and EPA's *Standard Methods for Examination of Water and Wastewater*. The PRGs/DMMP 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 4).

6.3. Conventional Testing Protocols

Conventional parameters should be analyzed according to the following specifications:

Grain size: Sediment grain size may be determined using either the PSEP (1986) or ASTM Method D-422 (modified). These methods subdivide the fines (i.e., silt and clay fractions) using pipette and hydrometer, respectively. The PSEP is generally recommended for site investigations but ASTM may be preferable for engineering calculations. One of the following sieve series must be used: (1) sieve numbers 5, 10, 18, 35, 60, 120, and 230 (PSEP), or (2) sieve numbers 4, 10, 20, 40, 60, 140, 200, and 230 (ASTM D-422 modified). In all cases, material passing the No. 230 sieve determines the percent fines. The use of hydrogen peroxide is not recommended.

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.

Total Organic Carbon: TOC is a key index parameter that affects the adsorptive capacity and bioavailability of organic contaminants and some metals in sediments. Sediment TOC analysis should follow PSEP (1996) for sample preparation (i.e. sample drying, homogenization, and acidification to remove inorganic carbon), with modifications suggested by Bragdon-Cook (1993) for high-temperature combustion followed by non-dispersive infrared detection (NDIR).

Acidification, combustion, and NDIR analysis should be conducted according to the instrument manufacturer's instructions, as specified in EPA Methods 5310B and 9060A.

The analysis of other conventional parameters may also be required, as listed in Table 6-1. In particular, analysis of ammonia and sulfides may be useful in interpreting bioassay test results (see Chapter 7), and determining whether conventional parameters may be contributing to sediment toxicity.

6.4. PHYSICAL SCREENING USING GRAIN SIZE AND ORGANIC CARBON

An initial screen of bulk sediment quality may be conducted using grain size and TOC content. 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 therefore, is not suitable for contaminated site 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 its physical properties (see Chapter 4). If the results are higher than 20 percent fines or greater than 0.5 percent TOC (i.e., the results exceed either or both of the physical screening criteria), 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 physical screening assessment and will be required to collect chemistry data. Metals and other inorganic constituents are the predominant CoCs associated with mining, and as a result, the toxicity of sediments in mining regions appears to be less well correlated with the organic carbon content of the sediments.

6.5. CHEMICAL TESTING PROTOCOLS AND GUIDELINES

There are three categories of CoCs that are considered in developing testing requirements for dredging projects:

1. **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.
2. **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.
3. **BCoCs:** Constituents with potential to bioaccumulate in higher-level organisms (e.g., humans, fish, birds, mammals). See Chapter 8 and Appendix C for a discussion and list of BCoCs.

6.5.1. Standard List of Chemicals of Concern

The standard CoCs are listed in Table 6-3, along with sediment quality SLs, which are discussed later in this chapter. Recommended analytical methods and quantitation limits are presented in Table 6-1. The standard CoCs have one or more of the following characteristics:

- A demonstrated or suspected adverse biological or human health effect (toxicity);
- A relatively widespread distribution above natural or background conditions in the Pacific Northwest (common occurrence); and
- A potential for remaining in a toxic form for long periods (i.e., years or decades) in the environment (environmental persistence).

In addition, certain chemicals have a propensity to enter the food chain and bioaccumulate in the tissues of biological organisms (i.e., BCoCs). Such chemicals are discussed further in Section 6.6 and Chapter 8.

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, the PRGs/DMMP may not require further testing of these chemicals unless there is a changed condition at the site.

Table 6-3 presents the dry-weight interpretive marine and freshwater SL values for standard CoCs, as well as two chemicals of special occurrence (tributyltin and total petroleum hydrocarbons, or TPH; see below). The derivation and use of these SL values are described in Section 6.8. The SL values in this table are predictive of direct toxicity to benthic and epibenthic organisms. Bioaccumulation-based guidelines have not yet been developed for sediments, but will be added to this table once they are available (see Chapter 8 for bioaccumulation testing requirements and procedures, as well as target tissue levels for test interpretation). Table 6-1 presents recommended preparation methods, analytical methods, and SQLs for sediments. The recommended methods have been able to achieve the SLs required for interpretation and screening of chemical data. Other methods may be proposed to the PRGs/DMMP for approval during the SAP review.

6.5.2. 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 TBT). Testing for TBT 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, and marine terminals). In marine sediments, pore water analysis has been shown to improve the reliability of toxicity predictions and is therefore required in marine environments (Michelsen et al., 1996); TBT pore water extraction protocols are described in Hoffman (1998). In freshwater environments, TBT shall be analyzed in bulk sediment on a dry-weight basis.

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 elevated levels of dioxin/furan compounds have been demonstrated in past testing. Dioxin is formed as an unintentional by-product of many industrial processes involving chlorine such as waste incineration, chemical and pesticide manufacturing, and pulp and paper bleaching. A P450 biomarker test may be used 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 PAHs and 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 the white paper at https://www.nwp.usace.army.mil/pm/e/rset.asp).

Total Petroleum Hydrocarbons (TPHs). Testing for TPH 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 petroleum storage tank or pipeline leaks). NWTPH-Dx (including diesel and residual range hydrocarbons) is the recommended method for bulk petroleum analysis in sediments. Because sediments are often comprised of weathered and unresolved petroleum mixtures, it is recommended that TPH be quantified using diesel and motor oil standards. Sediment samples should be processed using sulfuric acid and silica gel cleanup steps to remove potential interferences from other organic compounds and biogenic materials. Quantitation of bulk petroleum using EPH/VPH analysis (extractable and volatile petroleum hydrocarbons; Ecology 1997) is not currently recommended for sediments.

Volatile, gasoline-range petroleum compounds dissipate relatively quickly in sediments and are rarely observed at concentrations of concern unless an ongoing source of light-end petroleum is present. As a result, the need for analysis of NWTPH-G (gasoline range hydrocarbons) or component volatile organic compounds (e.g., ethylbenzene, xylene) is expected to be relatively rare.

Guaiacols. Guaiacol and chlorinated guaiacols may be required in areas where kraft pulp mills are located. Only guaiacol, and not chlorinated guaiacols, 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.

6.5.3. Evaluation and Nomination of Emerging Chemicals

An "emerging chemical" may be added to the list of chemicals of special occurrence 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 occurrence, 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 includes the following considerations:

- 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 SLs. The development of SLs will typically require 100 or more synoptic data points (i.e., paired chemical and biological testing results) from multiple studies and aquatic 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 in response to source controls. The rationale for listing or delisting chemicals of special occurrence or standard CoCs will be considered on a case-by-case basis using the criteria listed above during reviews of the SEF.

6.6. TISSUE TESTING

Tissue testing may be necessary if BCoCs are present at levels of concern (or above background concentrations if sediment bioaccumulation guidelines are not available) and follow-up bioaccumulation testing is warranted (see Chapter 8). Bioaccumulation testing may be conducted using either laboratory or field exposures. Animal tissue samples are collected and analyzed from controlled laboratory chambers or field-deployed cages, or are directly harvested from their natural environment.

Recommended tissue analytical methods and quantitation limits are presented in Table 6-3 for primary (List 1) BCoCs. These testing and analytical protocols 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). The PRGs/DMMP must approve any modifications of these protocols. Any requests for protocol modifications should occur during the preparation of the project SAP (see Chapter 4).

In addition to standard methods, "micromethods" have recently been developed for analysis of lipids, PCBs, and PAHs (Jones et al., 2005; Inouye and Lotufo 2006). Micromethods are potentially faster, less expensive, and use only one hundredth the tissue volume of standard methods with only a minor effect on analytical performance. As a result, micromethods are an optional analysis method for bioaccumulation tests with small test organisms and sample volume limitations; however, they are not recommended for fish tissue samples or other instances where sample volumes are not limited. Unfortunately, micromethods have very limited commercial availability at the present time.

6.7. Data Quality and Reporting

6.7.1. Quality Assurance/Quality Control (QA/QC)

To support sediment management decisions, it is imperative that 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 requirements are tailored to the scope and complexity of the project and the level of risk being managed.

The QA/QC measures, control limits, and contingency response procedures are outlined in a QA/QC chapter of the SAP for dredging projects. Field QA/QC procedures are described in Chapter 5. 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 prescribed in the analytical method specifications or in laboratory standard operating procedures (SOPs). The QA/QC information is presented in Chapter 11.

6.7.2. Analytical Sensitivity

Analytical sensitivity is characterized by method detection limits (MDLs) and SQLs (also known as reporting limits, practical quantitation limits, and others; EPA 1989a, DOD 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. The MDL studies are 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. For analysis of dioxins and PCB congeners using high-resolution gas chromatographic/mass spectrometric (GC/MS) methods, the sample-specific estimated detection limit (EDL) is analogous to the MDL, and the SQL may be estimated based on the lower calibration limit, statistical analysis of historical method blank data, or other method specified by the laboratory.

To generate useable data, achieve data quality objectives, and support sediment management decisions, the SQLs should be less than the SLs listed in Table 6-3.

Regarding analytical sensitivity, the following three scenarios are possible.

1. **SQL is less than SL**. 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 6.7.1), this produces data of the highest quality.
2. **MDL exceeds SL**. In this scenario, the analytical method used is not sufficiently sensitive to make an informed sediment management decision. An undetected result with a MDL exceeding the SL will be considered an exceedance of the SL unless it can be demonstrated that all reasonable steps were taken to control the MDL and SQL, including additional cleanup procedures, reextraction, and reanalysis as necessary. In such cases, the PRGs/DMMP 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 error.

3. **MDL is less than SL; SQL exceeds SL**. 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, reextraction, and reanalysis. These data are 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 the PRGs/DMMP. In all cases, sediments or extracts should be archived under proper storage conditions until the chemistry data are deemed acceptable by the regulatory agencies. This retains the option for re-analysis and lower-level quantitation, if necessary.

6.7.3. Reporting of Estimated Concentrations below the SQL

Laboratories have the ability to identify and provide estimated quantitations 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 6.7.2). 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.

6.7.4. Chemical Summations

Several chemical groups are reported as a summation of individual compounds. Summations are reported for total PAHs, low- and high-molecular weight PAHs (LPAHs and HPAHs), and total PCBs. Other chemical groups (e.g., carcinogenic PAHs, PCB congeners, and dioxins/furans) are typically summed using weighting factors proportional to the relative toxicity of the individual constituents (see toxicity equivalency factors or TEFs below). In general, the analytical laboratory will report results for individual chemicals, congeners, and isomers, and the data user will perform any required summations.

The rules for chemical summation are as follows:

- The group summation is performed using all detected concentrations. Undetected results are included in the summations at half the value of the MDL (½ MDL) for all chemical summations except PCB Aroclors and summations involving TEFs (see below). Undetected results for PCB Aroclors and toxicity equivalency factor (TEF) summations (PCB congeners, dioxins/furans) are not included in the summation (zero MDL) to avoid situations in which the MDLs overwhelm the detected data.
- 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 MDL and SQL of all the constituents are reported as the MDL and 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 (as Aroclors). 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.

DDT Isomers. Marine SLs are reported for the individual 4,4'- isomers of DDT, DDE, and DDD; no summations are performed. Freshwater SLs are reported for Total DDT, DDE, and DDD, each of which represents the sum of the 4,4'- and 2,4'- isomers.

Total Chlordane. Total chlordane is the sum of two major compounds (cis-chlordane and trans-chlordane, also known as alpha-chlordane and gamma-chlordane, respectively) and three minor compounds (cis-nonachlor, trans-nonachlor, and oxychlordane) derived from technical chlordane and its metabolites (Fox and Hoffman 2007). If PCBs are present in a sample, they may interfere with the three minor chlordane compounds, causing elevated reporting limits. If the three minor compounds are undetected at significantly higher reporting limits compared to the major compounds, due to PCB interference, then the PRGs/DMMP may allow the minor compounds to be excluded from the total chlordane summation.

Toxicity Equivalency Factor. TEF is 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. Toxicity equivalency factors 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 recommended that sediment-tissue partitioning relationships (i.e., biota-sediment accumulation factor or BSAF) be evaluated based on individual chemicals rather than the summed concentrations of a chemical group.

The use of TEFs for addressing both human health and ecological risks has been approved by EPA as well as the World Health Organization, and is therefore an acceptable approach under this SEF. For example, TEFs for dioxin-like chemicals (i.e., dioxins, furans, and coplanar PCB congeners) can be found in the *The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-Like Compounds* (Van den Berg et al., 2006). Wildlife TEFs for dioxin-like chemicals have been developed for mammals (Van den Berg et al., 2006), birds and fish (Van den Berg et al., 1998), and have been approved by EPA for use in ecological risk assessment (EPA 2008).

6.8. BENTHIC INTERPRETIVE GUIDELINES

Chemical SLs have been developed to predict and manage potential adverse biological effects on benthic and epibenthic organisms. For dredging projects, the SLs may be used to evaluate benthic risk associated with in-place sediments, for the newly exposed sediment surface after dredging, and at the unconfined open-water disposal site, as applicable. In addition to chemical analytical data, bioassay tests serve to integrate chemical and biological interactions of sediment contaminants, including bioavailability, by measuring toxic effects on sensitive benthic organisms (see Chapter 7).

The SLs listed in Table 6-3 are derived from regional chemistry and toxicity data from sediment sites in the Pacific Northwest. The regional sediment database includes paired data containing both chemical analytical results and bioassay testing results. Each SL is derived using at least three different biological endpoints and corresponds to a "no adverse effects level." Different statistical approaches were used to derive marine values (AET approach) and freshwater values (FPM approach), and as a result, the mathematical models used to derive the SL values are somewhat different in marine and freshwater systems, but both were designed to be consistent with the same narrative definition of no adverse effects levels.

The SL values presented in Table 6-3 are designed to be protective of direct toxicity to benthic and epibenthic organisms. To some extent, these SL values may also useful for protecting the invertebrate prey base of salmonid species listed under the Endangered Species Act (ESA). The use of amphipods and chironomids in freshwater bioassays is important as these are common prey species for salmonids, and development of additional freshwater chronic tests is another priority for protection of prey-base populations (see the white paper at https://www.nwp.usace.army.mil/pm/e/rset.asp). Development of sediment quality values for protection of ESA-listed benthic species was reviewed by an interagency working group and was determined not to be necessary, as there are no benthic species that are ESA-listed within the tri-state region that are present in areas where dredging projects are likely to occur.

If a chemical is not listed in Table 6-3, or if there is no value listed for that chemical, then the chemical is not a CoC for routine evaluations. Lack of an SL does not mean the chemical has not been evaluated, rather it means that the chemical is not a concern for benthic organisms in the Pacific Northwest. For unusual sites or projects where a chemical without a SL is present, with known sources, and concentrations are significantly elevated over those typically encountered at other sites, two approaches are possible. First, in some cases it may be possible to identify a listed CoC with similar chemical and toxicological properties that could be used as a surrogate for the unlisted chemical. Otherwise, bioassays would need to be conducted to directly measure site-specific toxicity.

Note that the SLs presented in Table 6-3 do not include bioaccumulative effects. If BCoCs are present at levels of concern, a separate bioaccumulation assessment will need to be performed (see Chapter 8 for further discussion).

6.8.1. Data Sources

Sediment quality values for marine sediments were developed using the AET approach. These values are well established in the Pacific Northwest and have been in use for almost two decades in regional dredging programs (e.g., EPA/Corps 1988; EPA/Corps et al., 1998a), federal cleanup programs (e.g., Commencement Bay, EPA 1989b), and state of Washington cleanup programs (per

SMS 1995, Chapter 173-204 WAC). The marine screening levels in Table 6-3 are derived from the state of Washington SMS to the extent they are available. However, whereas some of the SMS values for nonpolar organic compounds are normalized to organic carbon, the equivalent dry-weight values will be used in the SEF. These dry-weight values were calculated using the same regional database and the same AET methodology as the carbon-normalized values, but were derived using the unnormalized dataset (see PSEP 1988). Dry-weight and carbon-normalized SLs have been shown to provide similar levels of predictive reliability. Finally, because the SMS has not promulgated marine sediment quality values for chlorinated pesticides, these values were taken from the lowest AETs reported by the Corps (1996a).

More recently, the state of Washington developed and published an initial set of freshwater sediment quality guidelines using the FPM approach, which strives to optimize the balance between the sensitivity and reliability of the guidelines (Ecology 2003). Updated freshwater FPM values, which include greater geographic scope (including projects on both the east and west sides of the Cascades in Washington and Oregon) and acute and chronic/sublethal bioassay endpoints, were developed in 2008 through a multi-agency workgroup process and will be posted when accepted.

6.8.2. Freshwater vs. Marine Environments

The selection of the set of SLs will be based on the location at which sediment toxicity is being evaluated, i.e., the effects of in-place sediments or newly exposed surface material will be evaluated at the project site, and the effects of open-water disposal of dredged material will be evaluated at the disposal site. The PRGs/DMMP will follow the specifications of the Inland Testing Manual (EPA/Corps 1998c) in defining these environments: salinities less than 1 part per thousand (ppt) are considered freshwater, salinities greater than 25 ppt are considered marine, and salinities between 1 and 25 ppt are considered estuarine. In estuarine environments, the PRGs/DMMP should be consulted to determine which set of chemical SLs (freshwater or marine) to use.

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. For example, if freshwater sediments are proposed to be dredged and disposed at an open-water marine site, marine SLs, and test organisms are appropriate for assessing impacts of dredged material at the disposal location. However, freshwater SLs and test organisms are appropriate for assessing impacts of *in situ* sediments or newly exposed sediments left behind at the project site.

6.8.3. Sediment Quality Assessment for Dredging Projects

The SL values are intended to identify chemical concentrations that are at or below levels at which there is no reason to believe exposures to in-place sediments or dredged material disposal sites 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 8).

Sediments in dredged material management units (DMMUs) containing chemical concentrations at or below SL levels and bioaccumulation guidelines (or background, in the interim) are judged to be suitable for unconfined open-water disposal. Sediments proposed for open-water disposal with one or more chemical concentrations exceeding SL levels and/or bioaccumulation guidelines will require follow-up bioassay testing and/or bioaccumulation testing, respectively.

Biological testing provides a more site-specific measurement of the potential for 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 SL levels or bioaccumulation guidelines, and follow-up biological testing is not pursued, the associated DMMU will be determined unsuitable for open-water disposal.

Sediments that exceed SL levels or bioaccumulation guidelines and fail follow-on biological testing, if such testing is pursued, will need to be managed in an alternative and more protective manner such as a confined disposal facility (CDF; e.g., confined aquatic disposal site, nearshore fill site, upland disposal facility, or commercial landfill). If dredged sediments are intended to be placed in a CDF, and thus removed from direct contact with the aquatic environment, bioassay and bioaccumulation testing will not be necessary. However, other tests will likely be required for these sediments (e.g., effluent elutriate tests to characterize return flow from an impoundment, or leachate tests to characterize impacts to groundwater migrating through the confined sediments) depending on the location and configuration of the confined disposal facility (EPA/Corps 2003; also see Section 9.4.3).

Whether designated for open-water or confined disposal, short-term water quality effects may be caused by the disturbance and resuspension of sediments, especially contaminated sediments, by dredging and related construction activities at the dredging site. The evaluation of water column effects during dredging is described in Section 10.3. Dredging residuals, if sufficiently thick and contaminated, may linger beyond the dredging activity and contribute to long-term risk at the project site location, potentially including bioaccumulative risk. Dredging residuals are discussed further in Section 10.4. Other exposure pathways at the dredging and/or disposal site may be identified in the conceptual site model and should be evaluated as necessary (see Section 4.2.3).

CHAPTER 7. BIOLOGICAL (TOXICITY) TESTING

7.1. INTRODUCTION

Level 2B biological testing of sediment (see Section 4.3) will be required when chemical testing results indicate the potential for unacceptable adverse environmental or human health effects. A standard suite of bioassays is used evaluate the potential toxicity to bottom-dwelling (benthic) organisms and is required when one or more sediment screening levels (SLs; see Table 6-3) are exceeded in the dredged material. The results of these sediment bioassays are used to make a determination regarding the suitability of dredged sediment for aquatic disposal. A Level 2B bioaccumulation evaluation 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 (see Section 8.5 for additional information on bioaccumulation-related biological tests).

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 from interactions among chemicals or from bioavailability of chemicals to aquatic organisms. Because the relationship between total chemical concentrations and biological availability is poorly understood, when regulatory guideline values or risk screening criteria are exceeded, controlled laboratory bioassay and bioaccumulation tests are performed to provide additional lines of evidence for evaluating potential environmental effects.

The approach most often adopted is to expose representative aquatic/benthic species to 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 Level 2B sediment tests, and the interpretive criteria used for decision-making. For the recommended bioassay tests, references are provided for more detailed information on test protocols and test interpretation. Additional information on bioassays available to address project specific needs/evaluations is provided in Appendix B. In addition, Section 8.5 provides information on bioaccumulation tests.

7.2. 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 in general. 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. Marine tests species may be selected based on criteria such as salinity at the open-water disposal site considered for the dredged material, fines or clay content of sediments, and seasonal availability of organisms.

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). Additionally, biological test species may be selected based on environmental characteristics at the dredging site if there is concern regarding the sediment quality of residuals or for other regulatory (e.g., cleanup program) requirements.

7.2.1. 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 7.2.2). The recommended suite of marine sediment bioassays for use in the Pacific Northwest normally includes an acute amphipod test, a chronic *Neanthes* test, and a sediment larval test:

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

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

Amphipod Species. Amphipod selection is based on test sediment grain size and salinity. *Rhepoxynius abronius*, a free-burrowing amphipod, requires a porewater salinity of at least 25 ppt, has been shown to be sensitive to sediments with high (>60%) fines particularly those with high clay content and has been shown to exhibit mortalities greater than 20 percent in clean, reference area sediments with greater than 60% fines (DeWitt et al., 1988; Fox 1993). *Eohaustorius estuarius*, also a free-burrowing amphipod, can tolerate a broad range of porewater salinities [approximately 0-36 ppt (EPA 1994; Redmond et al., 2000; ASTM 2008)], and is suitable for use for the full range of grain sizes, except that there is some evidence that its survival is affected by high percent clay [>20% (DMMP 2008) or >70% (Environment Canada 1992)]. *Ampelisca abdita*, a tube-dwelling amphipod, can be used with porewater salinities from 0 to 34 ppt if overlying water is at least 28 ppt (EPA 1994), and for sediments with at least 10% fines (EPA 1994, ASTM 2008), but is not native to the Pacific Northwest and may not be available from suppliers at the specified juvenile life stage year-round. Proposed species must be submitted to the relevant regulatory agency prior to use, and must be documented in the Sampling and Analysis Plan (SAP) for the proposed dredging project or site investigation/risk assessment.

Echinoderm Species. Echinoderm species selection is primarily based on seasonal availability of individuals in spawning condition.

Bivalve Species. Mussels, *Mytilus* sp., are available in spawning condition most of the year. Oysters, *Crassostrea gigas*, can also be tested, but care should be taken to not use triploid organisms. Oysters may also be more restricted for use than mussels due to seasonal availability of individuals in spawning condition.

7.2.2. 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 environment [5 ppt or below]:

Amphipod – *Hyalella azteca* 10-day mortality test.

Midge – *Chironomus dilutus*[1] 10-day mortality and growth test.

Standard protocols exist for each of these tests, established both by ASTM and EPA (EPA 1994, ASTM 1995). 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 dilutus* 20-day mortality and growth test. Performance standards for reference and control sediment, as well as interpretive criteria for these longer-term freshwater tests, are provided in this chapter.

In addition, the Microtox® 100 Percent Sediment Porewater Extract Test, which is a 15-minute toxicity test that assesses decreased luminescence of the bacteria *Vibrio fischeri* exposed to a pH, dissolved oxygen and salinity-adjusted 100 porewater extract of the freshwater sediment sample, has been recently used in the state of Washington's SMS program. While its use in dredging programs is still under evaluation, information on for this test is provided here as its use has been increasing in the state of Washington. Protocols for the test are provided in Appendix C of Ecology's *Sediment Sampling and Analysis Plan Appendix* (Ecology 2008a; available at http://www.ecy.wa.gov/biblio/0309043.html).

7.2.3. Bioassay Testing Performance Standards

This section contains the specific 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.

[1] *Chirinomus dilutus* is the new name for the *Chironomus tentans*; there has been no change in the species recommended for testing.

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 7-1 summarizes the performance standards for negative controls and reference sediment for freshwater toxicity tests and Table 7-2 provides the same information for marine/estuarine toxicity tests. Additional QA/QC information for sediment toxicity tests are provided in Ecology's *Sediment Sampling and Analysis Plan Appendix* (Ecology 2008a).

Table 7-1. Interpretive Criteria and Performance Standards for Freshwater Biological Tests

Toxicity Test	Negative Control Performance Standard	Reference Sediment Performance Standard	1-Hit Criteria	2-Hit Criteria
Hyalella azteca 10-day mortality	C ≤ 20%	R ≤ 25%	T – R > 25% and T vs. R SS (p=.05)	T – R > 10% and T vs. R SS (p=.05)
Hyalella azteca 28-day mortality	C ≤ 20%	R ≤ 30%	T – R > 25% and T vs. R SS (p=.05)	T – R > 10% and T vs. R SS (p=.05)
Hyalella azteca 28-day growth	CF ≥ 0.15 mg/ind	RF ≥ 0.15 mg/ind	T/R < 0.6 and T vs. R SS (p=.05)	T/R < 0.75 and T vs. R SS (p=.05)
Chironomus dilutus 10-day mortality	C ≤ 30%	R ≤ 30%	T – R > 25% and T vs. R SS (p=.05)	T – R > 10% and T vs. R SS (p=.05
Chironomus dilutus 10-day growth	CF ≥ 0.48 mg/ind	RF/CF ≥ 0.8	T/R < 0.7 and T vs. R SS (p=.05	T/R < 0.8 and T vs. R SS (p=.05)
Chironomus dilutus 20-day mortality	C ≤ 32%	R ≤ 35%	T – R > 25% and T vs. R SS (p=.05)	T – R > 15% and T vs. R SS (p=.05)
Chironomus dilutus 20-day growth	CF ≥ 0.48 mg/ind	RF/CF ≥ 0.8	T/R < 0.6 and T vs. R SS (p=.05)	T/R < 0.75 and T vs. R SS (p=.05)
Microtox® decrease in luminescence	CF/CI ≥ 0.72	RF/CF ≥ 0.8	T/R < 0.75 and T vs. R SS (p=.05)	T/R < 0.85 and T vs. R SS (p=.05)

C = Control, CI = Control Initial, CF = Control Final
R = Reference, RF = Reference Final, T = Test Sample, SS = Statistically Significant

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. The sediment larval test utilizes a negative seawater control rather than a control sediment. Negative control reliability must be demonstrated.

Table 7-2. Interpretive Criteria and Performance Standards for Marine Biological Tests

Toxicity Test	DMMP Negative Control Performance Standard	DMMP Reference Sediment Performance Standard	DMMP 1-Hit Criteria Dispersive Disposal Site	DMMP 2-Hit Criteria Dispersive Disposal Site	DMMP 1-Hit Criteria Nondispersive Disposal Site	DMMP 2-Hit Criteria Nondispersive Disposal Site
Amphipod acute 10-day mortality	C ≤ 10% mortality	R ≤ C + 20% mortality	T – C > 20% and T – R > 10% and T vs. R SS (p=.05)	T – C > 20% and T vs. R SS (p=.05)	T – C > 20% and T – R > 30% and T vs. R SS (p=.05	T – C > 20% and T vs. R SS (p=.05)
Juvenile infaunal 20-day growth	C ≤ 10% mortality CG ≥ 0.38 mg/ind/day (Kendall 1996)	R ≤ 20% mortality RG/CG ≥ 80%	TG/CG < 80% and TG/RG < 70% and TG vs. RG SS (p=.05)	TG/CG < 80% and TG vs. RG SS (p=.05)	TG/CG < 80% and TG/RG < 50% and TG vs. RG SS (p=.05)	TG/CG < 80% and TG/RG < 70% and TG vs. RG SS (p=.05)
Sediment larval normalized combined mortality/abnormality (NCMA)	SC ≥ 70% normal survivors	RN ≥ 65% x SC	TN/SC < 80% and RN/SC - TN/SC > 15% and TN/SC vs. RN/SC SS (p=.10)	TN/SC ≤ 80% and TN/SC vs. RN/SC SS (p=.10)	TN/SC < 80% and RN/SC - TN/SC > 30% and TN/SC vs. RN/SC SS (p=.10)	TN/SC ≤ 80% and TN/SC vs. RN/SC SS (p=.10)

C = Control, CG = Control Growth Rate, SC = Seawater Control - Normal Larvae, SS = Statistically Significant
R = Reference, RG = Reference Growth Rate, RN = Reference - Normal Larvae
T = Test Sample, TG = Test Growth Rate, TN = Test - Normal Larvae

Kendall, D. 1996. Neanthes 20-Day Growth Bioassay – Further Clarification on Negative Control Growth Standard, Initial Size, and Feeding Protocol. PSDDA/SMS Clarification Paper.

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 organic carbon (TOC), ammonia, sulfides, and grain size (PSEP 1995).

All bioassays have performance standards for reference sediments. Failure for reference sediments to meet these standards may result in the requirement to retest the dredged material. In some cases, control sediments can be substituted for reference sediments if they have similar characteristics or if the PRGs/DMMP agree that this is appropriate (PSEP 1995, DMMP 2008), and the data will be interpreted accordingly (DMMP 2008).

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 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 should be conducted for the bioassays. For the marine biological tests, daily measurements of salinity, temperature, pH, and dissolved oxygen should be conducted for the amphipod and sediment larval tests. These measurements should be made every 3 days for the 20-day *Neanthes* growth test. Ammonia and total sulfides should be measured at test initiation and termination for all three tests where either of these chemicals is suspected as being a problem (Ecology 2008a). For the freshwater biological tests, daily measurements of temperature and dissolved oxygen should be conducted for the amphipod and midge tests. Conductivity, hardness, and alkalinity should be measured at test initiation and termination for the amphipod and midge tests. Monitoring of ammonia and total sulfides should be measured at test initiation and termination where either of these chemicals is suspected as being a problem (Ecology 2008a). Parameter measurements must be within the limits specified for each bioassay (DMMP 2008, Ecology 2008a).

7.2.4. Bioassay Interpretive Criteria

The response of bioassay organisms exposed to composited sediment representing each 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). This evaluation will determine whether dredged material is suitable or 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, or found unsuitable for aquatic disposal in a dredged material situation. The “one-hit” and “two-hit” nomenclature was developed for the PSDDA program and is used for interpreting marine/estuarine toxicity tests (see Table 7-2). Similarly for freshwater toxicity tests, criteria presented in Table 7-1 correspond to “one-hit” and “two-hit” failures.

One-Hit Failure. When **any one** biological test shows a test sediment response relative to the negative control and reference sediment that exceeds the one-hit failure bioassay-specific response guidelines and the difference from the reference response is statistically significant, the DMMU is judged to be unsuitable for aquatic disposal. The acceptable methods for determining statistical significance are provided in the DMMP Users’ Manual (DMMP 2008).

Two-Hit Failure. When **any two** biological tests show test sediment responses, which are less than the one-hit failure bioassay-specific guidelines, but shows a test sediment response relative to the negative control and reference sediment that exceeds the two-hit failure bioassay specific response guidelines, and the difference from reference response is statistically significant, the DMMU is judged to be unsuitable for aquatic disposal.

The method for determining statistical significance is discussed in DMMP Users’ Manual (DMMP 2008). This reference also contains a description of the BIOSTAT bioassay software developed by the Seattle District. This software contains the statistical tests to determine sediment suitability.

Table 7-2 provides a summary of interpretive criteria as well as negative control and reference sediment performance standards for the marine bioassays. Table 7-1 provides the same information for the freshwater bioassays. A narrative summary of the interpretive criteria are provided in the following sections.

7.2.5. Marine Bioassays “One-Hit” Failure

Amphipod Bioassay. For the amphipod bioassay, mean test mortality greater than 20 percent absolute over the mean negative control response, and greater than 10 percent (dispersive) or 30 percent (nondispersive) 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 70 percent (dispersive) or 50 percent (nondispersive) 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.

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

If the mean NCMA for a test sediment is greater than 20 percent, is 15 percent (dispersive) or 30 percent (nondispersive) absolute over the mean reference sediment NCMA, and is statistically different from the reference (alpha = 0.10), it is considered a one-hit failure.

7.2.6. Marine Bioassays “Two-Hit” Failure

When **any two** biological tests (amphipod, juvenile infaunal growth, or sediment larval) exhibit test sediment responses which are less than the bioassay-specific reference-comparison guidelines described above for a one-hit failure, but are statistically significant compared to the reference sediment (and less than 70 percent of the mean reference sediment growth rate for the *Neanthes* bioassay for nondispersive sites), the DMMU is judged to be unsuitable for unconfined open-water disposal.

7.2.7. Freshwater Bioassays “One-Hit” Failure

Amphipod 10-day Survival Bioassay. For the amphipod bioassay, mean test mortality greater than 25 percent over the mean reference response, and statistically different from the reference (alpha = 0.05), is considered a one-hit failure.

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

Midge 10-day Survival/Growth Bioassay. For the midge 10-day mortality test, a mean mortality in test sediment of 25 percent over reference and statistically different from reference (alpha = 0.05) is a one-hit failure. For the midge 10-day growth test, a mean reduction in biomass greater than 30 percent and statistically different from reference (alpha = 0.05) is considered a one-hit failure.

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

Microtox® Luminescence Bioassay. For the Microtox bioassay, a mean relative reduction in luminescence in test sediment porewater of 25 percent over the mean reference response, and statistically different from the reference (alpha = 0.05), is considered a one-hit failure.

7.2.8. Freshwater Bioassays “Two-Hit” Failure

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

Amphipod 28-day Survival/Growth Bioassay. For the amphipod 28-day survival bioassay, mean mortality in test sediment greater than 10 percent over the mean reference response, and statistically different from the reference (alpha = 0.05), is considered a two-hit failure. For the growth test, a mean reduction in biomass greater than 25 percent and statistically different from the reference (alpha = 0.05), is considered a two-hit failure.

Midge 10-day Survival/Growth Bioassay. For the midge 10-day mortality test, a mean mortality in test sediment of 10 percent over reference and statistically different from reference (alpha = 0.05) is a two-hit failure. For the midge 10-day growth test, a mean reduction in biomass greater than 20 percent and statistically different from the reference (alpha = 0.05) is considered a two-hit failure.

Midge 20-day Survival/Growth Bioassay. For the midge 20-day mortality test, a mean mortality in test sediment of 15 percent over the mean reference response, and statistically different from the reference (alpha = 0.05), is considered a two-hit failure. For the growth test, a mean reduction in biomass greater than 25 percent and statistically significance is considered a two-hit failure.

Microtox® Luminescence Bioassay. For the Microtox bioassay, a mean relative reduction in luminescence in the test sediment porewater of 15 percent over the mean reference response, and statistically different from the reference (alpha = 0.05), is considered a two-hit failure.

7.3. 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 TOC. In some areas of the Pacific Northwest region, the Corps and EPA have identified locations suitable for use as reference sites. Reference site grain-size should match, as closely as possible, that of the test sediment and/or the disposal environment. While there is no specified criteria established as to how closely the test and reference sediments should match in grain size and/or total organic carbon levels, one “rule of thumb” provided in DMMP Clarification Papers and in the DMMP User’s Manual (DMMP 2008) suggests that an ideal reference sediment would have less than 25 percent difference in percent fines and less than a 1 percent difference in TOC than that of the test sediment and/or the disposal environment.

Reference site selection and reference sample collection must be coordinated with the PRGs/DMMP, as well as any other state or federal agency with regulatory interest in the bioassay results. For the Puget Sound Region and for Grays Harbor and Willapa Bay in the state of Washington, the DMMP User’s Manual (DMMP 2008) provides additional information on identified reference sediment collection sites, as well as sampling guidelines for use at these collection sites.

For freshwater environments, approved reference sediment collection sites are not currently available. However, a DMMP Clarification Paper was prepared (Stirling and RSET 2008) that provides a process for the identification of freshwater reference sediment collection sites (also provided in a white paper available at https://www.nwp.usace.army.mil/pm/e/rset.asp). It is recommended that the project proponents use this process in identifying project or area specific freshwater reference sediment collection locations. If the control sediment is similar in grain size and in TOC levels to the test sediment, then it can be considered an acceptable substitute for the reference sediment and the data will be interpreted accordingly (DMMP 2008).

CHAPTER 8. BIOACCUMULATION EVALUATION

The Clean Water Act, the Marine Protection, Research and Sanctuaries Act, and other authorities require the assessment of the potential for bioaccumulation. This chapter was developed by an interagency Bioaccumulation Subcommittee composed of scientists representing agencies, consulting firms, and laboratories throughout the Pacific Northwest to address this requirement. To the best of the Subcommittee's knowledge, the resulting values and approaches represent best available science and are based on, and consistent with, federal and state agency risk assessment guidance.

The proposed approach in this chapter represents a change to the way in which bioaccumulation testing would be required and evaluated, in large part by elevating the significance of bioaccumulation within the overall testing framework and potentially increasing the frequency of bioaccumulation testing.

This chapter has identified default target tissue levels (TTLs) but does not provide sediment bioaccumulation triggers (BTs). Both agencies and applicants are encouraged to consider potential exposure pathways in determining whether testing is appropriate and what values to use for evaluation when considering bioaccumulation impacts. If you have any questions regarding this chapter, please contact your PRG/DMMP to determine what bioaccumulation test may be necessary for your project.

The RSET agencies are committed to continuing work with regional and national technical experts and stakeholders to further develop and evaluate approaches to assessing bioaccumulation impacts to meet our legal responsibilities in a manner that is scientifically defensible yet does not present an undue hardship on the regulated community. However, until these approaches are more fully reviewed, the existing approaches as described by the DMMP or the Oregon Department of Environmental Quality (ODEQ) will be considered as viable options and available to applicants to assess bioaccumulation until the approach outlined in this chapter is fully developed and reviewed for its regulatory applicability, reliability, and impacts.

The regulatory agencies in the state of Washington have been involved in executive-level discussions on open water disposal guidelines for dredged material containing dioxins in Puget Sound. A preferred option for assessing and managing risks for dioxin has been identified by agency staff and is currently under public review. In addition, the ODEQ has an approach as described in its Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment (2007). These efforts may or may not be directly applicable to coastal, freshwater, or riverine environments or to dispersive sites, which may require their own approach.

8.1. INTRODUCTION

Contaminants defined as "bioaccumulative" are those that accumulate in the bodies of receptor or food species at levels higher than those in their environment. Some of these compounds also "biomagnify" or increase in concentration up the food chain. A bioaccumulation evaluation is conducted if there is a reason to believe that chemicals present in sediments may contribute to levels in the aquatic food chain that could be harmful to fish or shellfish, or to wildlife or humans eating fish or shellfish. Federal- or state-listed threatened and endangered species are of particular concern, such as salmon and orca whales. Health effects to sensitive human populations, such as tribal and urban subsistence consumers, pregnant women, and children are also of concern.

A bioaccumulation evaluation is conducted as follows:

1. Determe whether there is a reason to believe that a bioaccumulation evaluation needs to be conducted (Section 8.2).
2. Identify bioaccumulative chemicals of concern (BCoCs) that are present or likely to be present in project sediments (Section 8.3).
3. Compare the concentrations of these BCoCs to interpretive guidelines for sediments or tissues (Section 8.4).
4. Conduct bioaccumulation tests or collect and measure concentrations in organisms in the area (Section 8.5).

Bioaccumulation tests are considered optional, and could be conducted under the following circumstances:

- Sediment BTs are exceeded and the project proponent wishes to over-ride that determination through comparison of test results to TTLs.
- Sediment BTs do not exist for some BCoCs in project sediments, and there is a reason to believe they are present and could bioaccumulate (alternatively, a comparison to background could be conducted).

Although frequently conducted as a Level 2B, 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 to avoid delay by a second round of sampling.

Currently, certain aspects of this evaluation are still conducted on a case-by-case basis. While protective tissue concentrations have been identified (TTLs), contaminant concentrations in sediments that may be harmful have not been fully evaluated or finalized. Currently, the SEF does not provide BTs for sediments; when they are developed, it may be on a district-by-district basis for for differing environments, as need and staff resources dictate. In the meantime, existing BTs may be used if they are protective and consistent with the concepts presented in this chapter. The ODEQ has established sediment BTs for use in Oregon, and the Seattle District also has bioaccumulation guidance. In areas without sediment BTs, or for individual chemicals for which bioaccumulation-based BTs are not yet available, a comparison to background concentrations should be conducted (see Section 8.4.3). Some existing BTs may be out of date or not fully protective; however, it is expected that there will be an interim timeframe in which districts are updating their existing guidance and conducting public review of the new values.

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 10).

This chapter includes information on establishing reason to believe for triggering a bioaccumulation evaluation, the identification of BCoCs, the interpretive criteria (TTLs) used for decision-making, recommended bioaccumulation tests, and species and the quality control requirements for each test. References are provided for more detailed information on test protocols and test interpretation. Appendix C provides information on the development of the BCoC lists for each Corps District, and Appendix D describes the derivation of the TTLs in detail.

8.2. REASON TO BELIEVE

The approach used to evaluate *reason to believe* will become more focused over time as sediment BTs become available. A fundamental assumption 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 in aquatic life is unknown and varies among and within water bodies due to many site-specific factors.

To move forward in the face of these unknowns, the RSET will rely on a weight of evidence approach using the factors listed below to develop a reason to believe that a bioaccumulation evaluation is or is not needed for an individual dredging project.

Reason to believe for dredging projects will be based on the following factors:

- The overall ranking for the area (see Chapter 4), indicating the likelihood that contaminated sediments are present.
- Known sources and existing sediment or tissue data at or near the project.
- Agency experience with past projects in the area.
- Comparison of any existing sediment or tissue data to the regional BCoC list (see Section 8.3), TTLs (Section 8.4), and sediment BTs (once developed). If sediment BTs are not available or are below background, comparison of sediment concentrations to background concentrations will be used to determine whether BCoCs are elevated (see Section 8.4.3).

In general, the agencies will conduct the initial determination of *reason to believe* upon receipt of a dredging application, and inform the applicant of specific bioaccumulation concerns. The BTs and/or background concentrations specific to the Corps District will be used as part of this evaluation. If there is no existing chemistry or fish tissue data for the project area, a reason to believe determination for bioaccumulation may need to be delayed until sediment chemistry data are collected.

The project proponent may also present information indicating that there is no *reason to believe* that one or more chemicals are likely to be present at levels of concern in aquatic life. Types of information that could be used include:

- Comparison of existing sediment data to sediment BTs or background concentrations.
- Comparison of existing bioaccumulation test results for other projects in the area to the TTLs.
- Collection/compilation of tissue data from the area and comparison to the TTLs.
- A project design that would reduce concentrations of bioaccumulative chemicals below levels of concern (e.g., dredging into native sediments followed by upland disposal). In this case, impacts during dredging would still need to be evaluated and should include consideration of potential bioaccumulation impacts.

8.3. BIOACCUMULATIVE CHEMICALS OF CONCERN

The BCoC lists (Appendix C) are used along with existing data (if available) to identify reason to believe for a new project in the same area. In addition, the BCoC lists are used along with the project chemistry data to identify chemicals for which a bioaccumulation evaluation should be conducted.

Three regions have been identified, each with their own BCoC list generally corresponding to the three Corps of Engineers Districts: (1) Puget Sound, Strait of Juan de Fuca, and coastal Washington; (2) Eastern Washington and Idaho; and (3) Oregon, including coastal areas, Willamette River, and the Columbia River where it borders Oregon and Washington. The regional BCoC lists for these areas are similar, but have minor differences related to chemical usage and detection in the three areas. The RSET-wide list (all chemicals listed in Table 8-1) is available as a default for areas where more specific data are not available. The analytical methods and detection limits associated with the BCoCs listed in Table 8-1 are provided in Chapter 6.

Detailed information on how the lists were derived can be found in Appendix C. In general, these chemicals meet all three of the following criteria: (1) they have a high enough K_{ow} (or known toxicity of the contaminants to human and ecological receptors) to be bioaccumulative (or have organic forms, in the case of metals); (2) they are known to have human health and/or ecological risks; and (3) they are found in sediments and/or tissues in the region with sufficient frequency to be of concern.

Agencies may opt to conduct or require bioaccumulation testing for additional BCoCs, if there is reason to believe they may be present. Similarly, cleanup sites are not limited to the regional BCoC lists developed to streamline dredging evaluations.

Table 8-1. Regional Bioaccumulative Chemicals of Concern (BCoCs) Lists

Chemical	Seattle District	Portland District	Walla Walla District[a]
Arsenic	X		X
Lead	X		X
Mercury	X	X	X
Selenium	X	X	X
Tributyltin	X	X	
Fluoranthene	X	X	X
Fluorene		X	
Pyrene	X	X	X
Hexachlorobenzene	X	X	X
Pentachlorophenol	X		X
Total Chlordanes	X	X	X
DDTs - Total	X	X	X
Dieldrin		X	X
Total Endosulfans		X	
gamma-HCH (Lindane)		X	
Methoxychlor		X	
Total PCB Aroclors[b]	X	X	
Total PCB Congeners[b]	X	X	
Dioxins/Furans	X	X	X

[a] BCoC list developed based on multiple lines of evidence due to limited sediment and tissue data; contact Walla Walla District for more information and see Appendix C.
[b] Aroclors would typically be analyzed for sediments, while congeners would be analyzed in tissues.

8.4. BIOACCUMULATION INTERPRETIVE GUIDELINES

Currently, bioaccumulation testing is required when there is reason to believe that specific CoCs may be present at levels that will lead to bioaccumulation at unacceptable levels at disposal sites. Reason to believe has previously been established by comparing sediment concentrations to BTs. However, most of these existing sediment BTs were based on the PSDDA program's 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.

As a first step toward developing sediment BTs, TTLs have been developed to be 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 dredging or cleanup.

The most significant obstacle in pursuing this approach is establishing BTs for sediments that are scientifically defensible, because of the site-specific nature of BSAFs. Nevertheless, this is a desired goal of the dredging program, as it will simplify the decision process for applicants and reduce the cost of testing. Ultimately, the RSET envisions that disposal site-specific or region-specific BSAFs will be available for development of sediment BTs. In the meantime, TTLs are provided below.

8.4.1. Target Tissue Levels

The Bioaccumulation Subcommittee identified several groups of receptors for which TTLs should be established:

- Aquatic life including Endangered Species Act (ESA) and special-status species (fish, mussels, snails, etc.);
- Wildlife consumption of fish and invertebrates; and
- Human consumption of fish and shellfish.

Tissue levels for the first two sets of receptors are based on back-calculation using established risk assessment techniques and receptors common in the Pacific Northwest (see Appendix D). Tissue levels for protection of aquatic life are based on tissue-residue-effects data contained in databases, such as the Environmental Residue Effects Database (ERED), once quality assurance has been applied. Each of the above receptor groups is protected under the regulatory programs addressing sediments; therefore, it is assumed that the lowest of the applicable levels will be used. However, the approaches and input values used to derive each of the levels are provided in Appendix D to support project- or site-specific evaluation. For example, fish consumption rates may vary by region, disposal site, or watershed, as may the wildlife and ESA receptors present.

Dredging agencies and site managers may modify these values based on best available science and site-specific factors, as recorded in a project decision document such as a suitability determination or record of decision. In addition, the SEF itself includes several sets of TTLs for different purposes. For example, human health exposure scenarios may be very different at an ocean disposal site than in an urban waterway.

8.4.1.1. Target Tissue Levels to Protect Aquatic Life

The TTLs shown in Table 8-2 for fish and other aquatic life were calculated using the species-specific life history parameters and the TRVs for the BCOCs identified in Appendix D, Section D.1. Two types of values are shown in Table D-4, based on their method of derivation. These values are based on the species sensitivity distribution (SSD) approach, and additional interim values are also presented that were calculated from water quality criteria and bioconcentration factors (ODEQ 2007). These interim values can be used until enough data are available to apply the SSD approach for all chemicals.

Table 8-2. Target Tissue Levels (TTLs) for Protection of Aquatic Life

Chemical	SSD Derived TTL[a]	AWQC Interim TTL Freshwater/Marine (mg/kg ww)
Arsenic[b]		6.6 / 1.6
Lead[b]		0.12 / 0.40
Mercury	0.11 mg/kg ww	
Selenium	7.9 mg/kg dw	
Tributyltin[c]	0.02 mg/kg ww 0.19 mg/kg ww	
Fluoranthene		19
Fluorene		NA
Pyrene		1.0
Hexachlorobenzene		32
Pentachlorophenol	0.001 mg/kg ww	
Total Chlordanes[b]		0.06 / 0.056
DDTs – Total	0.09 mg/kg ww	
4,4'-DDE		0.054
4,4'-DDD		0.054
Dieldrin		0.26
Total Endosulfans		NA
gamma-HCH (Lindane)		NA
Methoxychlor		NA
Total PCB Aroclors	1.4 mg/kg lipid	
Dioxins/Furans/coplanar PCBs		NA

NA = Not available; ww = wet weight
[a] Because these TTLs are compiled from the literature, they do not all have the same units.
[b] Where two values are shown, the first is a freshwater value and the second is a marine value.
[c] Two values are presented for tributyltin, one based on effects to gastropods and one based on an evaluation of multiple species (see Table D-1).

8.4.1.2. Target Tissue Levels to Protect Aquatic-dependent Wildlife

The TTLs for aquatic-dependent wildlife shown in Table 8-3 were calculated using the species-specific life history parameters and the TRVs for the BCoCs identified in Appendix D, Section D.2. Values are presented for ESA species [based on the no-observed-adverse-effect level (NOAEL)] and for population-level protection of other wildlife species in the Pacific Northwest [based on the lowest-observable-effect level (LOAEL)]. The lowest of the species-specific values are shown in Table 8-3 below for two different types of environments:

- TTL_{DW} is based on protection of marine species expected to be found in the vicinity of deep water, nondispersive disposal sites, such as the deeper sites in Puget Sound and ocean disposal sites offshore of Oregon. It includes bald eagle, osprey, northern sea otter, and orca whale.
- TTL_{NS} is based on protection of species that may be found in shallower coastal and inland areas, which would apply to marine or riverine dispersive disposal sites, projects in nearshore marine or estuarine areas, projects in freshwater areas, or beneficial use projects. It includes a much wider variety of species, such as great blue heron, belted kingfisher, hooded merganser, black-necked stilt, American avocet, spotted sandpiper, bald eagle, osprey, river otter, northern sea otter, American mink, and harbor seal.

To select individual species representative of a specific disposal site, project area, or cleanup site, see the species-specific TTLs presented in Appendix D, Tables D-5 through D-8.

Table 8-3. Target Tissue Levels (TTLs) for Protection of Aquatic-dependent Wildlife

Chemical	**Deep Water**		**Nearshore**	
	TTL_{DW} ESA (mg/kg ww)	**TTL_{DW} Pop. (mg/kg ww)**	**TTL_{NS} ESA (mg/kg ww)**	**TTL_{NS} Pop. (mg/kg ww)**
Arsenic	11	53	2.7	14
Lead	7.8	39	2.0	10
Mercury	0.06	0.12	***0.02***	0.03
Selenium	1.4	6.9	0.35	1.8
Tributyltin	28	42	8.2	21
Fluoranthene	7.4	36	3.8	19
Fluorene	790	3900	410	2000
Pyrene	7.4	36	3.8	19
Hexachlorobenzene	NA	NA	NA	NA
Pentachlorophenol	32	160	8.1	41
Total Chlordanes	1.2	5.1	0.26	1.3
DDTs – Total	0.01	0.05	0.01	0.05
Dieldrin	0.34	1.7	0.09	0.42
Total Endosulfans	NA	NA	NA	NA
gamma-HCH (Lindane)	NA	NA	NA	NA
Methoxychlor	NA	NA	NA	NA
Total PCB Aroclors	0.04	0.18	0.04	0.18
Dioxins/Furans/coplanar PCBs TEQ*	9.6×10^{-7}	2.6×10^{-5}	5.0×10^{-7}	8.5×10^{-6}

NA = Not available
Bold, italicized values are known to be near or below MDLs or SQLs. See Chapter 6 for tissue SQLs.
*Methods for calculating dioxin/furan/PCB TEQs are presented in Appendix D, Section D.2.6.15.

8.4.1.3. Target Tissue Levels to Protect Human Health

Table 8-4 shows the TTLs protective of human health. Three columns are available depending on project- or site-specific human uses as shown below (see Appendix D for details of the derivation of these values):

- TTL1 is protective of the general population, and should only be used in areas that are not tribal or urban subsistence areas and which do not have active recreational or commercial fisheries.
- TTL2 is protective of recreational anglers, most Asian and Pacific Islander groups, and mid-range tribal consumption rates.
- TTL3 is protective of high-end tribal consumption; for example, those who obtain most of their protein or food intake from fishing or shellfish collection.

The values listed in Table 8-4 are protective of both carcinogenic and non-carcinogenic toxic effects, and represent the lower of the two values where both exist for a chemical.

Table 8-4. Target Tissue Levels (TTLs) for Protection of Human Health

Chemical	TTL1 (mg/kg ww)	TTL2 (mg/kg ww)	TTL3 (mg/kg ww)
Arsenic	***0.002***	***0.00027***	***0.00008***
Lead	NA	NA	NA
Mercury	0.13	0.040	***0.012***
Selenium	6.5	2.0	0.6
Tributyltin	0.39	0.12	0.036
Fluoranthene	52	16	4.8
Fluorene	52	16	4.8
Pyrene	39	12	3.6
Hexachlorobenzene	0.0019	***0.00025***	***0.000075***
Pentachlorophenol	0.025	***0.0033***	***0.001***
Total Chlordanes	0.0086	***0.0011***	***0.00034***
DDTs – Total	0.0089	***0.0012***	***0.00035***
Dieldrin	***0.00019***	***0.000025***	***0.000007***
Total Endosulfans	7.8	2.4	0.72
gamma-HCH (Lindane)	0.0023	***0.00031***	***0.000092***
Methoxychlor	6.5	2.0	0.6
Total PCB Aroclors	***0.0015***	***0.00020***	***0.00006***
Dioxins/Furans/coplanar PCBs TEQ[a]	***2.3×10^{-8}***	***3.1×10^{-9}***	***9.2×10^{-10}***

NA – not available; lead is known to be toxic at very low levels, but EPA has not established toxicity values.
Bold, italicized values are known to be near or below MDLs or SQLs. See Chapter 6 for tissue SQLs.
[a] Methods for calculating dioxin/furan/PCB TEQs are presented in Appendix D, Section D.3.3.
ww = wet weight; TEQ = toxicity equivalent

8.4.2. Bioaccumulation Triggers for Sediments

At this time, BTs for sediments have not yet been developed and will likely be finalized taking into account localized differences in disposal environments such as salinity and currents. Appendix D provides general guidance for developing BSAFs and associated sediment BTs on a regional- or project-specific basis. Some areas have existing sediment BTs, reflecting various derivation methods. Some of these are consistent with the methods outlined in this chapter, and others need to be updated. Where BTs are protective and bioaccumulation-based, they may be used; otherwise, a comparison to background concentrations may be conducted. It is anticipated that there will be an interim period when the RSET agencies are updating their evaluation procedures and conducting public review. Therefore, the PRGs/DMMP should be contacted for the latest guidance on sediment BTs and/or evaluation procedures applicable to specific projects.

8.4.3. Comparison to Background Concentrations

Derivation methods for TTLs and sediment BTs contain conservative assumptions and methods that may result in very low values, although every attempt is being made to derive values that are realistic while still being protective and in compliance with state and federal regulations. Some of the TTL calculations do result in values that are below background concentrations and detection limits, and it is expected that the same will be the case for the sediment BTs. In these cases, the use of a TTL or sediment BT may be replaced by a comparison to background levels, or detection limits if background or risk-based levels are undetected.

The first step in this process is to establish background concentrations suitable for the disposal site and project area in question. The specific definition of background that applies often depends on state regulations, and may include natural concentrations and in some cases, globally distributed anthropogenic compounds. In most areas, the agencies will have collected this information on a regional basis, rather than a project-specific basis. Freshwater disposal or project environments may require more detailed evaluation than marine waters, as freshwater areas vary considerably over short distances, particularly with respect to natural metals concentrations. The Corps and other agencies are actively evaluating suitable sampling areas and background concentrations within their districts, and should be contacted for project-specific recommendations.

Once background concentration distributions have been identified for a region, whether on a programmatic or site-specific basis, these distributions will be used for comparison to project data. In most cases, the agencies will determine one or more threshold values that represent the upper end of the background distribution. In addition, the background data set used to calculate the threshold(s) will be available for comparison. If projects have less than 10 samples, each sample must be individually compared to the threshold(s) calculated by the agencies. If projects have more than 10 samples, the single-sample comparison approach described above may be used, or project proponents have the additional option of comparing the project distribution to the background distribution directly, without using a threshold.

The specific statistical methods to be used are as follows, based on a statistical experts' workshop conducted on October 7, 2008 in Seattle, Washington (the complete report can be found at https://www.nwp.usace.army.mil/pm/e/rset.asp):

- Nonparametric methods that do not rely on specific distributions are to be used. Substitutions for non-detects are not required and should not be conducted. See the experts' workshop report for nonparametric, non-substitution methods of calculating sums for classes of compounds such as dioxin/furan TEQ.

- For calculation of an upper threshold concentration based on a background data set with 10 or more samples, an upper tolerance limit (UTL) based on the 90th upper confidence limit on the 90th percentile is recommended. This corresponds roughly to containing 95 percent of the data in the background data set. The UTL should be calculated using the Kaplan-Meier nonparametric method.
- For calculation of an upper threshold concentration based on a background data set with less than 10 samples, ad hoc methods based on upper percentiles are recommended. The specific percentile will be based on the nature of the data set and agency discretion.
- For single-sample comparisons, project samples will be compared to the UTL (or other threshold, as appropriate), and if equal to or less than the UTL, the sediments will be considered suitable for open-water disposal. If above the UTL, the sediments will be considered unsuitable. A similar comparison could be conducted to evaluate whether a sample at a cleanup site exceeds background.
- Alternatively, the agencies may choose to conduct comparisons on a volume-weighted basis, with volume-weighted average concentrations not to exceed the UTL and an upper threshold for individual DMMUs. This approach takes into account the area-wide nature of bioaccumulation exposures and allows for limited averaging within and/or among projects disposed at the same time.
- For comparisons of project distributions to background distributions, both populations must have at least 10 samples. The comparison is to be made with the Wilcoxon-Mann-Whitney nonparametric test (or Gehan's test if multiple detection limits are present). If the project distribution is not statistically greater than the background distribution, the project sediments represented by the distribution will be considered suitable for open-water disposal. An additional comparison of the tails of the distributions may be conducted at agency discretion using a quantile test to determine whether individual project samples may be unrepresentative of the upper tail of the background distribution.

All statistical tests should be conducted using ProUCL 4.0, R, or an equivalent professional statistical package that contains the non-parametric tests described above.

Basing reason to believe on tissue and sediment elevations above background in the interim before BTs can be established, while somewhat unavoidable based on state and federal regulatory requirements, 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. It is recognized that this may present challenges for smaller projects; for these projects, see Section 4.3.2.

8.5. BIOACCUMULATION TEST METHODS

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. At the end of the test, tissue concentrations are measured and compared to the TTLs listed in Section 8.3, provided steady-state conditions are achieved or can be estimated. This is the most common approach used in the dredging program.

- **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 and may not address contaminated subsurface sediments that might be dredged.
- **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 sediments in place, 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.

8.5.1. Laboratory Bioaccumulation Tests

The Ocean Testing Manual (EPA/Corps 1991) and the Inland Testing Manual (Corps/EPA 1998c) 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 variegatus*) and a second 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 be 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., PCBs, TBT, and 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 (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 extrapolation of measured tissue concentrations to steady-state concentrations for these chemicals should be conducted (using chemical-specific information from published studies) prior to using this data to judge sediment suitability. Discussions should occur between the project proponent and the PRGs/DMMP and other relevant agencies to determine an appropriate study design based on the constituents of interest.

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, because subsurface sediments may have higher concentrations than surface sediments. Each of the following two methods assesses primarily surface sediments, and can be used when surface exposure is the only exposure pathway of concern or when surface sediments have similar or higher concentrations than subsurface sediments.

8.5.2. *In situ* Bioaccumulation Testing

Consensus-based 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 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 in the field 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 (see the white paper at https://www.nwp.usace.army.mil/pm/e/rset.asp for a complete discussion of marine and freshwater species that are available and the basis for the recommendations below).

8.5.2.1. 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* also frequently used).
Oysters: *Crassostrea gigas*, *Ostrea lurida*.
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.

8.5.2.2. 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 may 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 (Salazar and Salazar 1998), these include: (1) bivalves; (2) gastropods; and (3) decapods (crayfish). 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. A gastropod test may be recommended for areas where threatened, endangered, or candidate species of snails occur, such as in some waterways of Idaho. *Lumbriculus variegatus* (an oligochaete) has also been suggested by several agencies as a potential species that could be used. Further identification of *in situ* species will be conducted by RSET, as needed.

8.5.3. Collection of Field Organisms

This assessment involves measurements of tissue concentrations from individuals of the same species collected from 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 at or near the project site. The 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 the PRGs/DMMP and/or other relevant agencies prior to conducting such a field program to ensure consistency with project objectives.

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 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.

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).

CHAPTER 9. DISPOSAL ALTERNATIVES EVALUATION

9.1. INTRODUCTION

The need for a conceptual site model (CSM) and sampling and analysis procedures to enable sound management decisions were discussed in previous chapters. This chapter discusses dredged material 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 reader 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 evaluated to determine the best disposal option. Refer to the Dredging Operations and Technical Support Program (DOTS) website located at 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 is typically conducted in 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, floodplains, and wetlands may adversely affect water quality and aquatic life (PIANC 1990). Determining a disposal option can be one of the most costly, 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 CSM because sediment evaluation should always have a clearly defined purpose and objective(s). To assist in this evaluation, many agencies like the Corps and EPA and technical subcommittees like the Permanent International Association of Navigation Congresses (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 dredged material. 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.

9.2. OVERVIEW OF DREDGED MATERIAL DISPOSAL OPTIONS

The removal, transport, and placement of dredged sediments are the primary components of the “dredging process.” Each part of the 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 than planning for a project involving contaminated sediments. The main goal of a maintenance dredging project is to remove sediment to navigational depth and most of the planning tends to be directed to meeting this goal. The main goal for contaminated sediment dredging projects is usually the improvement and protection of the environment, as well as navigation. Therefore, managers for these projects are often forced to plan for all situations to be discussed with the regulatory and scientific community.

The primary disposal options in the Pacific Northwest are shown below. Other management options may also exist (e.g., natural recovery), but are not discussed in detail in this chapter.

- Unconfined Open Water
- Beneficial Use (see Chapter 12 for additional details)
- Confined In-water (Capping)
  - Thin Cap
  - Thick Cap
- Dredging with Confined Disposal
  - Confined Aquatic Disposal
  - Nearshore Fill
- Upland Disposal

Permitting and regulatory requirements for these various options vary from state to state, and between options. It is beyond the scope of this manual to detail regulations and permitting requirements for each of these options. Applicants should coordinate with their federal and/or state agency contacts to determine what regulations apply and what permits may be required. However, any discharge of dredged or fill material (all in-water disposal options) into waters of the United States will require authorization under Section 404 of the Clean Water Act (CWA), which will also require a Section 401 water quality certification.

9.3. Disposal Options for Uncontaminated Sediments

9.3.1. Unconfined Open-water Disposal

Open-water disposal is the placement of dredged material in rivers, lakes, estuaries, or oceans via pipeline dredging or release from a hopper dredge or barge. Dredged material can be placed in an approved open-water site using direct pipeline discharge, direct mechanical placement, or release from hopper dredges. Open-water disposal sites can be either predominantly nondispersive or dispersive. At nondispersive sites, most of the material is intended to remain on the bottom following placement. At dispersive sites, material may be dispersed either during placement or eroded from the bottom over time by current and/or wave action.

In some non-ocean waters and waters subject to the CWA, there may be interagency selected, operated, and monitored dredged material disposal sites. In Washington, the Puget Sound Dredged Disposal Analysis (PSDDA) agencies are responsible for certain sites. Locations and disposal site descriptions for these sites in Puget Sound are available at http://www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=DMMO&pagename=Users_Manual.

9.3.2. Ocean Disposal

In 1972, Congress enacted the MPRSA 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 of dredged material cannot occur unless a site is either selected temporarily by the Corps or permanently designated by EPA. For the transport of dredged material to an ocean disposal site, a permit is issued by the Corps, with EPA's concurrence, under the MPRSA. Permitting and site selection using EPA's environmental criteria are subject to EPA's concurrence.

For all other types of materials (non-dredged material, vessels, fish waste, etc.), EPA is the permitting agency for ocean dumping and is responsible for designating ocean dumping sites.

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 CWA must also comply with the applicable requirements of NEPA and its implementing regulations. In addition to the MPRSA, CWA, and NEPA, many federal laws, executive orders, policies, and guidance must be considered, as well as state environmental laws and regulations.

The geographical jurisdictions of the MPRSA and CWA are shown in Figure 2-1. As shown in this figure, an overlap of jurisdiction exists within the territorial sea. The regulatory guidelines for the specification of disposal sites for dredged or fill material lying inside of the baseline from which the territorial sea is measured, or into the territorial sea, are found at 40 CFR 230.2(b) and 33 CFR 336.0(b). The discharge of dredged material into the territorial sea is governed under MPRSA and the regulatory criteria at 40 CFR parts 220 to 228. In general, dredged material discharged as a structure or fill (e.g., beach nourishment, island creation, or underwater berms) and placed within the territorial sea is evaluated under the CWA and applicable state laws and regulations, while material disposed within the territorial sea as a "wasting" action is evaluated under the MPRSA.

The EPA-designated ocean dredged material disposal sites in the region are codified at 40 CFR 228.15(n). Coordinates for these ocean disposal sites, as well as restrictions and conditions for their use, are listed in that section. The use of EPA-designated dredged material disposal sites are further governed by site management and monitoring plans.

9.4. DISPOSAL OPTIONS FOR CONTAMINATED SEDIMENTS

Identification of reasonable disposal sites for contaminated sediments must take into account scientific methods that evaluate multiple criteria, including ecologic, geologic, hydrogeologic, economic, social, and other factors. The CWA and MPRSA generally prohibit the disposal of contaminated material into ocean waters (ocean waters are those waters seaward of the baseline). Contaminated sediment disposal regulations generally apply to the assessment of contaminated sediment and potential disposal scenarios in non-ocean waters, and they may differ for each state within EPA Region 10. Coordination with the appropriate state and federal agencies will be needed. Contaminated sediments can be removed by dredging, either through mechanical means (i.e., clamshell) or with suction (i.e., hydraulic cutterhead dredge).

9.4.1. 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 may be considered as an option when the costs of removal are deemed greater than the benefit, and navigation depths are not of primary concern. There are two types of caps:

- Thin Cap. A thin cap typically occurs in areas with lower 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.

9.4.1.1. Capping Benefits

Capping is one method to isolate contaminated sediment from the surrounding aquatic environment. Chemical contamination is isolated from the environment. Over time, and coupled with successful source control, the waterways can be expected to constitute much-improved habitat for invertebrates, fish, and birds.

9.4.1.2. Thin Cap

Thin capping, also known as enhanced natural recovery, is often used where hazards presented by contaminated sediment to human health and the environment is low. Thin capping improves the chemical or physical properties of the upper sediment bed, which constitute the biologically active zone. Thin capping typically has a target thickness of 3 feet 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 sediment bed 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 Wyckoff/Eagle Harbor Superfund Site located off Bainbridge Island, Washington (see EPA website at http://cfpub.epa.gov/supercpad/cursites/csitinfo.cfm?id=1000612).

9.4.1.3. Thick Cap

Placement of a thick cap over a problem area is intended to effectively contain and isolate the contaminated sediments from the benthic community in surface sediments, overlying water column and habitat. In navigation areas where the total thickness of contaminated sediment 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.

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.

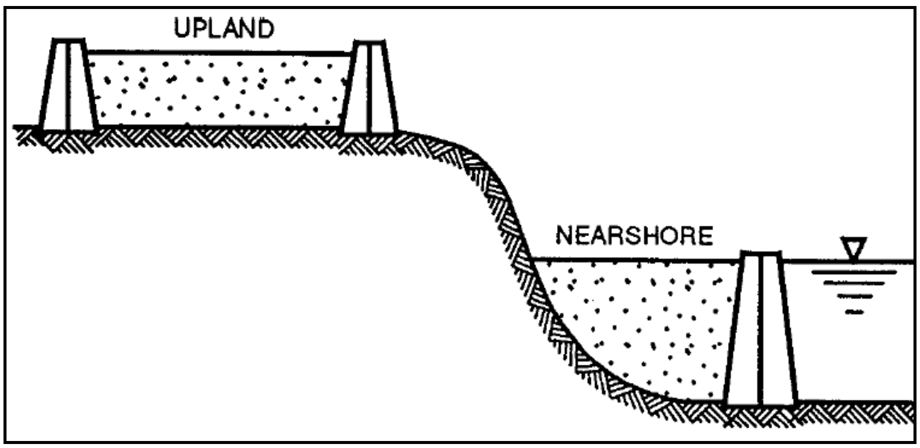
9.4.2. Confined Aquatic Disposal

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 aquatic environment. This can occur through contaminant migration, bioturbation, or cap erosion. Thus, a CAD may be of limited value in areas where future dredging would disturb the site or where currents, wave climate, and/or physical disturbance by navigation (e.g., anchor dragging or propeller wash) could impact the cap. The primary design components of a CAD are the physical (i.e., thickness and gradation) and chemical quality of the cap, depth, topography, and currents at the site. A CAD can be built without a net loss of habitat and in some instances, a net gain.

9.4.3. Nearshore Confined Disposal Facility

A nearshore confined disposal facility (CDF) typically involves 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 9-1). In this document, nearshore confined disposal does not refer to subaquatic capping or CAD.

Figure 9-1. Upland and Nearshore Confined Disposal Facilities



Nearshore confined disposal facilities provide an 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 down-drag of compressing soils along the pile sides.

Nearshore confined disposal facilities may 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. Permits may be challenging to obtain, with the primary issues being loss of habitat and mixing zones. Oregon requires a solid waste disposal permit or permit exemption for disposal or placement of dredge sediment in a nearshore or upland confined disposal site.

9.4.4. 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.

9.4.4.1. Solid Waste Landfills

Existing solid waste landfills may accept contaminated sediments, as long as those sediments do not designate as hazardous waste. Sediments that are hazardous waste must be sent to a Subtitle C landfill. These landfills have evaluation methods, acceptance criteria, and standards 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.

9.4.4.2. 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 facility. The main challenge of a 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. The primary long-term transport pathway is loss 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 the state of Washington, upland disposal facilities need to be designed and constructed in accordance with current state solid waste regulations. Oregon requires that upland disposal facilities receive a solid waste disposal permit or permit exemption for disposal or placement of dredge sediment at an upland site. Design and construction requirements will be addressed through Oregon's solid waste permit.

Characteristics used to evaluate upland disposal sites include the following:

- Site configuration and access;
- Topography, runoff patterns, and adjacent drainage;
- Groundwater levels, flow, and direction;
- Soil properties;
- Design and construction characteristics such as structural integrity and slope stability to prevent any leaching, migration, washout, seeps, capping or other means of preventing contaminant transport and exposure to contaminants; and
- Proximity to ecologically sensitive areas and/or human resources.

9.5. OTHER MANAGEMENT OPTIONS

Natural Recovery. Natural recovery of contaminated sediment may occur over time through a combination of several processes, including chemical degradation, diffusion from the sediment matrix into the water column, burial of contaminated sediment under newly deposited clean material, and mixing of contaminated sediment with clean sediments above and below through bioturbation. Models are often used to predict natural recovery within a given time frame. 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 contaminated sediments, 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.

CHAPTER 10. SPECIAL EVALUATIONS

10.1. INTRODUCTION

Chapters 4 through 8 provide a framework for the assessment and characterization of freshwater and marine sediments for dredging projects and contaminated sediment investigations. In most cases, the methods and procedures provided will be sufficient to evaluate the potential environmental effects of dredging and disposal activities, as well as the potential risk of in-place sediments left behind at the dredge site. However, in some cases additional information may be needed beyond the standard suite of physical, chemical, and biological tests to make informed sediment management decisions. 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 the PRGs/DMMP. For example, the following circumstances may warrant conducting special evaluations 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 7 and 8 are inappropriate;
- Additional information is needed regarding potential risks to 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 the PRGs/DMMP, site-specific tests or evaluations and interpretive criteria will be specified in coordination with the applicant. Special evaluations may include, but are not limited to, the following:

- Human Health/ Ecological Risk Assessment (Section 10.2),
- Elutriate Testing (Section 10.3), and
- Evaluation of Dredging Residuals (Section 10.4).

10.2. HUMAN HEALTH/ECOLOGICAL RISK ASSESSMENT

When deemed appropriate by the PRGs/DMMP, a human health and/or ecological risk assessment may be requested to evaluate a particular chemical of concern (CoC), such as dioxin, mercury, PCBs, and others. 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 the PRGs/DMMP and all parties actively participating.

Available state and federal risk assessment guidance documents are summarized below.

10.2.1. 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. The 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.

The 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. The guidance for Ecological Risk Assessment can be downloaded at http://www.deq.state.or.us/lq/cu/ecorisks.htm.

For human health risk assessment, both statute and rules provide the option of performing either a deterministic risk assessment or a probabilistic risk assessment. The ODEQ has developed a guidance document for each of these options. The guidance documents for Human Health Risk Assessment can be downloaded at http://www.deq.state.or.us/lq/cu/health.htm.

10.2.2. Washington State Risk Assessment Guidance

The state of Washington has adopted SMSs as Chapter 173-204 WAC. The standards 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 website: 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 at the following website: http://www.ecy.wa.gov/biblio/9406.html.

10.2.3. Idaho State Risk Assessment Guidance

The IDEQ's *Risk Evaluation Manual* presents a roadmap for evaluating risk from discovery through cleanup. 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. A copy of the manual can be downloaded at http://www.deq.idaho.gov/Applications/Brownfields/index.cfm?site=risk.htm.

10.2.4. Federal State Risk Assessment Guidance

In addition to the state-specific guidance cited above, the following EPA and Corps documents may also be consulted for additional guidance on risk assessment procedures and parameters.

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

EPA. 1989a. 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/oswer/riskassessment/ragsa/pdf/rags-vol1-pta_complete.pdf.

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/oswer/riskassessment/ecorisk/ecorisk.htm.

Corps. 1999. Risk Assessment Handbook Volume I: Human Health Evaluation. EM 200-1-4. Available at http://www.usace.army.mil/publications/eng-manuals/em200-1-4/toc.htm.

Corps. 1996b. Risk Assessment Handbook Volume II: Environmental Evaluation. EM 200-1-4. Available at http://www.usace.army.mil/publications/eng-manuals/em200-1-4vol2/toc.htm.

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, 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.

10.3. 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 Environmental Laboratory at the Engineering Research and Development Center (ERDC; see below), are used to predict water quality effects during dredging and disposal activities, particularly when contaminated sediments 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 site risk, potentially including bioaccumulation risk if residuals deposits are sufficiently thick and extensive (Bridges et al., 2008). Dredging residuals are generated when contaminated sediments 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 10.4.

10.3.1. Water Quality at the Dredging Site

Water quality effects at the point of dredging are evaluated using a dredging elutriate test (DRET; Di Giano et al., 1995) in conjunction with chemical partitioning calculations. As an initial screening evaluation, sediment concentrations that are not expected to cause adverse water quality effects when resuspended at the point of dredging may be estimated using EPA National Recommended Water Quality Criteria (http://www.epa.gov/waterscience/criteria/wqctable), equilibrium partitioning rules, and agency-recommended partitioning coefficients, as specified in EPA guidance documents (EPA 1996; 2002a, b; 2003 a, b, c; 2005). Level 2B secondary water quality criteria derived by the Oak Ridge National Laboratory (ORNL 1997) were used if National Recommended Water Quality Criteria were not available.

Bulk sediment concentrations derived in this manner may be used as guidance values to determine when DRET testing is required during site characterization (i.e., elutriate testing triggers). A summary of relevant water quality criteria, EPA-recommended partitioning coefficients, and elutriate testing triggers are compiled in Table 10-1 (freshwater) and Table 10-2 (marine). Dredging of bulk sediment concentrations below the elutriate testing trigger values would not be expected to exceed water quality criteria at the dredging site.

Elutriate testing triggers for metals are derived using the following equation:

$$\mathbf{ET_{metal} = K_d \times WQC}$$

where:

K_d is the metal partitioning coefficient in L/kg.
WQC is the acute water quality criterion in µg/L.

The calculation of elutriate testing triggers for organic constituents is modified in two important ways. First, the equilibrium partitioning coefficients are a function of the organic carbon content of the sediments:

$$\mathbf{K_d = K_{oc} \times foc}$$

where:

K_{oc} is the organic carbon-partitioning coefficient in L/kg-oc.
foc is the decimal fraction of organic carbon in kg-oc/kg-sed.

Second, because organic constituents are regulated on a “total” basis (whereas metals are regulated on a “dissolved” basis), both the dissolved and the particulate fractions of the water column concentration should be considered.

$$\mathbf{WC_{total} = WC_{diss} + WC_{part}}$$

$$\mathbf{WC_{diss} = SED_{bulk} / K_d}$$

$$\mathbf{WC_{part} = SED_{bulk} \times TSS_{inc} \times 10^{-6}}$$

where:

WC_{total} WC_{diss} and WC_{part} are the total, dissolved, and particulate water column concentrations in µg/L, respectively.

SED_{bulk} is the bulk sediment concentration in the dredge prism in µg/kg.
TSS_{inc} is the incremental added mass of suspended solids in the water column generated by the dredging action in mg/L.
10^{-6} is a conversion factor of milligrams per kilogram of sediment.

Rearranging these equations, solving for SED_{bulk}, and setting WC_{total} to the applicable WQC yields the following equation for deriving elutriate testing triggers for organic constituents:

$$\mathbf{ET_{organic} = WQC / [(TSS_{inc} \times 10^{-6}) + (K_{oc} \times foc)^{-1}]}$$

In Tables 10-1 and 10-2, elutriate testing triggers for organics are presented for a range of sedimentary organic carbon contents (examples are provided for 1 percent and 5 percent TOC) and dredging-induced TSS concentrations (examples are provided for 10 mg/L and 100 mg/L TSS). The site-specific TOC content is determined from chemical analysis of the dredge prism, as discussed in Chapter 6. The site-specific TSS concentrations generated by the dredging action may be predicted using computer models, as discussed in Section 10.3.3. The range of TSS concentrations used in these tables was derived from a literature survey of TSS concentrations measured during various dredging projects, as compiled by the Los Angeles Contaminated Sediments Task Force (2003). The TSS concentrations at distances of 100 to 300 feet from the dredges, which is consistent with typical mixing zone dimensions, ranged from about 10 mg/L to 100 mg/L. If significantly different TOC or TSS concentrations are expected at the project site, partitioning calculations should be modified accordingly.

Elutriate testing triggers derived in this manner are expected to be conservatively protective for the following reasons:

- The contaminant mass on the sediments is assumed to be an infinite source. In reality, as the mass on the sediment particles is depleted through desorption to the water column, decreasing equilibrium concentrations will be observed in both water and sediments.
- When sediments are resuspended during dredging, equilibrium concentrations in the water column are assumed to be achieved instantaneously. In reality, sediment desorption kinetics may delay the achievement of equilibrium, causing water column concentrations to be less than their theoretical maximum values.
- Equilibrium water column concentrations are estimated for the point of dredging. Typically, contaminant concentrations are further attenuated to between one-half and one-tenth of their initial values as a result of mixing within the construction zone, between the dredge and the water quality point of compliance (see Section 10.3.3).

Table 10-1. Elutriate Testing Triggers for Freshwater Sediment

METALS

Chemical	Acute WQC (µg/L)[a]	Reference	Log Kd (Log-L/kg)	Reference	Elutriate Testing Trigger (mg/kg)
Metals (mg/kg)					
Arsenic	340	[1]	4.0	[2]	3,400
Cadmium	2.0	[1]	4.7	[2]	100
Chromium	570	[1]	5.1	[2]	71,759
Copper	13	[1]	4.7	[2]	652
Lead	65	[1]	5.6	[2]	25,877
Mercury	1.4	[1]	5.3	[2]	279
Nickel	470	[1]	4.6	[2]	18,711
Silver	3.2	[1]	4.9	[2]	254
Zinc	120	[1]	5.1	[2]	15,107

ORGANICS

				TOC (%) =	1%	1%	5%	5%
				TSS (mg/L) =	10	100	10	100
Chemical	Acute WQC (µg/L)	Reference	Log Koc (Log-L/kg)	Reference	Elutriate Testing Trigger (µg/kg)	Elutriate Testing Trigger (µg/kg)	Elutriate Testing Trigger (µg/kg)	Elutriate Testing Trigger (µg/kg)
Polynuclear Aromatic Hydrocarbons (µg/kg)								
Naphthalene	807	[3]	3.30	[3]	16,099	16,070	80,429	79,714
Acenaphthylene	1,277	[3]	3.17	[3]	18,885	18,860	94,371	93,748
Acenaphthene	233	[3]	3.94	[3]	20,276	20,118	101,027	97,233
Fluorene	162	[3]	4.14	[3]	22,331	22,058	111,045	104,592
Phenanthrene	79	[3]	4.49	[3]	24,338	23,682	120,209	105,730
Anthracene	87	[3]	4.46	[3]	25,019	24,388	123,672	109,644
2-Methylnaphthalene	300	[3]	3.79	[3]	18,486	18,384	92,205	89,723
Fluoranthene	30	[3]	5.00	[3]	29,703	27,273	142,857	100,000
Pyrene	42	[3]	4.84	[3]	28,857	27,177	140,427	107,945
Benz(a)anthracene	9.2	[3]	5.58	[3]	33,696	25,342	146,952	60,286
Chrysene	8.3	[3]	5.62	[3]	33,216	24,420	143,161	56,090
Benzofluoranthenes (b+k)	2.7	[3]	6.18	[3]	35,494	16,258	116,310	23,849
Benzo(a)pyrene	4.0	[3]	6.00	[3]	36,364	20,000	133,333	33,333
Indeno(1,2,3-c,d)pyrene	1.2	[3]	6.61	[3]	34,735	9,635	80,486	11,438
Dibenz(a,h)anthracene	1.2	[3]	6.60	[3]	34,170	9,591	79,873	11,426
Benzo(g,h,i)perylene	1.8	[3]	6.40	[3]	36,137	12,875	100,211	16,673
Chlorinated Hydrocarbons (µg/kg)								
1,4-Dichlorobenzene	180	[4]	3.36	[5]	4,123	4,114	20,594	20,384
1,2-Dichlorobenzene	260	[4]	3.37	[5]	6,094	6,081	30,439	30,122
1,2,4-Trichlorobenzene	700	[4]	3.94	[5]	60,914	60,441	303,516	292,116
Phthalates (ug/kg)								
Diethyl phthalate	1,800	[4]	2.46	[5]	5,191	5,190	25,953	25,919
Di-n-butyl phthalate	190	[4]	4.53	[5]	64,163	62,270	316,539	275,266
Bis(2-ethylhexyl) phthalate	X	[1]	7.18	[6]	X	X	X	X
Miscellaneous Semivolatiles (µg/kg)								
Pentachlorophenol	19	[1]	2.77	[6]	112	112	559	558
Dibenzofuran	66	[4]	4.00	[5]	6,593	6,535	32,836	31,429

Table 10-1 (continued). Elutriate Testing Triggers for Freshwater Sediment

ORGANICS				TOC (%) =	1%	1%	5%	5%
				TSS (mg/L) =	10	100	10	100
Chemical	**Acute WQC (µg/L)**	**Reference**	**Log Koc (Log-L/kg)**	**Reference**	**Elutriate Testing Trigger (µg/kg)**	**Elutriate Testing Trigger (µg/kg)**	**Elutriate Testing Trigger (µg/kg)**	**Elutriate Testing Trigger (µg/kg)**
Pesticides (µg/kg)								
p,p'-DDD	0.19	[4]	6.00	[6]	1,727	950	6,333	1,583
p,p'-DDE			6.65	[6]				
p,p'-DDT	1.1	[1]	6.42	[6]	22,908	7,970	62,487	10,223
Aldrin	3.0	[1]	6.39	[6]	59,127	21,316	165,311	27,740
Chlordane	2.4	[1]	5.08	[6]	2,851	2,576	13,609	9,011
Dieldrin	0.24	[1]	5.28	[7]	449	384	2,088	1,171
Heptachlor	0.52	[1]	6.15	[6]	6,436	3,045	21,524	4,555
gamma-BHC (Lindane)	0.95	[1]	3.67	[5]	44	44	222	217
Total PCBs	2.0	[8]	5.49	[6]	5,995	4,722	26,767	12,142
Tributyltin[3/]								
TBT dry weight (µg/kg)	0.46	[1]	4.40	[9]	115	113	571	513

Notes:

[a] Water quality criteria for some metals (Cd, Cr, Cu, Pb, Ni, Ag, Zn) are based on an assumed hardness of 100 mg/L; these criteria should be adjusted to the site-specific hardness of the receiving water, as per Reference [1].

References:

[1] EPA National Recommended Water Quality Criteria (2006)

[2] EPA 2005, *Partition Coefficients for Metals in Surface Water, Soil, and Waste* EPA-600/R-05/074

[3] EPA 2003, *Equilibrium Partitioning Sediment Benchmarks: PAH Mixtures* EPA-600/R-02/013

[4] Oak Ridge National Laboratory 1996, *Toxicological Benchmarks for...Effects on Aquatic Biota*

[5] EPA 2002, *Equilibrium Partitioning Sediment Guidelines: Nonionic Organics* EPA-822/R-02/042

[6] EPA 1996, *Soil Screening Guidance User's Guide* EPA-540/R-96/018

[7] EPA 2002, *Equilibrium Partitioning Sediment Guidelines: Dieldrin* EPA-822/R-02/043

[8] State of Oregon OAR 340-041, Tables 20 and 33A

[9] EPA Region 10, 1996, *Recommendations for Screening Level for Tributyltin in Puget Sound Sediment*

X = Toxicity data shows DEHP is not toxic to aquatic organisms at or below its solubility limit; see Reference [1]

Table 10-2. Elutriate Testing Triggers for Marine Sediment

METALS

Chemical	Acute WQC (µg/L)	Reference	Log Kd (Log-L/kg)	Reference	Elutriate Testing Trigger (mg/kg)
Metals (mg/kg)					
Arsenic	69	[1]	4.0	[2]	690
Cadmium	40	[1]	4.7	[2]	2,005
Chromium (III)	1,100	[1]	5.1	[2]	138,482
Copper	4.8	[1]	4.7	[2]	241
Lead	210	[1]	5.6	[2]	83,603
Mercury	1.8	[1]	5.3	[2]	359
Nickel	74	[1]	4.6	[2]	2,946
Silver	1.9	[1]	4.9	[2]	151
Zinc	90	[1]	5.1	[2]	11,330

ORGANICS

				TOC (%) =	1%	1%	5%	5%
				TSS (mg/L) =	10	100	10	100
Chemical	**Acute WQC (µg/L)**	**Reference**	**Log Koc (Log-L/kg)**	**Reference**	**Elutriate Testing Trigger (µg/kg)**	**Elutriate Testing Trigger (µg/kg)**	**Elutriate Testing Trigger (µg/kg)**	**Elutriate Testing Trigger (µg/kg)**
Miscellaneous Semivolatiles (µg/kg)								
Pentachlorophenol	13	[1]	2.77	[6]	77	77	383	382
Pesticides (µg/kg)								
p,p'-DDD			6.00	[6]				
p,p'-DDE			6.65	[6]				
p,p'-DDT	0.13	[1]	6.42	[6]	2,707	942	7,385	1,208
Aldrin	1.3	[1]	6.39	[6]	25,622	9,237	71,635	12,021
Chlordane	0.09	[1]	5.08	[6]	107	97	510	338
Dieldrin	0.71	[1]	5.28	[7]	1,328	1,136	6,176	3,464
Heptachlor	0.053	[1]	6.15	[6]	656	310	2,194	464
gamma-BHC (Lindane)	0.16	[1]	3.67	[5]	7	7	37	37
Total PCBs	10	[8]	5.49	[6]	29,977	23,608	133,835	60,710
Tributyltin3/								
TBT dry weight (µg/kg)	0.42	[1]	4.40	[9]	105	103	521	469

Notes:

Freshwater sediment screening levels should be used for any organics not separately listed in this table

References:

[1] EPA National Recommended Water Quality Criteria (2006)
[2] EPA 2005, *Partition Coefficients for Metals in Surface Water, Soil, and Waste* EPA-600/R-05/074
[3] EPA 2003, *Equilibrium Partitioning Sediment Benchmarks: PAH Mixtures* EPA-600/R-02/013
[4] Oak Ridge National Laboratory 1996, *Toxicological Benchmarks for...Effects on Aquatic Biota*
[5] EPA 2002, *Equilibrium Partitioning Sediment Guidelines: Nonionic Organics* EPA-822/R-02/042
[6] EPA 1996, *Soil Screening Guidance User's Guide* EPA-540/R-96/018
[7] EPA 2002, *Equilibrium Partitioning Sediment Guidelines: Dieldrin* EPA-822/R-02/043
[8] State of Oregon OAR 340-041, Tables 20 and 33A
[9] EPA Region 10, 1996, *Recommendations for Screening Level for Tributyltin in Puget Sound Sediment*

10.3.2. Water Quality at the Disposal Site

Elutriate tests have also been developed to characterize water quality at the point of disposal. Different tests may be applicable, depending on the type of disposal site and the nature of disposal methods, including the following:

- 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). These manuals and the PRGs/DMMP should be consulted to determine when to perform these tests.

10.3.3. 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 reductions in water column concentrations that occur during transport through the mixing zone. The ADDAMS modeling system (Automated Dredging and Disposal Alternatives Modeling System, Schroeder et al. 2004, http://el.erdc.usace.army.mil/products.cfm?Topic=model&Type=drgmat), developed by the Corps Environmental Laboratory at ERDC, 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) predict water quality effects associated with dredging and open-water disposal operations, respectively. These models have benefited from nearly two decades of field calibration and validation studies under a variety of operational and site conditions. 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). These dilution models are recommended for use in state water quality programs in Washington, Oregon, and Idaho (ODEQ 2007, Ecology 2008b, IDEQ 2008).

10.3.4. Receiving Water Impacts

The elutriate testing and hydrodynamic modeling results are used to estimate water column concentrations in the receiving water at the 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 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, the PRGs/DMMP will use best professional judgment to determine 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.

10.3.5. 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). Alternatively the project proponent may elect to forego bioassay testing and instead implement engineering controls as needed to comply with water quality criteria and the conditions of the Water Quality Certification (see Section 10.3.6).

Elutriate bioassay 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. Before elutriate bioassay testing is conducted, an addendum to the SAP must be prepared for review and approval by the PRGs/DMMP that describes the proposed test organisms, test design, laboratory methods, and evaluation criteria.

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 (EPA/Corps 1998c).

10.3.6. Contingency Water Quality Controls

If unacceptable water quality effects are predicted to occur outside the authorized mixing zone, the project proponent must consult with RSET to determine what additional water quality controls or best management practices (BMPs) should be implemented to mitigate these effects. Additional water quality controls may also be required if water quality effects are difficult to predict or highly uncertain. These controls may include, but are not limited to, the following:

- Deployment of silt curtains, absorbent 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 that could include “early warning” stations, contingency plans, and adaptive management of construction operations to anticipate and avoid development of unacceptable water quality effects.

10.4. 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 contaminated sediment 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 engineering design process by developing an accurate CSM supported by adequate sampling density that describes the nature and extent of contamination, and faithfully captures the details of the contaminant distribution in the 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. Whereas water column effects during dredging are associated with intermittent and relatively short-term exposures, dredging residuals may contribute to long-term site risk, potentially including bioaccumulative risk if the residuals deposits are sufficiently thick and extensive (Bridges et al., 2008).

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

- Sediment dislodged by the dredge head 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 over-dredging into less contaminated material; and
- Extent of debris and obstructions.

Although not strictly "dredging" residuals, it should be noted that residual deposits of contaminated sediments 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, contaminated residuals may be dispersed outside the disposal site boundaries.

10.4.1. Predicting Dredging Residuals

Responding to sediment recontamination caused by dredging residuals can result in unforeseen impacts to project schedules and budgets if the project design does not adequately anticipate and plan for the possibility of residuals. Although dredging residuals are of greatest concern on contaminated sediment remediation projects, residuals may also need to be evaluated on some types of navigation dredging projects, especially larger projects that are cutting into more contaminated material at depth.

Currently, there is no commonly accepted method to accurately predict dredging residuals concentrations, but research in this area is ongoing (see Bridges et al., 2008). Recent work 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, allows 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) indicates contaminant concentrations in residuals are similar to the depth-averaged contaminant concentrations in the overlying dredge prism (Bridges et al., 2008). 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 percent to 9 percent of the total mass in the dredge prism, averaging about 5 percent of the dredge prism mass (Patmont and Palermo 2006; Bridges et al., 2008). However, total residuals (including undisturbed and generated fractions) have been measured up to 20 percent at sites with problematic field conditions. Problematic field conditions may include such factors as presence of debris, steep slopes, hardpan/bedrock layers, and relatively high water content sediments (an inherent characteristic of generated residuals and thus a concern for second-pass dredging), all of which contribute to increases in dredging residuals. To date, these 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 lower density, higher water content). In some cases, however, residuals may consolidate to near in situ sediment density within days or weeks.

10.4.2. 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, but may also be required for some navigation dredging projects where thick sequences of contaminated sediments are being removed, where more highly contaminated sediments are being uncovered at depth, and/or where the depth of contamination is not well defined. Typically grab samples are collected and analyzed for CoCs on 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 a 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 (Bridges et al., 2008; 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, if 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 design and construction.

CHAPTER 11. DATA SUBMITTALS

11.1. INTRODUCTION

The RSET recognizes that this chapter of the SEF only briefly describes the data submittal and quality assurance/quality control (QA/QC) process. The RSET will be working to develop a regional approach to data submittal and QA/QC, including QA2. In the meantime, applicants should contact their respective PRG or DMMP to get specific information on QA/QC procedures, if needed.

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

- A sediment characterization report, which includes the items listed in Section 11.2. The report will be scanned or the file added to the SEF website or a linked website so that the data will be available publicly (after quality assurance of the data and the suitability determination completed). The preferred method of sediment quality report publication is in digital Adobe® PDF (portable document format). Compact discs (CDs) of the reports should be available upon request or downloadable from the author agency's website.
- Quality assurance (QA1) and QA2 reports should be submitted to the PRGs/DMMP on one or two CDs (see Section 11.3).
- Other documents are extremely useful as part of the data submittal. These may include, but are not limited to, the following:
  - SAP,
  - Habitat Protection Plan,
  - CWA Section 404(b)(1) Evaluation, and
  - Contractor report with QA data included.

11.2. SEDIMENT CHARACTERIZATION REPORT

The preferred format for the sediment characterization report is the standard five-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:

1. QA report documenting deviations from the SAP and effects of QA deviations on test results;
2. A plan view showing the actual sampling locations;
3. The sampling coordinates in latitude and longitude, including the projection standard, units, and datum used;
4. Methods used to locate the sampling positions within an accuracy of 2 meters;
5. The compositing scheme;

6. The type of sampling equipment used, the protocols used during sampling and compositing, and an explanation of any deviations from the sampling plan;
7. Sampling logs with sediment descriptions;
8. Chain-of-custody procedures used;
9. Chemical and biological testing results including quality control information; and
10. Explanation of any deviations from the analysis plan.

11.3. Quality Assurance (QA) 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.

Additional information regarding the QA/QC for the Portland requirement area can be found in the following reference:

> PTI Environmental Services. 1989. 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, WA.

This reference is located on the RSET webpage at https://www.nwp.usace.army.mil/pm/e/rset.asp.

For the Seattle area, the Dredge Material Management Plan (DMMP) may be used for QA/QC procedures.

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, and others. The QA2 data may be submitted up to 3 months following sampling and should be sent directly to the PRGs/DMMP.

11.4. Environmental Information Management (EIM)

The EIM database 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 database (SEDQUAL) with the EIM database will improve functionality and database maintenance; Ecology will no longer be supporting SEDQUAL. The Corps Portland District will be using SEDQUAL as ongoing coordination efforts with Ecology continue.

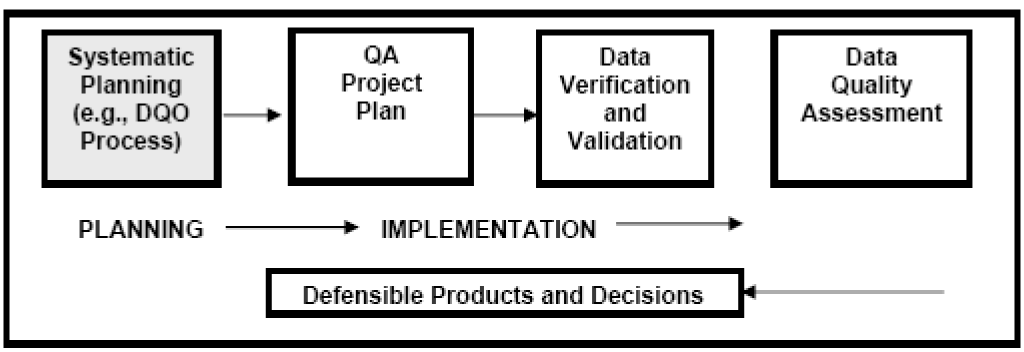
The EIM is a web-based program available to interface from the Ecology website at http://www.ecy.wa.gov/eim/. Users will need to establish an account and use the import module located at http://fortress.wa.gov/ecy/eimimport/submit.htm. Users will need to access the data using the Microsoft© Internet 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.

Since 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 on 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.

11.5. Field Data Collection Quality Assurance/Quality Control

Chapter 5 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 (Figure 11-1; 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 11-1. Project Life Cycle Components



11.6. Quality Assurance/Quality Control for Biological Data

Chapter 7 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.

CHAPTER 12. BENEFICIAL USES FOR SEDIMENT

This chapter provides an introduction to beneficial use and its importance to overall sediment management in the Pacific Northwest. For example, 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 for potentially reducing disposal costs 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 mean any use of dredged material other than deep-water 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, consistent with regulatory requirements that may apply to a given project.

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. One goal of managing dredged material is consider dredged material as a resource to be managed in a watershed context. Consistent with the goals of regional sediment management, use of dredged material to support coastal processes and other enhancements, discussed below, should be fostered wherever possible. While dredged material disposal locations/facilities/sites will always be needed in some capacity for sediments, especially contaminated sediments, 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 non-contaminated 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.

Beneficial use is strongly supported by the agencies. When considering dredged material for a beneficial use, issues regarding allowable contaminant concentrations, intensity of sampling to characterize the physical character of the material, and timing considerations should be addressed. Applicants should be encouraged to coordinate with their regional federal and state agency contacts when considering beneficial uses of dredged material.

Three technical manuals and guidance documents have been issued on both the federal and state levels on beneficial use of dredged material. The most recent is the joint EPA and Corps publication, *Identifying, Planning, and Financing Beneficial Use Projects Using Dredged Material Beneficial Use Planning Manual* (http://el.erdc.usace.army.mil/dots/budm/pdf/PlanningManual.pdf) that provides guidance for planning, designing, developing, and managing dredged material for potential beneficial uses. Other sites with useful information regarding beneficial use of dredged sediments include the Great Lakes Dredging Team (http://www.glc.org/dredging) and the Corps Engineer Manual No. 1110-2-5026, *Beneficial Uses of Dredged Material* (http://www.usace.army.mil/publications/eng-manuals/).

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Appendix A
Sample Handling Procedures

SAMPLE HANDLING PROCEDURES

This appendix provides detailed information concerning the sample handling procedures discussed in Chapter 5 of the SEF. All sample handling procedures should be specified in the Sampling and Analysis Plan (SAP).

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 non-contaminating 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 the Puget Sound Estuary Program (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 milliliters (mL) 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 information 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 1983] 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 containers obtained from the chemical and biological laboratories. See Table 5-1 in the main report 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 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, 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 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 B
Biological Testing Toolbox

Biological Testing Methods Evaluation

(Instructions follow the table)

Tool / Test Species	Method	Measurement Endpoints	Marine, Estuarine, or Freshwater	Reference No.	Acute / Chronic/ Chronic Surrogate	Sublethal Endpoint	Ease of Use	Repeat-ability	Organism Availability/ Seasonality	Holding Constraints	Protocol Status	Field Valid-ation	Current Interp. Criteria	Cost
Solid Phase Sediment Toxicity Tests (relevant for in-place sediments, effects at disposal site)														
Bivalve larvae (oyster-*Crassostrea gigas*)	48-h	Normal survival	Marine	1	CS	Y	1	1	1/2	N	3		W	M
Bivalve larvae (*Mytilus* spp.)	48-h	Normal survival	Marine	1	CS	Y	1	1	1/2	N	3		W	LM
Sea Urchin (*Strongylocentrotus purpuratus*)	48-h	Normal survival	Marine	1	CS	Y	1	1	1/2	N	3		W	LM
Sand dollar (*Dendraster excentricus*)	48-h	Normal survival	Marine	1	CS	Y	1	1	1/2	N	3		W	LM
Ampelisca abdita	10-day	Survival	Marine, estuarine	1, 2	A	N	2	1	2	N	3	Y	N, W	M
Eohaustorius estuarius	10-day	Survival	Marine, estuarine	1, 2	A	N/Y	1	1	1	N	3	Y	N, W	M
Rhepoxynius abronius	10-day	Survival/ reburial	Marine	1, 2	A	N/Y	1	1	1	N	3	Y	N, W	M
Grandidierella japonica	10-day	Survival	Marine, estuarine	2, 3	A	N	1	1	1	N	2		N	M
Leptocheirus plumulosus	10-day	Survival	Marine, estuarine	2, 3	A	N	1	1	1	size/age	3	Y	N, W	M
Corophium spp.	10-day	Survival	Marine, estuarine	2	A	N	2	1	2	?	2		N	M
Neanthes arenaceodentata	10-day	Survival	Marine, estuarine	4	A	N	1	1	only one supplier	size/age	3		N, W	M

Tool / Test Species	Method	Measurement Endpoints	Marine, Estuarine, or Freshwater	Reference No.	Acute / Chronic/ Chronic Surrogate	Sublethal Endpoint	Ease of Use	Repeat-ability	Organism Availability/ Seasonality	Holding Constraints	Protocol Status	Field Valid-ation	Current Interp. Criteria	Cost
Mysid shrimp	10-day	Survival	Marine, estuarine	5	A	N	1	1	1	N	1		?	M
Shrimp (*Panaeus, Palomonetes*)	10-day	Survival	Marine	2	A	N	1	1	3	?	2		N	M
Hyalella azteca	10-day	Survival	Estuarine, freshwater	2, 6, 7	A	N	1	1	1	N	3		N, W	M
Chironomus spp.* - Midge	10-day	Survival, growth	Freshwater	2, 6, 7	A	Y	1	1	1	N	3	Y (EPA 2000b)	N, W	M
Lumbriculus variegatus	10-day	Survival	Freshwater	2	A	Y	1	1	1	N	2		N	M
Tubifex tubifex	10-day	Survival	Freshwater	2	A	Y	1	1	1	N	2		N	M
Pristina spp. (naidia oligochaete)	10-day	Survival	Freshwater	2	A	Y	1	?	3	?	2		N	M
Hexagenia spp. (mayfly larvae)	10-day	Survival	Freshwater	2	A	Y	1	?	3	?	2		N	M
Anodonta spp. (freshwater mussel)	10-day	Survival	Freshwater	2	A	Y	1	?	3	?	2		N	
Neanthes arenaceodentata	20-day	Survival & growth	Marine, estuarine	1, 4	C	Y	1/2	1	only one supplier	size/age	3	Y	N, W	M
Armandia brevis	28-day	Survival & growth	Marine	8, 9, 10, 11	C	Y	2	?	3	age	2		?	H
Leptocheirus plumulosus	28-day	Survival/ growth/ repro.	Marine, estuarine	3, 12	C	Y	2/3	1/2	1	size/age	3	Y	N, W	H
Hyalella azteca	28-day	Survival & growth	Estuarine, freshwater	7	C	Y	2	2	1	N	3	Y (EPA 2000b)	N	H

Tool / Test Species	Method	Measurement Endpoints	Marine, Estuarine, or Freshwater	Reference No.	Acute / Chronic/ Chronic Surrogate	Sublethal Endpoint	Ease of Use	Repeat-ability	Organism Availability/ Seasonality	Holding Constraints	Protocol Status	Field Valid-ation	Current Interp. Criteria	Cost
Hyalella azteca	42-day	Survival & growth	Estuarine, freshwater	7	C	Y	2	2	1	N	3		N	H
Chironomus spp.* - Midge	20-day	Survival & growth	Freshwater	7	C	Y	1	2	1	age	3	Y	N, W	M
Chironomus spp.* - Midge	40-day	Life cycle	Freshwater	6, 7	C	Y	1	2	1	age	3	Y	N	M
Chironomous riparius	10- to 30-day	Survival, growth, head capsule width, emergence	Freshwater	6	C	Y	2	2	1	age	3		N	M
Hexagenia spp. - Mayfly	21- day	Survival & growth	Freshwater	6	C	Y			3	age	3		N	M
Daphnia, Ceriodaphnia	7-day	Survival, growth, repro.	Freshwater	6	C	Y	1	1	1	N	3		N	M
Diporeia spp. - Amphipod	28-day	Survival & behavior	Freshwater	6	C	Y			2/3	N	2		N	M
Tubifex tubifex	28-day	Survival & repro.	Freshwater	6	C	Y			1	N	2		N	M
Elutriate/Suspended Particulate (relevant for disposal site and effects during dredging event)														
Shrimp (*Palaemonates* sp., *Penaeus* sp.)	96-h	Survival	Marine	2	A	N	1	1	2	N	2		N	M
Cladocerans (*Daphnia, Ceriodaphnia)*	96-h	Survival	Freshwater	2	A	N	1	1	1	N	3		N	M
Fish, marine (*Menidia, Cypridon, Leurethes*)	96-h	Survival	Marine	2	A	N	1	1	1/2	N	3		N	M
Fish, freshwater *(Pimephales, Lepomis, Onchyrynchus, Ictalurus)*	96-h	Survival	Freshwater	2	A	N	1	1	1/2	N	3		N	M

Tool / Test Species	Method	Measurement Endpoints	Marine, Estuarine, or Freshwater	Reference No.	Acute / Chronic/ Chronic Surrogate	Sublethal Endpoint	Ease of Use	Repeat-ability	Organism Availability/ Seasonality	Holding Constraints	Protocol Status	Field Valid-ation	Current Interp. Criteria	Cost
Speckled Sandab (*Citharichtys stigmaeus*)	96-h	Survival	Marine	2	A	N	1	1	1	N	3		N	M
Cladocerans (*Daphnia, Ceriodaphnia)*	7-day	Survival & repro.	Freshwater	6	C	Y	1	1	1	N	3		N	L
Opossum Shrimp (*Mysidopsis bahia* or *Holmesimysis costata*)	96-h	Survival	Marine, estuarine	2	A	N	1	1	1	N	3		N	M
Microtox (Northwest method)	15-min	Bioillumination	Marine, estuarine, & freshwater	1	CS	Y	3	1	1	N	3	?Y	W	L
Sediment Bioaccumulation (Laboratory assay)														
Bivalve (*Macoma nasuta, Yolinda* sp., *Tapes* sp.)	28-day	Tissue burden	Marine	1, 13	NA	NA	1	NA	1	N	3		N, W	H
Nereis virens, Arenicola marina	28-day, 45-day	Tissue burden	Marine	1, 13	NA	NA	1	NA	1	N	3		N	H
Nepthys caecoides	28-day, 45-day	Tissue burden	Marine	1	NA	NA	1	NA	1	N	3		N, W	H
Neanthes arenaceodentata	28-day	Tissue burden	Marine	2	NA	NA	1	NA	only one supplier	size/age	3		N	H
Lumbriculus spp.	28-day	Tissue burden	Freshwater	13	NA	NA	2	NA	1	Y	3		N, W	H
Armandia brevis	28-day	Tissue burden	Marine	9	NA	NA	3	NA	3	age	1			H
Diporeia spp. - Amphipod	28-day	Tissue burden	Freshwater	13					3		1		N	H

** Recent literature notes that two species of Chironomous have likely been used in toxicity testing, all under the name of Chironomous dilutus. Since there is no way to deterimne which species may have been used in assays used to develop the FWSQGs, eiither species is acceptable, but correct species identification should be reported. See ASTM E1706-05*

Instructions for Biological Testing Methods Evaluation

Provided below are definitions of categories and their ranking codes.

Method. This category refers to the test duration.

Measurement Endpoints. This category refers to the possible test endpoint; however, some of these endpoints may not be used in every case (for example reburial).

Marine, Estuarine, Freshwater. No explanation necessary.

Reference No. Numbers refer to the References Section in this appendix.

Acute/Chronic/Chronic Surrogate. A = acute; C = chronic; CS = chronic surrogate.

Sublethal Endpoint. A yes/no question – does the test have a sublethal endpoint?

Ease of Use. 1 = easy, no special training; 2 = moderately hard, requires experience; 3 = difficult or tricky, requires special training.

Repeatability. 1 = round-robin tests or established control charts indicate a robust test – used frequently and shown to be reliable; 2 = endpoint is a little tricky and results variable; 3 = lack of data regarding repeatability.

Organism Availability/Seasonality. 1 = readily available year-round; 2 = readily available during a particular season; 3 = difficult to acquire.

Holding Constraints. A yes/no question - some animals are not held, so although they may be difficult to hold prior to testing, this is not an issue.

Protocol Status. 1 = experimental; 2 = a protocol has been established; 3 = standard test that is applied routinely or commercially.

Field Validation. Has there been a field validation study conducted to evaluate whether this tool is protective of the environment? A yes in this category does not imply that the field validation study indicated that the tool was indeed effective.

Current Interpretive Criteria. Do interpretive criteria exist for this method? If so, are there criteria in the Pacific Northwest (W) or anywhere else in the U.S. (N)?

Cost. L = <$200-$300 per sample; M = <$1,000 per sample; H = >$1,000 per sample. Of course this can vary depending on number of samples and special circumstances. Note that bioaccumulation tests are all considered expensive – but even with bioaccumulation tests, there is variation depending on the length of test, test volume, and test species.

Biological Endpoints

These endpoints are not commonly used in dredged sediment evaluations.
For reviews and selected assays, please see the References Section that follows this table.

Tool/Test Species	Reference No.
Sublethal Cellular Assays/Biomarkers	
Genotoxicity - Anaphase Aberration	1
Genotoxicity DNA Damage Index/Adducts	14
Genotoxicity - Micronucleii	15
Mixed-Function Oxygenases (MFOs) - EROD Activity	16, 17,18
MFOs - Benzopyrene hydroxylase (BPH)	19
Glutathione-S-transferase	18, 20, 21
P-glycoprotein	22
Oxidative Stress - Catalase	19, 23
Oxidative Stress - Superoxide dimutase (SOD)	19, 23, 24
Glutathione peroxidase	18, 25
Glutathione reducatase	18, 25
Glutathione redox states	18
Total glutathione (GSH)	25, 26
Liquid peroxidation - thiobarbituric acid reactive substances (TBARS)	25, 26
Metallothioneins	27
Heat-shock proteins	28
Achetylcholinesterase inhibition (AChE)	20
General overviews: biomonitoring	29, 30
General bioassessment, freshwater	31
General bioassessment, estuarine/marine	32
General overview, estuarine biomarkers	33
General overview, markers of oxidative stress	34

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Appendix C
Bioaccumulative Chemicals of Concern (BCoCs) Lists

Bioaccumulative Chemicals of Concern (BCoCs) Lists

The RSET adopted the approach for identifying BCoCs outlined in Hoffman (2007[1]; see http://www.nws.usace.army.mil/PublicMenu/documents/DMMO/Final_BCOC_Technical_Appendix_010807.pdf). This approach relies on a review of the occurrence of contaminants in sediments and tissue, chemical properties of contaminants such as K_{ow} or the known toxicity of the contaminants to human/ecological receptors, and comparison of tissue levels to available residue-effects levels. Contaminants are placed on one of four lists depending on the amount of information available and the weight-of-evidence indicating their potential to bioaccumulate, prevalence in the region, and toxicity. Because many bioaccumulative guidelines are below detection limits, our ability to definitively determine that contaminants are not present at risk-based levels is limited. The lists are described below and are periodically reviewed to determine if adjustments are needed.

List 1: Primary Bioaccumulative Chemicals of Concern. These are the primary chemicals expected to be addressed as part of a bioaccumulation evaluation. Chemicals are placed on List 1 based on hydrophobicity, frequency of detection in sediments and tissues, and known human health and ecological risks.

List 2: Candidate Bioaccumulative Chemicals. Chemicals are placed on List 2 because they meet some of the above criteria and may be BCoCs, but not enough data are available on their occurrence in the region to place them on List 1. Emerging chemicals of concern can often be found on this list. The RSET agencies may request analyses for one or more of these chemicals if there is a strong reason to believe that they may be significant for a given project.

List 3: Potentially Bioaccumulative Chemicals. 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. Chemicals are often placed on this list because it is not yet known if they present risks to human health and the environment.

List 4: Not Currently Considered Bioaccumulative. Chemicals are placed on List 4 if they are not likely to bioaccumulate due to their chemical properties or if they have been analyzed for but not found/only infrequently found in regional sediments and tissues.

The RSET made one modification to the approach outlined in Hoffman (2007). In the original 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 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 retaining them on List 1 would likely lead to an unnecessary number of bioaccumulation evaluations. Thus, metals were divided into those likely to bioaccumulate based on having organic forms or those not likely to bioaccumulate, and were placed on List 1 or List 4 accordingly. This provides a more consistent treatment of metals and organic chemicals and a better reflection of the actual tendency to bioaccumulate. The Seattle District reviewed and adopted this update in 2009.

Complete lists for all three Corps Districts, along with accompanying notes, are provided below.

[1] Hoffman, E. 2007. The Technical Basis for Revisions to the Dredged Material Management Program's Bioaccumulative Contaminants of Concern List. Prepared for the Dredged Material Management Program Agencies, Seattle, WA.

SEATTLE DISTRICT

The Seattle District lists are excerpted from Hoffman (2007). Technical definitions for each list, along with the supporting data, are located at http://www.nws.usace.army.mil/PublicMenu/documents/DMMO/Final_BCOC_Technical_Appendix_010807.pdf.

Seattle District List 1: Primary Bioaccumulative Chemicals of Concern

Arsenic
Chlordane
DDTs – Total
Dioxins/Furans
Fluoranthene
Hexachlorobenzene
Lead
Mercury
Pentachlorophenol
PCBs – Total Aroclors
Pyrene
Selenium
Tributyltin

Seattle District List 2: Candidate Bioaccumulative Chemicals

1,2,4,5-Tetrachlorobenzene
4-Nonylphenol, branched
Benzo(e)pyrene
Biphenyl
Chromium VI
Chlorpyrifos
Dacthal
Diazinon
Endosulfan
Ethion
Heptachloronaphthalene
Hexachloronaphthalene
Kelthane
Mirex
Octachloronaphthalene
Oxadiazon
Parathion
Pentabromodiphenyl ether
Pentachloronaphthalene
Perylene
Tetrachloronaphthalene
Tetraethyltin
Trichloronaphthalene
Trifluralin

Seattle District List 3: Potentially Bioaccumulative Chemicals

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
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

Seattle District List 3 (continued): Potentially Bioaccumulative Chemicals

Acenaphthene
Acenaphthylene
Aldrin
Alpha-BHC/Alpha-benzene hexachloride
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
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
Nonylphenol
Pentachloroanisole
Phenanthrene
Polybrominated terphenyls
Polychlorinated alkenes
Polychlorinated terphenyls
Pronamide
Tetradifon
Toxaphene

Seattle District List 4: Not Currently Considered Bioaccumulative Chemicals

1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Bromoxynil
Cadmium
Chromium
Copper
Dicamba
Dichlobenil
Dimethyl phthalate
Diuron
Endrin
Ethylbenzene
Fenitrothion
Guthion
Heptachlor
Hexachloroethane
Methyl parathion
Methyltin trichloride
Naphthalene
Nickel
N-nitroso diphenylamine
Phenol
Silver
Tetrachloroethene
Trichloroethene
Triphenyltin chloride
Zinc

PORTLAND DISTRICT

Comprehensive tissue data was not available from all areas regulated by the Portland District. However, the following list was generated through a review of the Portland Harbor tissue data for fish and shellfish, and is considered likely to capture any contaminants likely to be present in most areas. The same criteria used in Seattle District were used to develop the Portland District lists. Some List 3 chemicals on the more comprehensive Seattle District list were added to List 3 for Portland District for completeness.

Portland District List 1: Primary Bioaccumulative Chemicals of Concern

Dieldrin
Dioxin/furan TCDD toxicity equivalent
Fluoranthene
Fluorene
gamma-Hexachlorocyclohexane
Hexachlorobenzene
Mercury
Methoxychlor
Pyrene
Selenium
Total Chlordanes
Total DDTs
Total Endosulfans
Total PCB Aroclors
Total PCB Congeners
Tributyltin

Portland District List 2: Candidate Bioaccumulative Chemicals

1,2,4,5-Tetrachlorobenzene
4-Nonylphenol, branched
Arsenic
Benzo(e)pyrene
Biphenyl
Chlorpyrifos
Chromium VI
Dacthal
Diazinon
Ethion
Heptachloronaphthalene
Hexachloronaphthalene
Kelthane
Octachloronaphthalene
Oxadiazon
Parathion
Pentabromodiphenyl ether
Pentachloronapthalene
Perylene
Tetrachloronapththalene
Tetraethyltin
Trichloronapththalene
Trifluralin

Portland District List 3: Potentially Bioaccumulative Chemicals

1-Methylnaphthalene
1-Methylphenanthrene
1,2,3,4-Tetrachlorobenzene
1,2,3,5-Tetrachlorobenzene
1,2,3-Trichlorobenzene
1,3,5-Trichlorobenzene
2-Methylnaphthalene
2,6-Dimethylnaphthalene
4,4'-Dichlorobenzophenone
Acenaphthene
Acenaphthylene
Aldrin
Alkylated PAHs
alpha-Hexachlorocyclohexane
Anthracene
Antimony
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(g,h,i)perylene
Benzo(k)fluoranthene
Beryllium
beta-Hexachlorocyclohexane
Bis(2-ethylhexyl) phthalate
Butylbenzyl phthalate
Butyltin ion
Carbazole
Chrysene
delta-Hexachlorocyclohexane
Dibenzo(a,h)anthracene
Dibenzofuran
Dibenzothiophene
Dibutyl phthalate
Diphenyl
Endrin ketone
Ethoxylated nonylphenol phosphate
Indeno(1,2,3-cd)pyrene
Nonylphenol
Pentachloroanisole
Pentachlorophenol
Phenanthrene
Polybrominated terphenyls
Polychlorinated alkenes
Polychlorinated terphenyls
Pronamide
Retene
Tetrabutyltin
Tetradifon

Portland District List 4: Not Currently Considered Bioaccumulative Chemicals

1,2-Dichlorobenzene
1,2-Diphenylhydrazine
1,2,4-Trichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2-Chloronaphthalene
2,3,4,5-Tetrachlorophenol
2,3,5,6-Tetrachlorophenol
2,4-Dichlorophenol
2,4-Dimethylphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,6-Dinitrotoluene
2-Chlorophenol
2-Methylphenol
2-Nitroaniline
2-Nitrophenol
3-Nitroaniline
3,3'-Dichlorobenzidine
4-Bromophenyl phenyl ether
4-Chloro-3-methylphenol
4-Chloroaniline
4-Chlorophenyl phenyl ether
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
4,6-Dinitro-2-methylphenol
Aniline
Azobenzene
Benzoic acid
Benzyl alcohol
Bis(2-chloro-1-methylethyl) ether
Bis(2-chloroethoxy) methane
Bis(2-chloroethyl) ether
Bis(2-chloroisopropyl) ether
Bromoxynil
Cadmium
Chromium
Copper
Dibutyltin ion
Dicamba
Dichlobenil
Diethyl phthalate
Dimethyl phthalate
Di-n-octyl phthalate
Diuron
Endosulfan sulfate
Endrin
Endrin aldehyde
Ethylbenzene
Fenitrothion
Guthion
Heptachlor
Heptachlor epoxide
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Isophorone
Lead
Methyl parathion
Methyltin trichloride
Mirex
Naphthalene
Nickel
Nitrobenzene
N-Nitrosodimethylamine
N-Nitrosodiphenylamine
N-Nitrosodipropylamine
Oxychlordane
Phenol
Silver
Tetrachloroethene
Toxaphene
Trichloroethene
Triphenyltin chloride
Zinc

WALLA WALLA DISTRICT

Comprehensive tissue and sediment data were not available from all areas regulated by the Walla Walla District. Therefore, the approach used for the Seattle and Portland Districts cannot be applied until more data become available. The following list was generated through the use of multiple lines of evidence. A review of published toxicity, half-life, bioaccumulation factors, peer-reviewed literature, and use patterns was conducted, but no single line of evidence was considered definitive. Information on industrial and manufacturing chemicals of concern is extremely limited due to the lack of industrial development in the Walla Walla District. Considerable information on use patterns and environmental fate is available for agricultural chemicals for southeast Washington, Idaho, and eastern Oregon. The criteria used to develop the four lists were based on multiple lines of evidence for each constituent and do not rely on discreet cut-off values. A more detailed report describing the multiple line-of-evidence evaluation is in preparation; please contact the Walla Walla District for more information.

Walla Walla District List 1: Primary Bioaccumulative Chemicals of Concern

Arsenic
Chlordane
Dieldrin
Dioxins/Furans
DDTs – (includes DDD and DDE degradation products)
Fluoranthene
Hexachlorobenzene
Lead
Mercury
Pentachlorophenol
Pyrene
Selenium

Walla Walla District List 2: Candidate Bioaccumulative Chemicals

Cypermethrin
lambda-cyhalothrin
Triphenyltin
Zeta cypermethrin

Walla Walla District List 3: Potentially Bioaccumulative Chemicals

DCPA
Fenbutatin
Ethyl parathion

Walla Walla District List 4: Not Currently Considered Bioaccumulative Chemicals

Abamactin
Aceflourfen
Acefate
Acetamiprid
Acebenzolar
Aceflourfen
Acifluorfen*
Aclonifen*
Acrolein*
Ametryn
Amitriz
Azadirachtin
Azoxystrobin
Benefin
Benomyl
Benzyladenine
Bifenthrin
Bifenzate
Boscalid
Bromacil
Bromoxynil
Buprofezin
Butylate
Cadmium
Calcium polysulfide
Carbofuran
Carfetrazone ethyl
Clorimuron
Chlorsulfuron
Chromium
Clethodim
Clodinafop-propargil
Clofentazine
Clomazone
Clopyralid
Copper
Copper salts
Cyanamid
Cyanazine
Cycloate
Cyfluthrin
Cymoxanil
Cymorazine
Cyprodinil
Desmedipham
Dicamba potassium salt
Dicamba sodium salt
Diclofop methyl
Dicloran
Dicofol
Difenzoquat
Diflufenzopyr sodium
Dimethipin
Dimethomorph
Disulfoton
Diuron
Dodecadien
Dodecanol
Endothal
Esfenvalerate
Ethalfluralin
Ethephon
Ethion
Etoxazole
Famoxadone
Finamidone
Fenamiphos
Fenarimol
Fenbuconazole
Fenhexamid
Fenoxaprop P
Fenpropathrin
Fipronil
Fluazifop P butyl
Flucarbazone
Fludioxnil
Flumetsulam
Fluoxypr 1-methyl hex
Flutolanil
Formesafen
Fonofos
Foramsulfuron
Formetanate
Fosetyl al
Gibberelic acid
Giberellins A4 A7
Glufonisate ammonium
Halosulfuron
Harpin
Hexazinone
Hexythiazox

* Chemicals are not used or not detected in the area.

Walla Walla District List 4 (continued): Not Currently Considered Bioaccumulative Chemicals

Imazamthabenz
Imazamox
Imazapyr
Imazethapyr
Imidacloprid
Indoxacarb
Isoxaflutole
Kresoxim methyl
Lactofen
MCPA sodium salt
MCPB
Mesosulfuron methyl
Mesotrione
Metalaxyl
Methidathion
Methomyl
Methoxychlor
Metasulfuron methyl
Mevinphos
Monocarbamide
Myclobutanil
NAA
NAD
Naled
Napropamide
Naptalam
Nicosulfuron
Nickel
Oryzalin
Oxydementon methyl
Oxytetracycline
Oxythioquinox
*PCBs – Total Aroclors
Phenmedipham
Phosphamidon
Picloram
Piperonyl butoxide
Primsulfuron
Prohexidione calcium
Propachlor
Propamocarb hydrochloride
Propaconazole
Prosulfuron
Pymetrozine
Pyrazon
Pyrethrins
Pyridaben
Pyridate
Pyrimethanil
Pyriproxyfen
Quizalofop
Quizalofop ethyl
Rimsulfuron
Sethoxydim
Silver
Spinosad
Spiromesifen
Streptomycin
Streptomycin sulfate
Sulfentrazone
Sulfosulfuron
Tebufenozide
Tebuprimphos
Tefluthrin
Terbacil
Tetradecanol
Thiamethoxam
Thifensulfuron
Thiodicarb
Tralkoxydim
Triadimefon
Triasulfuron
Triazole
Tribenuron
*Tributyltin
Tridiphane
Trifloxystrobin
Triflumazole
Trifluralin
Triflusulfuron methyl
Triforine
Vernolate
Vinclozolin
Z, 8, Dodecanol acetate
Z, 8, Dodecanol
Zinc
Zinc phosphide
Zoxamide

* Chemicals are not used or not detected in the area.

Appendix D

Derivation of Bioaccumulation Target Tissue Levels (TTLs) and Sediment Bioaccumulation Triggers (BTs)

Appendix D
Derivation of Bioaccumulation Target Tissue Levels (TTLs) and Sediment Bioaccumulation Triggers (BTs)

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Derivation of Bioaccumulation Target Tissue Levels (TTLs) and Sediment Bioaccumulation Triggers (BTs)

This appendix identifies the methods used for calculating target tissue levels (TTLs) for each of the three identified exposure pathways in Sections D.1 to D.3 below. The TTLs will be used as part of reason to believe, to periodically review the regional bioaccumulative chemicals of concern (BCoC) lists over time, 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.

Derivation methods for TTLs contain conservative 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 and in compliance with state and federal regulations. Some of the calculations do result in TTLs that are below background concentrations and detection limits. In these cases, the use of a TTL will default to a comparison to background tissue levels, or detection limits if background levels are undetected. The agencies are currently involved in extensive regulatory, legal, technical, and stakeholder discussions around this issue, and further developments can be expected before the 2009/2010 dredging season, which will be subsequently incorporated into the SEF.

While sediment bioaccumulation triggers (BTs) have not yet been developed by RSET, Section D.4 discusses derivation methods that could be used on a regional, site-, or project-specific basis to do so. In addition, the Oregon Department of Environmental Quality (ODEQ) recently developed sediment BTs that can be used (ODEQ 2007).

D.1. TTL FOR AQUATIC LIFE

This section presents the approach used to develop TTLs for aquatic life. This TTL represents the concentration or target level of a bioaccumulative contaminant in tissue that is considered protective of aquatic organisms (fish and invertebrates). The tissue residue approach (TRA) has been used to generate protective TTLs that can be applied to both laboratory bioaccumulation tests and field collected organisms, where sufficient data was available to do so.

In addition, DEQ has recently derived TTLs for fish, shellfish and aquatic organisms for 19 constituents based on the regional BCOC list (ODEQ 2007). Seventeen of these TTLs were derived using the Water Quality Criteria Bioaccumulation Factor Approach (WQC-BCF) described in Section D.1.5 and two were derived using the RSET recommended Species Sensitivity Distribution (SSD) Approach as described in Section D.1.4.

The following sections provide information on the TRA methodology and the two specific methods for deriving TTLs that were used for the values presented in the SEF. The final section and Table D-1 present the currently proposed TTLs for aquatic life. Table D-2 presents the aquatic life TTLs from the ODEQ sediment bioaccumulation guidance (ODEQ 2007) for constituents not included in Table D-1. These can be used as interim values until aquatic life TTLs can be derived for these constituents based on the RSET recommended methodology.

There is no regulatory consensus on some of the specific details of the SSD methodology that RSET is recommending for the development of aquatic life TTLs. For example, there are differences in opinion amongst regulatory agencies as to which hazardous concentration percentile (HC_p) should be selected for identifying a protective aquatic life TTL. For the purpose of this version of the SEF, the rationale for the selected HC_p is provided (see Section D.1.4). It is expected that as the use of SSDs to develop aquatic life TTLs become more widespread, greater consistency in the application of the methodology will emerge amongst regulatory agencies. It is also expected that the aquatic life TTLs will be revised in the future to reflect the standard of practice in the use of this methodology.

Table D-1. Aquatic Life TTLs Based on SSDs

Chemical	Responses	Species	TRV HC_{05}	HC_{05} Method	Citation for Data
TCDD (TEQ)	Mortality	Fish ELS	0.039 ng/g lipid	From paper	Steevens et al., 2005
Mercury	Mortality, growth, reproduction, behavior	Fish	0.11 mg/kg ww	From paper	Beckvar et al., 2005
Tributyltin	Growth	All spp.	0.19 mg/kg ww	BurrliOZ	Meador et al., 2002b
Tributyltin	Reproduction	Gastropods	0.02 mg/kg ww	BurrliOZ	Meador et al., 2002b
Selenium	Sublethal	Fish ELS and juveniles	7.91 mg/kg dw	From criterion	EPA 2004
Total PCBs (Aroclors)	All	Salmonids	1.4 mg/kg lipid	BurrliOZ	Meador et al., 2002a
DDT	Mortality, growth, reproduction	Fish adult	0.09 mg/kg ww	From paper	Beckvar et al., 2005
Chlorophenols[a]	Mortality	All spp.	0.011 µmol/g ww	BurrliOZ	Meador 2006
Pentachloro-phenol	All sublethal	All spp.	0.001 mg/kg ww	BurrliOZ	Meador 2006
All hydrophobic organics[b]	Mortality	All spp.	2.16 µmol/g lipid	BurrliOZ	Di Toro et al., 2000

[a] – several compounds (2 CP, 3 CP, 4 CP, 2,3 DCP, 2,4 DCP, 2,5 DCP, 2,6 DCP, 3,5 DCP, 2,3,5 TCP, 2,4,5 TCP, 2,4,6 TCP, 2,3,4,6 TeCP; CP is chlorophenol, DCP, TCP, and TeCP and di-, tri-,tetra chlorophenol).

[b] – based on several compounds (1,2 and 1,4 dichloro-, difluoro-, and dibromobenzene, 1,2,3 and 1,2,4 trichlorobenzene, 1,2,3,4 tetrachlorobenzene, pentachlorobenzene, 1,1,2,2 tetrachloroethane, naphthalene and fluoranthene).

ELS = early life stage; dw = dry weight; ww = wet weight.

Table D-2. Aquatic Life TTLs based on AWQC (ODEQ 2007)

Chemical	CASRN	Freshwater TTL (mg/kg) ww	Marine TTL (mg/kg) ww
Arsenic	7440-38-2	6.6	1.6
Cadmium	7440-43-9	0.15	0.15
Chlordane	57-74-9	0.06	0.056
4,4’-DDE	72-55-9	0.054	0.054
4,4’-DDD	72-54-8	0.054	0.054
Dieldrin	60-57-1	0.26	0.26
Lead	7439-92-1	0.12	0.40
Pyrene	129-00-0	1.0	1.0
Flouranthene	206-44-0	19	19
Hexachlorobenzene	118-74-1	32	32

ww = wet weight; refer to ODEQ (2007) for additional information on these TTLs.

D.1.1. Chemicals for Which Aquatic Tissue Quality Guidelines Can Be Derived

In theory, tissue TTLs can be derived for any chemical or compound that is bioaccumulated into aquatic biota tissues. 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 water-based toxicity metric.

Tissue TTLs should not be derived for chemicals that fall into three rather broad categories:

1. Chemicals that do not appreciably bioaccumulate.
2. External toxicants and irritants.
3. Bioaccumulative compounds that do not result in measurable tissue residues due to rapid biotransformation.

Some chemicals are quite toxic without appreciable bioaccumulation. Cyanide is one example of a highly toxic chemical with a low bioaccumulation potential. Many chemicals in this group have high water solubility that may not preferentially partition from water to tissues, resulting in low tissue concentrations associated with toxicity.

External toxicants do not need to enter the body of an organism to elicit toxicity. These chemicals, such as contact herbicides and some irritants, act by destroying the cell wall or inducing mucus that can suffocate the gills. Many metals at high external exposure concentrations can also act this way. Additionally, 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.

One example of rapidly biotransformed compounds are the polycyclic aromatic hydrocarbons (PAHs). Because PAHs are extensively transformed in vertebrates, a tissue residue response curve can not be determined for fish; however this can be accomplished for invertebrates due to a weak cytochrome P450 system. For PAHs, recent work has demonstrated that fluorescent aromatic compounds (FACs) in bile can be used to assess bioaccumulation and toxicity. Meador et al. (2006, 2008) found a high correlation between bile FACs, dietary intake of PAHs, and toxicity in juvenile salmon. Biliary FACs are a surrogate measure of the internal tissue concentration and would be appropriate for characterizing exposure and toxicity in fish. The PAH metabolites in bile will be considered by RSET in future evaluations once candidate thresholds are developed by the National Oceanic and Atmospheric Administration.

D.1.2. Protocols for the Development of TTLs

Two approaches are described here for the development of tissue TTLs:

1. Using existing critical body residue (CBR) values. Chemical specific values are considered as a mean or preferably analyzed with a species sensitivity distribution (SSD). From the SSD, a protective tissue TTL is determined.
2. Predicted tissue-residue toxicity metrics using existing or modeled exposure media toxicity metrics and bioaccumulation factors (e.g., WQC-BCF approach).

Tissue TTLs can be developed for some chemicals using existing residue-effects information from the technical literature. The preferred approach is to examine the data as a SSD; however, if only a few data points are available (< 4), a mean and standard deviation may be determined and used as the chemical specific TTL. For chemicals without sufficient residue-effects information, a bioaccumulation model may be used to develop tissue TTLs; however, these values will have a higher level of uncertainty.

The strengths and limitations of each of the two primary tissue TTL development methods are described below, as are some of the available options within the two approaches.

D.1.3. Using Existing Critical Body Residue (CBR) Values and Species Sensitivity Distribution (SSD) Approach

The first step in this method for deriving TTLs is to identify existing CBR values. 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. One difficulty with using measured residue effects data to derive tissue TTLs 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 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 TTLs, but the limited available information for many chemicals in turn limits both the number and reliability of tissue TTLs derived from the literature.

The ERED database contains primarily results from studies examining survival, growth, and reproductive endpoints and has not compiled much of the available residue-effects literature on other responses, such as biochemical, physiological, morphological, and behavioral effects of bioaccumulated chemicals. Other specialized databases on tissue residues are being developed and introduced, such as the PCB residue database summarizing residue-effect data for dioxin-like toxicity in fish, mammals, and birds (EPA 2008).

In addition, the methods by which the residue-effects information is published and reported impose additional restrictions on the ability of scientists to evaluate and draw inferences from the existing data. Unlike water-based toxicity data, nearly all of which is reported as dose-response statistics (e.g. LC_{50}, EC_{20}, etc.), relatively little of the residue-effects literature is reported as such. Unfortunately, a large percentage of the available tissue-based toxicity metrics are expressed as lowest observed effects residues (LOERs), which are determined as the lowest dose producing a statistically significant adverse response compared to the control. The LOERs are dependent on the quantal nature of allocating exposure concentrations (often few and far between), a function of sample size (often low), highly prone to Type II error (finding no effect when in fact an effect exists), low power of the test, and a bright-line significance value ($\alpha = 0.05$) that ignores biologically important results. Occasionally the no observed effects residue (NOER) is used, which also exhibits potential flaws because it is not based on a toxicity response but represents negative evidence. The NOER values do not provide reliable information regarding the probability that a given toxicant concentration will not cause a biological response, and therefore should not be used directly to calculate TTLs.

Empirical Data

Once all available studies have been examined, those that are deemed acceptable are used to compile a list of values (e.g., LR_{50}, ER_{10}, LOER values). From these data, basic statistics, such as mean, variance, and confidence intervals, are produced with the algorithms. For tissue-residue toxicity data, many of the datasets are expected to follow a normal distribution because of the expected uniformity across species. For example, the LR_{50} data for chlorophenols and tributyltin as well as the TBT growth CBRs presented in this review are normally distributed (Meador 2006). When chemical-specific datasets are normally distributed, a mean and standard deviation may be calculated; however, these data can be subjected to an SSD evaluation (see below). If data sets contain less than 4 CBRs it is appropriate to simply calculate a mean and the lower 95% confidence interval (LCI) of the mean for use as the TTL. For those TTL values that are determined as a simple mean, a TTL for these data would be the lower 95% confidence limit of the mean. If the data are not normally distributed, an SSD approach is preferred (see below). For those chemical specific CBRs that are lognormally distributed, the appropriate algorithms also should be used because the standard equations are biased. Gilbert (1987) provides algorithms for calculating these basic statistics for log-normally distributed data.

D.1.4. SSD Approach

The SSD approach has been used extensively to examine toxic responses (Posthuma et al., 2002a). It has been used in various forms to determine water quality in Europe, water quality criteria (WQC) in the United States by the EPA (Stephan et al., 1985), to derive sediment quality guidelines (Long and Morgan 1991), and in various frameworks for ecological risk assessment.

The SSD can be strictly an empirical cumulative distribution function or a line may be fitted to the data based on the known distribution (e.g., lognormal) using the mean and standard deviation for the data. In recent years, the hazardous concentration percentile (HC_p; p = percentile) has become the standard way to select a concentration for protection. In many applications, the HC_{05}, or that concentration representing the 5^{th} percentile of the SSD is selected to protect the 100 - p percentile of all species. The HC_p for protection may be simply the 5^{th} percentile of the observed data or an interpolated value from a fitted distribution. One major drawback to the latter approach is the selection of the best distribution to fit the data. Goodness of fit tests (e.g., Kolmogorov-Smirnoff; K-S) can be used to test the chosen distribution. If the K-S test fails, alternate methods are recommended. Recently, bootstrap techniques have been applied to data sets to determine HC_p values (Newman et al., 2000). The main advantage of bootstrapping is that it is applied to the raw data and is non-parametric (no distribution is assumed); however, relatively large datasets are required (i.e., > 20 values).

There is one software program (BurrliOZ) that can be used to fit toxicity data to species sensitivity distribution. This program was developed by the CSIRO in Australia (http://www.cmis.csiro.au/envir/Burrlioz). This program will fit the entered values to the Burr Type 3 (Shao 2000), log-logistic, and lognormal distributions. BurrliOZ also calculates the HC_p effect concentration at various percentiles and the percent confidence interval for that HCp.

When an SSD is used to derive tissue TTLs, a policy decision is required to determine at what level of effect (or the proportion of species to be protected) the TTL should be set. For consistency with EPA's WQC derivation methodology and several ERA frameworks, the 5^{th} percentile of the adverse effects data for survival, reproduction, and growth is used as the selected TTL in the SEF (Stephan et al., 1985, Posthuma et al., 2002a).

The minimum number of values required for a chemical-specific, tissue-based SSD has not been determined. The number of data points needed to characterize the toxicity response is a function of the variability among species and the randomness of the selection. Most SSDs are constructed with media-based exposure metrics that are more variable than those based on tissue residues. For media exposures, the European Union Technical Guidance Documents prescribes 10 values from at least 8 taxa and the Netherlands requires four values from four taxa (Posthuma et al., 2002b). In some cases, an SSD with few data points will not change appreciably when more points are added. A minimum of four data points from four taxa for generation of an SSD has been selected for calculating TTLs under RSET. This value is also supported by Pennington (2003), who examined sample size on SSDs and HC_{05} determinations.

The aquatic life TTLs presented in Table D-1 are based on the HC_{05} point estimate as discussed above. Table D-1 also provides the source of the HC_{05} point estimate, either the original literature reference or the BurrliOZ software program described above.

D.1.5. Toxicity-Bioaccumulation Modeling Approach

A more general modeling approach for calculating TTLs may be used as was done by ODEQ for the development of the majority of the aquatic life TTLs presented in the Sediment Bioaccumulation Guidance (ODEQ 2007). For this method, a tissue CBR is derived from the product of an established water quality criterion and a generic bioconcentration factor (or bioaccumulation factor) that has been calculated using toxicokinetics, quantitative structure activity relationships (QSARs), or that represents the 95^{th} percentile of all BCFs for that chemical. As many water quality criteria and bioconcentration factors are already available, this approach can be used to quickly generate tissue TRVs for a number of chemicals. The ODEQ used readily available BCFs from EPA's water quality criteria documents (ODEQ 2007).

Tissue toxicity reference values (TRVs) derived using the WQC-BCF approach have many uncertainties. These uncertainties include the accuracy of water quality criteria used as an input to the model and using a single BCF (or BAF) to derive applicable tissue TRVs. Addressing these uncertainties during tissue TRV development may result in TRVs with large safety factors relative to the safety factors of tissue TRVs derived from SSDs. This is the less preferred of the two methods described in this section.

D.1.6. Factors to Consider

Biological Responses

One issue of concern that applies to both the bioaccumulation modeling and SSD generation approaches is selection of the toxicological endpoints to incorporate into TTL derivation. The list of endpoints to be considered is dependent on the statute. The Clean Water Act (CWA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and the Endangered Species Act (ESA) each prescribe a different approach for protecting species and they allow for a different set of biological responses in the derivation of such protective concentrations. The standard set of adverse responses includes effects on survival, reproduction, and growth. Other endpoints are available for consideration when developing tissue TTLs. Examples of additional endpoints to consider include toxicant effects on behavior, physiology, morphology, and biochemistry. Evaluation of these additional endpoints in TTL 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.

If sufficient data are available, separate TTLs should be developed for fish and invertebrates. This is desirable because these two major groups often exhibit differences in the abundance and affinity of receptors for some toxicants and they often exhibit different biological responses for the same dose. One example of this is dioxin toxicity, which is far more important for fish and less so for invertebrates. Additionally, these two groups may detoxify toxicants differently resulting in major differences in the biologically effective internal dose. This is the case for metals and some organics that are metabolized at different rates.

Endangered Species

Threatened and endangered species listed under the ESA are an important concern. Salmonids are one of the most commonly listed aquatic species that occur at many sites where the RSET framework will be applied. For media based exposure, salmonids are often one of the most sensitive species because of their high rates of prey ingestion and ventilation. For this reason, a species in the family Salmonidae is required for determination of a water quality criterion (Stephan et al., 1985). There are very few data for testing this hypothesis with tissue-residue toxicity statistics. In theory, it is expected that salmonids would exhibit similar sensitivity as other species; however, this is not certain. One review of tissue-residue toxicity metrics for chlorophenols and pentachlorophenol did show that some salmonids were more sensitive than other species, but not in every case (Meador 2006). It is highly recommended that residue-effects data for a surrogate species for an ESA listed species (e.g., rainbow trout for listed salmonids) be considered during any tissue TTL development.

For the SEF, two approaches will be used to develop TTLs protective of ESA species. First, for those TTLs which are derived using SSDs, the species included in the SSD will be evaluated to determine whether a salmonid or other ESA surrogate species was included and whether the corresponding TTL derived is protective of that species. If so, then the TTL will be considered protective of ESA species. For situations where ESA species or a surrogate toxicity data are not available, the TTL will be derived based on a NOER calculated using uncertainty factors as described in detail below. This analysis is still being conducted and ESA protective TTLs will be added to the SEF in the future revisions/updates to this document.

Uncertainty/Safety Factors

There is always uncertainty in developing guidelines or threshold values to be used for environmental protection. This uncertainty often necessitates the use of uncertainty (safety) factors to account for variability and to ensure that the proposed values will protect the intended species under most circumstances. Potential factors to be considered include laboratory to field uncertainty, predominance of mortality metrics, extrapolations of effect to no effect values, temporal factors, and species factors (ecologically or economically important species and ESA-listed species).

If a TTL is based mostly on mortality, it will not be useful for field assessments. Once organisms reach tissue concentrations likely to cause mortality, the population impacts will be severe and the probability of finding those individuals in field collections will be very small. A tissue TTL should be based on sublethal responses so that there is the possibility of observing those tissue concentrations in the field and evaluating when the levels are approaching important effect concentrations.

In situations where the low effect values are not based on an ESA species or surrogate, to derive an ESA-protective TTL, a low effect value (e.g., 5^{th} percentile of LOERs) should be extended to a no effect value (NOER), which can be accomplished with a safety factor (uncertainty factor). In many applications, a factor of 10 has been applied (Chapman et al., 1998; Duke and Taggart 2000); however, in some cases that value is higher (Pennington 2003).

For the current framework, it is recommended that the 5^{th} percentile (HC_{05}) of sublethal values be used. Any mortality-based toxicity metrics used in the derivation of a TTL will be subjected to a default lethal-to-sublethal ratio (LSR) of 10.

D.1.7. Summary of Aquatic Life TTLs

At this stage of the RSET process, it is recommended that existing tissue TTLs be used that have been developed for various toxicants and groups of species. Available TTLs are presented in Table D-1. Some of these values were used as recommended by the authors, when consistent with the recommended RSET approach. Other data sets were used with the BurrliOZ program to calculate HC_{05} values and the LCI of that value. Species mean values were determined where multiple values occurred in the data set. In situations where TTLs were based on mortality endpoints, a LSR of 10 was used to calculate a LOER value.

The TTLs presented in Table D-1 were derived based on the recommended empirical data-SSD approach. In addition, the ODEQ Sediment Bioaccumulation guidance (ODEQ 2007) has an aquatic life TTL for cadmium based on an SSD approach.

Aquatic Life TTLs for compounds for which SSD-based TTLs were not available but for which ODEQ has calculated TTLs based on the WQC-BCF methodology and the cadmium SSD TTL based on the HC_{05} point estimate are provided in Table D-2.

D.2. TTL FOR PROTECTION OF AQUATIC-DEPENDENT WILDLIFE

This section presents the approach used to develop TTLs for aquatic-dependent wildlife. This TTL represents the concentration or target level of a bioaccumulative contaminant in prey items that are 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 are predicted not to 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 in this framework, 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 (food ingestion) pathway tends to be the dominant source for bioaccumulative chemicals (Bridges et al., 1999).

It is important to note that TTLs for aquatic-dependent wildlife may not be protective of the prey species themselves (TTLs to protect prey species were developed above in Section D.1). However, TTLs that are protective of upper trophic level species are typically protective of species lower in the food chain. These TTLs are derived based on dietary 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 (or surrogate species) identified in a watershed must be available to calculate TTLs for specific aquatic-dependent wildlife (see Section D.2.3 for a list of available TRVs).

D.2.1. Selection of Aquatic-dependent Wildlife Receptors

Candidate aquatic-dependent wildlife receptors for freshwater and marine systems were identified by the Bioaccumulation Subcommittee to be considered “representative” or “sentinel” wildlife receptors based on feeding guilds expected for aquatic dependent wildlife in this region. These are presented in Table D-3, and include several avian and mammalian species that consume large amounts of fish and/or shellfish 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.

Recognizing the difficulties of developing TTLs on a site-specific basis, guidance is provided here for developing TTLs 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 TTLs for the prey items of additional wildlife species. However, it is likely that the concepts presented in this appendix will be applicable to most if not all areas where BCoCs that could impact higher trophic level wildlife are present.

Table D-3. 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
Hooded Merganser	*Mergus serrator*	Yes	Small fish and invertebrates
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	*Actitis macularia*	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 [2,3]	*Enhydra lutris lutris*	Yes	Marine shellfish and invertebrates
American Mink [1]	*Mustela vision*	Yes	Crustaceans (crayfish), fish
Harbor Seal [2]	*Phoca vituluna*	Yes	Marine fish, salmon, macroinvertebrates
Orca Whale [2]	*Orcinus orca*	Yes	Fish, marine mammals

[1] Predominantly a freshwater species
[2] Predominantly a marine species
[3] Washington State only

D.2.2. Calculation of TTLs

Target tissue levels for selected receptor species were calculated using one of the following two equations. In instances where an estimate of the daily food ingestion rate (FIR) is available on a total mass basis (e.g., kg wet weight), the following equation was used to calculate the TTL:

$$\mathbf{TTL_w} = \frac{\mathbf{TRV_w}}{(\mathbf{FIR/BW})} \qquad \textbf{Equation D-1}$$

where:

TTL_w = aquatic-dependent wildlife tissue bioaccumulation trigger (mg/kg, wet weight)
TRV_w = toxicity reference value for wildlife receptor (mg/kg body weight/day)
FIR = daily food ingestion rate for wildlife receptor (kg wet weight/day)
BW = body weight for wildlife receptor (kg)

In instances where an estimate of the FIR_a was estimated using an allometric scaling calculation that provides a daily FIR_a in units of kg/kg-body weight/day, the following equation was used to calculate the TTL:

$$\mathbf{TTL_w} = \frac{\mathbf{TRV_w}}{(\mathbf{FIR_a})} \qquad \textbf{Equation D-2}$$

where:

TTL_w = aquatic-dependent wildlife tissue bioaccumulation trigger (mg/kg, wet weight)
TRV_w = toxicity reference value for wildlife receptor (mg/kg-body weight/day)
FIR_a = daily food ingestion rate for wildlife receptor (kg wet weight/kg-body weight/day)

Food ingestion rates and body weights of site-specific wildlife species of interest were selected from available literature sources, including EPA's *Wildlife Exposure Factors Handbook* (EPA 1993b). Similarly, allometric scaling equations to calculate food ingestion rates for site-specific species were taken from EPA (1993b) and Nagy (2001).

D.2.3. Toxicity Reference Values (TRVs)

The TRVs used to calculate TTLs were selected from the identified primary literature sources that are protective of the receptors. The TRVs 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." Additional site- or project-specific parameters can be used to fine-tune the model and potentially adjust the TTL in an area, if warranted.

The use of TRVs in this document is consistent with the ODEQ's *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (2007). The ODEQ (2007) uses the lowest-observable-effect-level (LOAEL) as the basis for calculating TTLs protective of populations of the site-specific receptor and the no-observed-adverse effect level (NOAEL) to be protective of individuals of the site-specific receptor.

Additionally ODEQ (2007) uses several extrapolations if the desired toxicity threshold was not identified in the literature. The NOAELs were extrapolated to LOAELs by multiplying the NOAEL by 5. The LOAELs were extrapolated to NOAELS by multiplying the LOAEL by 0.1 (ODEQ 2007).

The hierarchy of sources of TRVs for use in the development of aquatic-dependent wildlife TRVs as determined by the Bioaccumulation Subcommittee is as follows:

1. EPA avian and mammalian NOAEL TRVs identified in the soil-screening level (SSL) guidance documents (EPA 2005-2007); and
2. ODEQ (2007) avian and mammalian NOAEL and LOAEL TRV's selected for use.

D.2.4. Aquatic-dependent Wildlife Receptors Parameters

As presented in Equations D-1 and D-2, the life history parameters required for the selected representative receptor species are body weight (BW) and food ingestion rate (FIR). The body weight selected for TTL calculations were based on mean female body weights, when available, as the NOAEL TRVs are frequently based on reproductive endpoints from exposure to female organisms. If mean female body weights were not available, mean adult body weights were used.

The following sections of text summarize the information used to select representative BW and FIR for aquatic-dependent wildlife species for which TTLs were calculated. These parameters are summarized in Table D-4.

Table D-4. Life History Parameters for Common Aquatic-dependent Wildlife Receptors in Freshwater and Marine Systems

Candidate Wildlife Receptors	Body Weight (kg)	Food Ingestion Rate (FIR)
Birds		
Great Blue Heron	2.2	0.388 kg ww/day
Belted Kingfisher	0.147	0.50 kg/kg -BW/day
Hooded Merganser	0.54	0.200 kg ww/day
Black-Necked Stilt	0.160	0.089 kg ww/day
American Avocet	0.312	0.138 kg ww/day
Spotted Sandpiper	0.0471	0.039 kg ww/day
Bald Eagle	4.5	0.54 kg ww/day
Osprey	1.88	0.395 kg ww/day
Mammals		
North American River Otter [1]	7.70	0.759 kg ww/day
Northern Sea Otter [2]	24.2	2.02 kg ww/day
American Mink[1]	0.974	0.156 kg ww/day
Harbor Seal [2]	76.5	0.458 kg ww/day
Orca Whale	7,500	280 kg ww/day

1 Predominantly a freshwater species.
2 Predominantly a marine species.

Great Blue Heron

Body Weight and Daily Food Ingestion Rate

Hartman (1961) and Palmer (1962), as cited in EPA (1993b), report that adult males (mean = 2.57 kg) are slightly heavier in weight than adult females (mean = 2.20 kg). Using the mean adult female body weight and the following regression equation referenced in EPA (1993b) relating the amount of food ingested per day to body weight for wading birds, the daily food ingestion rate was calculated to be 0.388 kg wet weight/day.

$$\log(\mathrm{FIR}) = 0.966 \log(\mathrm{BW}) - 0.640 \qquad \textbf{Equation D-3}$$

where:

FIR = daily food ingestion rate for wildlife receptor (g wet weight/day)
BW = body weight for wildlife receptor (g)

Diet Composition

Various studies referenced in EPA (1993b) confirm that the vast majority of a great blue heron's diet consists of fish. Other prey items identified include amphibians, reptiles, crustaceans, insects, birds, and mammals (EPA 1993b).

Belted Kingfisher

Body Weight and Daily Food Ingestion Rate

Salyer and Lagler (1946), as referenced in EPA (1993b), reported that the sexes are similar in size, although the female tends to be slightly larger. The BW selected to calculate the TTL is the mean of the adult BWs provided in EPA (1993b) which is 0.147 kg. The EPA (1993b) reports a FIR_a of 0.50 kg/kg-body weight/day for this species.

Diet Composition

The EPA (1993b) summarizes the literature with regards to belted kingfisher dietary habits. Belted kingfishers feed on fish that swim near the surface or in shallow waters. However, the diet of the belted kingfisher varies with availability of prey items and when fish are not available, have been shown to consume crayfish, other crustaceans, invertebrates, amphibians and reptiles.

Hooded Merganser

Body Weight and Daily Food Ingestion Rate

Dunning (1993) reported adult female hooded merganser BWs ranging from 0.54 to 0.68 kg and adult male body weights range from 0.68 to 0.91 kg. The BW selected to calculate the TTL is the lower of the adult female BWs provided in EPA (1993b) which is 0.54 kg. The daily food ingestion rate was estimated as a function of body weight using the following allometric equations developed for carnivorous birds (Nagy 2001).

$$\mathbf{FIR = 3.048 \times BW^{0.665}} \qquad \textbf{Equation D-4}$$

where:

FIR = daily food ingestion rate for wildlife receptor (g wet weight/day).
BW = body weight (g).

Using the lower of the average female body weight reported in Dunning (1993; 0.54 kg), the calculated food ingestion rate was 0.200 kg wet weight/day (using Equation D-4).

Diet Composition

Hooded mergansers feed primarily by diving for whatever small fish are abundant, but they will also eat aquatic invertebrates, especially as hatchlings (Csuti et al., 2001). They are also known to feed on crustaceans, aquatic insects, and small fish (Bendell and McNicol 1995).

Black-Necked Stilt

Body Weight and Daily Food Ingestion Rate

Robinson et al. (1999) reported that the weight of an adult black-necked stilt can range from 0.136 to 0.220 kg. The BW selected to calculate the TTL is the mean of the adult BWs provided in Robinson et al. (1999) which is 0.160 kg. The daily food ingestion rate was estimated as a function of body weight using the following allometric equations developed for carnivorous birds (Nagy 2001).

FIR = 3.048×BW$^{0.665}$ **Equation D-4**

where:

FIR = daily food ingestion rate for wildlife receptor (g wet weight/day)
BW = body weight (g)

Using the mean adult BW (0.160 kg) reported in Robinson et al. (1999) the calculated food ingestion rate was 0.089 kg wet weight/day (using Equation D-4).

Diet Composition

The California Wildlife Habitat Relationship System (CWHRS 2005) reported that the black-necked stilt forages in shallow water for insects, crustaceans, mollusks, other aquatic invertebrates, and some small fish.

American Avocet

Body Weight and Daily Food Ingestion Rate

Robinson et al. (1999) reported that the weight of an adult American avocet can range from 0.275 to 0.350 kg. The BW selected to calculate the TTL is the mean of the adult BWs provided in Robinson et al. (1999) which is 0.312 kg. The daily food ingestion rate was estimated as a function of body weight using the following allometric equations developed for carnivorous birds (Nagy 2001).

FIR = 3.048×BW$^{0.665}$ **Equation D-4**

where:

FIR = daily food ingestion rate for wildlife receptor (g wet weight/day).
BW = body weight (g).

Using the mean BW of 0.312 kg reported in Robinson et al. (1999), the calculated food ingestion rate was 0.138 kg wet weight/day (using Equation D-4).

Diet Composition

The CWHRS (2005) reported that the American avocet forages on mudflats, salt or alkali flats, in shallow-pond areas, and in salt ponds. Preferred foods include aquatic insects, crustaceans, snails, worms, and occasionally seeds of aquatic plants (Cogswell 1977 referenced in CWHRS 2005).

Spotted Sandpiper

Body Weight and Daily Food Ingestion Rate

Maxson and Oring (1980), as presented in EPA (1993b), reported average adult female and male body weights to be 0.0471 and 0.0379 kg, respectively. The BW selected to calculate the TTL is the mean of the adult female BW of 0.0471 kg. The daily food ingestion rate was estimated as a function of body weight using the following allometric equations developed for carnivorous birds (Nagy 2001).

$FIR = 3.048 \times BW^{0.665}$ **Equation D-4**

where:

FIR = Daily Food Ingestion Rate for wildlife receptor (g wet weight/day).
BW = body weight (g).

Using the average adult female body weight of 0.0471 reported in EPA (1993b), the calculated food ingestion rate was 0.039 kg wet weight/day (using Equation D-4).

Diet Composition

Spotted Sandpipers feed primarily on terrestrial and aquatic insects (Bent 1929; Csuti et al., 2001). They may occasionally feed on other benthic macroinvertebrates such as crustaceans, mollusks, and worms (Bent 1929; Csuti et al., 2001) or on leeches, small fish, and carrion (Oring et al., 1983).

Bald Eagle

Body Weight and Daily Food Ingestion Rate

Wiemeyer (1991) as cited in EPA (1993b), reported average adult female and male body weights for bald eagles to be 4.5 and 3.0 kg, respectively. The food ingestion rate was represented as 12% of the body weight on a wet-weight basis, based on a study by Stalmaster and Gessaman (1982), as cited in EPA (1993b), of free-flying eagles in Washington. Using the average female bald eagle body weight, the calculated food ingestion rate was 0.54 kg wet weight/day.

Diet Composition

Bald eagles are opportunistic foragers with site-specific food habits based on available prey species (Anthony et al., 1999; Buehler 2000). In most regions, bald eagles seek out aquatic habitats for foraging and prefer fish (Ehrlich et al., 1988; Buehler 2000). Bald eagles also eat carrion, various water birds, and small mammals (Csuti et al., 2001).

Osprey

Body Weight and Daily Food Ingestion Rate

Poole (1983), as cited in EPA (1993b), reported that the average adult female and male osprey body weights during courtship were 1.88 and 1.48 kg, respectively. The food ingestion rate was reported as 21% of the body weight on a wet weight basis, based on studies of adult female osprey in Massachusetts (Poole 1983, as cited in EPA 1993b). Using the average female osprey body weight of 1.88 kg, the calculated food ingestion rate was 0.395 kg wet weight/day.

Diet Composition

Osprey tend to feed solely on fish, primarily on slow-moving fish that swim near the water surface (Csuti et al., 2001). They may occasionally eat other types of vertebrate prey such as birds, reptiles, and small mammals, and they only rarely feed on invertebrates.

River Otter

Body Weight and Daily Food Ingestion Rate

The life history parameters selected for river otters are based on the accepted parameters for this species that is being used for the Portland Harbor Remedial Investigation/Feasibility Study (Windward 2005). Average adult female and male river otter body weights in western Oregon and Washington have been reported for trapped otters submitted to the U.S. Geological Survey (Grove 2004). Body weights were reported without pelts, and weights were adjusted to estimate body weight with pelts using a methodology agreed upon by EPA, EPA's partners, and the Lower Willamette Group in the preparation of the Ecological Preliminary Risk Evaluation (Windward 2005).

Estimated pelted body weights for adult female and male river otters were 9.46 and 11.15 kg, respectively. The daily food ingestion rate for river otter was estimated as a function body weight using the following allometric equation presented in Nagy (2001). Nagy (2001) provides two allometric equations for carnivorous mammals under the group "carnivora" and "carnivores." The allometric equation for the group "carnivora" was used for calculating the FIR as Nagy reports that the mammalian "carnivore" group excludes fish eating mammals (Nagy 2001).

$$FIR = 0.348 \times BW^{0.859}$$ **Equation D-5**

where:

FIR = daily food ingestion rate (g wet weight/day).
BW = body weight (g).

Using the female adult river otter body weight of 9.5 kg, the calculated female food ingestion rate was 0.91 kg wet weight/day.

Diet Composition

River otters are opportunistic carnivores that take advantage of food that is most abundant and easiest to catch, although fish are their primary prey (EPA 1993b). Other components of their diet may include aquatic invertebrates (including crayfish, mussels, clams, and aquatic insects), frogs, snakes, turtles, and occasionally scavenged small mammals and birds (Coulter et al., 1984; Csuti et al., 2001).

Northern Sea Otter

Body Weight and Daily Food Ingestion Rate

Kenyon (1969) as cited in WDFW (2004) reported average adult female and male sea otter body weights during to be 37.9 and 24.2 kg, respectively. The daily food ingestion rate for the sea otter was estimated as a function body weight using the following allometric equation developed for carnivorous mammals (Nagy 2001).

$$FIR = 0.348 \times BW^{0.859}$$ **Equation D-5**

where:

FIR = daily food ingestion rate (g wet weight/day).
BW = body weight (g).

Using the female juvenile river otter body weight of 24.2 kg, the calculated female food ingestion rate was 2.02 kg wet weight/day.

Diet Composition

Sea otters are a highly generalized consumer; most individuals specialize in one to four prey types and prey types differ among individuals (WDFW 2004). Observation of Washington State sea otters indicated that they preyed exclusively on invertebrates including clams, chitons, sea cucumbers, octopus, crabs, and sea urchins (WDFW 2004).

American Mink

Body Weight and Daily Food Ingestion Rate

Hornshaw et al. (1983), as presented in EPA (1993b), reported average farm-raised adult female and male BWs for mink in the summer to be 0.974 and 1.734 kg, respectively. The daily food ingestion rate was estimated as 16% and 12% of body weight on a wet weight basis, based on studies of farm-raised female and male mink in Michigan (Bleavins and Aulerich 1981), as presented in EPA (1993b). Using the female mink parameters, the calculated food ingestion rate for females was 0.156 kg wet weight/day.

Diet Composition

Mink are opportunistic feeders and consume a range of prey including muskrats, fish, frogs, crayfish, small mammals, and birds found near water (Csuti et al., 2001). The prey items of Mink are largely dependent on availability, and portions of fish in the mink diet vary widely across field studies.

Harbor Seal

Body Weight and Daily Food Ingestion Rate

Body weights for adult male and female harbor seals (84.6 and 76.5 kg, respectively) were based on Pitcher and Calkins (1979), as cited in EPA (1993b). The FIR for harbor seals was calculated using an allometric equation (Equation D-5) developed by Boulva and McClaren (1979), as cited in EPA (1993b).

$$\mathbf{FIR = 0.089 \times BW^{0.76}} \qquad \textbf{Equation D-6}$$

where:

FIR = daily food ingestion rate (g wet weight/day)
BW = body weight (g)

Using the adult female harbor seal body weight of 76.5 kg, the calculated female food ingestion rate was 0.458 kg wet weight/day.

Diet Composition

The harbor seal's diet varies seasonally and includes bottom-dwelling fish and species that can be caught in periodic spawning aggregations (e.g., herring, lance, and squid; EPA 1993b).

Orca Whale

Body Weight and Daily Food Ingestion Rate

The NMFS (2008) reported that adult male killer whales can reach weights up to 10,000 kg and female killer whales can reach weights up to 7,500 kg. The daily food ingestion rate for the orca whale was estimated as a function body weight using the following allometric equation developed for carnivorous mammals (Nagy 2001).

$FIR = 0.348 \times BW^{0.859}$ Equation D-5

where:

FIR = daily food ingestion rate (g wet weight/day).
BW = body weight (g).

Using the female adult orca whale body weight of 7,500 kg, the calculated female food ingestion rate was 280 kg wet weight/day.

Diet Composition

Literature information on the diet composition of resident orca's in Puget Sound indicates that both northern and southern resident killer whales eat Chinook salmon preferentially (Ford 2006). Chum salmon becomes the primary salmonid in the diet September-October once the other species of salmon return to the rivers. Very little is known about what the resident whales eat during the other months of the year.

D.2.5. TRVs for Avian Receptor Species

The following sections present the avian wildlife TRVs that were used for the calculation of wildlife TTLs. As discussed above, NOAEL and LOAEL TRVs were selected using the hierarchy of sources presented in Section D.2.3. The selected avian wildlife TRVs are summarized in Table D-5.

D.2.5.1. TRV for Arsenic

The avian NOAEL TRV for arsenic selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL Report for Arsenic (EPA 2005a). The avian NOAEL TRV for both carnivorous and insectivorous birds was reported to be 2.24 mg arsenic/kg body weight/day. This TRV was reported to be the lowest NOAEL value for the reproduction, growth, or survival endpoints.

The avian LOAEL TRV for arsenic selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The avian LOAEL TRV is reported to be 11.2 mg arsenic/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

Table D-5. Avian TRVs

Chemical	Avian NOAEL TRV (mg/kg/day)	Avian LOAEL TRV (mg/kg/day)	Reference
Arsenic	2.24	11.2	(1)
Lead	1.63	8.2	(1)
Mercury	0.013	0.026	(2)
Selenium	0.29	1.4	(1)
TBT	6.8	17	(2)
Fluorene	--	--	
Fluoranthene	--	--	
Pyrene	--	--	
Pentachlorophenol	6.73	33.6	(1)
Hexachlorobenzene	--	--	
p,p'-DDE	0.227	1.14	(1)
p,p'-DDD	0.227	1.14	(1)
p,p'-DDT	0.227	1.14	(1)
Methoxychlor	--	--	
Total Chlordanes	0.214	1.07	(2)
Dieldrin	0.0709	0.35	(1)
Total Endosulfan	--	--	
gamma-HCH (Lindane)	--	--	
Total PCBs Aroclors	0.2	0.6	(2)
Dioxins/Furans/coplanar PCBs TEQ	1.4×10^{-6}	7.0×10^{-6}	(2)

(1) EPA Soil Screening Level Reports; LOAEL values extrapolated from NOAEL TRVs by multiplying by 5.
(2) ODEQ (2007).
-- = not available

D.2.5.2. TRV for Lead

The avian NOAEL TRV for lead selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for lead (EPA 2005c). The avian NOAEL TRV for both carnivorous and insectivorous birds was reported to be 1.63 mg lead/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The avian LOAEL TRV for lead selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The avian LOAEL TRV is reported to be 8.2 mg lead/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

D.2.5.3. TRV for Mercury

The avian NOAEL TRV for methylmercury selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The avian NOAEL TRV was originally cited in EPA's Eco-SSL report (EPA 2006). The avian NOAEL TRV was reported to be 0.013 mg mercury/kg body weight/day.

The avian LOAEL TRV for methylmercury selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The Avian LOAEL TRV was originally cited in EPA's Eco-SSL report (EPA 2006). The avian LOAEL TRV was reported to be 0.026 mg mercury/kg body weight/day.

D.2.5.4. TRV for Selenium

The avian NOAEL TRV for selenium selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for selenium (EPA 2007e). The avian NOAEL TRV for both carnivorous and insectivorous birds was reported to be 0.29 mg selenium/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The avian LOAEL TRV for selenium selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The avian LOAEL TRV is 1.45 mg selenium/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

D.2.5.5. TRV for PAHs

The availability of avian TRVs for the PAHs identified as BCoCs (fluorene, fluoranthene, and pyrene) were evaluated by reviewing the Eco-SSL document for PAHs (EPA 2007d). The conclusion of the Eco-SSL evaluation of avian TRVs for PAHs was that there was insufficient information to derive TRVs for PAHs.

D.2.5.6. TRV for Pentachlorophenol

The avian NOAEL TRV for pentachlorophenol selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for pentachlorophenol (EPA 2007c). The avian NOAEL TRV for both carnivorous and insectivorous birds was reported to be 6.73 mg pentachlorophenol/kg body weight/day. This TRV was reported to be the lowest NOAEL for the reproduction, growth, or survival endpoints.

The avian LOAEL TRV for pentachlorophenol selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The avian LOAEL TRV is 33.7 mg pentachlorophenol/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

D.2.5.7. TRV for Hexachlorobenzene

No avian TRVs for hexachlorobenzene were identified from the sources used to derive wildlife TTLs.

D.2.5.8. TRV for DDT and Metabolites

The availability of avian TRVs for DDT and its metabolites, DDD, and DDE were evaluated by reviewing the Eco-SSL document for DDT and metabolites (EPA 2007a). This report states that there were sufficient data for the derivation of avian NOAEL TRV for DDT and that this TRV was also applicable for the metabolites of DDT (e.g., DDD and DDE). Therefore, for the calculation of wildlife TTLs for DDT and its metabolites, the NOAEL TRF value in EPA (2007a) was used.

The avian NOAEL TRV for DDT and its metabolites used in calculating the wildlife TTL is presented in EPA's Eco-SSL Report for DDT and its metabolites (EPA 2007a). The avian NOAEL TRV for both carnivorous and insectivorous birds was reported to be 0.227 mg DDx/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The avian LOAEL TRV for DDT and its metabolites selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The avian LOAEL TRV is 1.135 mg DDx/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

D.2.5.9. TRV for Methoxychlor

No avian TRVs for methoxychlor were identified from the sources used to derive wildlife TTLs.

D.2.5.10. TRV for Total Chlordanes

The avian NOAEL TRV for total chlordanes selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The avian NOAEL TRV was originally cited in Sample (1996) and was reported as a NOAEL value for the red-winged blackbird. The ODEQ divided this NOAEL value with an uncertainty factor of 10 to account for interspecies variability. The resulting NOAEL TRV for total chlordanes was 0.214 mg chlordanes/kg body weight/day.

The avian LOAEL TRV for total chlordanes selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The avian LOAEL TRV was originally cited in Sample (1996) and was reported as a LOAEL value for the red-winged blackbird. The ODEQ divided this LOAEL value with an uncertainty factor of 10 to account for interspecies variability. The resulting LOAEL TRV for total chlordanes was 1.07 mg chlordanes/kg body weight/day.

D.2.5.11. TRV for Dieldrin

The avian NOAEL TRV for dieldrin selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for dieldrin (EPA 2007b). The avian NOAEL TRV for both carnivorous and insectivorous birds was reported to be 0.0709 mg dieldrin/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The avian LOAEL TRV for dieldrin selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The avian LOAEL TRV is 0.35 mg dieldrin/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

D.2.5.12. TRV for Total Endosulfan

No avian TRVs for total endosulfan were identified from the sources used to derive wildlife TTLs.

D.2.5.13. TRV for gamma-HCH (Lindane)

No avian TRVs for lindane were identified from the sources used to derive wildlife TTLs.

D.2.5.14. TRV for Total PCB Aroclors

The avian NOAEL TRV for total PCB aroclors (as aroclor 1254) selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The avian NOAEL TRV was originally cited in EPA (1995) and was reported as the NOAEL value for aroclor 1254 developed for the Great Lakes Water Quality Initiative. The NOAEL TRV for total PCB aroclors (as aroclor 1254) was 0.2 mg PCBs/kg body weight/day.

The avian LOAEL TRV for total PCB aroclors (as aroclor 1254) selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The avian LOAEL TRV was originally cited in EPA (1995) and was reported as the LOAEL value for aroclor 1254 developed for the Great Lakes Water Quality Initiative. The LOAEL TRV for total PCB aroclors (as aroclor 1254) was 0.6 mg PCBs/kg body weight/day.

D.2.5.15. TRV for Dioxin/Furan/PCB Congeners TEQs

The avian NOAEL TRV for dioxin/furan/PCB congeners selected for use in calculating the wildlife TTL is presented in ODEQ (2007). Dioxin, furan, and PCB TEQs are expressed as 2,3,7,8-TCDD equivalents; therefore, toxicity studies involving exposure of birds to 2,3,7,8-TCDD were reviewed. The avian NOAEL TRV was originally cited in EPA (1995) and was reported as the NOAEL value for 2,3,7,8-TCDD developed for the Great Lakes Water Quality Initiative. The NOAEL TRV for dioxin/furan/PCB congeners was 1.4×10^{-6} mg TEQ/kg body weight/day.

The avian LOAEL TRV for dioxin/furan/PCB congeners selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The avian LOAEL TRV was extrapolated from the NOAEL value by multiplying by 5. The LOAEL TRV for dioxin/furan/PCB congeners was calculated to be 7.0×10^{-6} mg TEQ/kg body weight/day.

D.2.5.16. TRV for Tributyltin (TBT)

The avian NOAEL TRV for tributyltin selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The avian NOAEL TRV was originally cited in Sample (1996) and was reported as a NOAEL value for the Japanese quail. The form of tributyltin used in this study was reported to be bis(tributyltin)oxide (TBTO). The resulting NOAEL TRV for tributyltin was 6.8 mg tributyltin/kg body weight/day.

The avian LOAEL TRV for tributyltin selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The avian LOAEL TRV was originally cited in Sample (1996) and was reported as a LOAEL value for the Japanese quail. The form of tributyltin used in this study was reported to be bis(tributyltin)oxide (TBTO). The resulting LOAEL TRV for tributyltin was 16.9 mg tributyltin/kg body weight/day.

D.2.6. TRVs for Mammalian Receptor Species

The following sections present the mammalian wildlife TRVs that were used for the calculation of wildlife TTLs. As discussed above, NOAEL and LOAEL TRVs were selected using the hierarchy of sources presented in Section D.2.3. The mammalian wildlife TRVs are summarized in Table D-6.

Table D-6. Mammalian TRVs

Chemical	Mammalian NOAEL TRV (mg/kg/day)	Mammalian LOAEL TRV (mg/kg/day)	Reference
Arsenic	1.04	5.2	(1)
Lead	4.7	24	(1)
Mercury	0.016	0.027	(2)
Selenium	0.143	0.72	(1)
TBT	2.34	3.5	(2)
Fluorene	65.6	328	(1)
Fluoranthene	0.615	3.05	(1)
Pyrene	0.615	3.05	(1)
Pentachlorophenol	8.42	42.1	(1)
Hexachlorobenzene	--	--	
p,p'-DDE	0.147	0.74	(1)
p,p'-DDD	0.147	0.74	(1)
p,p'-DDT	0.147	0.74	(1)
Methoxychlor			
Total Chlordanes	0.458	0.94	(2)
Dieldrin	0.015	0.08	(1)
Total Endosulfan	--	--	
gamma-HCH (Lindane)	--	--	
Total PCBs Aroclors	0.12	0.23	(2)
Dioxins/Furans/coplanar PCBs TEQ	8.0×10^{-8}	2.2×10^{-6}	(2)

(1) EPA Soil Screening Level Reports; LOAEL values extrapolated from NOAEL TRVs by multiplying by 5.
(2) ODEQ (2007).
-- = not available

D.2.6.1. TRV for Arsenic

The mammalian NOAEL TRV for arsenic selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for arsenic (EPA 2005a). The mammalian NOAEL TRV for both carnivorous and insectivorous mammals was reported to be 1.04 mg arsenic/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The mammalian LOAEL TRV for arsenic selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The mammalian LOAEL TRV is reported to be 5.2 mg arsenic/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

D.2.6.2. TRV for Lead

The mammalian NOAEL TRV for lead selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for lead (EPA 2005c). The mammalian NOAEL TRV for both carnivorous and insectivorous mammals was reported to be 4.70 mg lead/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The mammalian LOAEL TRV for lead selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The mammalian LOAEL TRV is reported to be 23.5 mg lead/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

D.2.6.3. TRV for Mercury

The mammalian NOAEL TRV for methylmercury selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The mammalian NOAEL TRV was originally cited in EPA (1995) and was reported as the NOAEL value for methylmercury developed for the Great Lakes Water Quality Initiative. The NOAEL TRV for methylmercury was 0.016 mg methylmercury/kg body weight/day.

The mammalian LOAEL TRV was for methylmercury selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The mammalian LOAEL TRV was originally cited in EPA (1995) and was reported as the LOAEL value for methylmercury developed for the Great Lakes Water Quality Initiative. The LOAEL TRV for methylmercury was 0.027 mg methylmercury/kg body weight/day.

D.2.6.4. TRV for Selenium

The mammalian NOAEL TRV for selenium selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for selenium (EPA 2007e). The mammalian NOAEL TRV for both carnivorous and insectivorous mammals was reported to be 0.143 mg selenium/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The mammalian LOAEL TRV for selenium selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The mammalian LOAEL TRV is 0.715 mg selenium/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

D.2.6.5. TRV for PAHs

The availability of mammalian TRVs for the PAHs identified as BCOCs (fluorene, fluoranthene, and pyrene) were evaluated by reviewing the Eco-SSL document for PAHs (EPA 2007d). The Eco-SSL evaluation for mammalian TRVs for PAHs was separated into two classes of PAHs; low-molecular weight PAHs (LPAH) which includes fluorene and high-molecular weight PAHs (HPAH) which includes fluoranthene and pyrene.

The mammalian NOAEL TRV for LPAH selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for PAHs (EPA 2007d). The Mammalian NOAEL TRV for both carnivorous and insectivorous mammals was reported to be 65.6 mg LPAH/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs. This TRV will be used for fluorene.

The mammalian NOAEL TRV for HPAH selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for PAHs (EPA 2007d). The mammalian NOAEL TRV for both carnivorous and insectivorous mammals was reported to be 0.615 mg HPAH/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs. This TRV will be used for fluoranthene and pyrene.

The mammalian LOAEL TRV for LPAH selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The mammalian LOAEL TRV is 328 mg LPAH/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5. This TRV will be used for fluorene.

The mammalian LOAEL TRV for HPAH selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The mammalian LOAEL TRV is 3.05 mg HPAH/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5. This TRV will be used for fluoranthene and pyrene.

D.2.6.6. TRV for Pentachlorophenol

The mammalian NOAEL TRV for pentachlorophenol selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for pentachlorophenol (EPA 2007c). The mammalian NOAEL TRV for both carnivorous and insectivorous mammals was reported to be 8.42 mg pentachlorophenol/kg body weight/day. This TRV was reported to be the geometric mean of NOAEL values for the reproduction and growth endpoints.

The mammalian LOAEL TRV for pentachlorophenol selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The mammalian LOAEL TRV is 42.1 mg pentachlorophenol/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

D.2.6.7. TRV for Hexachlorobenzene

No mammalian TRVs for hexachlorobenzene were identified from the sources used to derive wildlife TTLs.

D.2.6.8. TRV for DDT

The availability of mammalian TRVs for DDT and its metabolites, DDD, and DDE were evaluated by reviewing the Eco-SSL document for DDT and metabolites (EPA 2007a). This report states that there were sufficient data for the derivation of mammalian NOAEL TRV for DDT and that this TRV was also applicable for the metabolites of DDT (e.g., DDD and DDE). Therefore, for the calculation of wildlife TTLs for DDT and its metabolites the NOAEL TRV value in EPA (2007a) was used.

The mammalian NOAEL TRV for DDT and its metabolites selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for DDT and its metabolites (EPA 2007a). The mammalian NOAEL TRV for both carnivorous and insectivorous mammals was reported to be 0.147 mg ddx/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The mammalian LOAEL TRV for DDT and its metabolites selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ's sediment bioaccumulation guidance (ODEQ 2007). The mammalian LOAEL TRV is 0.735 mg ddx/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

It should be noted that the TTLs for total DDTs presented in Table 8-3 of the main report (TTLs for protection of aquatic-dependent wildlife) are based on the egg-based TRV presented in Section D.2.8.1.

D.2.6.9. TRV for Methoxychlor

No mammalian TRVs for methoxychlor were identified from the sources used to derive wildlife TTLs.

D.2.6.10. TRV for Total Chlordanes

The mammalian NOAEL TRV for total chlordanes selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The mammalian NOAEL TRV was originally cited in Sample (1996) and was reported as a NOAEL value for the mouse. The ODEQ divided this NOAEL value with an uncertainty factor of 10 to account for interspecies variability. The resulting NOAEL TRV for total chlordanes was 0.458 mg chlordanes/kg body weight/day.

The mammalian LOAEL TRV for total chlordanes selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The mammalian LOAEL TRV was originally cited in Sample (1996) and was reported as a LOAEL value for the mouse. The ODEQ divided this LOAEL value with an uncertainty factor of 10 to account for interspecies variability. The resulting LOAEL TRV for total chlordanes was 0.915 mg chlordanes/kg body weight/day.

D.2.6.11. TRV for Dieldrin

The mammalian NOAEL TRV for dieldrin selected for use in calculating the wildlife TTL is presented in EPA's Eco-SSL report for dieldrin (EPA 2007b). The mammalian NOAEL TRV for both carnivorous and insectivorous mammals was reported to be 0.015 mg dieldrin/kg body weight/day. This TRV was determined based on EPA (2003) guidance for selecting NOAEL-based TRVs.

The mammalian LOAEL TRV for dieldrin selected for use in calculating the wildlife TTL was calculated using the extrapolation method provided in ODEQ (2007). The mammalian LOAEL TRV is 0.075 mg dieldrin/kg body weight/day and was extrapolated from the NOAEL TRV by multiplying by 5.

D.2.6.12. TRV for Total Endosulfan

No mammalian TRVs for total endosulfan were identified from the sources used to derive wildlife TTLs.

D.2.6.13. TRV for gamma-HCH (Lindane)

No mammalian TRVs for lindane were identified from the sources used to derive wildlife TTLs.

D.2.6.14. TRV for Total PCB Aroclors

The mammalian NOAEL TRV for total PCBs selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The mammalian NOAEL TRV was originally cited in Millsap (2004) and was reported as the NOAEL value for total PCBs developed for mink. The NOAEL TRV for total PCBs was 0.12 mg PCBs/kg body weight/day.

The mammalian LOAEL TRV was for total PCBs selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The mammalian LOAEL TRV was originally cited in Millsap (2004) and was reported as the LOAEL value for total PCBs developed for mink. The LOAEL TRV for total PCBs was 0.23 mg PCBs/kg body weight/day.

It should be noted that the TTLs for Total PCBs Aroclors presented in Table 8-3 of the main report (TTLs for protection of aquatic-dependent wildlife) are based on the egg-based TRV presented in Section D.2.8.1.

D.2.6.15. TRV for Dioxin/Furan/PCB Congeners TEQ

The mammalian NOAEL TRV for dioxin/furan/PCB congeners TEQ selected for use in calculating the wildlife TTL is presented in ODEQ (2007). Dioxin, furan, and PCB TEQs are expressed as 2,3,7,8-TCDD equivalents. The mammalian NOAEL TRV was originally cited in Tillit (1996) and was reported as the NOAEL value developed for mink. The NOAEL TRV for dioxin/furan/PCB congeners was 8.0×10^{-8} mg TEQ/kg body weight/day.

The mammalian LOAEL TRV for dioxin/furan/PCB congeners TEQ selected for use in calculating the wildlife TTL is presented in ODEQ (2007). Dioxin, furan, and PCB TEQs are expressed as 2,3,7,8-TCDD equivalents. The mammalian LOAEL TRV was originally cited in Tillit (1996) and was reported as the LOAEL value developed for mink. The LOAEL TRV for dioxin/furan/PCB congeners was 2.2×10^{-6} mg TEQ/kg body weight/day.

It should be noted that the TTLs for dioxin/furan/PCB congeners TEQ presented in Table 8-3 of the main report (TTLs for protection of aquatic-dependent wildlife) are based on the egg-based TRV presented in Section D.2.8.1.

D.2.6.16. TRV for Tributyltin (TBT)

The mammalian NOAEL TRV for tributyltin selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The mammalian NOAEL TRV was originally cited in Sample (1996) and was reported as a NOAEL value for the mouse. The form of tributyltin used in this study was reported to be bis(tributyltin)oxide (TBTO). The ODEQ divided this NOAEL value with an uncertainty factor of 10 to account for interspecies variability. The resulting NOAEL TRV for tributyltin was 2.34 mg tributyltin/kg body weight/day.

The mammalian LOAEL TRV for tributyltin selected for use in calculating the wildlife TTL is presented in ODEQ (2007). The mammalian LOAEL TRV was originally cited in Sample (1996) and was reported as a LOAEL value for the mouse. The form of tributyltin used in this study was reported to be bis(tributyltin)oxide (TBTO). The ODEQ divided this NOAEL value with an uncertainty factor of 10 to account for interspecies variability. The resulting LOAEL TRV for tributyltin was 3.5 mg tributyltin/kg body weight/day.

D.2.7. TTLs for Aquatic-dependent Wildlife

The TTLs for aquatic-dependent wildlife were calculated using the species-specific life history parameters selected in Section D.2.4 combined with the TRVs for the BCoCs identified in Sections D.2.5 and D.2.6. As previously discussed, TTLs for wildlife were calculated using either Equation D-1 or Equation D-2 depending on how the FIR was calculated for the selected sentinel wildlife species.

The TTLs for aquatic-dependent wildlife are presented in Tables D-7 through D-10.

Table D-7. NOAEL Based TTLs for Avian Aquatic-dependent Wildlife

Chemical	Great Blue Heron	Belted Kingfisher	Hooded Merganser	Black-necked Stilt	American Avocet	Spotted Sandpiper	Bald Eagle	Osprey
Arsenic	12.7	4.5	6.1	4.0	5.1	2.7	19	11
Lead	9.24	3.3	4.4	2.9	3.7	2.0	14	7.8
Mercury	0.07	0.03	0.04	0.02	0.03	0.02	0.11	0.06
Selenium	1.6	0.58	0.78	0.52	0.66	0.35	2.4	1.4
TBT	38	14	18	12	15	8.21	57	32
Fluorene	--	--	--	--	--	--	--	--
Fluoranthene	--	--	--	--	--	--	--	--
Pyrene	--	--	--	--	--	--	--	--
Pentachloro-phenol	38	14	18	12	15	8.13	56	32
Hexachloro-benzene	--	--	--	--	--	--	--	--
p,p'-DDE	1.3	0.45	0.61	0.41	0.51	0.27	1.9	1.1
p,p'-DDD	1.3	0.45	0.61	0.41	0.51	0.27	1.9	1.1
p,p'-DDT	1.3	0.45	0.61	0.41	0.51	0.27	1.9	1.1
Methoxychlor	--	--	--	--	--	--	--	--
Total Chlordanes	1.21	0.43	0.58	0.38	0.48	0.26	1.8	1.0
Dieldrin	0.40	0.14	0.19	0.13	0.16	0.09	0.59	0.34
Total Endosulfan	--	--	--	--	--	--	--	--
gamma-HCH (Lindane)	--	--	--	--	--	--	--	--
Total PCBs Aroclors	1.13	0.40	0.54	0.36	0.45	0.24	1.7	0.95
Dioxins/Furans/ coplanar PCBs TEQ	7.9×10^{-6}	2.8×10^{-6}	3.8×10^{-6}	2.5×10^{-6}	3.2×10^{-6}	1.7×10^{-6}	1.2×10^{-5}	6.7×10^{-6}

TTLs in units of mg/kg wet weight; -- = not available

Table D-8. LOAEL Based TTLs for Avian Aquatic-dependent Wildlife

Chemical	Great Blue Heron	Belted Kingfisher	Hooded Merganser	Black-necked Stilt	American Avocet	Spotted Sandpiper	Bald Eagle	Osprey
Arsenic	63	22	30	20	25	14	93	53
Lead	46	16	22	15	19	9.9	68	39
Mercury	0.15	0.05	0.07	0.05	0.06	0.03	0.22	0.12
Selenium	8.22	2.9	3.9	2.6	3.3	1.8	12	6.9
TBT	96	34	46	31	38	21	140	81
Fluorene	--	--	--	--	--	--	--	--
Fluoranthene	--	--	--	--	--	--	--	--
Pyrene	--	--	--	--	--	--	--	--
Pentachloro-phenol	191	67	91	60	76	41	280	160
Hexachloro-benzene	--	--	--	--	--	--	--	--
p,p'-DDE	6.5	2.3	3.1	2.1	2.6	1.4	9.5	5.4
p,p'-DDD	6.5	2.3	3.1	2.1	2.6	1.4	9.5	5.4
p,p'-DDT	6.5	2.3	3.1	2.1	2.6	1.4	9.5	5.4
Methoxychlor	--	--	--	--	--	--	--	--
Total Chlordanes	6.1	2.1	2.9	1.9	2.4	1.3	8.9	5.1
Dieldrin	1.9	0.70	0.95	0.63	0.79	0.42	2.9	1.7
Total Endosulfan	--	--	--	--	--	--	--	--
gamma-HCH (Lindane)	--	--	--	--	--	--	--	--
Total PCBs Aroclors	3.4	1.2	1.6	1.1	1.4	0.72	5.0	2.9
Dioxins/Furans/ coplanar PCBs TEQ	3.9×10^{-5}	1.4×10^{-5}	1.9×10^{-5}	1.3×10^{-5}	1.6×10^{-5}	8.5×10^{-6}	5.8×10^{-5}	3.3×10^{-5}

TTLs in units of mg/kg wet weight; -- = not available

Table D-9. NOAEL Based TTLs for Mammalian Aquatic-dependent Wildlife

Chemical	North American River Otter	Northern Sea Otter	American Mink	Harbor Seal	Orca Whale
Arsenic	11	12	6.5	174	28
Lead	49	56.3	29	785	126
Mercury	0.17	0.19	0.10	2.67	0.42
Selenium	1.5	1.71	0.89	23.89	3.8
TBT	24	28	15	391	63
Fluorene	684	786	410	10957	1757
Fluoranthene	6.4	7.4	3.8	102	16.5
Pyrene	6.4	7.4	3.8	102	16.5
Pentachlorophenol	88	101	53	1406	225
Hexachlorobenzene	--	--	--	--	--
p,p'-DDE	1.5	1.8	0.92	24.5	3.9
p,p'-DDD	1.5	1.8	0.92	24.5	3.9
p,p'-DDT	1.5	1.8	0.92	24.5	3.9
Methoxychlor	--	--	--	--	--
Total Chlordanes	4.8	5.5	2.9	76.5	12.3
Dieldrin	0.16	0.18	0.09	2.51	0.40
Total Endosulfan	--	--	--	--	--
gamma-HCH (Lindane)	--	--	--	--	--
Total PCBs Aroclors	1.2	1.4	0.75	20	3.2
Dioxins/Furans/ coplanar PCBs TEQ	8.3×10^{-7}	9.6×10^{-7}	5.0×10^{-7}	1.3×10^{-5}	2.1×10^{-6}

TTLs in units of mg/kg wet weight; -- = not available

Table D-10. LOAEL Based TTLs for Mammalian Aquatic-dependent Wildlife

Chemical	North American River Otter	Northern Sea Otter	American Mink	Harbor Seal	Orca Whale
Arsenic	54	62	32	868	139
Lead	250	288	150	4009	643
Mercury	0.28	0.32	0.17	4.5	0.72
Selenium	7.5	8.6	4.5	120	19
TBT	36	42	22	585	94
Fluorene	3400	3900	2000	54800	8800
Fluoranthene	32	36	19	509	82
Pyrene	32	36	19	509	82
Pentachlorophenol	439	504	260	7032	1128
Hexachlorobenzene	--	--	--	--	--
p,p'-DDE	7.7	8.9	4.6	124	20
p,p'-DDD	7.7	8.9	4.6	124	20
p,p'-DDT	7.7	8.9	4.6	124	20
Methoxychlor	--	--	--	--	--
Total Chlordanes	9.8	11.2	5.9	157	25.2
Dieldrin	0.84	0.9	0.50	13.4	2.1
Total Endosulfan	--	--	--	--	--
gamma-HCH (Lindane)	--	--	--	--	--
Total PCBs Aroclors	2.4	2.7	1.4	38.4	6.2
Dioxins/Furans/ coplanar PCBs TEQ	2.3×10^{-5}	2.6×10^{-5}	1.40×10^{-5}	3.7×10^{-4}	5.9×10^{-5}

TTLs in units of mg/kg wet weight; -- = not available

D.2.8. TTLs Using Egg-Based Toxicity Reference Value Studies

In addition to providing dietary-based TTLs protective of aquatic dependent wildlife, TTLs were also calculated using bird egg-based TRVs. Some types of chemicals such as DDE, PCBs, "dioxin-like" compounds, mercury, and selenium have demonstrated effects on avian development at the level of the egg. In these cases, developing TTLs based on eggs may be 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 may not result in TTLs that are sufficiently protective of reproductive effects. The following egg-based model for developing tissue trigger levels was used to develop the egg-based TTLs.

$$\mathbf{TTL = TRV_{egg} / BMF_{egg}}$$ **Equation D-7**

where:

- TTL = tissue concentration in prey protective of avian predators (mg/kg, wet weight).
- 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 greatest challenge for developing egg-based TTLs at this time is the lack of available egg-based TRVs and prey-to-egg BMFs. For egg-based TRVs, the TRV values provided in ODEQ's *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (ODEQ 2007) were used. The ODEQ (2007) presents NOAEL and LOAEL egg-based TRVs for dioxins/furans congeners (as 2,3,7,8-TCDD TEQs), PCBs as Aroclor 1254, DDE (applied to total DDT), and mercury.

D.2.8.1. Egg-Based Toxicity Reference Value

The egg-based TRVs used to calculate egg-based TTLs are summarized in Table D-11.

Table D-11. Parameters and TTLs for Egg-based Prey Tissue TTLs

Chemical	Egg-based NOAEL TRV (mg/kg)	Egg-based LOAEL TRV (mg/kg)	Ref.	BMF_{egg} Bald Eagle	BMF_{egg} Osprey	Ref.	NOAEL Bird Egg TTL (Bald Eagle)	LOAEL Bird Egg TTL (Bald Eagle)	NOAEL Bird Egg TTL (Osprey)	LOAEL Bird Egg TTL (Osprey)
Mercury	0.5	2.5	(1)	2.8	2.8	(1)	0.18	0.89	0.18	0.89
DDT (total)	1.0	4.2	(1)	75	87	(1)	0.01	0.06	0.01	0.05
Dioxins/ Furans/ coplanar PCBs TEQ	3.0×10^{-4}	4.0×10^{-4}	(1)	16	10	(1)	1.9×10^{-5}	2.5×10^{-5}	3.0×10^{-5}	4.0×10^{-5}
Total PCBs Aroclor	4.0	20	(1)	110	11	(1)	0.04	0.18	0.36	1.8

TTLs in units of mg/kg wet weight; Reference (1) - ODEQ 2007.

TRV for Dioxin/Furan/PCB Congeners TEQ

Egg-based TRVs for dioxin/furans/PCB congeners TEQ were selected from those values provided in ODEQ (2007). Dioxin/furan TRVs are expressed as 2,3,7,8-TCDD equivalents; therefore, the egg-based TRV presented for 2,3,7,8-TCDD TEQs in ODEQ (2007) were selected.

The egg-based NOAEL TRV for dioxin/furans/PCB congener TEQ was reported to be 0.0003 mg/kg. The egg-based LOAEL TRV for dioxin/furans/PCB congener TEQ was reported to be 0.0004 mg/kg.

TRV for Total PCBs

Egg-based TRVs for total PCB (as aroclor 1254) were selected from those values provided in ODEQ (2007). The egg-based NOAEL TRV for PCB TEQs was reported to be 4.0 mg/kg. The egg-based LOAEL TRV for PCB TEQs was reported to be 20.0 mg/kg.

TRV for DDE (applied to Total DDT)

Egg-based TRVs for total DDT were selected from those values provided in ODEQ (2007). The egg-based NOAEL TRV for total DDT was reported to be 1.0 mg/kg. The egg-based LOAEL TRV for total DDT was reported to be 4.2 mg/kg.

TRV for Mercury

Egg-based TRVs for mercury were selected from those values provided in ODEQ (2007). The egg-based NOAEL TRV for mercury was reported to be 0.5 mg/kg. The egg-based LOAEL TRV for mercury was reported to be 2.5 mg/kg.

D.2.8.2. Biomagnification Factor (BMF_{egg}) from Prey to Egg

The BMF_{egg} values for deriving egg-based TTLs were selecting using the same sources presented above for the selection of egg-based TRVs. The ODEQ (2007) presents BMF_{egg} values for both the bald eagle and osprey for the following compounds: PCB TEQs, total PCBs as aroclors, DDE, and mercury. As there are BMF_{egg} values provided for all compounds for which egg-based TRVs were available, the ODEQ values were selected for the calculation of TTLs. The BMF_{egg} values from ODEQ (2007) are presented in Table D-11.

D.2.8.3. Prey Tissue Bioaccumulation Triggers

Prey TTLs developed using egg-based TRVs were calculated using Equation D-5 and the species specific (bald eagle or osprey) BMF_{egg} Factors provided in ODEQ (2007). The calculated TTLs are presented in Table D-11.

D.3. TTL FOR HUMAN HEALTH

This section describes how the TTLs presented in Table 8-2 of the main report were derived for protection 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. For dredged material disposal, particularly in deep-water areas, this will be the only complete exposure pathway. 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, the initial focus on fish and shellfish consumption is appropriate.

The TTLs 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. The EPA-approved toxicity values are described on the EPA Integrated Risk Information System web site[2] and EPA's Provisional Peer Reviewed Toxicity Values for Superfund.[3] Additional interim toxicity values can be obtained by contacting EPA's National Center for Environmental Assessment.[4] The TTLs for carcinogenic effects of BCoCs were calculated using the following equation and exposure assumptions:

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

[2] http://www.epa.gov/iris/search.htm
[3] http://hhpprtv.ornl.gov/
[4] http://cfpub2.epa.gov/ncea/cfm/aboutncea.cfm?ActType=AboutNCEA

where:

TTL_H =	target tissue level in fish or shellfish tissue (mg/kg wet weight)
TR =	target risk for individual carcinogens ($1x10^{-6}$)
AT_c =	averaging time (70 years x 365 days/year)
BW =	body weight (70 kg)
0.001=	conversion of grams fish to kg
EF =	exposure frequency (365 days/year)
ED =	exposure duration (30 or 70 years)
FI =	fraction of intake assumed from site (1.0)
IR =	ingestion rate for fish and shellfish (54, 142, or 584 g/day)
CSF =	carcinogenic slope factor [chemical-specific; $(mg/kg\text{-}day)^{-1}$]

For non-carcinogenic effects, the following equation and exposure assumptions were used to derive TTLs for fish and shellfish tissue:

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

where:

TTL_H =	target tissue concentration in fish or shellfish (mg/kg wet weight)
THQ =	target hazard quotient (1)
AT_n =	averaging time (30 or 70 yrs x 365 days/year)
BW =	body weight (70 kg)
0.001 =	conversion of grams to kg
EF =	exposure frequency (365 days/year)
ED =	exposure duration (30 or 70 years)
FI =	fraction of intake assumed from site (1.0)
IR =	ingestion rate for fish and shellfish (54, 142, or 584 g/day)
RfD =	reference dose for non-cancer effects (chemical-specific; mg/kg-day)

D.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) was used, consistent with regulatory requirements set 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, TTLs for individual BCoCs were set at risk levels of 10^{-6}.

In deriving TTLs for non-cancer endpoints, a cumulative hazard index of 1.0 was used. TTLs for individual BCoCs were also derived through application of a hazard quotient of 1.0. Where multiple BCoCs are present at concentrations greater than the non-cancer TTL, the agencies may consider additional evaluation to determine whether the BCoCs could affect the same target organs at the concentrations present. If this is the case, it may be appropriate to adjust the TTLs to result in a cumulative hazard index of 1.0.

D.3.2. Exposure Assumptions

The following exposure assumptions were used to develop the default RSET TTLs for protection of human health. Following both EPA and state guidelines, the exposure estimate is intended to be a high end, but not worst-case, scenario. The exposure parameters include some values that are average for the population (e.g., body weight), some that have several possible choices (e.g., consumption rate), and some that have significant built-in safety factors and are therefore quite conservative (e.g., carcinogenic slope factors and reference doses). This combination of central tendency and upper bound exposure parameter values should result in the desired overall high end exposure.

Exposure assumptions will in general be based on the conceptual site model discussed in Chapter 3. When cleanup and navigational dredging projects are occurring in the same area, it will be especially important to ensure that the conceptual site model and exposure assumptions used are coordinated, particularly with respect to the concentrations that will remain at the project site after dredging.

Children may be more exposed to environmental toxicants because they consume more food and water per unit body weight than adults (EPA 2002). The EPA's guidelines for cancer risk assessment note that children may be more sensitive to toxic chemicals than adults and have provided limited methodology to compute enhanced children's cancer risks (EPA 2005d).

Despite a desire to assess risks posed by environmental contaminants to children, children's fish consumption rates have not been as well quantified as adult rates. For example, issues with regional estimates of tribal children's fish consumption rates include small sample sizes (CRITFC 1994; Toy et al., 1996; Suquamish 2000), inclusion of more than one child from the same household leading to lack of independence of results (Suquamish 2000), and potential reporting of adult as children's rates (CRITFC 1994). Given uncertainties in children's consumption rates, RSET guidance will utilize default exposure parameters based on adult consumption. This position may be modified on a site-specific basis or as better data on children's fish consumption are obtained.

D.3.2.1. Consumption Rates

The TTLs are intended to be protective of all populations (e.g., recreational, subsistence, Native American). To meet this objective, fish consumption rates for various populations present in the region were reviewed to determine several representative default consumption rates that could be used. Because consumption rates are highly variable among various populations, it was considered appropriate to derive more than one set of rates depending on the specific situation. Project proponents may propose, or agencies may require, use of the consumption rate that is most representative of the dredged material disposal site or project site involved. In addition to these three default consumption rates, where site-specific consumption studies have been conducted, these can be applied on a case-by-case basis, subject to agency approval. The three selected sets of consumption rates represent, conceptually:

1. General population in a coastal state – 54 g/day. This value is promulgated in MTCA for protection of the general population (WAC 173-340-730). This value would only be used if the disposal or project site in question was not located within a tribal fishing area, urban subsistence fishing area, or active recreational fishing area.

2. High-end recreational or mid-range subsistence consumers – 175 g/day. This value has recently been negotiated between EPA Region 10 and ODEQ for use in the water quality program. It falls within the first-tier (Tulalip) tribal consumption range (97.6 g/day not including salmon; 243 g/day fish and shellfish including salmon) proposed for use by EPA Region 10 as one of the

default values for Superfund sites (EPA 2007f)[5]. This value was derived from two studies of tribal consumption among Washington and Oregon tribes (CRITFC 1994; Toy et al., 1996). This level is also similar to that used by California EPA of 166 g/day for the 95th percentile of sports and recreational anglers (California EPA 2001). Finally, a recent study of Asian and Pacific Islander consumption rates in King County found a mean consumption of 117 g/day and an upper 90th percentile of 236 g/day (Sechena et al., 2003).

3. High-end tribal subsistence consumers – 584 g/day. This value represents the upper-tier tribal subsistence value (Suquamish, not including salmon) proposed for use by EPA Region 10 as one of the default values for Superfund sites in Puget Sound (EPA 2007f, Suquamish 2000). Because it does not include salmon, a higher rate may be appropriate for areas with similar higher-tier tribal consumption where sediment contamination would be expected to contribute to contaminant body burdens in salmon (e.g., ordinarily migratory species trapped behind dams).

It is recognized that a wide variety of seafood consumption rates, ranging from 6.5 g/day to 796 g/day, are in use by various state and federal agencies and tribes in the Pacific Northwest. No single framework could hope to capture all of these. However, the three rates selected above are intended to be representative of three conceptual ranges of consumption rates, and to serve as default values that users and agencies can select. Site- or project-specific risk assessments or consumption studies can be substituted for these values upon agency approval.

Note that seafood consumption rates used in risk assessment are affected by many factors, including: seafood consumption survey design, how the survey population is defined, how the source of seafood is considered in consumption rate derivation (e.g. purchased or harvested from a particular geographic area), whether non-consumers of seafood are included in the survey sample used to derive rates, the environmental factors affecting the surveyed population (e.g. does habitat limit resource use, are there fears of chemical contamination or fish consumption advisories), whether weighting factors are applied to consumption rates for survey respondents to estimate consumption rates for a larger population, whether or not anadromous species are included in the consumption rate, and the statistic chosen to represent consumption (e.g. mean, median, 90th or 95th percentile). The references included in this section should be consulted for a complete understanding of the basis of a consumption rate included here.

D.3.2.2. Exposure Duration and Frequency

Exposure duration for the general population was set at 30 years, which represents estimates of how long an average person might spend in one area, and reflects EPA guidance for general population risk assessments. Exposure duration for consumption rates (2) and (3) above are intended to reflect tribal consumption, for which 70 years is considered more appropriate as site fidelity is higher than in the general population. Because the consumption rates are daily consumption rates already averaged over a year, the exposure frequency is 365 days/year.

D.3.2.3. Body Weight

A range of body weights is currently in use for various adult populations, including 63 kg for Asian and Pacific islanders, 70 kg for the general population, and 79-82 kg for tribal populations. This is a

[5] These consumption rates are upper percentile values from survey data that include only consumers of seafood. Rates included in EPA's Framework (EPA 2007f) are intended to represent consumption of seafood harvested from Puget Sound. The API rates cited here represent consumption of seafood regardless of source (e.g. purchased or harvested).

very small deviation compared to the overall uncertainty in the risk-based values. Therefore, as with the consumption rate, the body weight selected for the default RSET concentrations is in the middle of this range at 70 kg.

D.3.2.4. Fractional Intake or Area Use Fraction

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. The RSET TTLs were developed based on a default fractional intake of 100 percent. Alternative fractional intake rates may be considered, subject to agency approval, as part of a site-specific risk assessment or established regional policy. For example, the use of the tribal subsistence consumption rates established for Puget Sound use a fractional intake based on the fraction caught within Puget Sound (EPA 2007f).

D.3.2.5. Carcinogenic Slope Factors and Reference Doses

The cancer potency factors and reference doses in use at the time these values were developed are listed in Table D-12. Unless otherwise noted, these values are from EPA's Integrated Risk Information System. These values will be periodically reviewed for updates and the resulting TTL_H values updated accordingly.

Table D-12. Carcinogenic Slope Factors and Reference Doses

Chemical	CAS Number	Reference Dose (mg/kg-day)	Carcinogenic Slope Factor $(mg/kg\text{-}day)^{-1}$
Arsenic	7440-38-2	0.0003	1.5
Lead	7439-92-1	NA	NA
Mercury	7439-97-6	0.0001	--
Selenium	7782-49-2	0.005	--
Tributyltin	688-73-3	0.0003	--
Fluoranthene	206-44-0	0.04	--
Fluorene	86-73-7	0.04	--
Pyrene	129-00-0	0.03	--
Hexachlorobenzene	118-74-1	0.0008	1.6
Pentachlorophenol	87-86-5	0.03	0.12
Total Chlordanes	57-74-9	0.0005	0.35
DDTs - Total	50-29-3	0.0005	0.34
Dieldrin	60-57-1	0.00005	16
Total Endosulfans	115-29-7	0.006	--
gamma-HCH (Lindane)	58-89-9	0.0003	1.3
Methoxychlor	72-43-5	0.005	--
Total PCB Aroclors	1336-36-3	0.00002[a]	2
Dioxins/Furans/PCB congeners	1746-01-6	0.000000001	130000

NA - Not available; lead is known to be toxic at very low levels, but EPA has not established toxicity values.
[a] Based on aroclor 1254, the most frequently found aroclor in sediments for which an RfD is available.

D.3.3. Compounds with a Common Toxic Mechanism

Tissue contaminant concentrations that trigger sediment bioaccumulation testing are usually computed for individual compounds. However, deriving TTLs 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, TTLs may be developed on a chemical class basis. Chlorinated dioxins/furans and polychlorinated biphenyls (CDFBs) are the primary chemical class for which TTLs have been calculated at the group level.

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).

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

If the total tissue TCDD TEQ exceeds the TTL 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 2000). The most recent effort occurred at an expert meeting organized by the World Health Organization (WHO) in 2005 (Van den Berg et al., 2006). The 2005 WHO effort supplanted TEFs developed in 1998 (Van den Berg et al. 1998) and utilized multiple lines of evidence to develop a consensus based list of TEFs. Table D-13 provides the WHO 2005 TEFs for dioxins, furans, and PCBs.

Table D-13. WHO 2005 TEFs for Dioxins, Furans, and PCBs

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	0.0003
Polychlorinated dibenzofurans	
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.03
2,3,4,7,8-PeCDF	0.3
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
1,2,3,6,7,8,9-HpCDF	0.01
1,2,3,4,6,7,8,9-OCDF	0.0003
PCBs	
3,3',4,4'-TCB	0.0001
3,4,4',5-TCB	0.0003
2,3,3',4,4'-PeCB	0.00003
2,3,4,4',5-PeCB	0.00003
2,3',4,4',5-PeCB	0.00003
2',3,4,4',5-PeCB	0.00003
3,3',4,4',5-PeCB	0.1
2,3,3',4,4',5-HxCB	0.00003
2,3,3',4,4',5'-HxCB	0.00003
2,3',4,4',5,5'-HxCB	0.00003
3,3',4,4',5,5'-HxCB	0.03
2,3,3',4,4',5,5'-HpCB	0.00003

Abbreviations: T-tetra, Pe-penta, Hx-hexa, Hp-hepta, O-Octa,
DD-dibenzodioxin, DF-dibenzofuran, CB-chlorobiphenyl

D.4. SEDIMENT BIOACCUMULATION TRIGGERS

It can be 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 Environmental 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.

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 that 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 Environmental (1995) and Exponent (1998).

For the purposes of the dredging program, the most relevant BSAF may be at the disposal site (for non-dispersive sites), since this is where the material will reside after dredging and the long-term exposures of concern may occur. The BSAFs for the project site or 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.

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. The 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.

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