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A Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater EcosysteR-T /TT1 1C /P

A Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater Ecosystems

Volume II – Design and Implementation of Sediment Quality Investigations

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Disclaimer

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Executive Summary

Traditionally, concerns relative to the management of aquatic resources in freshwater ecosystems have focused primarily on water quality. As such, early aquatic resource management efforts were often directed at assuring the potability of surface water or groundwater sources. Subsequently, the scope of these management initiatives expanded to include protection of instream (i.e., fish a affected fish and wildlife populations. Furthermore, fish in many of these areas often have higher levels of tumors and other abnormalities than fish from reference areas. Contaminated sediments have also threatened the viability of many commercial ports through the imposition of restrictions on dredging of navigational channels and disposal of dredged materials. Overall, contaminated sediments have been linked to 11 of the 14 beneficial use impairments that have been documented at the Great Lakes AOCs. Such use impairments have also been observed elsewhere in Canada and the United States.

In response to concerns raised regarding contaminated sediments, responsible authorities throughout North America have launched programs to support the assessment, management, and remediation of contaminated sediments. The information generated under these programs provide important guidance for designing and implementing investigations at sites with contaminated sediments. In addition, guidance has been developed under various sediment-related programs to support the collection and interpretation of sediment quality data. While such guidance has unquestionably advanced the field of sediment quality assessments, the users of the individual guidance documents have expressed a need to consolidate this information into an integrated ecosystem-based framework for assessing and managing sediment quality in freshwater ecosystems (i.e., as specified under the Great Lakes Water Quality Agreement). Practitioners in this field have also indicated the need for additional guidance on the applications of the various tools that support sediment quality assessments. Furthermore, the need for additional guidance on the design of sediment quality monitoring programs and on the interpretation of the resultant data has been identified.

This guidance manual, which comprises a three-volume series and was developed for the United States Environmental Protection Agency, British Columbia Ministry of Water, Land and Air Protection, and Florida Department of Environmental Protection, is not intended to supplant the existing guidance on sediment quality assessment. Rather, this guidance manual is intended to further support the design and implementation of assessments of sediment quality conditions by:

- Presenting an ecosystem-based framework for assessing and managing contaminated sediments (Volume I);
- Describing the recommended procedures for designing and implementing sediment quality investigations (Volume II); and,
- Describing the recommended procedures for interpreting the results of sediment quality investigations (Volume III).

The first volume of the guidance manual, ***An Ecosystem-Based Framework for Assessing and Managing Contaminated Sediments in the Freshwater Ecosystems***, describes the five step process that is recommended to support the assessment and management of sediment quality conditions [illegible] health assessments; Chapter 6). The information compiled on each of the tools includes: descriptions of its applications, advantages, and limitations; discussions on the availability of standard methods, the evaluation of data quality, methodological uncertainty, and the interpretation of associated data; and, recommendations to guide the use of each of these individual indicators of sediment quality conditions. Furthermore, guidance is provided on the interpretation of data on multiple indicators of sediment quality conditions (Chapter 7). Together, the information provided in the three-volume series is intended to further support the design and implementation of focused sediment quality assessment programs.

List of Acronyms

%	percent
µg	microgram
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µmol/g	micromoles per gram
AET	apparent effects threshold
AETA	Apparent Effects Threshold Approach
Al	aluminum
ANOVA	analysis of variance
AOC	Area of Concern
APHA	American Public Health Association
ARCS Program	Assessment and Remediation of Contaminated Sediments Program
ASTM	American Society for Testing and Materials
AVS	acid volatile sulfides
BCE	British Columbia Environment
BCWMA	British Columbia Waste Management Act
BEST	biomonitoring of environmental status and trends
BSAF	biota-sediment bioaccumulation factor
CA	Consensus Approach
CAC	Citizens Advisory Committee
CCME	Canadian Council of Ministers of the Environment
CCREM	Canadian Council of Resource and Environment Ministers
CDF	confined disposal facility
CEPA	Canadian Environmental Protection Act
CERCLA	

DM	dredged material
DO	dissolved oxygen
DOE	Department of the Environment
DOI	Department of the Interior
DQO	data quality objective
DSI	detailed site investigation
DW	dry weight
EC	Environment Canada
EC_{50}	median effective concentration affecting 50 percent of the test organisms
EEC	European Economic Community
ELA	Effects Level Approach
EMAP	Environmental Monitoring and Assessment Program
EPT	Ephemeroptera, Plecoptera, Trichoptera (i.e., mayflies, stoneflies, caddisflies)
EqPA	Equilibrium Partitioning Approach
ERL	effects range low
ERM	effects range median
EROD	ethoxyresorufin-*O*-deethylase
ESB	equilibrium partitioning-derived sediment benchmarks
FCV	final chronic values
FD	factual determinations
FIFRA	Federal Insecticide, Rodenticide and Fungicide Act

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LRMA	Logistic Regression Modeling Approach
mean PEC-Q	mean probable effect concentration quotient
MESL	MacDonald Environmental Sciences Ltd.
MET	minimal effect threshold
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mIBI	macroinvertebrate index of biotic integrity
-min	- minutes
mm	millimeter
MPRSA	Marine Protection, Research, and Sanctuaries Act
MS/MSDs	matrix spike/matrix spike duplicates
MSD	minimum significant difference
n	number of samples
NAWQA	National Water Quality Assessment
NEPA	National Environmental Policy Act
NG	no guideline available
NH_3	unionized ammonia
NH_4^+	ionized ammonia
NOAA	National Oceanic and Atmospheric Administration
NOEC	no observed effect concentration
NPDES	National Pollutant Discharge and Elimination System
NPL	National Priorities List
NPO	nonpolar organics
NR	not reported
NRDAR	natural resource damage assessment and restoration
NSQS	National Sediment Quality Survey
NSTP	National Status and Trends Program
NT	not toxic
NYSDEC	New York State Department of Environmental Conservation
OC	organic carbon
OC pesticides	organochlorine pesticides
OECD	Organization of Economic Cooperation and Development
OEPA	Ohio Environmental Protection Agency
OERR	Office of Emergency and Remedial Response
OPA	Oil Pollution Act
OPTTS	Office of Prevention, Pesticides, and Toxic Substances
OSW	Office of Solid Waste
OW	The Office of Water
PAET	probable apparent effects threshold
PAHs	polycyclic aromatic hydrocarbons
PARCC	precision, accuracy, representativeness, completeness, and comparability
PCBs	polychlorinated biphenyls
PCDDs	polychlorinated dibenzo-*p*-dioxins
PCDFs	polychlorinated dibenzofurans
PCS	permit compliance system

PEC	probable effect concentration (consensus-based)
PEC-Q	probable effect concentration quotient
PEL	probable effect level
PEL-HA28	probable effect level for *Hyalella azteca*; 28-day test
PQL	protection quantification limit

TMDL	total maximum daily load
TOC	total organic carbon
tPAH	total polycyclic aromatic hydrocarbons
TRA	Tissue Residue Approach
TRG	tissue residue guideline
TRV	toxicity reference values
TSCA	Toxic Substances Control Act
USACE	United States Army Corps of Engineers
USDOI	United States Department of the Interior
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VOC	volatile organic compound
WDOE	Washington Department of Ecology
WMA	Waste Management Act
WQC	water quality criteria
WQS	water quality standards
WW	wet weight

Glossary of Terms

Acute toxicity – The response of an organism to short-term exposure to a chemical substance. Lethality is the response that is most commonly measured in acute toxicity tests.

Acute toxicity threshold – The concentration of a substance above which adverse effects are likely to be observed in short-term toxicity tests.

Altered benthic invertebrate community – An assemblage of benthic invertebrates that has characteristics (i.e., mIBI score, abundance of EPT taxa) that are outside the normal range that has been observed at uncontaminated reference sites.

Aquatic ecosystem – All the living and nonliving material interacting within an aquatic system (e.g., pond, lake, river, ocean).

Aquatic invertebrates – Animals without backbones that utilize habitats in freshwater, estuaries, or marine systems.

Aquatic organisms – The species that utilize habitats within aquatic ecosystems (e.g., aquatic plants, invertebrates, fish, amphibians and reptiles).

Benthic invertebrate community – The assemblage of various species of sediment-dwelling organisms that are found within an aquatic ecosystem.

Bioaccumulation – The net accumulation of a substance by an organism as a result of uptake from all environmental sources.

Bioaccumulation-based

Chemical benchmark – Guidelines for water or sediment quality which define the concentration of contaminants that are associated with low or high probabilities of observing harmful biological effects, depending on the narrative intent.

Chemical of potential concern – A substance that has the potential to adversely affect surface water or biological resources.

Chronic toxicity – The response of an organism to long-term exposure to a chemical substance. Among others, the responses that are often measured in chronic toxicity tests include lethality, decreased growth, and impaired reproduction.

Chronic toxicity threshold – The concentration of a substance above which adverse effects are likely to be observed in long-term toxicity tests.

Congener – A member of a group of chemicals with similar chemical structures (e.g., PCDDs generally refers to a group of 75 congeners that consist of two benzene rings connected to each other by two oxygen bridges).

Consensus-based probable effect concentrations (PECs) – The PECs that were developed from published sediment quality guidelines and identify contaminant concentrations above which adverse biological effects are likely to occur.

Consensus-based threshold effect concentrations (TECs) – The TECs that were developed from published sediment quality guidelines and identify contaminant concentrations below which adverse biological effects are unlikely to occur.

Contaminants of concern (COC) – The substances that occur in environmental media at levels that pose a risk to ecological receptors or human health.

Contaminated sediment – Sediment that contains chemical substances at concentrations that could potentially harm sediment-dwelling organisms, wildlife, or human health.

Conventional variables – A number of variables that are commonly measured in water and/or sediment quality assessments, including water hardness, conductivity, total organic carbon (TOC), sediment oxygen demand (SOD), unionized ammonia (NH_3), temperature, dissolved oxygen (DO), pH, alkalinity

Core sampler – A device that is used to collect both surficial and sub-surface sediment samples by driving a hollow corer into the sediments.

Degradation – A breakdown of a molecule into smaller molecules or atoms.

DELT abnormalities – A number of variables that are measured to assess fish health, including deformities, fin erosion, lesions, and tumors.

Piscivorus wildlife species – The wildlife species

Simultaneously extracted metals (SEM) – Divalent metals - commonly cadmium, copper, lead, mercury, nickel, and zinc - that form less soluble sulfides than does iron or manganese and are solubilized during the acidification step (0.5m HCl for 1 hour) used in the determination of acid volatile sulfides in sediments.

Stressor – Physical, chemical, or biological entities that can induce adverse effects on ecological receptors or human health.

Surface water resources – The waters of North America, including the sediments suspended in water or lying on the bank, bed, or shoreline and sediments in or transported through coastal and marine areas. This term does not include ground water or water or pd24 Tc -31.6-0 4.72 0m0

Chapter 1. Introduction

In response to concerns raised regarding contaminated sediments, a number of programs have been established or expanded to support the assessment and management of contaminated sediments in the United States and Canada (Appendix 1 of Volume II). The information generated under these programs provides important guidance for designing and implementing investigations at sites with contaminated sediments (see USEPA 1994a; MacDonald 1994a; 1994b; Reynoldson *et al.* 2000; Ingersoll *et al.* 1997; USEPA and USACE 1998a; ASTM 2001a; USEPA 2000a; Krantzberg *et al.* 2001). While these guidance documents have unquestionably advanced the field of sediment quality assessment, the users of these individual guidance documents have expressed a need to consolidate this information into an integrated ecosystem-based framework for assessing and managing sediment quality in freshwater ecosystems.

This guidance manual, which comprises a three-volume series and was developed for the United States Environmental Protection Agency, British Columbia Ministry of Water, Land and Air Protection, and Florida Department of Environmental Protection, is not intended to supplant the existing guidance documents on sediment quality assessment (e.g., USEPA 1994a; Reynoldson *et al.* 2000; USEPA and USACE 1998a; USEPA 2000a; ASTM 2001a; Krantzberg *et al.* 2001). Rather, this guidance manual is intended to further support the design and implementation of assessments of sediment quality conditions by:

- Presenting an ecosystem-based framework for assessing and managing contaminated sediments (Volume I);
- Describing the recommended procedures for designing and implementing sediment quality investigations (Volume II); and,
- Describing the recommended procedures for interpreting the results of sediment quality investigations (Volume III).

The first volume of the guidance manual, ***An Ecosystem-Based Framework for Assessing and Managing Contaminated Sediments in Freshwater Ecosystems***, describes the five step process recommended to support the assessment and management of sediment quality conditions (i.e., relative to sediment-dwelling organisms, aquatic-dependent wildlife, and human health). Importantly, the document provides an overview of the framework for ecosystem-based sediment quality assessment and management (Chapter 2). The recommended procedures for identifying sediment quality issues and concerns and compiling the existing knowledge base are described (Chapter 3). Furthermore, the recommended procedures for establishing ecosystem goals, ecosystem health objectives, and sediment management objectives are presented (Chapter 4). Finally, methods for selecting ecosystem health indicators, metrics, and targets for assessing contaminated sediments are described (Chapter 5). Together, this guidance is intended to support planning activities related to contaminated sediment assessments, such that the resultant data are likely to support sediment management decisions at the site under investigation. More detailed information on these and other topics related to the assessment and management of contaminated sediments can be found in the publications that are listed in the Bibliography of Relevant Publications (Appendix 2).

The second volume of the series, ***Design and Implementation of Sediment Quality Investigations***, describes the recommended procedures for designing and implementing sediment quality assessment programs. More specifically, an overview of the recommended framework for assessing and managing sediment quality conditions is presented in this document (Chapter 2). In addition, Volume II describes the recommended procedures for conducting preliminary and detailed site investigations to assess sediment quality conditions (Chapters 3 and 4). Furthermore, the factors that need to be considered in the development of sampling and analysis plans for assessing contaminated sediments are described (Chapter 5). Supplemental guidance on the design of sediment sampling programs, on the evaluation of sediment quality data, and on the management of contaminated sediment is provided in the Appendices to Volume II. The Appendices of this document also describe the types and objectives of sediment quality assessments that are commonly conducted in freshwater ecosystems.

The third volume in the series, ***Interpretation of the Results of Sediment Quality Investigations***, describes the four types of indicators that are commonly used to assess contaminated sediments, including sediment and pore-water chemistry data (Chapter 2), sediment toxicity data (Chapter 3), benthic invertebrate community structure data (Chapter 4), and bioaccumulation data (Chapter 5). Some of the other indicators that can be used to support assessments of sediment quality conditions are also described (e.g., fish health assessments; suppo032 Tc 0 N01331 Tw01ted sedsRE(Chapter descriptions of its applications, advantages, and limitations; discussions on the availability of standard methods, the evaluation of data quality, methodological uncertainty, and the interpretation of associated data; and, recommendations to guide its use. Furthermore, guidance is provided on the interpretation of data on multiple indicators of sediment quality conditions (Chapter 7). Together, the information provided in the three-volume series is intended to further support the design and implementation of focused sediment quality assessment programs.

Chapter 2. Recommended Framework for Assessing and Managing Sediment Quality Conditions

2.0 Introduction

Guidance on the design and implementation of sediment quality investigations is available from a number of sources (e.g., WDOE 1995; USEPA 1994a; 1998a; 1999b; 2000a; USEPA and USACE 1998a; ASTM 2001a). Based on a review of the guidance generated to date, the following framework was developed to assist in the design and implementation of efficient and effective sediment quality assessments. This framework identifies the steps that should be followed in conducting site-specific sediment quality assessment programs and comprises the following elements (Figure 1):

- Identifying sediment quality issues and concerns;
- Evaluating existing sediment quality data;
- Designing and implementing preliminary and detailed site assessments;
- Developing and implementing remedial action plans; and,
- Conducting confirmatory monitoring and assessment.

The recommended framework is intended to provide general guidance to support the sediment quality assessment process (Figure 2). More detailed guidance on preliminary and detailed site investigations is provided in Chapter 3 (Figures 3 and 4) and Chapter 4 (Figure 5) of Volume II, respectively. Importantly, this guidance is not intended to supplant any program-specific guidance that has been developed previously (e.g., USEPA 1997a).

2.1 Identify Sediment Quality Issues and Concerns

The first phase of a site-specific sediment quality assessment involves the evaluation of sediment issues and concerns at the area (or site) under investigation (see Chapter 3 of Volume I for additional information). As a first step in this process, the pertinent historical information on the area under consideration is collected and reviewed. More specifically, information is required on the types of industries and businesses that operate or have operated in the area, on the location of wastewater treatment plants, on land use patterns in upland areas, on stormwater drainage systems, on residential developments, and on other historic, ongoing, and potential activities within the area. These data provide a basis for identifying potential contaminant sources in the area. Information on the chemical composition of wastewater effluent discharges, types of substances likely to be associated with non-point sources, and physical/chemical properties [e.g., octanol-water partition coefficients (K_{ow}), organic carbon partition coefficients (K_{oc}), solubility] of those substances provides a basis for developing an initial list of chemical of potential concern (COPCs; i.e., the substances that could be posing risks or hazards to ecological receptors or human health) at the site. By evaluating the probable environmental fate of these COPCs, it is possible to establish a list of COPCs and areas of interest with respect to sediment contamination at the site (Figure 3).

In addition to information on contaminant sources, information should be collected that helps define the ecosystem health goals and objectives (if these have not already been defined; Chapter 4 of Volume I). In many jurisdictions, protection and restoration of the designated uses of the aquatic ecosystem represents a primary ecosystem health goal for areas of concern. As such, ecosystem goals in freshwater systems may be based on protection of the ecosystem as a whole, maintenance of viable populations of sportfish species, protection of human health (e.g., swimmable and fishable), or a variety of other considerations (e.g., regional stormwater management, industrial development). In turn, information on existing uses of the site provides a basis for making decisions regarding the nature and extent of the investigations that should be conducted at the site. Mudroch and McKnight (1991), Baudo and Muntau (1990) and MacDonald (1989) provide detailed descriptions of the types of background information (e.g., location and nature of industrial facilities, location and characteristics of point source effluent discharges, location of stormwater discharges, land and water uses in the vicinity of the site, and location of sediment depositional zones) that should be obtained and guidance on how these data may be used to help define sediment quality issues and concerns.

The existing data on the various indicators selected for assessing sediment quality conditions should also be collected and

for ships), and copper (which is often used in antifouling paints for pleasure craft) should be measured. Similarly, elevated concentrations of polycyclic aromatic hydrocarbons (PAHs) and lead are frequently observed in sediments in the vicinity of urban stormwater discharges. In agricultural areas, persistent pesticides and nutrients should be considered in sediment quality assessments. At minimum, data on the levels of metals, PAHs, and polychlorinated biphenyl (PCBs) are needed to assess sediment contamination at most sites. It is also important to determine if the available biological effects data (e.g., acute toxicity tests) are relevant for determining if the management objectives established for the site have been compromised by contaminated sediments (i.e., the results of chronic toxicity tests and/or benthic invertebrate community assessments are usually needed to determine if sediment-dwelling organisms are likely to be or have been adversely affected by sediment contamination).

Development of a project database is an important element of the overall sediment quality assessment process. Designing and populating the project database early in the process (i.e., during the collation of existing information) is beneficial to support the evaluation of current conditions and the identification of any additional investigations that may be needed at the site. In general, a relational database format is the most flexible for conducting subsequent analyses of the historic data (Field *et al.* 1999; 2002; Crane *et al.* 2000). Importantly, the format of the database should support linkage to various analytical tools, such as NOAA's Query Manager and Marplot applications and ESRI's Spatial Analyst and ArcView applications (MacDonald and Ingersoll 2000).

If the results of the data evaluation process indicate that sufficient quantities of acceptable quality data are available, then initiating the data interpretation process is possible. However, if the sediment chemistry or other historical effects data are considered to be of unacceptable quality or are not considered to adequately represent the site, additional data may be required to complete the sediment quality assessment. Such data gaps may be addressed by

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completion of a Stage I PSI, which primarily involved compilation and evaluation of existing sediment quality data and related information).

A number of important and potentially costly decisions are dependent on the results of the DSI. For this reason, it is essential that the DSI be based on a detailed study design, as articulated in the SAP and the associated QAPP. More specifically, the study should be designed to confirm or refute the presence of COPCs, to determine the spatial extent of chemical contamination (both in surficial and in deeper sediments), to identify chemical gradients (which can be used to identify possible sources of contamination), and to identify the location of sediment hot spots. While whole-sediment chemistry, sediment toxicity, and benthic invertebrate community structure are a primary focus of this investigation, the DSI should also provide data for assessing the nature, severity, and extent of contamination in surface water, pore water, and biological tissues (including sediment-dwelling organisms, fish, and wildlife, as appropriate) and for assessing the status of fish communities inhabiting the area. Such information on the levels of COPCs can then be evaluated relative to the SQGs, water quality criteria (WQC), or tissue residue guidelines (TRGs; Volume III). In this way, it is possible to identify the COCs at the site.

While the results of chemical analysis of environmental samples provide important information for assessing the risks that contaminated sediments pose to human health and han then be>B

2.5 Remedial Action Planning

The results of the DSI provide the information needed to assess the risks to aquatic organisms, aquatic-dependent wildlife, and human health associated with exposure to sediment-associated COPCs. At sites where such risks are not deemed to be significant, further action is likely to be limited to periodic monitoring to assess trends in environmental contamination. At other sites, remedial action may be needed to reduce risks to acceptable levels. Accordingly, a feasibility study is typically conducted following completion of the DSI to analyze the benefits (i.e., risk reduction), costs, and risks associated with various remedial options (Suter *et al.* 2000). The results of the feasibility study, then, provide the information needed to develop a remedial action plan (RAP) for the site.

Development of an RAP is a critical component of the contaminated site remediation

Chapter 3. Conducting a Preliminary Site Investigation

3.0 Introduction

A PSI should be conducted at all sites that are suspected of containing contaminated sediments (see Section information on land use practices, designated water uses, contaminant sources, and ambient environmental conditions in the area.

The data collected during Stage I of the PSI should provide a basis for determining the nature and location of potential sources of contaminants to aquatic ecosystems.

Together, the information collected in the first phase of the PSI should provide a basis for determining if sediment contamination is likely to represent an unacceptable risk to the environment or to human health. Sediment contamination should be suspected if toxic or bioaccumulative substances have been or are likely to have been released into the aquatic ecosystems at or near the site, or if ambient monitoring data indicate that sediment contamination has occurred at or near the site (i.e., based on exceedances of SQGs). If the minimum data requirements have been met and evaluation of these data indicates that sediment contamination is unlikely, then the need for further action at the site is generally obviated. If the minimum data requirements have not been met, then the outstanding data gaps should be identified and preparations for proceeding to the next stage of the process should be made. Depending on the nature and extent of contamination and on the complexity of the site, investigators may choose to conduct a Stage II PSI or move directly to the DSI.

3.2 Stage II Investigation

A Stage II PSI is conducted if the results of the Stage I investigation indicate that the sediments at the site are likely to be contaminated with toxic or bioaccumulative substances. The second stage of the PSI is intended to provide information on the nature, location, and magnitude of sediment contamination at the site. The existing sediment chemistry data, which were assembled in Stage I, may be used in this investigation if they provide suitable areal coverage, include the substances on the refined list of COPCs, and are of sufficient quality. However, additional sediment sampling is required when existing data are of insufficient quality or quantity to support an assessment of sediment quality at a site. The Stage II PSI consists of two main elements, including the data collection phase and the data interpretation phase of the investigation.

3.2.1 Data Collection

A Stage II PSI should be conducted when the results of the Stage I PSI indicate that sediments are likely to be contaminated by toxic and/or bioaccumulative substances, but insu

The procedures that will be used to identify and quantify the chemical substances in the sediment samples should also be described in the SAP. As a first step, a list of substances for chemical analysis should be compiled from the list of COPCs that was prepared in Stage I. This list should also include the variables that provide ancillary information for interpreting the resultant sediment chemistry data (e.g., TOC, AVS, NH_3, H_2S, Al, Li). Although the preferred analytical method for each analyte can also be specified in the SAP, establishing performance-based criteria for evaluating the analytical results may be preferable in many circumstances. Such criteria, which are articulated in the data quality objectives (DQOs) established for the investigation, provide analytical laboratories with a clear understanding of the project analytical requirements and, hence, a basis for selecting and/or refining methods that will assure that the project DQOs are met.

The procedures that will be applied to assure the overall integrity of the sampling program and the quality of the resultant data should be described in a QAPP (USEPA 1991a; 1991b; 1991c; 1991d; 2000c). The QAPP, which is typically included as an appendix to the SAP, should apply to both the field and laboratory components of the program. Some of the important elements that need to be contained in a QAPP include:

- Project organization and responsibilities;
- Personnel training and instruction;
- Data quality objectives, including the methods that will be used for assessing precision, accuracy, completeness, representativeness, and comparability of the data generated;
- Sampling procedures, including sampling equipment, decontamination of equipment, collection of field duplicates, generation of field blanks, positional data collection, sample containers, sample identification and labeling, sample preservation and holding times, field documentation, and field data sheets;
- Sample custody and transportation, including field custody procedures, chain-of-custody documentation, sample packaging and transport, and laboratory log-in procedures and documentation;
- Analytical methods, including target detection limits, accuracy, and precision for each analyte (i.e., DQOs);

background concentrations. For this reason, the third step of the data analysis should involve comparison of the data from the site to regional background concentrations and/or contemporary background concentrations of each COPC. The substances that exceed both the SQGs and background levels should be considered to be the contaminants of concern (COCs) at the site. Some of the methods for determining background concentrations of metals and organic contaminants are described in Appendix 2 of Volume III of this guidance manual. Further information on the interpretation of sediment chemistry data is also provided in Volume III.

Chapter 4. Conducting a Detailed Site Investigation

4.0 Introduction

A detailed site investigation (DSI) is required if the results of the preliminary site investigation (PSI; which is conducted using sediment chemistry data) indicate that sediments are sufficiently contaminated to impair the beneficial uses of the aquatic ecosystem (i.e., pose unacceptable risks to sediment-dwelling organisms, and aquatic-dependent wildlife, or human health). The information collected and compiled during the PSI should be used to design the DSI. As the PSI was conducted to evaluate the nature, magnitude, and extent of sediment contamination at the site, the results of the investigation should provide the information needed to identify which substances occur in sediments at potentially harmful levels (e.g., in excess of the SQGs), describe the range of concentrations of priority substances, and identify the locations that contain elevated levels of sediment-associated COPCs. Importantly, the PSI should also provide essential background information on the site, such as the location of contaminant discharges and spills. As such, the PSI provides critical information for designing a well-focused DSI.

The DSI is designed to provide the information needed to assess risks to sediment-dwelling organisms, wildlife, and human health associated with exposure to contaminated sediments. In addition, the DSI should provide the necessary and sufficient information to support the evaluation of remedial alternatives and the development of a RAP. Because the results of the DSI will be used directly to support sediment management decisions, the scope of this investigation will necessarily be broader than that of a PSI. More specifically, the DSI should be designed to answer four main questions, including:

- Does the presence of COPCs in whole sediments and/or pore water pose an unacceptable risk to the receptors under consideration (i.e., sediment-dwelling organisms, aquatic-dependent wildlife, or human health)?
- What is the nature, severity, and areal extent of the risk to each receptor under consideration?

- Which COPCs are causing or substantially contributing to the risk to the receptor under consideration (i.e., the COCs)?
- What are the concentrations of COPCs, by media type, that are associated with negligible risk to the receptor under consideration?

The DSI consists of two elements, including the data collection phase and the data interpretation stage. The follow.000gs 1.71 (elements,)487-0.002 Tw 7.2 c 1.43 0 TdOhap4 0 provD

- Describe the sediment sampling, handling, and storage procedures that will be used for obtaining sediment samples for toxicity and bioaccumulation testing;
- Describe the toxicity tests that will be conducted on the sediment samples, including the associated description of the selected metrics (e.g., survival and growth);
- Describe the procedures that will be used to assess bioaccumulation;
- Describe the procedures that will be used for sampling the benthic invertebrate community, including associated descriptions of the selected metrics (e.g., benthic index); and,
- Describe the quality assurance procedures that will be used in the field and the t

sediment contamination. In general, a biased sampling design is preferred for the DSI because it can be used to focus sampling effort on the areas that are most likely to be contaminated (i.e., by conducting targeted sampling to delineate the location and extent of hot spot areas). Within the original SSZ (i.e., the area sampled during the PSI), intensive sampling should be conducted in the vicinity of sediment hot spots to confirm the results of the PSI, to determine the areal extent of contamination at each hot spot, and to identify gradients in contaminant concentrations. Outside the original SSZ, biased sampling should be used to target potential hot spots (i.e., near the contaminated areas within the original SSZ) and random sampling should be used to investigate the potential for contamination in other areas.

Importantly, the DSI sampling program should be designed to determine the concentrations of COPCs in both surficial and deeper sediments. The sampling plan should identify the location of each site that will be sampled, with de[illegible]

In addition to the foregoing considerations, development of the DSI sampling program should consider additional factors that apply to each of the key indicators of sediment quality conditions, including sediment chemistry data, sediment toxicity data, benthic invertebrate community assessments, and bioaccumulation assessments (Krantzberg *et al.* 2000). Some additional considerations that should be taken into account in designing the DSI sampling program are discussed in the following sections. Additional guidance on each of these indicators is provided in Volume III.

4.1.1 Sediment Chemistry

The procedures that will be used to identify and quantify the chemical substances in the sediment samples should be described in the sampling and analysis plan (see Chapter 2 of Volume III for more information). As a first step, a list of substances for chemical analysis should be compiled using the results of the PSI and other considerations (e.g., substances used to calculate mean SQG-quotients). This list should also include the variables that provide ancillary information for interpreting the resultant sediment chemistry data (e.g., TOC, AVS, Al, Li). The preferred analytical method for each analyte can also be specified in the sampling plan; however, it may be more prudent to let the analytical laboratory select the methods based on the DQOs for the project. Clearly articulating the data quality requirements (i.e., accuracy, precision, and detection limits) to the laboratory personnel at the outset of the project is likely to minimize the potential for problems later.

The procedures that will be used to assess the biological effects associated with contaminated sediments should also be included in the sampling plan. Biological assessment is an essential tool for evaluating sediment quality conditions at contaminated sites because it provides important information for interpreting sediment chemistry data. The five types of biological assessments that are commonly conducted at sites with contaminated sediments include toxicity testing, benthic invertebrate community assessments, bioaccumulation testing, fish health, and fish community structure. More detailed information on each of these indicators is presented in Volume III of this guidance manual.

4.1.2 Toxicity Testing

The selection of appropriate toxicity tests is an important element of the overall biological assessment process (Chapter 3 of Volume III). Provision of guidance in this area is particularly important because various regulatory programs (e.g., dredged material analysis programs) have developed conventions that may not be directly applicable for DSIs at sites with contaminated sediments. Because sediment-dwelling organisms are exposed to contaminated sediments for extended periods, at least one chronic toxicity test on a sensitive sediment-dwe

- Individual (e.g., morphological changes, biomarkers);
- Population (e.g., abundance of keystone species; population age/size structure);
- Community structure (e.g., benthic index, multivariate analyses); and,
- Community function (e.g., energy transfer, functional groups).

All of the various measurement endpoints are evaluated based on departure from an expected or predicted condition (such as observations made at appropriate reference sites). Uncertainty in the application of these techniques stems from incomplete knowledge of the system (i.e., what represents normal conditions); systematic error in the method being used; and, the sampling scale selected (Ingersoll *et al.* 1997). Of the organization scales evaluated, the measurement endpoints which provide information on the status of invertebrate populations and community structure were considered to be the most reliable (Reynoldson *et al.* 1995; Ingersoll *et al.* 1997).

4.1.4 Bioaccumulation Assessments

Bioaccumulation assessments are used to evaluate the extent to which sediment-associated COPCs accumulate in the tissues of sediment-dwelling organisms (see Chapter 5 of Volume III for additional information on bioaccumulation assessments; ASTM 2001d). In laboratory bioaccumulation tests, individuals of a single species are exposed to field-collected sediments under controlled conditions. After an established period of exposure (usually 28 days), the tissues of the test species are analyzed to determine the concentrations of COPCs. Bioaccumulation is considered to have occurred if the final concentrations of the COPCs in tissues exceed the concentrations that were measured in tissue at the beginning of the test or in the tissues of organisms exposed to control sediment [illegible]

An expert panel evaluated the uncertainty associated with all four of the procedures established for conducting bioaccumulation assessments (Ingersoll *et al.* 1997). The results of this evaluation indicate that bioaccumulation is a highly variable endpoint that primarily provides information on exposure to contaminants. It is particularly useful for determining the bioavailability of sediment-associated contaminants. Of the four approaches evaluated, laboratory assessments were considered to be the most reliable and are recommended for assessing bioaccumulation potential at contaminated sites. The preferred test species for freshwater bioaccumulation assessments is the oligochaete (*Lumbriculus variegatus)*; however, many other species may be used in this application (see ASTM 2001d). It should be noted that such data do not necessarily provide a direct means of estimating tissue residues in the field. For this reason, it is also recommended that the tissues of resident species also be collected and analyzed to provide a basis for assessing hazards to human health and aquatic-dependent wildlife species (i.e., by comparing measured tissue concentrations to tissue residue guidelines).

4.1.5 Other Tools for Assessing Sediment Quality Conditions

While sediment chemistry, sediment toxicity, benthic invertebrate community structure, and bioaccumulation data represent the primary tools for assessing sediment quality conditions in freshwater ecosystems, there are a number of other tools that can be used to support the sediment quality assessment process. For example, in certain circumstances it may be necessary to identify the substances that are causing or substantially contributing to the effects observed in the investigation (i.e., COCs). In these cases, spiked sediment toxicity tests and/or toxicity identification evaluation (TIE) procedures can be used to help identify the putative causal agents. In addition, numerical SQGs can be used to assist in the identification of the substances that are causing or substantially contributing to sediment toxicity (Wenning and Ingersoll 2002). Furthermore, various data analytical approaches, such a.0007 Tc 0.ihDTSY (btip2 Tm (While Tj -0.0005 Tc 3.regr0 Tdntification)Tj 0.0373 Tc 4.29s

Implementation of a well-designed sampling program is likely to provide the data needed to conduct a comprehensive assessment of sediment quality conditions at the site. More information on the design of sediment quality sampling programs is provided in Chapter 5 of Volume II, while the elements of sampling and analysis plans are described in Appendix 3 of Volume II.

4.2 Data Interpretation

Interpretation of the data collected in the DSI is more involved than the interpretation of Stage II PSI data. As was the case for the PSI, the review and evaluation of the quality assurance information (i.e., in light of the acceptance criteria that were established in the QAPP) represents the first stage of the data interpretation process. This initial evaluation provides a basis for assessing the validity of the resultant data and determining if additional sampling is required.

In the second step of the data analysis process, the data collected in the DSI are compiled and used to assess exposures to contaminated sediments, the effects of contaminated sediments on ecological receptors and human health, and the risks posed by contaminated sediments to beneficial uses of the aquatic ecosystem. The objectives of the exposure assessment are to identify the receptors at risk, describe the relevant exposure pathways, and determine intensity and areal extent of the exposure to COPCs. Sediment chemistry data and/or pore-water chemistry data may be used, in conjunction with applicable benchmarks (e.g., SQGs, water quality criteria, background levels) to identify the areas, depths, and degree of contamination at the site and in nearby areas. If significant contamination (i.e., > SQGs) is observed at or nearby the boundaries of the SSZ (either in surficial sediments or at depth), then additional sampling may be required to fully characterize the spatial extent of contamination.

The primary objective of the effects assessment is to describe the nature and severity of effects that are being caused by contaminated sediments. Sediment chemistry data can also be used in the effects assessment to estimate the probability that specific types of effects would be associated with exposure to contaminated sediments (i.e., using the dose-response relationships established for individual COPCs or groups of COPCs; e.g., Swartz 1999;

MacDonald *et al.* 2000; USEPA 2000d; Wenning and Ingersoll 2002). Additionally, the results of the toxicity tests can be used to determine if sediments with elevated concentrations of COPCs (i.e., relative to the SQGs) are toxic to aquatic organisms. Contaminants may be present in relatively unavailable forms or other factors may be mitigating toxicity at the sites that have elevated chemical concentrations but are not toxic to sediment-dwelling organisms. The results of benthic invertebrate community assessment can also be used to evaluate the effects of contaminated sediments on sediment-dwelling organisms. Agreement among the three measures of adverse biological effects (i.e., the SQGs, toxicity tests, and benthic appendices that facilitate access to and/or re-analysis of the information. The reader is directed to Volume III of this guidance manual for more information on the interpretation of data on individual and multiple indicators of sediment quality conditions generated during the DSI.

Chapter 5. Developing Sampling and Analysis Plans for Assessing Sediment Quality Conditions

5.0 Introduction

A primary goal of most sediment quality assessment programs is to determine if the presence of toxic chemicals in sediment is adversely affecting sediment-dwelling organisms. When sediments contain bioaccumulative substances, a primary goal of assessment programs is to determine if these contaminants are accumulating in the tissues of aquatic organisms to such an extent that they pose a hazard to sediment-dwelling organisms, aquatic-dependent wildlife, or human health. More specifically, sediment assessments can be used to:

- Determine the relationship between toxic effects and bioavailability;
- Investigate interactions among chemicals;
- Compare the sensitivities of different organisms;
- Determine spatial and temporal distribution of contamination;
- Evaluate hazards of dredged material;
- Measure toxicity as part of product licensing or safety testing;
- Rank areas for clean up; and,
- Evaluate the effectiveness of remediation or management practices.

Considering the diversity of reasons for conducting sediment quality assessments and the variety of programs under which such assessments can be implemented (see Appendix 1 of Volume II), it is not feasible to provide guidance on the design of sediment quality assessments that applies uniformly to every application. Therefore, this chapter is intended to compliment the general guidance that was provided on preliminary and detailed site investigations (i.e., PSIs - Chapter 3; DSIs - Chapter 4 of Volume II) by identifying the essential elements of SAPs for assessing contaminated sediments, including:

- Background information on the site;
- Objectives of the sediment assessment program;
- Field sampling methods;
- Sample handling procedures;
- Technical oversight and auditing;
- Quality assurance and quality control procedures;
- Data validation and quality control;
- Data evaluation and validation
- Data analysis, record keeping, and reporting;
- Health and safety; and,
- Responsibilities of the project team members.

Each of these elements of SAPs are briefly described in the following sections of this chapter (see Table 3 for a sediment sampling and analysis plan outline and checklist). More detailed information on several key issues related to the design of sampling programs for assessing contaminated sediments in provided in Appendix 3 of Volume II.

5.1 Background Information

Development of a sampling and analysis plan that explicitly addresses the objectives of the sediment quality assessment program requires background information on the site under investigation. The types of background information that should be collected to inform the design of the sediment quality assessment program include (WDOE 1995):

- Site history;
- Regulatory framework (e.g., NPDES, NRDAR, CERCLA; see Appendix 1 of Volume II);

- Results of previous investigations (including data on physical, chemical, and biological conditions);
- Location and characteristics of historic and current contaminant sources in the vicinity of the site, including stormwater discharges, wastewater discharges, hazardous waste storage/disposal, and, hazardous material spills;
- Location of depositional areas; and,
- Designated water uses.

Collectively, this information provides a basis for identifying the sediment quality issues and concerns at the site, including the COPCs and areas of interest (Chapter 3 of Volume I). This information also supports the design of a sampling program that characterizes the nature, extent, and severity of sediment contamination.

Review of available historical data is important both in the selection of sampling stations and in subsequent data interpretation. Local experts should be consulted to obtain information on site conditions and on the origin, nature, and degree of contamination. Other potential sources of information include government agency records, municipal archives, harbor commission records, news media reports, past geochemical analyses, hydrographic surveys, and bathymetric maps. Potential sources of contamination should be identified and their locations noted on a map or chart of the proposed study area. An inspection of the site is recommended when developing a study plan to assess the completeness and validity of the collected historical data and to identify any significant changes that might have occurred at the site since the historical data were collected. Conducting some reconnaissance sampling to refine the sampling design is also useful (i.e., which may be focused on particle size distribution, TOC, total petroleum hydrocarbons, or some other suitable indicators of chemical contamination). Reconnaissance sampling is particularly helpful in defining appropriate station locations for targeted sampling or to identify appropriate strata for stratified sampling or subareas for multistage sampling.

5.2 Objectives of the Sediment Investigation

The objectives of sediment quality assessments can vary markedly depending on the regulatory program under which they are conducted. Descriptions of the types and objectives of sediment quality assessments that are being conducted under various regulatory programs are provided reference or control sediments representative of the physical characteristics of the test sediment (i.e., grain 904Ye, organc rcarbon) may be useful n 9he se evalution s.

5.3 Field Sampling Methods

The purpose of the sampling program is to collect undisturbed sediment samples from one or more stations within the assessment area. Such samples are typically collected to support physical-chemical analyses, toxicity testing, benthic invertebrate community assessments and/or bioaccumulation assessments. To assure that field personnel are adequately prepared to collect the required sample volumes from each sampling station, it is essential that the methods that will be used to collect sediment samples in the field be fully described in the project SAP. The selection of such methods for collecting sediment samples will be influenced by a variety of factors, including:

- Sampling design;
- Type of sampling platforms available;
- Location of and access to the sampling stations;
- Physical characteristics of the sediments;
- Number of sites to be sampled;
- Water depth;
- Number and experience of personnel; and,
- Budget.

In general, the sediment samplers that are used in most freshwater sediment assessments can be classified into two major categories, grab samplers and corers (USEPA 2001a; ASTM 2001c). Some of the commonly utilized grab samples include Birge-Ekman grab samplers (standard and petite), Ponar grab samplers (standard and petite), Van Veen grab samplers (standard and large), and Shipek grab sampler. Hand corers, single-gravity corers, multiple-gravity corers, box corers piston corers, and vibratory corers represent the primary classes of sediment corers that are currently available. Specific methods are also available for obtaining pore-water samples. The advantages and disadvantages of various sediment samplers are described in Table 4 (WDOE 1995). The minimum sample volumes to support physical-chemical analyses and toxicity testing are presented in Table 5.

To enhance comparability of the resultant data, the same method should be used to collect samples from all of the sampling station within the assessment area, whenever practicable. However, the need to collect both surficial and deeper sediments may preclude this possibility in certain circumstances. The reader is directed to Mudroch and McKnight (1991), Mudroch and Azcue (1995), USEPA (2001a), and ASTM (2001c) for more information on the collection of sediment samples.

5.4 Sample Handling Procedures

The sediment samples that are collected in the field are likely to be subjected to a physical, chemical, and/or biological testing to support the overall sediment assessment program. The methods that are applied for handling, preserving, transporting, and storing the samples are dependent on the objectives of the study and the type of testing to which each sample will be subjected. In cases where data on multiple indicators of sediment quality conditions are to be generated, the importance of synoptically-collected sediment samples cannot be over stated (i.e., collecting sufficient volumes of sediment at each station to facilitate the preparation of a subsample for toxicity testing and subsamples for chemical analysis from a single, homogenized sediment sample). Appropriate methods for handling, transporting, and storing sediment samples for chemical analysis and toxicity testing are presented in ASTM (2001c) and USEPA (2001a). The recommended storage temperatures and maximum holding times for physical-chemical analyses and sediment toxicity testing are presented in Table 6. Recommended chain-of custody procedures and methods for delivering sediment samples to analytical laboratories are summarized in WDOE (1995).

5.5 Technical Oversight and Auditing

In many cases, the field component of the sediment quality assessment is conducted by contractors who have ready access to sampling vessels and equipment. While these contractors may have a good deal of experience in the collection of environmental media, there may be unique aspects of the sediment quality assessment that require special attention in the field (e.g., collection of matching samples for chemical analysis, toxicity testing, and benthic community structure). For this reason, it is recommended that one or more individuals be assigned the task of providing technical oversight and auditing of all aspects of the field program. This individual would be responsible for reviewing the SAP (and associated QAPP), overseeing the training of the field crew, confirming sample locations prior to sampling, observing sample collection procedures, documenting any inconsistencies and errors that are observed, assuring that corrective actions are taken, and documenting sample handling and transport procedures.

5.6 Quality Assurance Project Plan

A QAPP, which outlines specific steps that will be used to perform the study, should be

5.8 Data Analysis, Record Keeping, and Reporting

Data analysis, record keeping, and reporting represent essential elements of a sediment quality assessment. For this reason, the procedures that are to be used to support the assessment should be described in the SAP. The recommended procedures for interpreting individual and multiple lines of evidence are presented in Chapter 7 of Volume III. Additional information on data analysis, record keeping, and reporting is provided in WDOE (1995).

5.9 Health and Safety Plan

It is recommended that a comprehensive health and safety plan be included in the project SAP. The health and safety plan should cover all aspects of worker safety during the collection, handling, transport, and analysis of sediment samples (USEPA 2001a; ASTM 2001c). The health and safety plan should include a list of the tasks to be performed, a listing of key personnel and responsibilities, a description of the chemical and physical hazards associated with the site, and an analysis of the health and safety risks associated with each task. In addition, the plan should include an air monitoring plan, a description of the personal protective equipment that will be used for each task (including contingencies), procedures for decontaminating personnel and equipment, procedures for disposing of contaminated media and equipment, a description of safe work practices, and standard operating procedures. Finally, a contingency plan, personnel training requirements, a medical surveillance program, and record-keeping procedures should be included in the health and safety plan. The members of the sampling team should be reminded about key health and safety issues related to sampling and sample preparation prior to initiating activities on each day of the sampling program.

5.10 Project Schedule

A project schedule represents an important component of the SAP. The project schedule should clearly specify when each element of the sediment quality assessment will be completed. Some of the activities that should be included in the project schedule include field mobilization, field sampling (including time for sampling sub-areas and sequencing for sampling each station), field demobilization, shipment of samples to laboratories, initiation and completion of physical, chemical, and biological analyses, initiation and completion of data validation, completion of data reports, and completion of interpretive reports. Because laboratories may not be available on demand, it is important to consider holding times for chemical and biological samples when developing sampling schedules for the field program. In addition to supporting the technical aspects of the program, a detailed project schedule is likely to support the administrative components of the process (i.e., funding, contracting, etc.).

5.11 Project Team and Responsibilities

The SAP should include a brief description of the responsibilities of each member of the project team. In general, the project team will include a project manager, a number of scientists that are responsible to various field and laboratory components of the project, and a number of field and laboratory technicians. In addition, a QA/QC coordinator, database coordinator, data analysts, and other specialists are likely to play important roles during the planning and implementation of the investigation.

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Tables

Table 1. Examples of chemicals that should be measured on a site-specific basis (from WDOE 1995).

Chemical Contaminant	Reason for Suspected Presence in Sediments
Ammonia	* S26 0 Td (ST /TTn2605.1with fish processing plaMC /and aquacult

Table 2. A matrix of data interpretation tools for assessing ecological impairments associated with contaminated sediments (from Krantzberg *et al.* 2000).

Use Impairment	Assessment Element	Data Interpretation Tools	Sample References
Restriction on fish and wildlife consumption	Bioaccumulation	Equilibrium partitioning, comparison to guidelines	USEPA 1989; Beltran and Richardson 1992
Degradation of fish and wildlife populations	Community structure, bioaccumulation	Food web model, weight of evidence	USEPA 1989; Beltran and Richardson 1992
Fish tumors or other deformities	Bioaccumulation, chemistry	Reference frequencies	Baumann 1992
Bird or animals deformitites or reproduction problems	Bioaccumulation, community structure	Food web model, comparison to reference conditions, weight of evidence	Jaagumagi and Persaud 1996
Degradation of benthos	Community structure, toxicity (bioassays)	Comparison to reference conditions	Jaagmagi and Persaud 1996; Reynoldson *et al.* 1997
Restrictions on dredging activities (no open water disposal)	Chemistry, toxicity (bioassays), stability*	Comparison to guidelines and/or reference conditions	Persaud *et al.* 1993; USEPA 1998c
Eutrophic or undesirable algae	Chemistry, stability	Modeling	PDEP 1998
Degradation of aesthetics	Chemistry, stability	Comparison to reference conditions	
Added costs to agriculture or industry (to prevent or avoid contaminated water)	Chemistry, stability	Comparison to reference conditions	

Table 2. A matrix of data interpretation tools for assessing ecological impairments associated with contaminated sediments (from Krantzberg *et al.* 2000).

Use Impairment	Assessment Element	Data Interpretation Tools	Sample References
Dregraded phytoplankton and zooplankton populations	Bioaccumulation, chemistry, stability	Comparison to reference conditions, target nutrient loads	Bierman *et al.* 1984
Loss of fish and wildlife habitat	Chemistry, bioaccumulation, toxicity, benthos, stability	Comparison to reference conditions, weight of evidence	Minns *et al.* 1996

*Physical sediment characteristics, quiescent versus energetic site characteristics, etc.

Table 3. Sediment sampling and analysis plan outline and checklist (from WDOE 1995).

Introduction and Background Information

* Site history
* Regulatory framework (e.g., NPDES, MTCA, SMS, CERCLA)
* Summary of previous investigations, if any, of the site
* Location and characteristics of any current and/or historical wastewater or storm water discharge(s) at the site
* Location and characteristics of any current and/or historical wastewater or storm water

Table 3. Sediment sampling and analysis plan outline and checklist (from WDOE 1995).

Laboratory Analytical Methods
* Chemical analyses and target detection limits
* Biological analyses
* Corrective actions

Quality Assurance and Quality Control Requirements
* QA/QC for chemical analyses
* QA/QC for biological analysis
* Data quality assurance review procedures

Data Analysis, Record Keeping, and Reporting Requirements
* Analysis of sediment chemistry data
* Analysis of biological test data
* Data interpretation
* Record keeping procedures
* Reporting procedures

Health and Safety Plan (required for cleanup investigations)
* Description of tasks
* Key personnel and responsibilities
* Chemical and physical hazards
* Safety and health risk analysis for each task
* Air monitoring plan
* Personal protective equipment
* Work zones
* Decontamination procedures
* Disposal procedures for contaminated media and equipment
* Safe work procedures
* Standard operating procedures
* Contingency plan
* Personnel training requirements
* Medical surveillance program
* Record keeping procedures

Schedule
* Table or figure showing key project milestones

Project Team and Responsibilities
* Description of sediment sampling program personnel
* Table identifying the project team members and their responsibilities

References
* List of references

Table 4. Advantages and disadvantages of various sediment samplers (from WDOE 1995).

Sampler	Sediment Depth Sampled	Advantages	Disadvantages
Surface Sediment Samplers			
van Veen or Young grab	0-3 cm	Useful in deep water and on most substrates. Young grab coated with inert polymer. Large sediment volume obtained. May be subsampled through lid.	Loss of fine surface sediments and sediment integrity may occur during sampling. Incomplete jaw closure possible. Young grab is expensive. Both may require a winch.
Ponar grab	0-10 cm	Commonly used. Large volume of sediment obtained. Adequate on most substrates. Weight allows use in deep waters. Good sediment penetration.	Loss of fine surface sediments and sediment integrity may occur during sampling. Incomplete jaw closure occurs occasionally. Heavy and requires a winch.
Petite Ponar grab	0-10 cm	Similar in design to the Ponar grab, but smaller and more easily handled from a small boat. Can be deployed by hand without a winch in shallow water.	Small volume. Loss of fine surface sediments and sediment integrity may occur during sampling. Incomplete jaw closure occurs occasionally. May require winch in deeper water.
Ekman or box dredge	0-10 cm	Relatively large volume of sediment may be obtained. May be subsampled through lid. Lid design reduces loss of surficial sediments as compared to many dredges. Usable in moderately compacted sediments of varying grain sizes.	Loss of fine surface sediments may occur during sampling. Incomplete jaw closure occurs in coarse-grain sediments or with large debris. Sediment integrity disrupted.
Petersen grab	0-30 cm	Large sediment volume obtained from most substrates in deep waters.	Loss of fine surface sediments and sediment integrity. Incomplete jaw closure may occur. May require winch.
Orange-peel grab	0-30 cm	Large sediment volume obtained from most substrates. Efficient closure.	Loss of fine surface sediments and sediment integrity. Requires winch.

Table 5. Minimum sediment samples sizes and acceptable containers for physical/chemical analyses and sediment toxicity tests (from WDOE 1995).

Sample Type	Minimum Sample Size[a]	Container Type[b]
Physical/Chemical Analyses		
Grain size	100–150 g	P,G
Total solids	50 g	P,G
Total volatile solids	50 g	P,G[c]
Total organic carbon	25 g	P,G
Ammonia	25 g	P,G
Total sulfides	50 g	P,G[c]
Oil and grease	100 g	G
Metals (except mercury)	50 g	P,G
Mercury	1 g	P,G
Volatile organic compounds	50 g	G,T[c]
Semivolatile organic compounds	50–100 g	G
Pesticides and PCBs	50–100 g	G,T
Toxicity Tests		
Amphipod (*Hyalella azteca*)	0.1 L per replicate (0.8 L per station)	G
Mayfly (*Hexagenia limbata*)	0.2 L per replicate (1.0 L per station)	G
Midge (*Chironomus tentans*)	0.1 L per replicate (0.8 L per station)	G
Frog embryo *(Xenopus laevis)*	45 g (dry weight) per station	G
Microtox® solid phase or deionized water	200 g (wet weight) per station	G

[a]Recommended field sample sizes (wet weight basis) for one laboratory analysis. If additional laboratory analyses are required (e.g., laboratory replicates, allowance for having to repeat an analysis), the field sample size should be increased accordingly. For some chemical analyses, smaller sample sizes may be used if comparable sensitivity can be obtained by adjusting instrumentation, extract volume, or other factors of the analysis.

[b]P - linear polyethylene; G - borosilicate glass; T - polytetrafluorethylene (PTFE, Teflon®)-lined cap.

[c]No headspace or air pockets should remain. If such samples are frozen in glass containers, breakage of the container is likely to occur.

Table 6. Storage temperatures and maximum holding times for physical/chemical analyses and sediment toxicity tests (from WDOE 1995).

Sample Type	Storage Temperature	Maximum Holding Time
Grain Size	Cool, 4°C	6 months
Total solids	Cool, 4°C Freeze, -18°C	14 days 6 months
Total volatile solids	Cool, 4°C Freeze, -18°C	14 days 6 months
Total organic carbon	Cool, 4°C Freeze, -18°C	14 days 6 months
Ammonia	Cool, 4°C	7 days
Total sulfides	Cool, 4°C (1 N zinc acetate)	7 days
Oil and grease	Cool, 4°C (HCl) Freeze, -18°C (HCl)	28 days 6 months
Metals (except mercury)	Cool, 4°C Freeze, -18°C	6 months 2 years
Mercury	Freeze, -18°C	28 days
Semivolatile organic compounds; pesticides and PCBs; PCDDs/PCDFs	Cool, 4°C Freeze, -18°C	10 days 1 year
after extraction	Cool, 4°C	40 days
Volatile organic compounds	Cool, 4°C Freeze, -18°C	14 days 14 days
Sediment toxicity tests	Cool, 4°C Cool, 4°C, nitrogen atmosphere	2 weeks[a] 8 weeks[a]

HCl - hydrochloric acid; PCB - polychlorinated biphenyl; PCDD - polychlorinated dibenzo-*p*-dioxin; PCDF - polychlorinated dibenzofuran.

[a] The PSEP (1995) protocols recommend a maximum holding time of 2 weeks, but recognize that it may be necessary under certain circumstances to extend the holding time to accommodate a tiered testing strategy in which chemical analyses are conducted prior to toxicity testing. The PSDDA program, for example, allows sediments to be stored in the dark in a nitrogen atmosphere at 4°C for up to 8 weeks.

Table 7. Quality control procedures for organic analyses (from WDOE 1995).

Quality Control Procedure	Frequency	Control Limit	Corrective Action
Instrument Quality Assurance/Quality Control			
Initial Calibration	As recommended by PSEP (1989a) and specified in analytical protocol	≤30 %RSD for SVOCs and VOCs; ≤20 %RSD for PCBs. Relative response factors ≥0.05 for SVOCs and VOCs	Laboratory to recalibrate and reanalyze affected samples
Continuing Calibration	After every 10–12 samples (6 samples for PCBs) or every 12 hours (6 hours for PCBs), whichever is more frequent, and after the last sample of each work shift	≤25 %D for SVOCs and VOCs; ≤ 15 %D for PCBs. Relative response factors ≥ 0.05 for SVOCs and VOCs	Laboratory to recalibrate and reanalyze affected samples
Method Quality Assurance/Quality Control			
Holding Times	Not applicable	1 year (samples stored frozen [-18°C]) or 14 days (samples stored at 4°C) for SVOCs and PCBs; analyze extract within 40 days; 14 days (samples stored at 4°C) for VOCs	Qualify data or collect fresh samples
Method Blank	With every extraction batch; every 12-hour shift for VOCs	Analyte concentration >PQL (the LOD constitutes the warning limit)	Laboratory to eliminate or greatly reduce contamination; reanalyze affected samples
Surrogate Compounds	Added to every sample as specified in analytical protocol	EPA CLP control limits	Laboratory to follow EPA CLP protocols (reanalyzes or reextraction may be required)
Matrix Spike Sample and Matrix Spike Duplicate	With every sample batch or every 20 samples, whichever is more frequent	Recovery of 50–150 percent; precision of ≤50 RPD	Follow EPA CLP protocols

Table 7. Quality control procedures for organic analyses (from WDOE 1995).

Quality Control Procedure	Frequency	Control Limit	Corrective Action
Method Quality Assurance/Quality Control (cont.)			
Laboratory Control Sample	With every sample batch or every 20 samples, whichever is more frequent	Recovery of 50–150 percent	Laboratory to correct problem and reanalyze affected samples
Internal Standards	Added to every sample as specified in analytical protocol	Area response of 50–200 percent of calibration standard; retention time within 30 seconds of calibration standard	Laboratory to correct problem and reanalyze affected samples
Detection Limits	Not applicable	Target detection limits should be established at one-half of the TEC values (MacDonald *et al.* 2000)	Laboratory must initiate corrective actions (which may include additional cleanup steps as well as other measures, see) and contact the QA/QC3.04 267.91 1 Tf 0.T
Field Quality Assurance/Quality Control			
Field Replicates	At project manager's discretion	Not applicable	
Blind Certified Reference Material	Overall frequency of 5 percent of field samples	Within 95 percent confidence interval of true value	

Table 8. Quality control procedures for metal analyses (from WDOE 1995).

Quality Control Procedure	Frequency	Control Limit	Corrective Action
Instrument Quality Assurance/Quality Control			
Initial Calibration	Daily	Correlation coefficient > 0.995	
Initial Calibration Verification	Immediately after initial calibration		
Continuing Calibration Verification	After every 10 samples or every 2 hours, whichever is more frequent, and after the last sample		
Initial and Continuing Calibration Blanks	Immediately after initial calibration, then 10 percent of samples or every 2 hours, whichever is more frequent, and after the last sample		
ICP Interelement Interference Check Sample	At the beginning and end of each analytical sequence or twice per 8 hour shift, whichever is more frequent		
Method Quality Assurance/Quality Control			
Holding Times	Not applicable		

Table 8. Quality control procedures for metal analyses (from WDOE 1995).

Quality Control

Table 8. Quality control procedures for metal analyses (from WDOE 1995).

Quality Control Procedure	Frequency	Control Limit	Corrective Action
Matrix Quality Assurance/Quality Control (cont.)			
Field Replicates	At project manager's discretion	±e11.04 0 0 ID 7 >>6d	ET2.ec(€)TjdP <</MCID AdRDL26 0 Td (po
Cross-Contamination Blanks	At project manager's discretion		
Blind Certified Reference Material	Overall frequency of 5 percent of field samples		

Table 9. Quality control procedures for conventional analyses (from WDOE 1995).

Analyte	Suggested Control Limit				
	Initial Calibration	Continuing Calibration	Calibration Blanks	Laboratory	Laboratory

Figures

Figure 1. Overview of the process for designing and implementing sediment quality investigations.

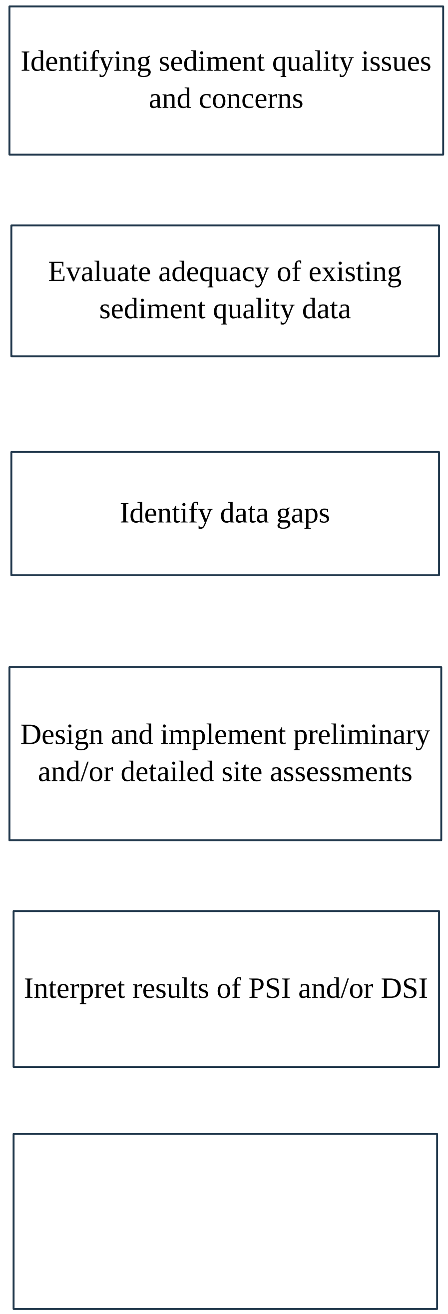


Figure 3. An overview of Stage I of the preliminary site investigation (PSI).

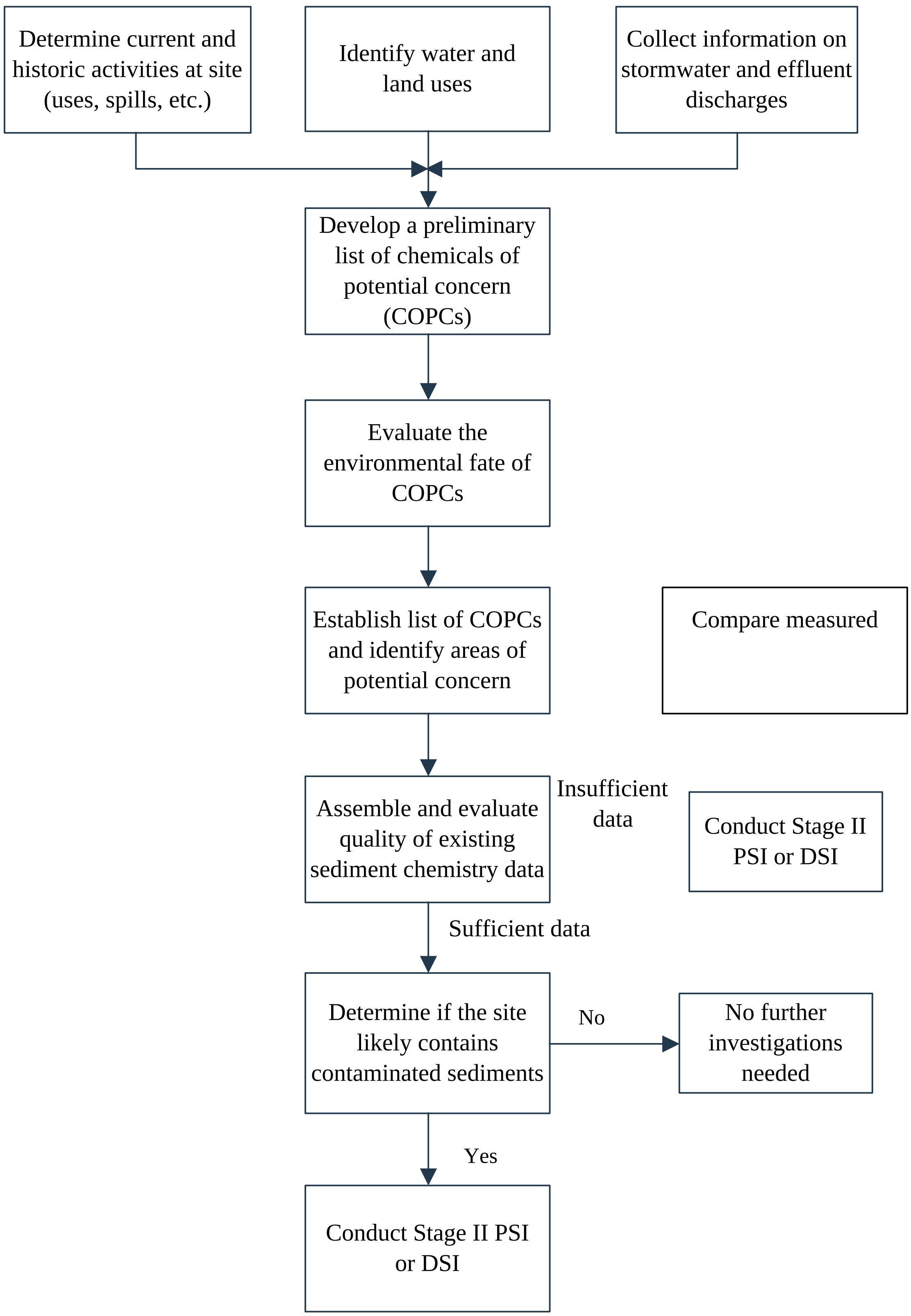


Figure 4. An overview of Stage II of the preliminary site investigation (PSI). A Stage II PSI is conducted if the results of the first stage of the PSI indicates that sediments are likely to be contaminated with toxic or bioaccumulative substances.

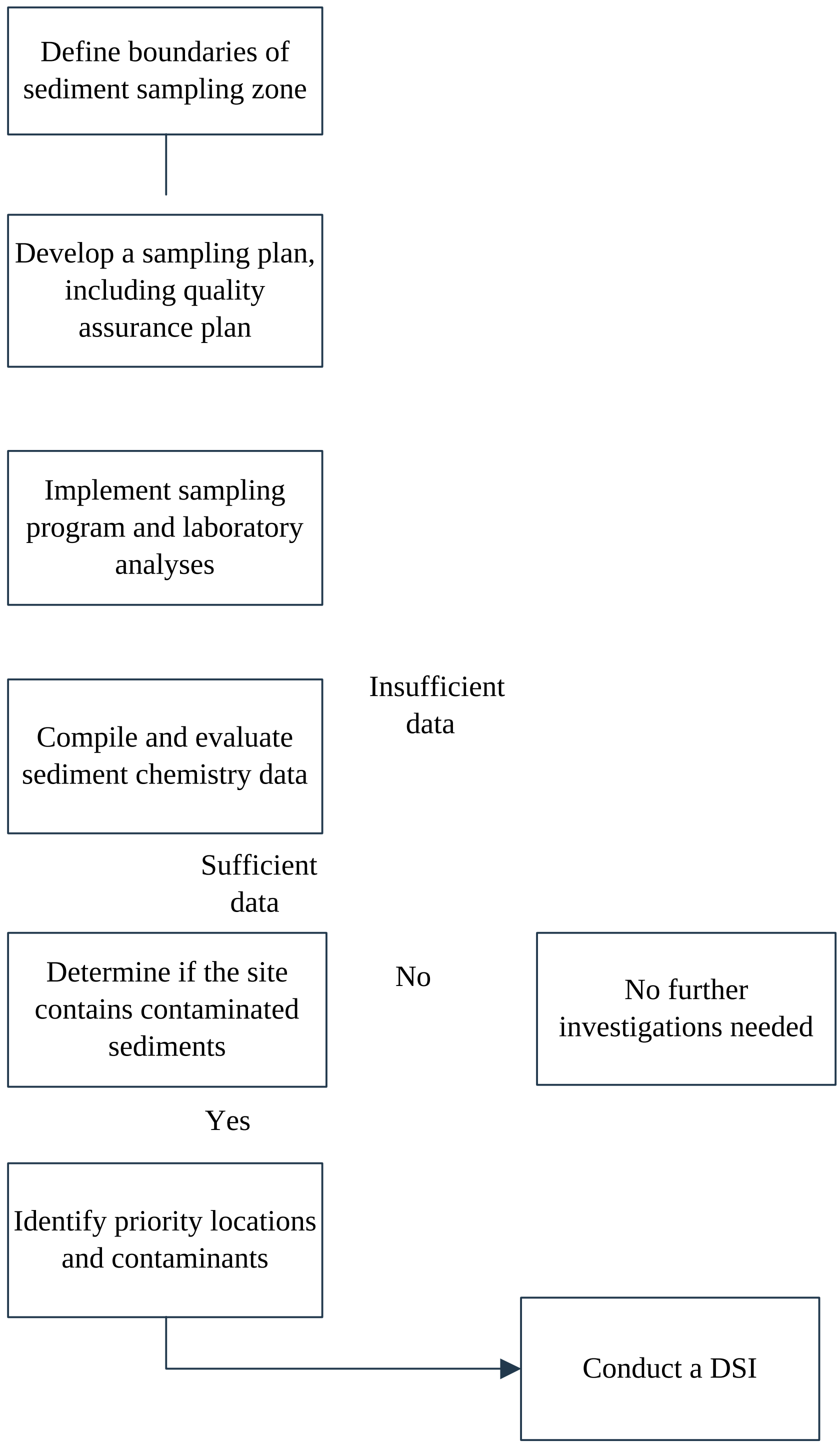


Figure 5. An overview of the detailed site investigation (DSI).

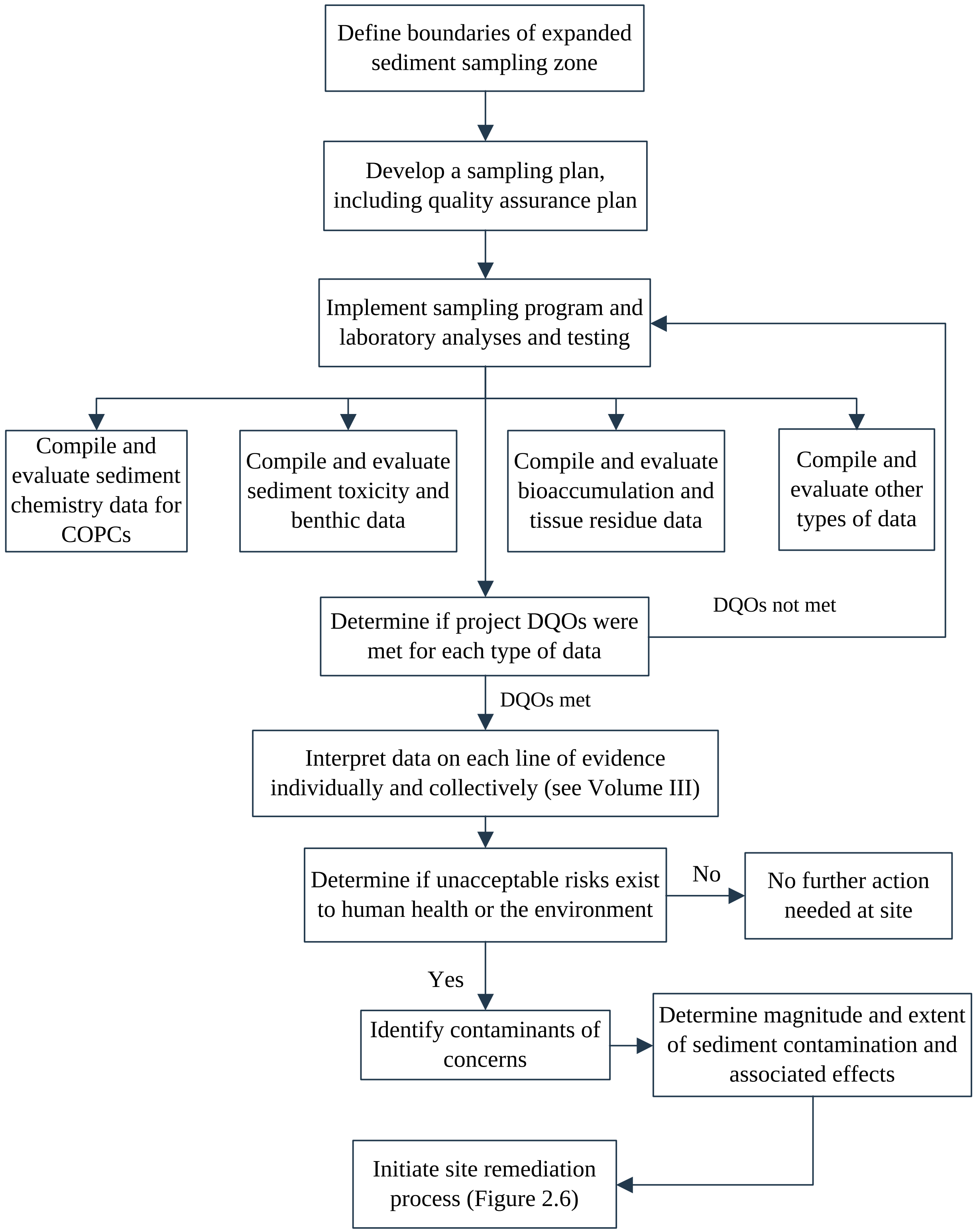
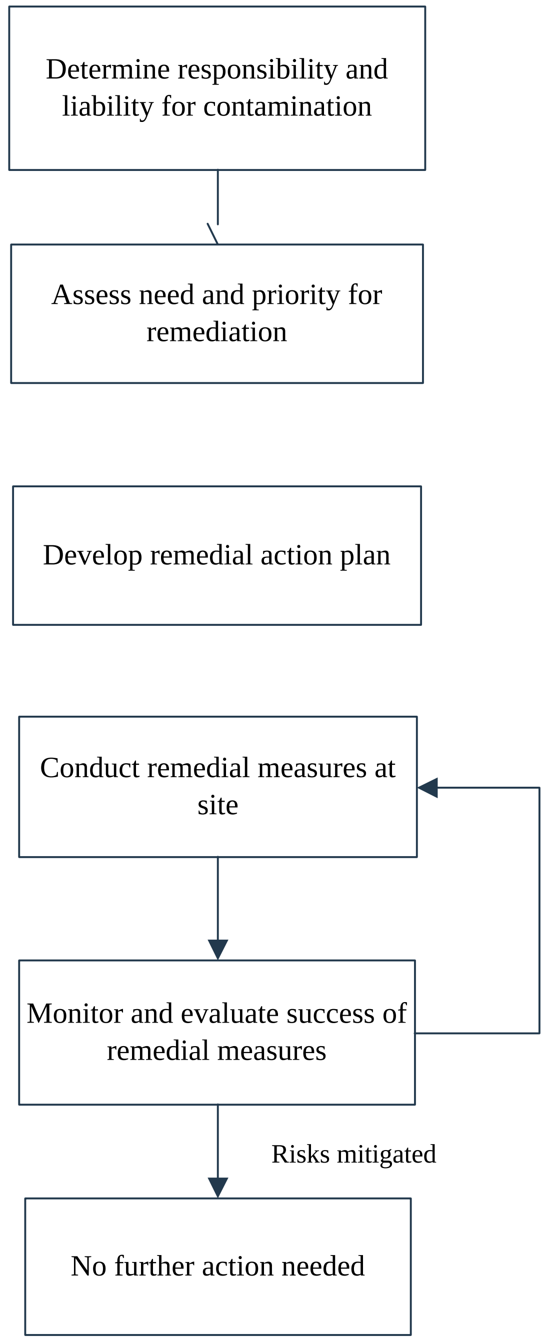


Figure 6. An overview of the contaminated site remediation process.



Appendices

Appendix 1 Types and Objectives of Freshwater Sediment Quality Assessments

A1.0 Introduction

Discharges of toxic and bioaccumulative substances into aquatic ecosystems have been reduced in the last 30 years. Nevertheless, persistent chemicals of potential concern (COPCs) in sediments continue to pose potential risks to human health and the environment (USEPA 1994a; USEPA 1997b). Elevated concentrations of COPCs in bottom sediments and associated adverse effects have been documented throughout North America. Contaminated sediments have been identified as a significant environmental concern at 42 of the 43 Great Lakes Areas of Concern (AOCs; IJC 1988; 1997) and at numerous other sites in the United States and Canada.

The extent of sediment contamination and associated adverse effects in the United States have been summarized in the USEPA National Sediment Inventory (USEPA 1997b; 2002). The results of this assessment indicate that substances such as metals, PAHs, PCBs, dichlorodiphenyl-trichloroethane (DDT), and polybrominated diphenyl esters are chemicals of major concern at sites throughout the country. Although a comparable national assessment has not been completed in Canada, there is abundant evidence that freshwater sediments throughout Canada have been contaminated due to human activities (MacDonald *et al.* 1993; Smith *et al.* 1996; Zarull *et al.* 2001). These results emphasize the extent to which sediments have been contaminated by human activities and underscore the need for reliable information to support the management of contaminated sediments.

Concerns regarding the effects of contaminated sediments on beneficial water uses have prompted action under a number of federal, state, and provincial programs. Importantly, investigations have been conducted throughout North America to assess the nature, extent, and severity of sediment contamination. Although these investigations often have a number of common elements, their objectives frequently differ depending on the regulatory program under which they are conducted. The following sections of this appendix provide descriptions of the types of assessments that are being conducted under various regulatory programs, including:

- State and Tribal Water Quality Standards and Monitoring programs;
- Total Maximum Daily Load (TMDL) program;
- National Pollutant Discharge Elimination System (NPDES) permitting program;
- Dredged Material Management program;
- Ocean Disposal program;
- Comprehensive Environmental Response, Compensation, and Liability Act (i.e., CERCLA; Superfund) program;
- British Columbia Contaminated Sites program;
- Resource Conservation and Recovery Act (RCRA) program;
- Federal Insecticide, Rodenticide and Fungicide Act (FIFRA) program;
- Toxic Substances Control Act (TSCA) program;
- Damage Assessment and Restoration program; and,
- Status and Trends Monitoring programs.

A description of the objectives of each of these types of programs is presented in the following sections of this document. This information on the objectives of each regulatory program and on the types of sediment quality assessments that are being conducted was obtained primarily from USEPA (1993; 1998a; 2000a) and ASTM (2001a). A description of the Contaminated Sediment Management Strategy that has been developed by USEPA (which has the primary authority for managing contaminated sediments in the United States) to guide sediment management initiatives is provided in Appendix 2 of Volume II (USEPA 1998a).

A1.1 State and Tribal Water Quality Standards and Monitoring Programs

The primary objective of state and tribal water quality standards and monitoring programs is to protect and maintain designated uses of aquatic ecosystems. USEPA recommends that States and Tribes use their narrative water quality criteria (e.g., "no toxics in toxic amounts") to protect sediment quality, as necessary to support the protection and maintenance

- Develop TMDLs according to this ranking.

The TMDLs provide the information needed to determine the reductions in point and non-point source discharges necessary to attain and maintain water quality standards. In this way, TMDLs represent important tools for managing water quality conditions because they facilitate allocation of assimilative capacity among the multiple sources of COPCs that are present within a receiving water body.

Information to support the development of TMDLs that consider sediment quality conditions may include the use of whole-sediment toxicity tests, benthic community surveys, sediment chemistry data, SQGs, and TIEs (USEPA 1998a; Volume III). Using the approach recommended by USEPA, states or tribes would utilize whole-sediment toxicity tests and other appropriate tools to interpret their narrative criteria with respect to sediment toxicity (i.e., in the absence of applicable state or tribal numerical sediment quality standards; USEPA 2000c). If the applicable state or tribal water quality standard is not attained for a water body, then the water body would be listed under Section 303(d) of the CWA and a TMDL would need to be developed. Numerical SQGs, along with TIEs, whole-sediment toxicity tests, or spiked-sediment toxicity tests, can be used to help identify the substances that are causing or substantially contributing to sediment toxicity (i.e., COCs). These substances are then targeted for the development of TMDLs. Numerical SQGs provide a basis for determining the magnitude of the reductions in contaminant concentrations needed to mitigate sediment toxicity. Sediment quality modeling can be used in development of TMDLs that address sediment toxicity. There are a number of sediment models available (Ingersoll *et al.* 1997), but sediment modeling is a relatively resource-intensive tasks and the results must be field validated to confirm their reliability. Historic sediment chemistry and contaminant loading data can also be used to estimate the loading reductions needed to achieve the narrative criteria with respect to sediment toxicity. Follow-up monitoring should include sediment chemistry analyses to verify that numeric targets are being met, as well as whole-sediment toxicity tests to verify that the sediments are not toxic.

A1.3 National Pollutant Discharge and Elimination System Permitting Program

The objective of the NPDES permitting program is to establish water quality-based effluent discharge limits to protect receiving waters from contamination by point sources (USEPA 2000c). NPDES permits represent the primary tools for ensuring that point source effluent discharges do not compromise our ability to meet applicable water quality standards. Since 1994, sediment contamination has been considered in the selection of new industrial categories of chemicals for the development of effluent quality criteria. However, most NPDES permits do not contain discharge limits that are specifically developed to protect sediment quality. Some of the information that can be used to support decision making on NPDES permits relative to sediment quality conditions includes whole-sediment toxicity tests, TIE procedures, bioaccumulation tests, sediment chemistry data, and SQGs (USEPA 1998a; Volume III [overprinted: wat32(1998a;EV0.5803)3 TOc.89l d.494,use(conside)Tj 0 g.16drge]

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A1.4 Dredged Material Management Program

The objective of the Dredged Material Management program is to evaluate the potential environmental effects associated with the disposal of dredged material in open water and in confined disposal sites, as well as the possibility of using dredged material for beneficial purposes, such as beach enrichment (USEPA 1992). Decisions on the management of dredged materials are primarily supported by information on the toxicity of whole sediments and elutriates in short-term tests (i.e., 4- to 10-day exposures), and on the bioaccumulation of sediment-associated contaminants (USEPA and USACE 1998a). As such, the dredged material management program, which is authorized under Section 103 of the Marine Protection, Research, and Sanctuaries Act (MPRSA) and Section 404 of the CWA, relies heavily on the results of effects-based testing to evaluate the suitability of dredged material for disposal. Although there is no requirement for utilizing sediment chemistry data in the evaluation of dredged material, such data could form part of the information base evaluated to determine whether further assessment of contaminated sediment is warranted (USEPA and USACE 1998a). mat1.53 T6.avily

- 20-day whole-sediment toxicity test with polychaetes, in which growth is the endpoint measured; and,
- 28-day whole-sediment bioaccumulation test with clams, in which tissue residue levels is the endpoint measured.

Decisions regarding the suitability of a material for open water disposal are then made based on the results of these tests. If all tests pass, the material is considered to be rapidly rendered harmless (RRH) and, hence, suitable for open water disposal. If the material is found to be not toxic to amphipods but one of the other tests fail, then disposal is allowed only with special handling techniques.

sediment assessments are used both in site assessment and in remedy selection (USEPA 1993).

In the Superfund program, SQGs have been used by investigators during the screening level ecological risk assessment, which is conducted as part of the Remedial Investigation/Feasibility Study (CDM 1999; USEPA 2000c; MacDonald *et al.* 2002). In this application, SQGs have been used to help identify COPCs and areas of interest at contaminated sites. Substances that occur at concentrations below SQGs would generally not be carried through as COPCs into the baseline ecological risk assessment. However, substances that occur at concentrations above the SQGs would warrant further investigation (i.e., COPCs). While SQGs are primarily used for screening purposes, they can also be used to support the establishment of preliminary remedial goals (PRGs) at sites with contaminated sediments (USEPA 2000d; MacDonald *et al.* 2001; 2002). The results of site-specific evaluations of the predictive ability of the SQGs provide a basis for assessing their applicability as PRGs.

A1.7 British Columbia Contaminated Sites Program

The objective of the component of the British Columbia Contaminated Sites program is to manage contaminated sites to protect human health and the environment. A tiered framework has been established to support the assessment and management of contaminated sediments in the province. Identification of the site as potentially containing contaminated sediments represents the first tier in the framework. There are a number of property management activities that the concentrations and distributions of contaminants at the site. The measured concentrations of each analyte are then compared to numerical SQGs to determine if the site is legally contaminated (i.e., if one of more substances exceed the SQGs in more that 10% of the samples). Further investigation or remediation is required at sites that are found to have contaminated sediments.

A1.8 Resource Conservation and Recovery Act Corrective Action Program

The objective of the RCRA program is to clean up hazardous waste sites to protect human health, welfare, and the environment (USEPA 2000c). USEPA has authority to assess whether releases from a hazardous waste treatment, storage, or disposal facility have contaminated sediments and whether corrective action is required (USEPA 1998a). Under this program, sediments may be identified as toxic using the RCRA toxicity characterization leaching process (USEPA 1993). Under this process, concentrations of various chemicals in a leachate are compared to concentrations established to protect human health and the environment. The information used to support decision-making relative to contaminated sediments is similar to that described above for Superfund (Section A1.6; USEPA 1993).

A1.9 Federal Insecticide, Rodenticide and Fungicide Act Program

The objective of the FIFRA program is to evaluate the effects on non-target organisms of new and existing chemicals registered as pesticides (USEPA 2000c). While the program considers all potential exposure routes, contaminated sediments represent an important route of exposure for substances that

A1.10 Toxic Substances Control Act Program

The objective of the TSCA program is to reduce the risks associated with possible releases of existing and new chemicals that are

Subsequently (1996), the National Oceanic and Atmospheric Administration (NOAA) issued regulations for the assessment of damages resulting from a discharge or a substantial threat of discharge of oil. Where both oil and other hazardous substances have been released, the DOI regulations are considered to take precedence, although the NOAA regulations may also provide useful guidance.

The NRDAR process consists of two main steps, including a pre-assessment screen and a damage assessment. In the pre-assessment screen, readily available data and information are reviewed to determine if the trustees have a reasonable probability of making a successful damage claim. If the results of the pre-assessment screen indicate that a damage assessment is warranted, then an assessment plan is developed to guide the design and implementation of the assessment, and to communicate the proposed assessment methods to potentially responsible parties and to the public. Under the DOI regulations, two types of assessments may be conducted, including Type A and Type B assessments. The Type A assessment involves a simplified process that relies only minimally on field observations and applies to minor, short duration releases of oil and/or [illegible]

from over 21,000 sampling stations in the United States were compiled to evaluate sediment chemistry, chemical residues in edible tissue of aquatic organisms, and sediment toxicity. The information contained in this database were then utilized to conduct a screening level assessment of the potential for adverse effects on human and environmental health. This database has now been updated with recently-collected information to support the second report to Congress on sediment quality conditions in the United States (USEPA 2001b).

The NSTP is designed to monitor spatial and temporal trends of chemical contamination and biological responses to that contamination. Temporal trends are being monitored through the Mussel Watch project, in which mussels and oysters are collected annually at about 200 sites throughout coastal and estuarine areas of the United States. Spatial trends have been described on a national scale using data on the concentrations of COPCs in surface sediments collected from 240 sites distributed throughout the coastal and estuarine United States under both the Mussel Watch and Benthic Surveillance Projects. In addition, the Benthic Surveillance Project has measured chemical concentrations in fish livers and performed histological analyses of fish for evidence of biological responses to chemical contamination. The sediment assessment portion of the NSTP is primarily focused on the collection and interpretation of data on whole-sediment chemistry for major COPCs (organic and inorganic chemicals), whole-sediment toxicity tests, pore-water toxicity tests, toxicity tests with organic extracts of sediments, and benthic community surveys.

The NAWQA program was designed to describe the status and trends in the quality of the Nation's ground- and surface-water resources and to provide an understanding of the natural and human factors that affect the quality of these resources. As part of the program, investigations are being conducted in 59 areas called "study units" located throughout the United States. These investigations are designed to provide a framework for national and regional water-quality assessment. Regional and national synthesis of information from study units will consist of comparative studies of specific water-quality issues using nationally consistent information. The sediment assessment portion of NAWQA is based primarily on whole-sediment chemistry for major COPCs (organic and inorganic chemicals).

Appendix 2 USEPA Contaminated Sediment Management Strategy

The USEPA has primary authority under a variety of statutes to manage contaminated sediments in the United States (Table A2.1). The USEPA Contaminated Sediment Management Strategy (USEPA 1998a) established the following four goals for managing contaminated sediments, including:

- To prevent further contamination of sediments that may cause unacceptable ecological or human health risks;
- When practical, to clean up existing sediment contamination that adversely affects the Nation's waterbodies or their uses, or that causes other significant effects on human health or the environment;
- To ensure that sediment dredging and the disposal of dredged material continue to be managed in an environmentally-sound manner; and,
- To develop and consistently apply methodologies for analyzing contaminated sediments.

The USEPA plans to employ its pollution prevention and source control programs to address the first goal. To accomplish the second goal, USEPA plans to use a range of risk management alternatives to reduce the volume and effects of existing contaminated sediments, including natural recovery, *in situ* containment, and contaminated sediment removal. Finally, USEPA is developing tools for use in pollution prevention, source control, remediation, and dredged material management to meet all of these goals. These tools include national inventories of sediment quality and environmental releases of contaminants, numerical assessment guidelines to evaluate contaminant concentrations, and standardized methods for conducting toxicity tests to evaluate the bioaccumulation and toxicity of sediment samples (USEPA 1997a; 2000a).

The Clean Water Act is the single most important law dealing with quality of surface waters in

Sanctuaries Act, the Marine Protection and Research Act, and the Oil Pollution Act playing complimentary roles.

Each USEPA program office intends to develop guidance for interpreting the tests conducted within the tiered framework and to explain how the information generated within each tier would be used to trigger regulatory action. Depending on statutory and regulatory requirements, the program specific guidance will describe how decisions are to be made, potentially involving a weight of evidence approach, a pass-fail approach, or comparisons to reference sites. The following two approaches are currently being used by USEPA: (1) the Office of Water-U.S. Army Corps of Engineers dredged material testing framework; and, (2) the OPPTS ecological risk assessment tiered testing framework. USEPA and USACE (1998b) describes the dredged material testing framework, while Smrchek and Zeeman (1998) summarizes the OPPTS testing framework. A tiered testing framework has not yet been selected for Agency-wide use, but some of the components have been identified.

Appendix 3 Additional Considerations for Designing Sediment Quality Sampling Programs

A3.0 Introduction

To be effective, a sediment quality sampling program must be designed to fulfill the specific objectives that have been established for the assessment. The types and objectives of freshwater sediment quality assessments were discussed in Appendix 1 of Volume II. In addition, guidance on the design and implementation of preliminary and detailed site investigations was provided in Chapter 3 and Chapter 4 of Volume II, respectively, of this guidance manual. Furthermore, the key elements of sampling and analysis plans for assessing contaminated sediments were identified in Chapter 5 of Volume II. The supplemental guidance that is offered in this appendix is intended to provide additional information on the design of sediment quality sampling programs, including the selection of control and reference sediments. This information was obtained primarily from USEPA (2001a), ASTM (2001c) and CDM (2000).

A3.1 Selection of Sampling Stations

The study area (or site) refers to the body of water that contains the sampling station(s) to be evaluated, as well as adjacent areas (land or water) that might influence the conditions of the sampling station. The size and characteristics of the study area will influence the sampling design and station positioning methods. The boundaries of the study area need to be defined using a hydrographic chart or topographic map.

The selection of an appropriate sampling design is one of the most critical steps designing the study. The design will be a product of the general study objectives. Station location and sampling methods will necessarily follow from the study design. Ultimately, a study design should control extraneous sources error to the extent possible so that data are directly applicable for addressing the project objectives.

area. Depending on the types of analyses desired, such sampling can become expensive unless the study area is relatively small or the density of stations is relatively low. Systematic sampling can be effective for detecting previously unknown "hot spots" in the study area.

Targeted sampling of sediments is appropriate for situations in which any of the following apply: (1) relatively small-scale features or conditions are under investigation; (2) small numbers of samples (e.g., fewer than 20 observations) will be evaluated; (3) there is reliable historical and physical knowledge about the feature or condition under investigation; (4) the objective of the investigation is to screen an area(s) for contamination at levels of concern; or, (5) schedule or budget limitations preclude the possibility of implementing a statistical design (USEPA 2001a).

Targeted sampling designs can often be quickly implemented at a relatively low cost. As such, this type of sampling can meet schedule constraints that cannot be met by implementing a more rigorous statistical design. In many situations, targeted sampling offers an additional important benefit of providing an appropriate level-of-effort for meeting objectives of the study within a limited budget. Targeted sampling does not allow the level of uncertainty in the field sampling to be accurately quantified. In addition, targeted sampling limits the inferences that can be made to the units actually analyzed and the extrapolation from those units to the overall population from which the units were collected.

Stratified random sampling consists of dividing the target population into non-overlapping parts or subregions (e.g., watersheds), which are termed strata, to obtain a better estimate of the mean or total for the entire population. The information required to delineate the strata and estimate sampling frequency needs to be known before sampling. This information is typically obtained from historic data or by conducting a reconnaissance survey. Sampling locations are randomly selected from within each of the strata. In stratified designs, the selection probabilities may differ among strata.

A related design is multistage random sampling, in which large subareas within the study area are first selected (usually on the basis of professional knowledge or previously collected information). Stations are then randomly located within each subarea to yield average or pooled estimates of the variables of interest. This type of sampling is especially useful for statistically comparing variables among specific parts of a study area.

Use of random sampling designs may miss relationships among variables, especially if there is a relationship between an explanatory and a response variable. As an example, estimation of COPC concentrations nearby an outfall requires data from a number of sampling stations, including those located directly adjacent to the outfall and those that are located further from the outfall. A simple random sample of stations may not capture the entire range, because the high end of the gradient would likely be under-represented in the design.

Probability-based sampling designs avoid bias in the results of sampling by randomly assigning and selecting sampling locations. A probability-based design requires that all sampling units have a known probability of being selected. Stations can be selected on the basis of a random scheme or in a systematic way (e.g., sample every 10 meters along a randomly chosen transect). In simple random sampling, all sampling units have an equal probability of selection. This design is appropriate for estimating means and totals of environmental variables if the population is homogeneous. To apply simple random sampling, it is necessary

The number of samples collected is usually determined by the size of the sampling station, type and distribution of COPCs being measured, heterogeneity of the sediment, concentrations of COPCs in the sediments, sample volume requirements, and desired level of statistical resolution. Accordingly, sample requirements needs to be determined on a case-by-case basis. The number of samples to be collected will ultimately be an outcome of the questions asked. For example, if one is interested in characterizing effects of a point source or a gradient (e.g., effects of certain tributaries or land uses on a lake or estuary), then many samples in a relatively small area may need to be collected and analyzed. If, however, one is interested in identifying "hot spots" or locations that are highly contaminated within a watershed or large water body, relatively few samples at targeted locations may be appropriate. The number of samples to be collected usually results from a compromise between the ideal and the practical. The major practical constraints are the logistics of sample collection and the costs of analyses.

The objective of collecting replicate samples at each sampling station is to allow for quantitative statistical comparison within and among different stations. Separate subsamples from the same grab or core sample might be used to measure the variation within a sample but not necessarily within the station. The collection of separate samples within a sampling station can impart valuable information on the spatial distribution of contaminants at the station and on the heterogeneity of the sediments within the station. However, the collection of replicate samples at each station will dramatically increase the analytical chemical costs needed for the assessment. Approaches that can be used to determine the number of replicates required to achieve a minimum detectable difference at a specific confidence level and power are outlined in USEPA (2001a). Traditionally, acceptable coefficients of variation vary from 10 to 35%,

A3.3 Control and Reference Sediments

Sediment toxicity and bioaccumulation tests must include a control sediment (sometimes called a negative contropa5M0,r2GNING criteria are met in a reference sediment included in the study design. In these cases, it might be reasonable to infer that other samples

D = Second sample value (duplicate value).

Precision of reported results is a function of inherent field-related variability and/or laboratory analytical variability, depending on the type of QC samples that are submitted. Data may be evaluated for precision using the following types of samples (in order of priority): field duplicates, laboratory duplicates, laboratory control sample/laboratory control sample duplicates (LCS/LCSDs), or matrix spike/matrix spike duplicates (MS/MSDs).

The acceptable

quantitative parameter that is most concerned with the proper sampling design and the absence of cross-contamination of samples. Acceptable representativeness is achieved through:

- Careful, informed selection of sampling sites;
- Selection of testing parameters and methods that adequately define and characterize the extent of possible contamination and meet the required parameter reporting limits;
- Proper gathering and handling of samples to avoid interferences and prevent contamination and loss; and,
- Collection of a sufficient number of samples to allow characterization.

Representativeness is assessed qualitatively by reviewing the sampling and analytical procedures and quantitatively by reviewing the results of analyses of blank samples. If an analyte is detected in a method, preparation, or rinsate blank, any associated positive result less than five times the detection limit (10 times for common laboratory COPCs) may be considered a false positive. Holding times are also evaluated to determine if analytical results are representative of sample concentrations.

Completeness - Completeness is a measure of the amount of usable data obtained from a measurement system compared to the amount that was expected to be obtained under correct normal conditions. Usability is determined by evaluating the PARCC parameters excluding completeness. Those data that are validated, evaluated and are not considered estimated, or are qualified as estimated or non-detect are all considered to be usable. Rejected data are not considered usable. Completeness is calculated using the following equation:

$$\text{Percent Completeness} = (DO \div DP) \times 100$$

where:

DO = Data Obtained and usable; and,
DP = Data Planned to be obtained.

A completeness goal of 90 percent is often applied to sediment quality assessments.

Comparability - Comparability is a qualitative parameter. Consistency in the acquisition, handling, and analysis of samples is necessary for comparing results. Application of standard methods and appropriate quality control procedures are the primary means of assuring comparability of results with other analyses performed in a similar manner.

Appendix Tables

Appendix Figures

Figure A1.1. Overview of the tiered approach for assessing the environmental effects of dredged material management alternatives (from USEPA and USACE 1998a).

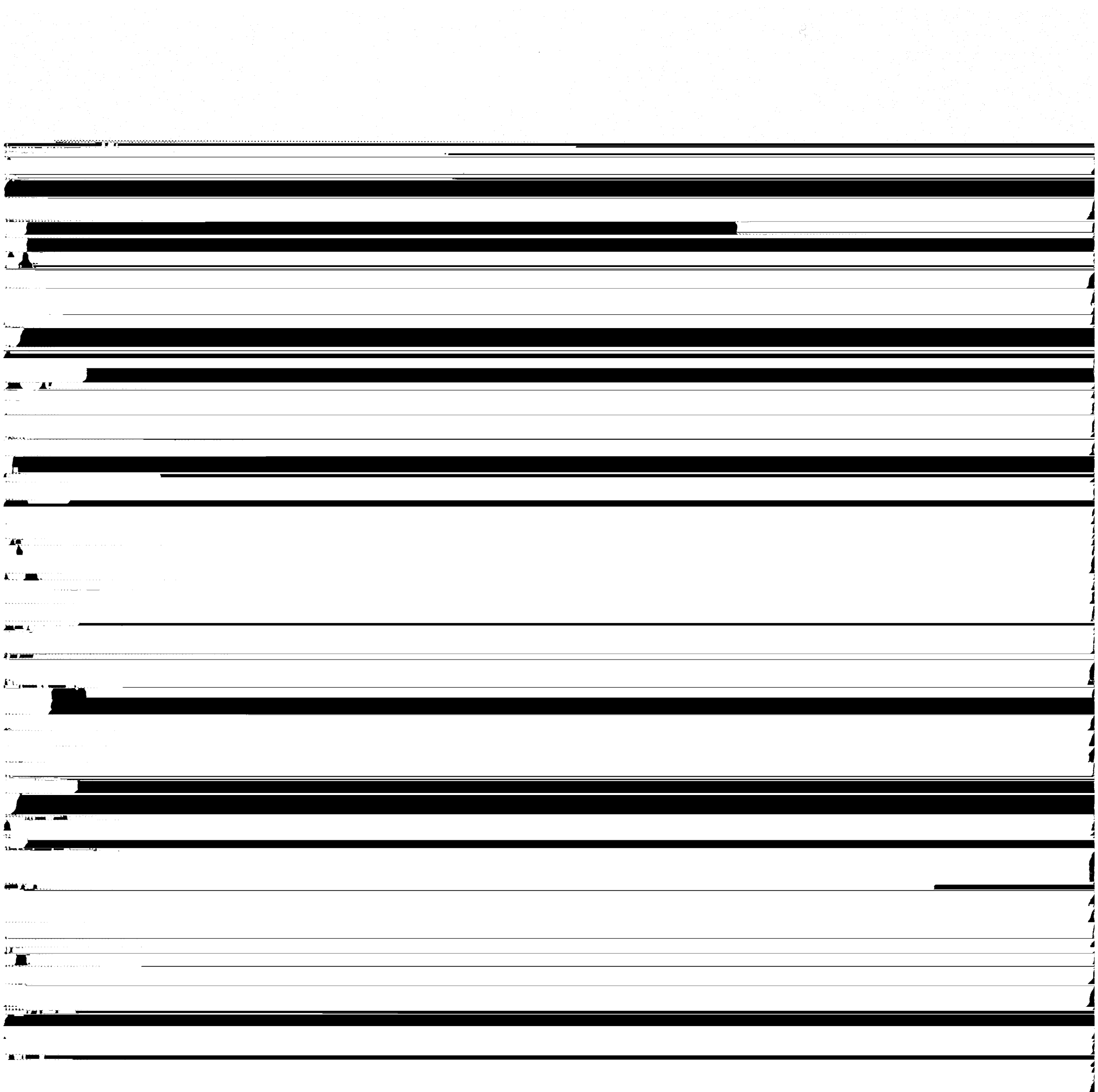

Figure A1.2. Simplified overview of tiered approach to evaluating potential impact of aquatic disposal of dredged material (from USEPA and USACE 1998a).

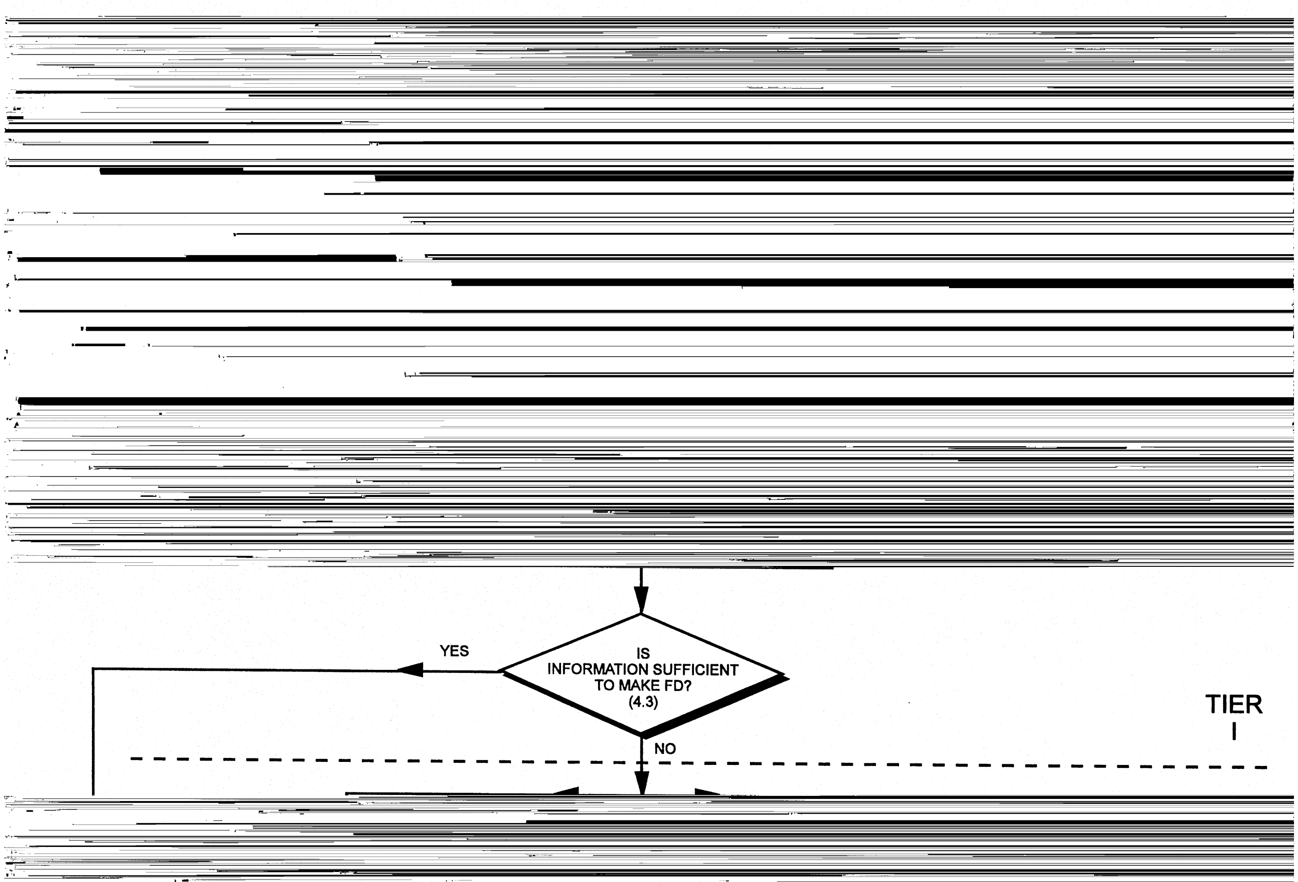

Figure A1.3.

Figure A1.4. Illustration of the tiered approach to evaluating potential benthic impacts of deposited dredged material (from USEPA and USACE 1998a).