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Washington, DC 20460

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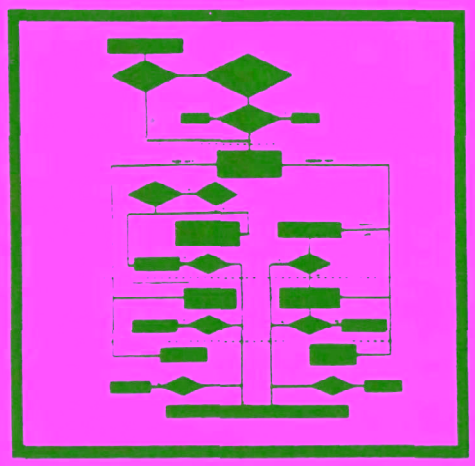
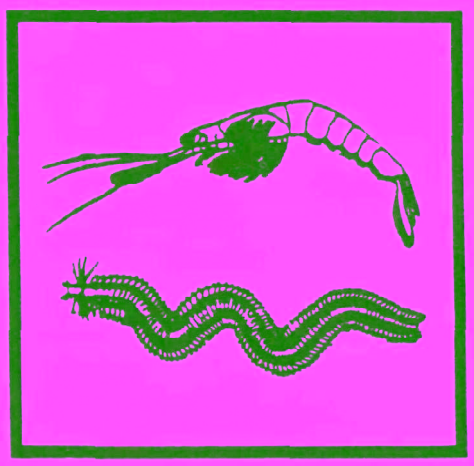
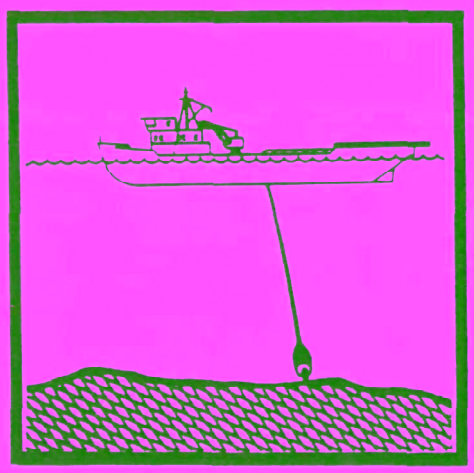
Water

Draft Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters







U.S. Environmental Protection Agency

Department of the Army
U.S. Army Corps of Engineers

United States
Army Corps of Engineers

Transmittal of the January, 1990 Draft Testing Manual

"Ecological Evaluation of Proposed Discharge of

Dredged Material Into Ocean Waters"

In 1977, the Environmental Protection Agency (EPA) and the US Army Corps of Engineers (CE) released the testing manual titled "Ecological Evaluation of Proposed Discharge of Dredged Materials Into Ocean Waters" (commonly referred to as the "Green Book"). This manual was for use in determining the suitability of dredged materials for ocean disposal under the Ocean Dumping Regulations (40 CFR 220-228). Since 1977 the CE and EPA have been improving on the methods in the 1977 testing manual and have developed this revised draft manual to update and eventually replace the 1977 manual.

This document is still in draft form and is only being distributed at this time for review. It has not been approved for use and is not to be used for decision making until it is revised based upon comments received and issued in final form.

EPA and CE intend to revise and finalize this draft manual approximately six months after its release (July, 1990). At that time there will be a notice in the Federal Register announcing availability of and effective date of the new manual. The final manual would not be used to make decisions until several months after the Federal Register announcement in order to allow regulators and laboratories time to gear up for the new procedures.

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DRAFT ECOLOGICAL EVALUATION OF PROPOSED DISCHARGE OF DREDGED MATERIAL INTO OCEAN WATERS

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STATUS OF THIS DRAFT MANUAL

This is a **DRAFT** manual printed solely for the purpose of review. It is not to be used until that review process has been completed, necessary revisions made, and the final manual approved for use by both EPA and the CE.

Mention of commercial products in this document does not constitute official endorsement or approval of the use of such products.

PREFACE

According to Section 103 of Public Law 92-532 (the Marine Protection, Research, and Sanctuaries Act of 1972), any proposed dumping of dredged material into ocean waters must be evaluated through the use of criteria published by the Environmental Protection Agency (EPA) in Title 40 of the Code of Federal Regulations, Parts 220-228 (40 CFR 220-228). This testing guidance manual contains procedures applicable to the evaluation of potential environmental impacts of the ocean disposal of dredged material. It will be periodically revised and updated as warranted by advances in regulatory practice and technical understanding. When this manual is approved by EPA and the Corps of Engineers (CE), it will replace the July 1977 manual entitled "Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters," which will no longer be applicable.

The manual was prepared by Battelle Memorial Institute - Duxbury Operations and EA Engineering, Science, and Technology, Inc. as part of a contract between Battelle Memorial Institute - Duxbury Operations and EPA's Office of Marine and Estuarine Protection (EPA Contract No. 68-C8-0105). The EPA Work Assignment Manager was Mr. David Redford, the Work Assignment Leaders were Dr. Richard Peddicord and Ms. Nancy O'Mara, and the Technical Monitors were Dr. Christine Werme and Dr. Carlton Hunt. Development of the manual was overseen by a group headed by Mr. Redford and composed of Mr. Norman Rubinstein and Dr. John Gentile of the EPA Environmental Research Laboratory, Narragansett, RI, and Drs. Robert Engler, Thomas Wright, and Thomas Dillon of the U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. The manual was written by scientists at Battelle Memorial Institute - Duxbury Operations and EA Engineering, Science, and Technology, Inc. Although many staff members contributed to the manual, lead authors contributed to each section, as follows:

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Review of the manual was conducted by EPA through the Marine Operations Division of the Office of Marine and Estuarine Protection, and by the Corps of Engineers through the Office, Chief of Engineers, and the Environmental Laboratory of the Waterways Experiment Station.

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PART I

GENERAL CONSIDERATIONS

1.0 INTRODUCTION

1.1 BACKGROUND

Section 103 of the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA), Public Law 92-532, specifies that all proposed operations involving the transportation and dumping of dredged material into ocean waters have to be evaluated to determine the potential environmental impact of such activities. This is done by the Secretary of the Army, using criteria developed by the Administrator of the Environmental Protection Agency (EPA) in consultation with the Secretary. In accordance with Section 103 of the MPRSA, the Corps of Engineers (CE) is the permitting authority for dredged material, subject to EPA review. Environmental evaluations have to be in accordance with applicable criteria published in Title 40, Code of Federal Regulations, Parts 220-228 (40 CFR 220-228), hereinafter referred to as "the regulations." Proposed ocean disposal of dredged material also has to comply with the permitting and dredging regulations found in Title 33 CFR, Parts 320-330 and 335-338.

Appendix A of this manual contains a reprinting of 40 CFR Parts 220-228. However, this manual addresses only the technical requirements that apply to dredged material bioassay and bioaccumulation testing (see 227.6 and 227.13).

One of the main purposes of Section 103 of the MPRSA is to regulate and limit adverse ecological effects of ocean dumping of dredged material. Consequently, the regulations emphasize evaluative techniques such as bioassays and bioaccumulation testing, which provide relatively direct estimates of the potential for environmental impact.

1.2 APPLICABILITY

This implementation manual is applicable to all activities involving the transportation of dredged material for the purpose of dumping it in ocean waters outside the baseline from which the territorial sea is measured. The guidance in this manual is applicable to dredging operations conducted under permits as well as to Federal projects conducted by the CE.

In this manual terms like "dredging project," etc. are used in the broadest sense to include both Federal projects and operations conducted under permits. The procedures in this manual do not apply to activities excluded in Section 220.1 of the regulations.

Although it is important to remember that the regulations are legally binding and that the guidance provided in this manual is necessarily responsive to the specific requirements of these regulations, the manual is not intended to carry the force of law. This document does, however, contain jointly acceptable technological approaches for evaluating the potential environmental impacts of the ocean disposal of dredged material as agreed upon by CE and EPA. Dredged material considered for ocean disposal should be evaluated by the procedures described in this manual to determine its potential for environmental impacts.

This manual provides guidance on technical methods for testing dredged material to assess its compliance with the applicable bioassay-based provisions of the regulations (e.g., 40 CFR 227.6; 227.13). Dredged material evaluated under the procedures in this manual and found to comply with those portions of the regulations may be disposed at a designated ocean dredged material disposal site if it satisfies all other applicable requirements of 40 CFR 220-228, the terms and conditions of the site designation, and the requirements of Title 33 CFR, Parts 320-330 and 335-338.

Some dredged material evaluated in accordance with the technical procedures of this manual may demonstrate a potential for unacceptable adverse environmental impacts. If so, a careful case-by-case evaluation of management options for these materials will be necessary. If the ocean dumping option is to be pursued, particular attention should be given to utilizing specific management actions in order to minimize or eliminate potentially unacceptable impacts. The decision of whether such material may be allowable for ocean disposal under the MPRSA and the applicable regulations, and the procedural steps to be followed in making this determination, are issues beyond the scope of this manual.

1.3 PURPOSE AND SCOPE

This manual was developed under the direction of a joint EPA/CE work group. This manual provides a balance between technical state-of-the-art

and routinely implementable guidance for using the evaluative procedures specified in the regulations. Guidance is included on the appropriate uses and limitations of the various procedures and on sound interpretation of the results.

This manual contains summaries and discussions of the procedures for ecological evaluation of dredged material required by the regulations, tests to implement them, definitions, sample collection and preservation procedures, evaluative procedures, calculations, interpretive guidance, and supporting references required for the evaluation of dredged material discharge applications in accordance with the regulations. Even so, this manual cannot stand alone. It is imperative that the supporting references be consulted for detailed or more comprehensive guidance whenever indicated. Before any evaluations are begun, THIS MANUAL AND ESPECIALLY THE REGULATIONS IN 40 CFR 220-228 SHOULD BE READ IN THEIR ENTIRETY, and citations and references should be consulted to obtain an understanding of the guidance the manual provides. The technical procedures in this manual are designed only for dredged material and should not be used for any other materials unless definitive research demonstrates their applicability.

This manual contains evaluative procedures considered to be acceptable tools for regulation. As warranted by experience with this manual and the development of new procedures, sections of this manual will be updated periodically and the availability of these updates will be announced. Because this manual is national in scope, it cannot address every local concern, and cannot provide detailed guidance appropriate to every such issue. Therefore, development of more detailed implementation guidance tailoring the procedures of this manual to local needs is encouraged. It is essential to the ecological evaluation approach in the manual that detailed technical agreements on the approaches to be used for all disposal applications be developed jointly and cooperatively by the CE District Engineer and the EPA Regional Administrator, considering the input of involved local parties and the appropriate scientists in both agencies. Local guidance has to comply with all applicable regulations, and should be reviewed and approved by headquarters and be fully compatible with the guidance in this manual. If there is disagreement between a CE District and EPA Region, disputes should be resolved jointly by CE and EPA headquarters.

1.4 CHANGES AND REVISIONS FROM THE PREVIOUS MANUAL

This manual will replace the document entitled "Ecological Evaluation of Proposed Discharges of Dredged Material into Ocean Waters," published by EPA and CE in 1977, with a second printing in 1978. This draft revised manual provides implementation guidance compatible with the 1977 Ocean Dumping Regulations (Title 40, Code of Federal Regulations, Parts 220-228). The revised manual reflects experience gained since 1977 with environmental regulation of the ocean disposal of dredged material. Although many changes have been made in the format and content of the manual, the general approach of providing the technical rationale of the regulations, test procedures, and interpretive guidance is the same, and this manual is consistent with the provisions of the existing regulations. The test end points and evaluative guidance have been refined, but the basic concepts are very similar to those of the earlier manual.

The manual has been structured for better presentation of the expanded information now available about environmental evaluation of dredged material. Part I of the manual is similar in content to Parts I and II of the 1977 manual, with the addition of a chapter that discusses the concepts of tiered testing and appropriate reference and control materials. Part II addresses how to evaluate potential environmental impact at each tier of evaluation and provides guidance on how to use the results at each tier to make decisions. Part III is analogous to the appendices of the 1977 manual. It gives field and laboratory guidance for gathering data and discusses quality assurance/quality control considerations. The regulations of 40 CFR 220-228 are reprinted in Appendix A, and detailed technical guidance on mixing calculations is contained in Appendix B.

1.5 DEFINITIONS

The following terms are briefly defined and interpreted for purposes of this guidance document. See Subpart G of the regulations for complete definitions of terms used in the regulations.

Constituents: Chemical substances, solids, organic matter, and organisms associated with or contained in or on dredged material.

Control sediment: A natural sediment essentially free of contaminants and compatible with the biological needs of the test organisms such that it has no discernable influence on the response being measured in the test. Test procedures are conducted with the control sediment in the same way as the reference sediment and dredged material. The purpose of the control sediment is to confirm the biological acceptability of the test conditions and to help verify the health of the organisms during the test. Excessive mortality in the control sediment indicates a problem with the test conditions or organisms, and can invalidate the results of the corresponding dredged material test.

Disposal site: An EPA approved precise geographical area within which ocean disposal of dredged material is permitted under conditions specified in permits issued under Section 103 of the MPRSA. Such sites are identified by boundaries established by (1) coordinates of latitude and longitude for each corner, or by (2) coordinates of latitude and longitude for the center point and a radius in nautical miles from that point. Appropriate datum for latitude and longitude should be indicated. Boundary coordinates shall be identified as precisely as is warranted by the accuracy with which the site can be located with existing navigational aids or by the implantation of transponders, buoys, or other means of marking the site.

Dredged material: Material excavated or dredged from waters of the United States and ocean waters.

Dumping: The disposition of material subject to the exclusions of paragraph 220.2(e) of the regulations and 33 CFR Parts 320-330 and 335-338.

Initial mixing: That dispersion or diffusion of liquid, suspended particulate, and solid phases of a waste which occurs within four hours after dumping. The limiting permissible concentration shall not be exceeded beyond the boundaries of the disposal site during initial mixing, and shall not be exceeded at any point in the marine environment after initial mixing.

Limiting permissible concentration (LPC): The concentration of dredged material in the water column that, after allowance for initial mixing, does not exceed applicable marine water-quality criteria or a toxicity threshold of 0.01 of the acutely toxic concentration. The LPC of the suspended particulate and solid phases will not cause unreasonable toxicity or bioaccumulation (see Section 227.27 of the regulations for the complete definition).

Management Action: Those actions considered necessary to rapidly render harmless the material proposed for disposal in the marine environment (e.g. non-toxic, non-bioaccumulative).

May: May is used to mean "is allowed to"; can is used to mean "is able to" and might is used to mean "could possibly."

Must: Must in this manual refers to requirements that have to be addressed in the context of compliance with the ocean dumping regulations.

Ocean: Those waters of the open seas lying seaward of the baseline from which the territorial sea is measured (see Section 220.2[c] of the regulations).

Reference sediment: A sediment, substantially free of contaminants, that is as similar to the grain size of the dredged material and the sediment at the disposal site as practical, and reflects conditions that would exist in the vicinity of the disposal site if no dredged material disposal had ever occurred, but all other influences on sediment condition had taken place. These conditions have to be met to the maximum extent possible. If it is not possible to fully meet these conditions, tests should use organisms that are not sensitive to the grain size differences among the reference sediment, control sediment, and dredged material. The reference sediment serves as a point of comparison to identify potential effects of contaminants in the dredged material.

Regulations: Procedures and concepts published in the Code of Federal Regulations Title 40, Parts 220-228 for evaluating proposals for dumping dredged material in the ocean.

Should: Should is used to state that the specified condition is recommended and ought to be met unless there are clear and definite reasons not to do so.

2.0 OVERVIEW OF THE REGULATIONS

The potential effects of ocean disposal of dredged material on marine organisms and human uses of the ocean may range from unmeasurable to important. These effects may differ at each disposal site and have to be evaluated on a case-by-case basis. The regulations provide the requirements for such an evaluation, with an emphasis on the direct assessment of biological impacts. The permitting procedure for proposed ocean disposal of dredged material is found in Part 225 of the regulations. Part 227 summarizes the requirements that apply to dredged material technical evaluation and contains procedural requirements for evaluating all dredged materials proposed for ocean dumping. Part 227.1 makes some, but not all, sections of Part 227 applicable to dredged material evaluations. This chapter of the manual summarizes the major requirements for dredged material evaluations. However, it is essential that decisions be based on a full reading and application of the regulations, and not on this summary.

2.1 PART 225: CORPS OF ENGINEERS (CE) DREDGED MATERIAL PERMITS

The application and authorization for ocean disposal of dredged material is outlined in Part 225. Section 225.2 establishes the informational requirements for evaluating proposed dredged material actions and Section 225.3 describes the procedure for evaluating the economic feasibility of alternative methods or sites. An especially important aspect of Part 225 is that the regulations allow for a waiver of the criteria to be sought if the proposed action is denied but dredging is essential and no feasible alternatives are available. EPA has to determine that the proposed dumping will have no unacceptable adverse effect on municipal water supplies, shellfish beds, fishery areas, wildlife areas or recreational areas before granting the waiver.

2.2 PART 227, SUBPART A: GENERAL

Part 227, Subpart A defines the purpose, scope, and applicability of Part 227. It also establishes general criteria applicable to disposal of dredged material.

2.3 PART 227, SUBPART B: ENVIRONMENTAL IMPACT

Subpart B sets general and specific criteria that has to be satisfied for disposal of dredged material in the ocean. Subpart B details procedures to be used in evaluating whether dredged material proposed for ocean dumping complies with the applicable provisions of Part 227. Section 227.5 establishes important prohibitions applicable to dredged material.

2.3.1 Trace Contaminants

Section 227.6 prohibits dumping of certain constituents as other than trace contaminants in an otherwise acceptable dredged material. This is a key section of the regulations. TRACE CONTAMINANTS ARE NOT DEFINED IN TERMS OF NUMERICAL CHEMICAL LIMITS, BUT RATHER IN TERMS OF PERSISTENCE, TOXICITY AND BIOACCUMULATION THAT WILL NOT CAUSE AN UNACCEPTABLE ADVERSE IMPACT AFTER DUMPING. This is expressed in regulatory language in paragraphs 227.6(b) and (c).

By this definition of trace contaminants, marine organisms are regarded, in a sense, as analytical instruments for determining the environmentally adverse consequences (if any) of any contaminants present. This definition of trace contaminants requires that the lack of unacceptable adverse effect in biological studies be taken to mean that contaminants are absent, or present only in amounts and/or forms that are not environmentally active, and therefore do not exceed the trace contaminant definition. When effects occur in dredged material tests, it is not possible within the present state of knowledge to determine which constituent(s) caused the observed effects. Therefore, it has to be assumed that they are caused by materials described in Section 227.6, because it cannot be established that this is not the case. This would mean that one or more contaminants are present in greater than trace concentrations. In practice, the exact identity of the contaminant(s)

causing the effect is of little concern under 40 CFR 227 because ocean disposal of dredged material that causes an unacceptable effect should not occur. Following this reasoning, unacceptable bioaccumulation of any potentially harmful constituent, whether listed in Section 227.6 or not, could make the dredged material potentially undesirable.

Because assessment of trace contaminants depends upon the determination of the potential for effects, an assessment cannot be made until the impact evaluation is completed and interpreted. Only then can effects, and thus the presence of materials as other than trace contaminants, be determined. Paragraphs 227.6(f) and (g) are important in relation to trace contaminants because they provide the possibility of management techniques to deal with dredged materials that may contain some constituents as other than trace contaminants.

2.3.2 Biological Evaluations

As specified in paragraph 227.13(c) the evaluation process emphasizes potential biological effects, rather than chemical presence, of the possible contaminants. It is important to recognize that dredged material bioassays are not precise predictors of environmental effects. They are best regarded as quantitative estimators of these effects. In order to avoid adding more uncertainty to their interpretation, the bioassays given in this manual use mortality as the primary endpoint. The importance of this response to individual organisms involved is clear, but the state of ecological understanding is such that it is difficult to predict the ecological consequences of the death of a given percent of the test population of a particular species. That is, mortality of a certain percent of the organisms of a particular species in a laboratory test does not imply that the population of that species around the disposal site would decline by the same percent if the proposed disposal took place. Even if such a decline were to occur, there is presently no good basis for estimating whether the ecological effects of loss at the disposal site of 10 percent of a particular species would be inconsequential or major. The manual provides guidance under the regulations on determining the magnitude of mortality that may be considered a real increase. However, the manual does not provide quantitative guidance on interpreting the ecological meaning of the mortality observed. The regulations consider statistically

significant increases above certain levels in mortality compared to the reference sediment as potentially undesirable.

Bioaccumulation is included in the required evaluations by paragraphs 227.6(b) and (c). Bioaccumulation indicates biological availability of contaminants in the dredged material. It also assesses the potential for long-term accumulation of contaminants in aquatic food webs to levels that might be harmful to consumers, which could include man, without killing the intermediate organisms. To use bioaccumulation in a decision, it is necessary to predict whether there will be a cause-and-effect relationship between the animal's presence in dredged material and a meaningful adverse elevation of body burden of contaminants above that of similar animals not exposed to the dredged material.

It is difficult to quantify either the ecological consequences of a given tissue concentration of a bioaccumulated contaminant or the consequences of that body burden to the animal. This manual does not provide quantitative guidance on interpreting the ecological meaning of the bioaccumulation observed. The regulations consider statistically significant increases in bioaccumulation in animals exposed to the dredged material compared with animals exposed to the reference sediment as potentially undesirable. Because a statistically significant difference is not a quantitative prediction that an ecologically important impact would occur in the field, this manual discusses additional factors to be weighed in evaluating potential ecological impact of bioaccumulation in Sections 6.2 and 7.2. This is more likely to result in environmentally sound evaluations than is reliance on statistical significance alone. However, the tests described in this manual can indicate the <u>potential</u> for such an ecological impact on a case-specific basis. As pointed out in the preceding discussion of Part 227, Subpart B, the trace contaminants determination cannot be made until bioaccumulation potential is evaluated.

Biological evaluations serve to integrate the chemical and biological interactions of the suite of contaminants present in a dredged material sample by measuring their effects on test organisms. In this way, biological methods are more direct and specific than chemical evaluations, which have to infer interactions and effects based on sediment contaminant data alone. Within the constraints of experimental conditions and the endpoint of effect measured, biological evaluations provide for a

quantitative comparison of the effect of a dredged material and acceptable conditions as represented by reference sediments. Thus, a statistically significant result in this comparison indicates that the dredged material in question causes a direct and specific biological effect under test conditions, and therefore, has the potential to cause an ecologically unacceptable impact. These results will be used to determine the acceptability of the material for ocean disposal.

2.4 PART 227, SUBPART C: NEED FOR OCEAN DUMPING

Subpart C is primarily an evaluation of the need for ocean dumping. Initially, no disposal alternative is considered more desirable than any other, and the evaluation is made on a case-by-case basis. That is, confined or upland disposal cannot be considered environmentally preferable to ocean disposal unless consideration of potential environmental impacts (e.g., groundwater contamination, leachate and runoff impacts, permanent alteration of the site) shows it to be so. Similarly, ocean disposal cannot automatically be considered the most desirable alternative.

2.5 PART 227, SUBPART D: IMPACT OF THE PROPOSED DUMPING ON AESTHETIC, RECREATIONAL, AND ECONOMIC VALUES

Before a proposed disposal action may be approved, the probable impacts on aesthetics, recreation, and economic values have to be evaluated, as described in Subpart D. Although this is a nontechnical evaluation, information from the technical assessment described in Subpart B may be useful. Section 227.19 requires that the results of the Subpart D assessment be expressed, insofar as possible, in quantitative terms.

2.6 PART 227, SUBPART E: IMPACT OF THE PROPOSED DUMPING ON OTHER USES OF THE OCEAN

Subpart E is related to Subpart D, but it requires evaluation of specific actual or potential uses of the disposal site environs, including but not limited to those listed in Section 227.21. These are evaluations for which specific quantitative tests cannot be given. However, much information developed in the Subpart B technical evaluations will be

relevant to the assessment of potential impacts on living resources and their utilization.

2.7 PART 227, SUBPART G: DEFINITIONS

Subpart G provides definitions for the concepts used in test protocols for performing the evaluations required by Section 227.6 and 227.13 of the regulations. These evaluations are required to determine compliance with the limiting permissible concentration as defined in Part 227.27.

2.7.1 Limiting Permissible Concentration

2.7.1.1 Water Column

The limiting permissible concentration (LPC) applicable to potential water column impacts is defined in Part 227.27(a). The LPC for the portion of dredged material that will remain in the water column is the concentration of any dissolved dredged material constituent which, after allowance for initial mixing, will not exceed applicable marine water quality criteria, and when there are contaminants of concern for which there are no marine water quality criteria, will not be acutely toxic. Chemical analyses are performed for contaminants that may be released from dredged material in dissolved form and the results are compared to water quality criteria for these contaminants after allowance for initial mixing. This provides an indirect evaluation of potential biological impacts, because water quality criteria were derived from toxicity tests of solutions of the various contaminants. Section 4.2 discusses selection of contaminants of concern in the water column, Chapter 8 discusses sample collection and preservation methods, and Chapter 9 discusses analytical procedures.

When dredged material contains contaminants of concern for which there are no applicable marine water quality criteria or when synergistic effects are suspected, the material remaining in the water column has to be shown to be nontoxic and nonbioaccumulative after initial mixing. Bioassays provide information on the toxicity of contaminants not included in the water quality criteria, and also indicate possible interactive

effects of multiple contaminants. Guidance on conducting water column bioassays is contained in Chapter 10 of the manual. Because concern about bioaccumulation is focused on the possibility of impacts associated with gradual uptake over long exposure times, primary attention is given to dredged material deposited on the bottom. Bioaccumulation from the material remaining in the water column is considered to be of minor concern due to the short exposure time and low exposure concentrations resulting from rapid dispersion and dilution. The discussion of biological evaluations in Section 2.3.2 of this manual is critical to realistic assessment of the potential for impacts in the water column.

2.7.1.2 Benthic Environment

Research conducted by CE and EPA since the inception of MPRSA has shown that the greatest potential for environmental impact from dredged material lies in the benthic environment. This is because deposited dredged material is not mixed and dispersed as rapidly or as greatly as the portion of the material that may remain in the water column, and bottom-dwelling animals live and feed in and on deposited material for extended periods. Therefore, the major evaluative efforts should be placed on deposited material and the benthic environment, unless there is reason to do otherwise. The regulations require that bioassays be used after initial mixing to evaluate the potential impact of deposited dredged material, except material excluded from testing. Chemical analyses of dredged material are needed to determine the presence and concentration of contaminants that might be of environmental concern, including concerns about bioaccumulation. However, at present, chemical analyses cannot be used to directly evaluate the biological effects of any contaminants or combination of contaminants present in dredged material. Therefore, animals are used in bioassays to directly determine the biological availability and potential for impacts of contaminants associated with dredged material. Guidance on conducting bioassays with deposited dredged material is found in Chapter 10, and bioaccumulation guidance is contained in Chapter 11. Understanding the discussion of biological evaluations in Section 2.3.2 is critical to realistic assessment of the potential for impacts on the benthic environment.

While sediment chemistry cannot be used to predict biological effects, it can be used to identify contaminants of concern. Chemistry can be used to demonstrate that there is "reasonable assurance that such material has not been contaminated by such pollution" (227.13(b)(3)(ii).

2.7.2 Estimation of Initial Mixing

Part 227.29 describes methods for estimation of initial mixing. These methods are applied in evaluating the potential for impacts of the portion of dredged material that remains in the water column; all water quality, bioassay, and bioaccumulation data have to be interpreted in light of initial mixing according to Part 227.29. This is necessary since biological effects (which are the basis for water quality criteria) are a function of biologically available contaminant concentration and exposure time of the organisms. Laboratory bioassays expose organisms to constant concentrations for fixed periods of time, whereas in the field both concentration and exposure time to a particular concentration change continuously due to mixing and dilution. Both factors interact to control the degree of biological impact; thus it is necessary to incorporate the mixing expected at the disposal site into the interpretation of data.

2.7.3 Species Selection

Parts 227.27(c) and (d) specify that water column bioassays will use appropriate sensitive water column marine organisms, and benthic bioassays will use appropriate sensitive benthic marine organisms.

Part 227.27(c) defines appropriate sensitive water column marine organisms as at least one species each representative of phytoplankton or zooplankton, crustacean or mollusc, and fish species chosen from among the most sensitive species accepted by EPA and CE as being reliable test organisms to determine potential water column impacts. Phytoplankton tests can theoretically indicate the potential for stimulation or inhibition by the dredged material in question. However, phytoplankton tests with the portion of dredged material remaining in the water column are extremely difficult to conduct and interpret. This is caused by interferences and predation on the test species by protozoa in the dredged material being tested. It is widely believed that potential effects on phytoplankton are

generally of little environmental concern at ocean dredged material disposal sites, due to the extremely variable characteristics of natural phytoplankton assemblages and to the rapid mixing and dilution that occurs in the water column. Therefore, unless there is a specific reason to be concerned about potential effects of the proposed operation on phytoplankton, this manual recommends that a zooplankton species be selected to fulfill that portion of the species requirement. Laboratory procedures for conducting water column bioassays are found in Chapter 10.

Part 227.27(d) defines appropriate sensitive benthic marine organisms as at least one species each representing filter-feeding, deposit-feeding and burrowing species chosen from among the most sensitive species accepted by EPA and CE as being reliable organisms to determine potential benthic impacts. These are broad, overlapping categories, and the manual recommends different species for bioassays and bioaccumulation testing. Species for bioassays with deposited sediment generally should include a deposit-feeding amphipod. Bioaccumulation tests generally should include a deposit- feeding bivalve mollusc and a burrowing polychaete. Procedures for conducting bioassays are found in Chapter 10, and bioaccumulation procedures are found in Chapter 11.

PART II

EVALUATION OF POTENTIAL ENVIRONMENTAL IMPACT

3.0 OVERVIEW OF TESTING AND EVALUATION

3.1 REFERENCE AND CONTROL SEDIMENTS

It is important to distinguish clearly between reference and control sediments in the context of testing for benthic impacts. Test procedures are conducted on the control and reference sediments in the same way as on the dredged material proposed for ocean disposal.

3.1.1 Control Sediments

Control sediment is a natural sediment essentially free of contaminants. The essential characteristic of control sediment is that it be fully compatible with the needs of the test organisms such that it have no discernible influence on the response being measured in the test. The results of the control sediment tests are used to verify the health of organisms used in testing and the acceptability of test conditions. Excessive mortality in the control sediment indicates a problem with testing conditions or organisms and can invalidate the corresponding test results.

3.1.2 Reference Sediment

Reference sediment is the key to the evaluation of dredged material. Results of tests using reference sediment provide the point of comparison (reference point) to which effects of dredged material are compared. A determination of the potential for dredged material proposed for disposal to cause unacceptable adverse impact can be made by comparing results of tests using reference material to the results of tests using dredged material.

A reference sediment is a sediment, substantially free of contaminants, that is as similar to the grain size of the dredged material and the sediment at the disposal site as practical, and reflects conditions that would exist in the vicinity of the disposal site if no dredged material disposal had ever occurred, but all other influences on sediment condition had taken place. These conditions have to be met to the maximum extent possible. If it is not possible to fully meet these conditions,

tests should use organisms that are not sensitive to grain size differences among the reference sediment, control sediment, and dredged material. Alternatively, grain size effects may be accounted for by an approach similar to that taken by DeWitt, et al. (1988). The reference sediment serves as a point of comparison to identify potential effects of contaminants in the dredged material.

3.1.2.1 Reference Sediment Sampling Location

According to the definition in Section 1.5, reference sediment is substantially free of contaminants, as similar to the grain size of the dredged material and the sediment at the disposal site as practical, and reflects conditions that would exist in the vicinity of the disposal site if no dredged material disposal had ever taken place, but all other influences on sediment condition had occurred. With this is mind, reference sediment is collected outside the boundaries of the dredged material disposal site, but near enough to the disposal site that the reference sediment is in the same water mass and subject to all the same influences (except previously disposed dredged material) as the disposal site. If there is a potential for sediment migration, reference sediment should not be collected from the area outside the disposal site in the direction of net sediment transport.

Reference sediment may be collected from a single reference sediment sampling point that satisfies the conditions in this section and meets the requirements of the reference sediment definition in Section 1.5. This is known as the reference point approach.

Alternatively, reference sediment may be collected from a number of locations within a reference area that satisfies the conditions in this section and meets the requirements of the reference sediment definition in Section 1.5. This is known as the reference area approach.

In the reference area approach, the reference location is not viewed as a single station or point, but as the entire area in the environs of the disposal site, excluding the disposal site itself. Rather than characterize the reference area by sampling at a single point, it is characterized by a number of samples taken throughout the reference area. The intensity of the reference sediment sample gathering should be tailored to the physical, chemical, and biological characteristics of the disposal

site, particularly the dispersal characteristics of the site. Reference area samples may be composited according to the compositing guidance in Section 8.2.4. The composited or individual samples are then tested for chemistry, toxicity and bioaccumulation by the same methods used for dredged material testing. The reference data thus generated are compared to the corresponding dredged material data in the same way reference data have traditionally been used.

3.1.2.2 Reference Sediment Sampling Interval

Reference sediment has to be collected and tested at the time of each dredged material test if the reference point approach is used. In this approach, a new sample of reference sediment is collected from the specified reference sediment sampling point for each test or test series and is tested simultaneously with the dredged material being evaluated. Logistical considerations might make it impractical to use the reference area approach at the time of each test.

The reference area approach may be implemented on a periodic basis. Reference sediment is collected from the reference area and all appropriate chemistry, bioassay, and bioaccumulation tests are performed on it. The reference data thus generated are used as the basis for evaluating all dredged material tested during some specified time period. The reference area is resampled and retested to update the reference data periodically as appropriate.

Using the periodic reference area approach, reference data are established for each disposal site and for each type of test. Reference toxicity data have to be established for each benthic species that will be required for testing of dredged material proposed for disposal at that site during the specified time period. Reference bioaccumulation data have to be established for each species that will be required for bioaccumulation testing of dredged material proposed for disposal at that site during the specified time period. Reference bioaccumulation data have to be established for each contaminant likely to be of concern in dredged material proposed for disposal at that site during the specified time period. Development of reference data using all appropriate species and contaminants for all dredged material that may be proposed for a disposal site during the specified time period will require planning and

coordination. However, most ocean disposal sites receive dredged material from relatively few locations so that standardization of species for testing and advance identification of potential contaminants of concern for bioaccumulation should be possible.

3.1.2.3 Reference Sediment Sampling

The importance of thoughtful selection of the approach to reference sediment sampling cannot be overemphasized. To ensure that the reference sediment is properly located, information gathered during the site designation process or other similar studies should be completed for both the disposal site and the reference area. Information on the potential for migration of dredged material from the disposal site is particularly important in this regard.

As discussed in Chapter 8, a well-designed sampling plan is essential to the collection, preservation, and storage of samples so that potential toxicity and bioaccumulation can be accurately assessed. The implementation of such a plan is equally essential for dredged material, control sediment, and reference sediment sampling. The sample collection, preservation, and storage guidance of Chapter 8 is applicable to dredged material, control sediment and reference sediment.

3.2 TIERED TESTING AND EVALUATION

The tiered approach to testing used in this manual is designed to aid in generating necessary toxicity and bioaccumulation information, but not more information than necessary. This allows optimal use of resources by focusing the least effort on dredging operations where potential (or lack thereof) for unacceptable adverse impacts is clear, and expending the most effort on operations requiring more extensive investigation to determine the potential (or lack thereof) for impacts. To achieve this objective, the procedures in this manual are arranged in a series of tiers, or levels of intensity of investigation. The initial tier uses readily available information that can be sufficient for evaluation in some cases. Dredging operations that obviously have very low potential for unacceptable adverse environmental impact generally should not require intensive investigation

to reach a decision. Evaluation at successive tiers is based on more extensive and specific information that may be more time consuming and expensive to generate, but that allows more and more comprehensive evaluations of the potential for environmental effects.

A tiered, or hierarchical, approach to testing and evaluation allows the use of a necessary and sufficient level of testing for each specific dredging operation. The initial tiers (Tiers I and II) use existing information and relatively simple, rapid procedures for determining potential environmental impact of the dredged material in question. For certain dredged materials with readily apparent potential for environmental impact (or lack thereof), information collected in the initial tiers may be sufficient for making decisions. However, more extensive evaluation (Tiers III and IV) may be needed for other materials with less clear potential for impact or for which inadequate information exists. Successive tiers use more intensive evaluation procedures that provide more detailed information about potential impacts of the dredged material. The intent of the tiered approach is to use resources efficiently by testing only as intensely as necessary to provide sufficient information for making decisions. The tiered approach minimizes excessive testing of dredging operations for which this is unnecessary and appropriately directs more intense testing to operations that require more technical information for evaluation. Tiered testing results in more efficient completion of required evaluations and reduced costs, especially to low risk operations.

It is neither necessary nor desirable that evaluation of every dredged material proceed through all tiers in sequence. If information warrants, it is acceptable to proceed directly to Tiers II, III, or IV. It is also fully acceptable to carry water column and benthic evaluations, or toxicity and bioaccumulation evaluations, to different tiers to generate the information necessary and sufficient to determine compliance with the regulations. Prior to initiating testing, it is essential that the informational requirements of preceding tiers be thoroughly understood and that the information necessary for decision-making at the advanced tier be assembled. For example, it is always appropriate to gather all relevant existing information and identify the chemicals of concern for the dredged material in question. Although these activities are components of Tier I, they have to be conducted even if a complete evaluation at the initial tiers is not considered appropriate.

It is only necessary to proceed through the tiers until information sufficient to determine compliance or noncompliance with the regulations has been obtained. For example, if existing information is sufficient to demonstrate there is no potential for unacceptable adverse impact, compliance with the regulations can be determined without additional testing. Similarly, if historical data have consistently shown a particular dredged material to be obviously unacceptable, an exhaustive evaluation may not be necessary to determine that the material is not in compliance with the regulations.

After any of the first three tiers is completed, one of three decisions can be made according to the evaluative guidance in Chapters 4-7 of this manual: (1) information is sufficient to determine compliance with the regulations, (2) information is sufficient to determine noncompliance with the regulations, or (3) information is insufficient to make a determination. In the last case, the evaluation may proceed to the next or higher tier for further testing. Upon completion of testing at Tier IV, two decisions are possible: (1) the information is sufficient to determine compliance with the regulations, or (2) the information is sufficient to determine noncompliance with the regulations. The decision to terminate the process may be made at any point.

Tiered testing will be most useful in situations where increased technical information will provide for better decision-making. This does not mean that the most controversial dredging operations will always benefit from testing in the later or higher-numbered tiers because a large part of the controversy surrounding an operation may not be due to a lack of test information, but to the influence of nontesting issues on the decision-making process.

The Tier I evaluation helps to identify the needed information, and to determine appropriate tiers and tests necessary to collect this information. In all cases it is appropriate to gather the existing information used in Tier I, although it may be clear without formal Tier I evaluation that further assessment will be necessary. It is, however, always necessary to identify the contaminants of concern, if any, at the Tier I level. Tiers I-III are intended to suffice for almost all evaluations. Tier IV is not intended for routine use. Use of Tier IV on more than rare occasions could indicate a reluctance to use adequate information to make appropriate decisions at earlier tiers.

With some dredged materials, biological effects will be easily determined, but bioaccumulation potential will require more investigation, or vice versa. In other cases, determinating potential benthic effects may require more investigation than evaluating water column effects. The tiered testing approach used in the manual accommodates such situations by providing for independent evaluation of biological effects and bioaccumulation, and water column and benthic effects, only to the extent needed to make a decision about each.

The tests in the tiers presented in the manual reflect appropriate practice for regulation at this time and will be refined in the future as knowledge increases. The testing guidance for each tier in Part III of the manual includes specific guidance on topics such as appropriate types of tests, test design and conditions, determining acceptability of tests, and statistical frameworks for interpretation of results. Part II of the manual provides evaluative guidance for using bioassay and bioaccumulation data from each tier of testing to determine compliance with the regulations.

It is important to emphasize that testing at every tier is not required for every situation. A dredged material may enter the tiered testing hierarchy at any point. At any tier, failure to satisfactorily determine the potential for unacceptable environmental impacts results in additional testing at a subsequent, more complex tier unless a decision is made to seek other disposal alternatives. If there is reason to believe that contamination exists and existing information is not adequate to support a decision, testing can begin at Tier II, III, or IV without conducting the evaluation at each preceding tier. It would be rare to immediately go to Tier IV. The tiered testing approach permits the flexibility to most efficiently evaluate dredged materials in a time-effective way. More complex evaluation techniques are necessary only in those situations where the potential effects of contaminants in the dredged materials can only be evaluated with additional technical information.

Although the tiered testing approach outlined in this manual provides an effective means of implementing the regulations, it is recognized that the evaluation of dredged material is an evolving field. It is anticipated that as new methods of evaluation are developed and accepted, they can be integrated into the tiered framework. With the advent of acceptable new

evaluation procedures, the tiered approach will be maintained due to the efficiency afforded by its hierarchical design.

The specific tiered approach used in the manual is summarized in Figure 3.1, and presented in more detail in Figures 3.2 and 3.3. These figures are intended only as generalized summaries and do not contain all the details provided in the text. The figures have to be used in close conjunction with a careful reading of the complete discussions in text. The figures refer to sections of the text with key discussions of major points.

The following discussion briefly overviews the testing and evaluation guidance in the manual, and integrates the figures with the text. By necessity this overview is not detailed, and cannot be used as a stand-alone basis for regulation. The only acceptable basis for regulation is the full text of the regulations and the manual.

As illustrated in Figure 3.1, the evaluation begins in Tier I with the compilation of all existing information relevant to the operation in question (Section 4.1). If existing chemical information is not adequate, a chemical analysis of the dredged material should be performed on contaminants of concern. Information collected in Tier I is evaluated to determine whether it is sufficient for decision-making, as described in Section 4.3. If the information is sufficient, a determination is made (Figure 3.1) as to whether the material is (1) sand, (2) suitable for beach nourishment, or (3) similar to the disposal site and from an area far removed from pollution sources (Section 4.3). If so, the material meets the Section 227.13(b) criteria and is acceptable for ocean disposal at a designated site if all other requirements of the regulations are satisfied. If not, the existing information (which has already been judged sufficient for decision-making) is used to determine whether the dredged material can be disposed without exceeding the LPC in compliance with Section 227.13(c) of the regulations (Figure 3.1 and Section 4.3). This is the same standard used to judge acceptability in Tiers II-IV when new data are necessary. The dredged material is acceptable for ocean disposal if it can meet the LPC and Section 227.13(c), and if it cannot meet the LPC and Section 227.13(c) ocean disposal without management action is not acceptable (Section 4.3). If the initial decision is that the information is not sufficient for decision-making, further evaluation in Tiers II, III, and/or IV, as appropriate, is required (Figure 3.1).

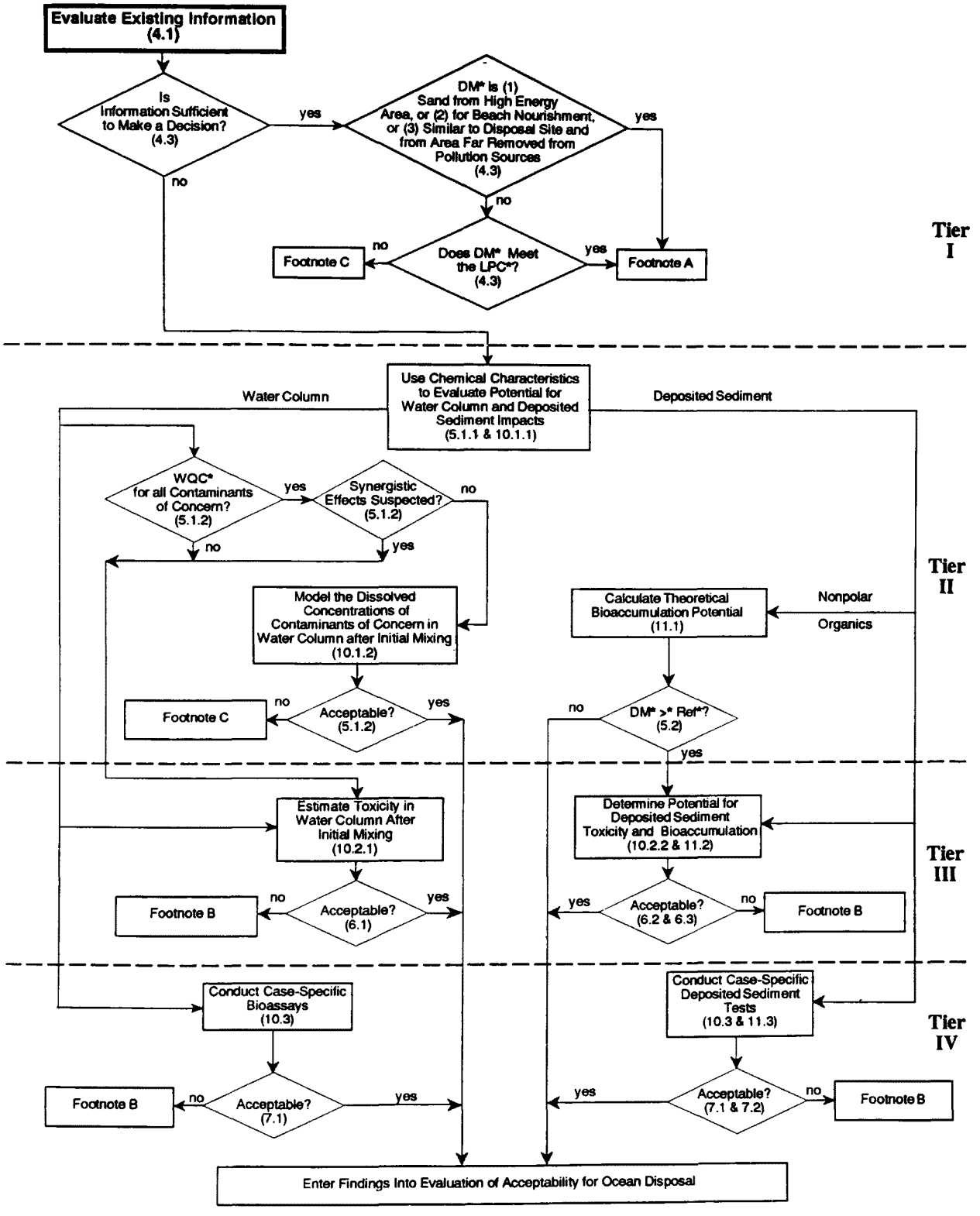

Figure 3-1. Overview of tiered approach to evaluating potential impacts of ocean disposal of dredged material. Sections in which applicable discussions begin in the manual are indicated.

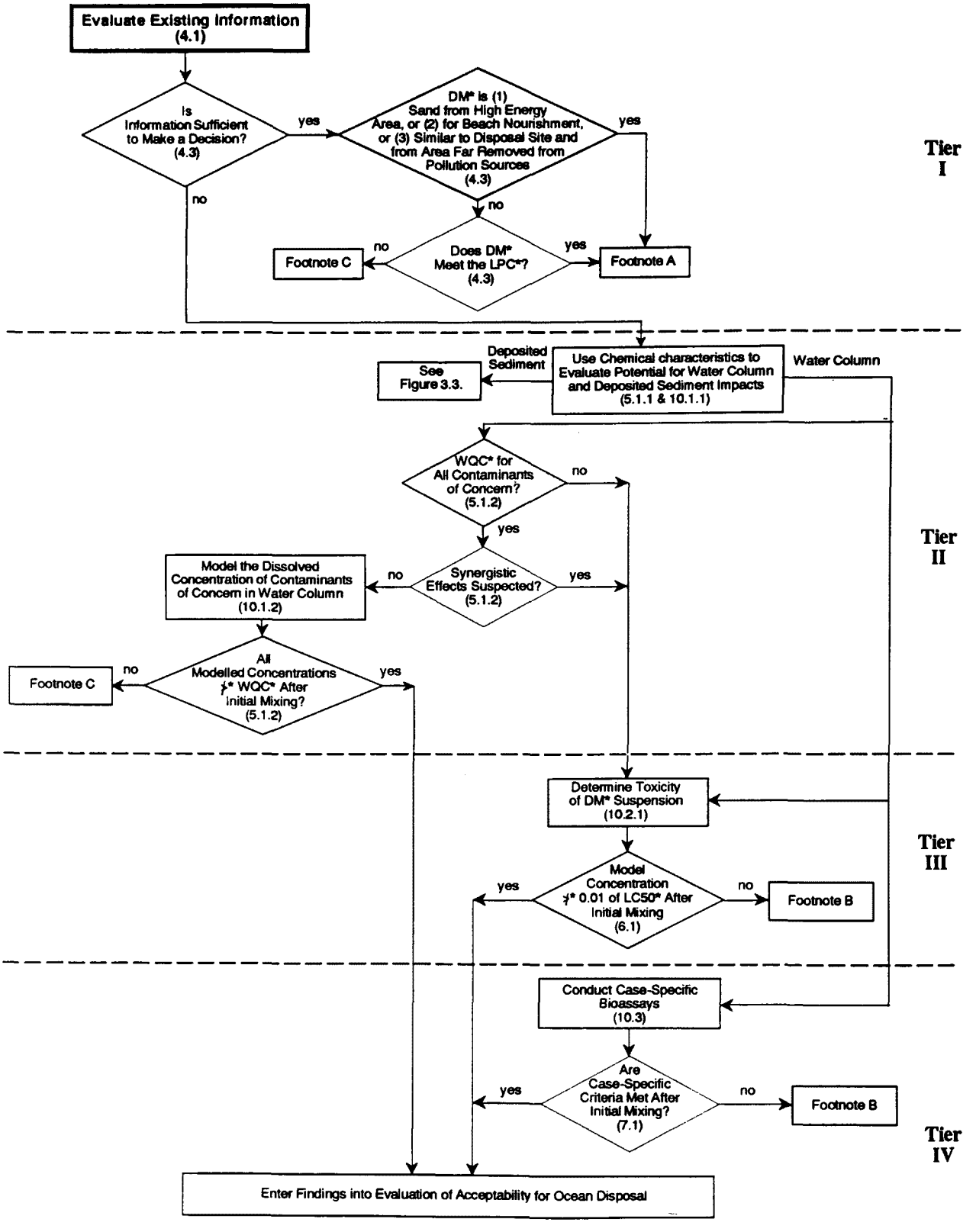

Figure 3.2. Illustration of tiered approach to evaluating potential water column impacts of dredged material. Sections in which applicable discussions begin in the manual are indicated.

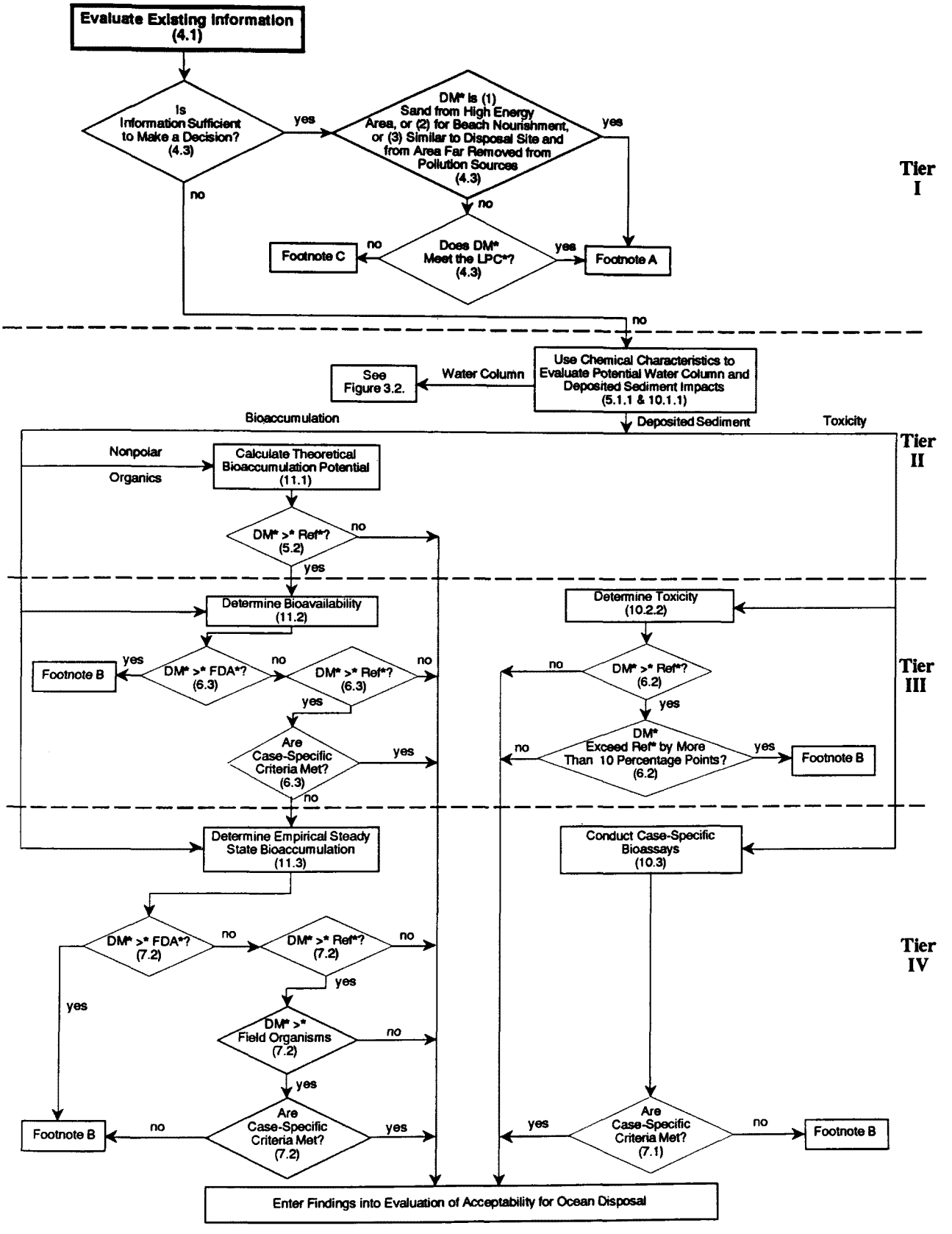

Figure 3.3. Illustration of tiered approach to evaluating potential benthic impacts of deposited dredged material. Sections in which applicable discussions begin in the manual are indicated.

*KEY TO NOMENCLATURE

DM — Dredged material
LPC — It is necessary to demonstrate, using existing data comparable to the data that would be generated if testing were conducted, that the limiting permissible concentration (LPC) would not be exceeded.
> — Is statistically greater than
$\ngtr$ — Is not statistically greater than
WQC — Applicable Marine Water Quality Criteria
LC50 — Acutely toxic concentration, i.e., lethal concentration to 50% of test organisms
Ref — Reference material
FDA — Food and Drug Administration Action Levels for Poisonous or Deleterious Substances in Fish and Shellfish for Human Consumption

NOTES:

A. Ocean disposal at a designated site is acceptable if all other requirements of the regulations are satisfied.

B. Ocean disposal without management action is not acceptable.

C. Ocean disposal is not acceptable.

Figure 3.4. Key to Figures 3.1, 3.2, and 3.3.

Tier II begins with a determination of the need for additional water column testing. The need for additional testing is determined, as described in Section 10.1.1, using a dispersion model of the disposal site and the physical and chemical characteristics of the dredged material, and considering initial mixing. If the contamination is sufficiently low and initial mixing is sufficiently great according to the evaluative guidance in Section 10.1.1, additional water column testing is not required. If additional water column testing is required, the potential for impacts is determined in Tier II (Figure 3.2) if there are water quality criteria for all contaminants of concern and synergistic effects are not suspected (see paragraph 227.13(c) of the regulations). The potential for water column impacts is determined in Tier II by comparison to applicable marine water quality criteria after consideration of initial mixing, as described in Section 10.1.2 (Figure 3.2). If the concentrations predicted by modeling of all contaminants of concern for which applicable marine water quality criteria exist are below the appropriate criteria, the findings are entered into the evaluation of acceptability for ocean disposal (Section 5.1.2 and Figure 3.2). If the modeled concentration of any contaminant exceeds its criterion after consideration of initial mixing, ocean disposal without management action is unacceptable (Section 5.1.2 and Figure 3.2).

In Tier II, the potential for benthic impacts related to bioaccumulation of nonpolar organic compounds is evaluated according to the guidance in Section 11.1 (Figure 3.3). This involves calculation of theoretical bioaccumulation potential of nonpolar organics based on partitioning between the organic carbon in sediments and the lipids in organisms, as discussed in Section 11.1. If theoretical bioaccumulation potential from the dredged material is lower than from the reference sediment, further testing for bioaccumulation of these nonpolar organic contaminants is not required. If theoretical bioaccumulation potential of the dredged material exceeds that of the reference sediment, or if there are contaminants of concern that are not non-polar organics, bioaccumulation testing in Tier III and/or IV is required (Section 5.2 and Figure 3.3).

Testing continues in Tier III if the information generated in Tier II is not adequate for decision-making (Figure 3.1). Tier III water column testing consists of evaluation of the toxicity of the suspended and dissolved portions of the dredged material that remain in the water column,

after consideration of initial mixing, as described in Section 10.2.1 (Figure 3.2). If the concentration of dredged material predicted by modeling to remain in the water column after initial mixing is greater than 0.01 of the corresponding LC50, ocean disposal without management action is not acceptable (Section 6.1 and Figure 3.2). If the predicted concentration is less than 0.01 of the LC50, the findings are entered into the evaluation of acceptability for ocean dumping (Section 6.1 and Figure 3.2).

Tier III benthic tests consist of bioassays (Section 10.2.2) and bioaccumulation tests (Section 11.2), as illustrated in Figure 3.3. Benthic bioassays are evaluated by comparison to the toxicity of the reference sediment (Figure 3.3). Ocean disposal without management action is not acceptable (Section 6.2, and Figure 3.3) if the dredged material toxicity: (1) is statistically greater than the reference sediment, and (2) exceeds reference toxicity by at least 10 percentage points (or another specified value - see Section 6.2). This approach is discussed in more detail in Section 6.2. If both conditions (1) and (2) are not met, the findings are entered into the evaluation of acceptability for ocean disposal (Section 6.2 and Figure 3.3). Tier III bioaccumulation results render ocean disposal without management action not acceptable if FDA limits are statistically exceeded (Section 6.3 and Figure 3.3). If body burdens in animals exposed to the dredged material do not statistically exceed FDA limits or body burdens in animals exposed to the reference sediment, the findings are entered into the evaluation of acceptability for ocean disposal (Section 6.3 and Figure 3.3). If results do not statistically exceed FDA limits but statistically exceed reference values, further evaluation using specific criteria is required (Section 6.3 and Figure 3.3).

Tier IV bioassay testing is intended for only occasional use in unusual circumstances warranting specifically designed special case studies (Figure 3.1). Tier IV water column and benthic bioassays are discussed in Chapter 10, and interpretive guidance is discussed in Sections 7.1 and 7.2. Tier IV benthic and water column bioassays have to be interpreted in relation to case-specific criteria (Figures 3.2 and 3.3) developed as discussed in Section 7.1. Tier IV bioaccumulation evaluation consists of determination of steady state bioaccumulation (Figure 3.3) as described in Section 11.3. If steady state body burdens statistically exceed an FDA

limit, ocean disposal without management action is not acceptable (Section 7.2 and Figure 3.3). If body burdens in animals exposed to dredged material do not exceed FDA limits or body burdens of reference animals, the findings are entered into the evaluation of acceptability for ocean disposal (Section 7.2 and Figure 3-3). Body burdens not statiscally exceeding FDA limits but statistically higher than reference are compared to body burdens in similar organisms living around, but not in, the proposed disposal site. If body burdens from the dredged material do not statistically exceed the body burden of these field organisms, the findings are entered into the evaluation of acceptability for ocean disposal (Section 7.2 and Figure 3.3). If body burdens from the dredged material exceed those of field organisms, it is determined whether the dredged material meets the case-specific criteria that have been developed for this particular dredging operation (Section 7.2 Figure 3.3). If so, the findings are entered into the evaluation of acceptability for ocean disposal. If not, ocean disposal without management action is not acceptable (Section 7.2 and Figure 3.3).

This tiered, or hierarchical, testing approach allows the appropriate level of testing to be used for each specific dredging operation.

4.0 TIER I

The purpose of Tier I is to determine whether a decision on compliance with the LPC can be made on the basis of existing information. Another purpose of Tier I is to identify the contaminants of concern (if any) in that particular dredged material. Tier I is based on existing information but includes a physical and chemical inventory of the dredged material if such information is not already assembled. Existing data and information, such as historical records of activities that reasonably could have introduced contaminants into the dredged material, may provide sufficient evidence to make a decision on compliance with the regulations about certain dredged materials with readily apparent potential for impacts. Conversely, material with no history of contamination can be excluded from testing and found to be in compliance with the regulations. Tier I evaluation may show that further evaluation at subsequent tiers is appropriate, or the Tier I evaluation may lead to the conclusion under Section 227.13(b) of the regulations (see Appendix A) that no further testing for contaminant-related impacts is required. Alternatively, Tier I can show that existing information is sufficient to determine compliance or lack of compliance with Section 227.13(c) of the regulations.

As illustrated in Figure 3.1, Tier I is based on a compilation of all relevant existing information. This information gathering includes chemical and physical analysis of the dredged material if adequate data do not already exist, and identification of the contaminants of concern in that particular dredged material. All of the information is evaluated to determine whether it provides adequate basis for decision making. If not, testing in Tiers II-IV, as appropriate, is necessary (Figure 3.1). If the information is adequate for decision making, the acceptability of the dredged material according to the criteria set forth in Section 227.13 of the regulations can be determined (Figure 3.1). On the other hand, the dredged material can be shown by existing information to pose high potential impact on the marine environment in which case ocean disposal without management action is not acceptable. (Figure 3.1).

4.1 COMPILATION OF EXISTING INFORMATION

The focus of the Tier I evaluation is on 227.13(b) and the potential for contaminant-associated impacts upon ocean dumping. The information-gathering phase of Tier I evaluations has to be as complete as is reasonably possible and existing information from all reasonably available sources has to be included. Although no minimum requirements exist, a more complete inventory of available information will increase the likelihood that decisions concerning the impacts of dredged material may be made at initial tiers. Sources of available information include the following, without limitation:

- Available results of prior physical, chemical, and biological tests of the material proposed to be dumped or of materials shown to be similar to the material proposed to be dumped.
- Available results of prior field monitoring studies of the material proposed to be dumped or of materials shown to be similar to the materials proposed to be dumped.
- Available information describing the source of the material to be dumped which would be relevant to identification of potential contaminants of concern.
- Existing data contained in files with EPA or CE or otherwise available from public or private sources. Examples of sources from which relevant information might be obtained include:
    - Selected Chemical Spill Listing (EPA)
    - Pesticide Spill Reporting System (EPA)
    - Pollution Incident Reporting System (U.S. Coast Guard)
    - Identification of In-place Pollutants and Priorities for Removal (EPA)
    - Hazardous waste sites and management facilities reports (EPA)
    - CE studies of sediment pollution and sediments
    - STORET, BIOS, CETIS, and ODES (EPA)
    - Water and sediment data on major tributaries (U.S. Geological Survey)
    - NPDES permit records
    - Section 404(b)(1) evaluations
    - Pertinent and applicable research reports
    - Section 103 evaluations
    - Port Authorities
    - Colleges/Universities

- Records of state environmental agencies
- Published scientific literature

Evaluation of all reasonably available information allows determination of the potential for contaminants to have been introduced to the dredged material. This information, evaluated with consideration of the physical nature of the dredging site, dredged material, and the proposed disposal site, allows a determination of whether the dredged material complies with Section 227.13(b) (Appendix A). Decisions about compliance will be made on a case-by-case basis for each proposed disposal operation, and specific quantitative guidance applicable to all situations nationwide cannot be offered. More detailed guidance for reaching decisions about compliance may be developed by the CE District and EPA Region considering available scientific information and locally important concerns. This information will be important in reaching an administrative decision that complies with the requirements of Section 227.13(b). In evaluating the likelihood that disposal of a dredged material may cause contaminant-associated impacts, concern decreases with the increase of factors such as the following:

- Isolation of the dredging operation from known existing and historical sources of pollution
- Time since historical sources of pollution have been remediated
- Number and frequency of maintenance dredging operations since remediation
- Mixing and dilution occurring between the pollution source and the dredging site
- Transport and potential deposition of sediment in the dredging area from sources other than those potentially affected by pollution
- Grain size of the dredged material.

Concern regarding contaminant-associated impact increases with the increase of factors such as the following:

- Number, amount, and toxicological importance of contaminants known to have been introduced to the dredging site

- Number, amount, and toxicological importance of contaminants suspected to have been introduced to the dredging site
- Number, amount, and toxicological importance of contaminants with continuing input from existing sources
- Number, amount, and toxicological importance of contaminants from historical sources no longer active

These and other considerations are complexly interrelated; i.e., the acceptable degree of isolation from sources of pollution depends on the number, amount, and importance of the contaminants as well as on all other factors. These considerations have to be evaluated for every dredged material. Even so, it is desirable that guidance be developed, based on technical evaluations, that describes the emphasis on factors deemed appropriate in each area. In all cases, the decisions based on these factors have to comply with the requirements of Section 227.13(b).

To provide an adequate basis for determining compliance or lack of compliance with the environmental impact criteria of Section 227.13(c), existing information should reflect current conditions and should be comparable to the data that would be generated if the dredged material were to be tested in Tiers II, III, or IV, as appropriate. Toxicity relative to the reference sediment and bioaccumulation of contaminants of concern relative to the reference sediment should be known. There should be sufficient information to determine that the potential for water column impacts is low enough that additional data are unnecessary or that water quality criteria would not be exceeded or the concentration would not exceed 0.01 of the applicable LC50 after consideration of initial mixing.

4.2 IDENTIFICATION OF CONTAMINANTS OF CONCERN

In the Tier I decision sequence (Figure 3.1), the first possibility is that more information is required to determine compliance with the regulations. A critical prerequisite to generating this information is deciding, on a case-by-case basis, which contaminants are of concern in the particular dredged material being evaluated. To determine the contaminants

of concern, it may be necessary to supplement available information with additional chemical analyses of the dredged material.

On a national scale, dredged material may contain a variety of chemicals. It is difficult to specify a single suite of contaminants that adequately addresses all environmental concerns about all dredged materials in the country. The contaminants of concern in a particular dredged material has to be identified on a case-by-case basis. In some dredged materials there may be no contaminants of concern. Different dredging operations may have their own set of contaminants of environmental concern that should be adequately evaluated for each operation. The selection of the appropriate contaminants of concern for each dredged material is crucial to the success of the testing program.

Identifying specific contaminants, if any, that are of concern in a particular dredged material relies on the information collected for Tier I, which provides a preliminary basis for determining potential contamination of the dredged material. In some instances, it may be sufficient to perform confirmatory analyses for specific contaminants of concern. In other cases, where the initial evaluation indicates a variety of contaminants of concern may be present, chemical analysis of the dredged material could provide a useful inventory, and a bulk chemical scan conducted according to the guidance in Section 9.3 may be appropriate.

From the list of contaminants shown by existing information and additional analyses to be potentially present in the regions dredged material, it is necessary to determine which specific contaminants are of concern in terms of potential environmental impacts. Some contaminants are always of interest because of provisions of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention) and the incorporation of these contaminants into the MPRSA and Sections 227.5 and 227.6 of the regulations. In identifying contaminants of concern, contaminants necessary to determine compliance with the requirements of Section 227.6 of the regulations have to be included. Other contaminants that might reasonably be expected to cause unacceptable adverse impacts if the dredged material in question were placed in the ocean should be included.

Current knowledge is inadequate to predict biological effect based on the presence of contaminants in dredged material. Therefore, those

chemicals identified as contaminants of concern will be evaluated according to the biological effects-based criteria in Section 227.13 (Appendix A). Sediment chemistry data describing the concentration of contaminants of concern should not be directly used to make decisions regarding the acceptability of dredged material for ocean disposal. This information should be considered when selecting appropriate bioassay/bioaccumulation testing procedures and species to be evaluated, and when reviewing the results obtained from these tests. That is, the presence and levels of contaminants of concern can be used on a case by case basis when reviewing the validity of bioassay/bioaccumulation results. Chemistry data should only be used as a feedback trigger to indicate the need for further evaluation of the QA/QC to assist in determining if the bioassay/bioaccumulation tests were conducted properly. If the QA/QC review indicates that the tests were improperly conducted, re-testing would be appropriate.

The contaminants of concern in each dredged material should be identified on the basis of the following, keeping in mind the discussion in Sections 9.4.1 and 9.5.1 and the requirements of Section 227.6 of the regulations:

- Presence in the dredged material
- Presence in the dredged material relative to the concentration in the reference material
- Toxicological importance
- Persistence in the environment
- Propensity to bioaccumulate from sediments. The major chemical properties controlling this are:

  <u>Hydrophobicity</u>: Literally, "fear of water"; the property of neutral (i.e., uncharged) organic molecules that causes them to associate with surfaces or organic solvents rather than to be in aqueous solution. The presence of a neutral surface such as an uncharged organic molecule causes water molecules to become structured around the intruding entity. This structuring is energetically unfavorable, and the neutral organic molecule tends to be partitioned to a less energetic phase if one is available. In an operational sense, hydrophobicity is the reverse of aqueous solubility. The octanol/water partition coefficient (K_{ow}, log K_{ow}, or log P) is a measure of hydrophobicity. The tendency for organic chemicals to bioaccumulate is related to their

hydrophobicity. Bioaccumulation factors increase with increasing hydrophobicity up to a log K_{ow} of about 6.00. At hydrophobicities greater than about log K_{ow} = 6.00 bioaccumulation factors tend to not increase due, most likely, to reduced bioavailability.

Aqueous Solubility: Chemicals such as acids, bases, and salts that speciate (dissociate) as charged entities tend to be water soluble and those that do not speciate (neutral and nonpolar organic compounds) tend to be insoluble, or nearly so. Solubility favors rapid uptake of chemicals by organisms, but at the same time favors rapid elimination, with the result that soluble chemicals generally do not bioaccumulate to a great extent. The soluble free ions of certain heavy metals are exceptional in that they bind with tissues and thus are actively bioaccumulated by organisms.

Stability: For chemicals to bioaccumulate they must be stable, conservative, and resistant to degradation. Organic compounds with structures that protect them from the catalytic action of enzymes or from nonenzymatic hydrolysis tend to bioaccumulate. Phosphate ester pesticides do not bioaccumulate because they are easily hydrolyzed. Unsubstituted polynuclear aromatic hydrocarbons (PAH) can be broken down by an initial enzymatic opening of ring structures. The presence of electron-withdrawing substituents tends to stabilize an organic molecule. Chlorines, for example, are bulky, highly electronegative atoms that tend to protect the nucleus of an organic molecule against chemical attack. Chlorinated organic compounds bioaccumulate to high levels because they are easily taken up by organisms, and once in the body, they cannot be readily broken down and eliminated.

Stereochemistry: The spatial configuration, i.e., stereochemistry, of a neutral molecule affects its tendency to bioaccumulate. Molecules that are planar tend to be more lipid soluble (lipophilic) than globular molecules of similar molecular weight. For neutral organic molecules, planarity generally correlates with higher bioaccumulation unless the molecule is easily metabolized by an organism.

These and other considerations important to identifying contaminants of concern are complexly interrelated and have to be evaluated individually for each dredged material. Even so, it is desirable that guidance be developed, based on technical evaluations, that describes the emphasis on various factors deemed appropriate for identifying contaminants of concern in each area. In all cases, decisions based on these factors have to comply with the requirements of Section 227.13 (Appendix A).

4.3 DETERMINATION OF COMPLIANCE

After consideration of all available information one of the following conclusions is reached (Figure 3.1):

- Existing information does not provide a sufficient basis for making a decision about whether dredged material complies with Section 227.13 of the regulations. In this case, further evaluation in Tiers II, III, and/or IV is appropriate.

- Existing information provides a sufficient basis for making a decision about whether the dredged material complies with Section 227.13 of the regulations.

In the latter case, based on consideration of available information, one of the following conclusions is reached (Figure 3.1):

- The material complies with the Section 227.13(b) criteria for exclusion from further testing (Appendix A). If so, no further information on contaminants is necessary to determine compliance.

- The material does not comply with the Section 227.13(b) criteria, but does comply with the Section 227.13(c) criteria and the limiting permissible concentration (Appendix A). If so, no further information on contaminants is necessary to determine compliance.

- The material does not comply with either the Section 227.13(b) or 227.13(c) criteria and the limiting permissible concentration (Appendix A). If so, no further information is necessary to determine non-compliance. The decisions of whether such material might be allowable for ocean disposal under the MPRSA and the applicable regulations, and the procedural steps to be following in making this determination, are issues which are beyond the scope of this manual.

5.0 TIER II EVALUATION

At Tier II, the chemical and physical characteristics of the dredged material and the general environmental conditions at the disposal site are evaluated. Tier II consists of a determination of the necessity for, and perhaps conduct of, additional water column testing (Figure 3.2), and an evaluation of the potential for benthic impacts (Figure 3.3). Water column testing should be conducted only if shown by the evaluation to be necessary. If water quality criteria exist for all contaminants of concern and synergistic effects are not suspected, water column impacts are evaluated (if necessary) by comparison of applicable marine water quality criteria to the dissolved contaminant concentration within the site boundary using the 4 hr initial mixing period, or anywhere after initial mixing (Figure 3.2). If water quality criteria do not exist for all contaminants of concern, or synergistic effects are suspected, water column impacts are evaluated by toxicity testing (Section 227.13(c)(2)(ii) of the Regulations) in Tier III, rather than in Tier II (Figure 3.2). Current water quality criteria for the protection of marine life can be obtained from the U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Criteria and Standards Division, Standards Branch (WH-585), 401 M Street S.W., Washington, D.C. 20460.

The conceptual purpose of Tier II is to provide a reliable, rapid screen for potential impacts and thus eliminate the need for further testing. In relation to the water column evaluations, applicable marine water quality criteria serve this purpose. However, for benthic evaluations, there is not widespread agreement that any single dredged material evaluative procedure fully satisfies this objective and is suitable for use in Tier II. If technically sound sediment quality criteria can be developed and promulgated by EPA, these criteria might be incorporated into Tier II evaluations. At present, the biological availability of nonpolar organic compounds in dredged material to benthic organisms is evaluated on the basis of theoretical bioaccumulation potential in Tier II (Figure 3.3). This procedure provides for decisions as well as indicating the magnitude of bioaccumulation likely to be associated with nonpolar organic contaminants in the dredged material.

5.1 WATER COLUMN EFFECTS

Tier I evaluation may lead to the conclusion that the existing information is not sufficient to make a decision. In this case, Section 227.13(c) of the regulations (Appendix A) calls for testing to determine the potential for water column and benthic impacts. This potential is determined in Tiers II, III, and/or IV, as appropriate.

The Tier II evaluation of potential water column effects is a two step process. The first step is to determine whether additional testing is necessary (Sections 5.1.1 and 10.1.1). The testing guidance in Section 10.1.2 and/or 10.2.1, and the evaluation guidance in Section 5.1.2 and/or 6.1, are implemented only if additional testing is shown in Section 5.1.1 to be necessary.

5.1.1 Determination of Need for Additional Water Column Testing

The first step of Tier II is to determine whether evaluation of the potential for water column impacts (Figure 3.2) requires additional testing. In most cases the potential for water column impacts is so low that existing test data will suffice. A standardized calculation approach is used to determine whether additional water column testing is required. This approach uses the bulk chemical concentrations of the dredged material and the dilution predicted to occur in the water column at the proposed disposal site to determine whether additional testing for potential water column impacts is necessary. The procedures for this standardized calculation are described in detail in Section 10.1.1.2.

If the final results of this calculation based on bulk chemistry for all contaminants of concern for which applicable marine water quality criteria exist are less than the criteria after consideration of initial mixing, no additional testing for potential water column impacts is necessary (Figure 3.2). If the calculation for any contaminant of concern exceeds its applicable marine water quality criterion after consideration of initial mixing, additional testing for water column impacts in Tiers II, III, and/or IV is necessary to determine compliance (Figure 3.2). This

calculation cannot be used to predict water column impacts; it can be used only to determine whether additional testing for potential water column impacts, as described in the following section, is necessary.

5.1.2 Determination of Potential for Water Column Impacts

If additional water column testing of dredged material is determined to be necessary in Section 5.1.1, the regulations (Appendix A) are very specific about tests to be performed and criteria to be met:

> Section 227.13
>
> (c)...dredged material can be considered to be environmentally acceptable for ocean dumping only under the following conditions:
>
> (1) The material is in compliance with the requirements of Section 227.6; and...
>
> (2)(i) All major constituents of the liquid phase are in compliance with the applicable marine water quality criteria after allowance for initial mixing; or...
>
> (ii) When the liquid phase contains major constituents not included in the applicable marine water quality criteria, or there is reason to suspect synergistic effects of certain contaminants, bioassays on the liquid phase of the dredged material show that it can be discharged so as not to exceed the limiting permissible concentration as defined in paragraph (a) of Section 227.27...
>
> (d) For the purposes of paragraph (c)(2), major constituents to be analyzed in the liquid phase are those deemed critical by the District Engineer, after evaluating and considering any comments received from the Regional Administrator, and considering known sources of discharges in the area.

Evaluation by comparison to applicable marine water quality criteria is conducted in Tier II, whereas bioassays, which are somewhat more complex, are conducted in Tier III. The first step in testing for potential water column impacts is determination of the appropriate test to apply. According to Section 227.13(c)(2) of the regulations, evaluation in comparison to applicable marine water quality criteria in Tier II is appropriate only when there are applicable marine water quality criteria for all contaminants of concern and there is no reason to suspect synergistic effects (Figure 3.2). If these conditions are not met,

bioassays are conducted in Tier III (Figure 3.2), and evaluated according to guidance in Section 6.1.

If additional water column testing is necessary, applicable marine water quality criteria exist for all contaminants of concern, and there is no reason to suspect synergistic effects, one of the following conclusions is reached on the basis of concentrations of dissolved contaminants of concern (Section 9.4) after consideration of initial mixing (Section 10.1.2):

- Concentrations of dissolved contaminants of concern in the dredged material, after allowance for initial mixing, do not exceed applicable marine water quality criteria beyond the boundaries of the disposal site within the first 4 hr after dumping or at any point after the first 4 hr. Therefore, the dredged material complies with the water quality criteria requirements of Section 227.13(c)(2)(i) (Appendix A). If so, no further information is necessary to determine compliance with the regulations regarding water column impacts, but benthic impacts have to be considered. If the information warrants, it is acceptable to determine compliance with the water column effects criteria of Section 227.13(c)(2)(i) at Tier II, and determine compliance with the benthic effects criteria at another tier.

- Concentrations of dissolved contaminants of concern in the dredged material, after allowance for initial mixing, exceed applicable marine water quality criteria beyond the boundaries of the disposal site within the first 4 hr after dumping and/or at any point after the first 4 hr. In this case, the dredged material does not comply with the water quality criteria requirements of Section 227.13(c)(2)(i) (Appendix A), and ocean disposal is not acceptable.

5.2 BENTHIC IMPACTS

As discussed in Section 5.0, the currently available Tier II procedure for evaluating potential benthic impacts consists of evaluation of theoretical bioaccumulation potential (TBP). The TBP is calculated according to the guidance in Section 11.1. At present, this calculation can be performed for nonpolar organic compounds, but not polar organic compounds, organometals, or metals. If such constituents are contaminants of concern in a dredged material requiring bioaccumulation evaluation, that evaluation has to take place in Tier III and/or IV.

In the Tier II benthic impact evaluation, a comparison is made between TBP calculated for the nonpolar organic contaminants of concern in dredged

material and for the same constituents in the reference sediment. If all the contaminants of concern in the dredged material are nonpolar organics, one of the following conclusions is reached based on this comparison:

- The theoretical bioaccumulation potential (TBP) for the nonpolar organic contaminants of concern in the dredged material does not exceed the TBP for the reference sediment and therefore, the dredged material complies with bioaccumulation aspects of the benthic criteria in Section 227.13(c)(3). If so, no further information is necessary to determine compliance with the bioaccumulation regulations, but biological effects also have to be considered to determine compliance with the benthic criteria in Section 227.13(c)(3) (Appendix A). If the information warrants, it is acceptable to determine compliance with the bioaccumulation aspects of the benthic criteria of Section 227.13(c)(3) at Tier II, and determine compliance with the biological effects aspects of the benthic criteria at another tier. Potential water column impacts also have to be considered.

- The theoretical bioaccumulation potential (TBP) for the contaminants of concern in the dredged material exceeds the TBP of reference sediment. In this case, the information is not sufficient to determine whether the dredged material complies with the bioaccumulation aspects of the benthic criteria in Section 227.13(c)(3) and further evaluation of bioaccumulation in Tiers III and/or IV is appropriate. Potential water column impacts also have to be considered.

Although the calculation of TBP is used to evaluate nonpolar organic compounds in Tier II, a particular dredged material may contain contaminants of concern for which it may be inappropriate to make this calculation. For these contaminants, bioaccumulation has to be evaluated in Tiers III and/or IV. However, even if the dredged material contains other contaminants of concern in addition to nonpolar organic contaminants of concern, it is still useful to calculate the TBP. TBP provides an indication of the magnitude of bioaccumulation of nonpolar organics that may be encountered in Tier III and/or IV testing. Additionally, if the TBP of the nonpolar organics meets the decision guidance in this section, the calculation may eliminate the need for further evaluation of these compounds and thereby reduce efforts in Tier III and/or IV.

6.0 TIER III EVALUATION

Tier III testing assesses the impacts of contaminants in the dredged material on appropriate sensitive organisms to determine if there is potential for the dredged material to have an unacceptable adverse impact. The Tier III assessment methods are bioassays and bioaccumulation tests (Figures 3.1-3.3). The bioassays use lethality as the primary endpoint because the importance of this endpoint is easily interpreted. The bioassays are acute tests using organisms representative of the water column and benthic environments at the disposal site. The recommended procedures for water column bioassays (Figure 3.2) use appropriate sensitive marine water column organisms. The assay for benthic impacts (Figure 3.3) uses deposited sediment and appropriate sensitive benthic marine organisms.

Both toxicity and bioaccumulation have to be considered to fully evaluate the potential for impact (Figure 3.1). An evaluation of bioaccumulation potential will determine the potential for uptake of contaminants by organisms. Bioaccumulation tests may be conducted in the laboratory (Section 11.2). The Tier III information is usually sufficient for decision making, or it may, in rare cases, indicate that further information on toxicity or bioaccumulation (or both) is required at Tier IV.

6.1 WATER COLUMN BIOASSAYS

If additional water column testing has been shown necessary (Section 5.1.1), and the water quality criteria approach cannot be used (Section 5.1.2), the Tier III water column evaluation (Figure 3.2) considers the effects, after allowance for initial mixing, of dissolved contaminants plus those associated with suspended particulates on water column organisms. According to Section 227.13(c)(2)(ii) of the regulations (Appendix A), the bioassay approach is used when there are not applicable marine water quality criteria for all contaminants of concern or there is reason to suspect synergistic effects of certain contaminants. The bioassay and initial mixing data results are generated as described in Section 10.2.

The limiting permissible concentration (LPC) is defined in Section 227.27(a)(2) (Appendix A) as:

> That concentration of dredged material in the receiving water which, after allowance for initial mixing, as specified in Section 227.29, will not exceed a toxicity threshold defined as 0.01 of a concentration shown to be acutely toxic to appropriate sensitive marine organisms in a bioassay carried out in accordance with approved EPA procedures.

After considering this requirement, one of the following conclusions is reached:

- The concentration of dissolved plus suspended contaminants, after allowance for initial mixing, does not exceed 0.01 of the acutely toxic concentration beyond the boundaries of the disposal site within the first 4 hr after dumping or at any point after the first 4 hr. Therefore, the dredged material complies with the water column toxicity criteria of Sections 227.13(c)(2)(ii) and 227.13(c)(3) (Appendix A). If so, no further information is necessary to determine compliance with the regulations regarding water column impacts, but benthic impacts have to be considered. If the information warrants, it is acceptable to determine compliance with the water column effects criteria of Sections 227.13(c)(2)(ii) and 227.13(c)(3) at Tier III and determine compliance with the benthic effects criteria at another tier.

- The concentration of dissolved plus suspended contaminants, after allowance for initial mixing, exceeds 0.01 of the acutely toxic concentration beyond the boundaries of the disposal site within the first 4 hr after dumping, and/or at any point after the first 4 hr. Therefore, the dredged material does not comply with the water column toxicity criteria of Sections 227.13(c)(2)(ii) or 227.13(c)(3) (Appendix A). The decision of whether such material might be allowable for ocean disposal under MPRSA, and the applicable regulations and the procedural steps to be followed in making this determination are issues which are beyond the scope of this manual.

6.2 BIOASSAYS ON BENTHOS

Evaluation of benthic bioassays in Tier III (Figure 3.3) is based on data generated according to the guidance in Section 10.2.2. For benthic effects evaluation, the LPC of the solid phase of dredged material is applicable and is defined in Section 227.27(b) (Appendix A) as:

> ...that concentration which will not cause unreasonable acute or chronic toxicity or sublethal adverse effects based on bioassay results using...appropriate sensitive benthic marine organisms...

Bioassay results are judged unreasonable when mortality in the dredged material is both (1) statistically greater than in the reference sediment, and (2) exceeds mortality in the reference sediment by at least 10 percentage points. That is, if reference mortality in a particular test were 7 percent, dredged material mortality would be judged unreasonable if it were statistically higher than in the reference sediment and was 17 percent or greater. Ten percentage points is to be used unless another value is developed for use. Statistically significant increases are considered unreasonable when they exceed reference mortality in the test by a margin at least as large as the mortality typically observed in the reference sediment. Therefore, if values other than 10 percent are to be used, they should be derived for each reference sediment, and should be specific to each test species and test endpoint. The data supporting the values should meet quality assurance standards and provide an adequate basis for regulation.

After considering this guidance, one of the following conclusions is reached:

- Mortality in the dredged material is not statistically greater than in the reference sediment, or does not exceed mortality in the reference sediment by at least 10* percentage points. Therefore, the dredged material complies with the benthic bioassay criteria of Section 227.13(c)(3) (Appendix A). If so, no further information is necessary to determine compliance with the bioassay regulations, but bioaccumulation also has to be considered under Section 227.13(c)(3). If the information warrants, it is acceptable to determine compliance with the benthic bioassay criteria of Section 227.13(c)(3) at Tier III, and to determine compliance with the bioaccumulation criteria of Section 227.13(c)(3) at another tier. Potential water column impacts also have to be considered.

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* This value may be replaced in local decision guidance by the species- and reference sediment-specific values discussed in the preceding text paragraph if such values are developed.

Mortality in the dredged material is statistically greater than in the reference sediment and exceeds the mortality in the reference sediment by at least 10* percentage points. In this case, the dredged material does not comply with the benthic bioassay criteria of Section 227.13(c)(3) (Appendix A). The decision of whether such material might be allowable for ocean disposal under the MPRSA and the applicable regulations and the procedural steps to be followed in making this determination, are issues which are beyond the scope of this manual.

6.3 BIOACCUMULATION BY BENTHOS

The potential for bioaccumulation, as well as toxicity, has to be in compliance with the regulations before a dredged material can be considered acceptable for ocean dumping. The Tier III benthic bioaccumulation tests provide for the determination of bioavailability through 10 day exposure tests if all contaminants of concern are metals or 28 day exposure tests if any contaminants of concern are organic or organometallic compounds. Information for evaluating bioaccumulation potential in Tier III for each of the contaminants of concern comes from Section 11.2. Identification of the specific contaminants of concern in each dredged material is discussed in Section 4.2.

Bioaccumulation of most compounds, if it occurs, will be detectable after the Tier III 10 or 28 day exposure period, even though steady state may not have been reached. Thus, while the Tier III tests may not determine steady state bioaccumulation, they provide useful information about the potential for bioaccumulation (i.e., bioavailability).

Concentrations of contaminants of concern determined in tissues of benthic organisms following 10 or 28 day exposure to the dredged material are compared initially to applicable Food and Drug Administration (FDA) Action Limits for Poisonous or Deleterious Substances in Fish and Shellfish for Human Consumption, if such limits exist for the contaminants.

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* This value may be replaced in local decision guidance by the species- and reference sediment-specific values discussed in the preceding text paragraph if such values are developed.

Current action limits may be obtained from the U.S. Food and Drug Administration, Industry Programs Branch, Bureau of Foods (HFF-326) 266 C Street S.W., Washington DC 20204.

Action levels for poisonous or deleterious substances are established by the FDA for levels of contaminants in human food and animal feed. The action levels are established and revised according to criteria specified in Title 21, Code of Federal Regulations, Parts 109 and 509. Action levels are levels above which FDA can take legal action to remove products from the market. Limits are based on human health and economic considerations, and do not consider the potential for environmental impacts on the contaminated organisms or their nonhuman predators. Because contamination of seafood in excess of FDA limits is considered a threat to human health, the guidance in this manual is that concentrations in excess of FDA limits in any test species may be considered unacceptable. This guidance applies even though the test species may not be a typical human food item, because contaminants can be transferred through aquatic food webs and uptake to FDA levels in one species indicates the potential for accumulation in other species. However, because FDA limits take economic impacts on fisheries into account and do not consider ecological effects, the limits cannot be used to judge the acceptability or unacceptability for ocean disposal of dredged material that results in body burdens less than the FDA limits.

Based on the comparison to FDA limits, one of the following conclusions is reached:

- Tissue concentrations of one or more contaminants of concern are statistically greater than applicable FDA action limits. Therefore, the dredged material does not comply with the bioaccumulation aspects of the benthic criteria of Section 227.13(c)(3) (Appendix A). The decision of whether such material might be allowable for ocean disposal under the MPRSA and the applicable regulations, and the procedural steps to be followed in making this determination, are issues which are beyond the scope of this manual.

- Tissue concentrations of all contaminants of concern are not statistically greater than applicable FDA action limits or there are no FDA limits for the contaminants of concern. In this case, the information is insufficient to determine compliance with the bioaccumulation aspects of the benthic criteria of Section 227.13(c)(3) (Appendix A) and the dredged material has to be further evaluated in Tier III as described below for bioaccumulation potential before a decision can be made.

Concentrations of contaminants determined in tissues of organisms following the 10 or 28 day exposure to dredged material and less than FDA action limits or in the absence of FDA limits are compared to contaminant concentrations in tissues of organisms similarly exposed to reference sediment. One of the following conclusions is reached based on this comparison:

- Tissue concentrations of contaminants of concern in organisms exposed to dredged material do not statistically exceed those of organisms exposed to the reference sediment and therefore the dredged material complies with the bioaccumulation aspects of the benthic criteria of Section 227.13(c)(3) (Appendix A). If so, no further information is necessary to determine compliance with bioaccumulation regulations, but benthic toxicity effects also have to be considered to determine compliance with the benthic criteria of Section 227.13(c)(3). Potential water column impacts also have to be considered.

- Tissue concentrations of contaminants of concern in organisms exposed to dredged material statistically exceed those of organisms exposed to the reference material. In this case, it is desirable that the District Engineer and Regional Administrator develop and agree upon case-specific evaluative criteria, based on technical evaluations made with local input, that emphasize the various factors deemed appropriate in each area for determining compliance with the bioaccumulation aspects of the benthic criteria of Section 227.13(c)(3) (Appendix A).

In evaluating bioaccumulation potential to determine compliance with the benthic criteria of Section 227.13(c)(3) when bioaccumulation of contaminants of concern in organisms exposed to dredged material statistically exceeds bioaccumulation in organisms exposed to reference sediment in Tier III testing, concern over potential adverse impacts increases in direct relation to the following:

- The number of species in which bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material.

- The number of contaminants for which bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material.

- The magnitude by which bioaccumulation from the dredged material exceeds bioaccumulation from the reference material.

- The toxicological importance of the contaminants with bioaccumulation from the dredged material statistically exceeding their bioaccumulation from the reference material.

- The phylogenetic diversity of the species in which bioaccumulation from the dredged material statistically exceeds bioaccumulation from the reference material.

- The propensity for the contaminants with statistically significant bioaccumulation to biomagnify within aquatic food webs (Biddinger and Gloss, 1984; Kay, 1984).

- The magnitude of toxicity, and number and phylogenetic diversity of species exhibiting greater mortality in the dredged material than in the reference material.

- The magnitude by which contaminants with bioaccumulation from the dredged material exceeding their bioaccumulation from the reference material also exceed the concentrations found in comparable species living in the vicinity of the proposed disposal site.

These and perhaps other factors are complexly interrelated; i.e., the acceptable level of each factor depends on its interaction with all the other factors. These factors have to be considered in developing case-specific criteria (if needed) for dredged material assessed for bioaccumulation in the final step of Tier III. After considering these factors, one of the following decisions is reached:

- The dredged material complies with the bioaccumulation aspects of the benthic criteria of Section 227.13(c)(3) (Appendix A). If so, no further information is necessary to determine compliance with bioaccumulation regulations, but toxicity and water column effects also have to be considered to determine compliance with Section 227.13(c).

- The information is insufficient to determine compliance with the bioaccumulation aspects of the benthic criteria of Section 227.13(c)(3) (Appendix A), and further evaluation of steady state bioaccumulation Tier IV is necessary to show compliance.

6.4 REFERENCES

Biddinger, G.R. and Gloss, S.P. 1984. The importance of trophic transfer in the bioaccumulation of chemical contaminants in aquatic ecosystems. Residues Reviews. Vol. 91:104-130

Kay, S.H. 1984. Potential for biomagnification of contaminants within marine and freshwater food webs, Technical Report D-84-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

7.0 TIER IV EVALUATION

Where a decision regarding toxicity or bioaccumulation has not been reached at earlier (i.e., lower numbered) tiers or where circumstances warrant, Tier IV evaluations (Figure 3.1) are used to determine compliance with Section 227.13(c) (see Appendix A). Tier IV tests consist of bioassays and bioaccumulation tests to determine the long-term effects of exposure to dredged material. Tier IV tests may be conducted for water column evaluations (Figure 3.2) or benthic evaluations (Figure 3.3). In both cases, Tier IV tests should be carefully selected to address the specific issues relevant to the case in question. Whatever the Tier IV test, the case-specific evaluative criteria for these tests have to be determined beforehand, and agreed upon by EPA and CE, and have to be adequate to determine compliance with the requirements of Section 227.13(c).

7.1 BIOASSAYS

Tier IV bioassays (Figure 3.2) should measure sensitive indicators of long-term effects of clear ecological importance, such as survival, reproduction, and perhaps time to onset of reproduction. Tier IV bioassays might be of longer duration than Tier III tests and might simulate the exposure conditions expected at the disposal site. Tier IV bioassays of deposited dredged material should maximize exposure to sediment-associated contaminants by focusing on sediment-ingesting organisms.

Because of the limited availability of appropriate and widely accepted procedures for Tier IV bioassays, these tests should be carefully selected to address specific needs of each individual dredging operation. Tier IV tests should be designed to provide more detailed information about the effects of exposure to the dredged material than Tier III testing. Tier IV might be appropriate when there is sufficient evidence to require testing for carcinogens, mutagens, or teratogens under Section 227.13(c) of the regulations.

Tier IV allows generation of appropriate information about the proposed disposal operation and there is no option for generation of additional information. As discussed previously, even with the development of appropriate and acceptable new test procedures, including those for chronic exposures, it is anticipated that the case-by-case design and implementation of tests will continue to be a necessary component of Tier IV evaluations.

Case-specific evaluative criteria have to be developed for interpreting the results of Tier IV bioassays. These criteria have to be adequate to determine compliance with the requirements of Section 227.13(c) of the regulations.

7.2 BIOACCUMULATION BY BENTHOS

When a decision cannot be reached on the basis of the 10 or 28 day bioavailability data, it is appropriate to determine steady state bioaccumulation of the contaminants of concern in Tier IV (Figure 3.3). Tissue samples used for this evaluation may be collected in the field (Section 11.3.2) or generated by laboratory exposure of test organisms to the dredged material (Section 11.3.1). As with the Tier III evaluation of bioavailability from the 10 or 28 day tests, the first step in the evaluation of steady state bioaccumulation is the comparison of steady state concentrations of contaminants of concern to FDA Action Limits for Poisonous or Deleterious Substances in Fish and Shellfish for Human Consumption. Following this comparison, one of the following conclusions is reached:

- The steady state bioaccumulation of contaminants of concern statistically exceeds FDA action limits. Therefore, the dredged material does not comply with the bioaccumulation aspects of the benthic criteria in Section 227.13(c)(3) (Appendix A). The decision of whether such material might be allowable for ocean disposal under the MPRSA and the applicable regulations, and the procedural steps to be followed in making this determination, are issues which are beyond the scope of this manual.

- The steady state bioaccumulation of contaminants of concern does not statistically exceed FDA action limits. The information is therefore not sufficient to determine whether the dredged material complies with the bioaccumulation aspects of the benthic criteria in Section 227.13(c)(3) (Appendix A). In this case, further

evaluation is necessary before a decision about acceptability can be made.

Steady state tissue concentrations of contaminants of concern that do not statistically exceed FDA action limits are next compared to steady state concentrations of these contaminants determined in organisms exposed to reference sediment. Based on this comparison, one of the following conclusions is reached:

- Steady state concentrations in organisms exposed to dredged material are determined not to statistically exceed those of organisms exposed to reference sediment, and therefore the dredged material complies with the bioaccumulation aspects of the benthic criteria in Section 227.13(c)(3) (Appendix A). No further information is necessary to determine compliance with the bioaccumulation regulations; however, benthic toxicity effects also have to be considered to determine compliance with Section 227.13(c). Potential water column effects also have to be considered.

- Steady state concentrations in organisms exposed to dredged material statistically exceed those of organisms exposed to reference sediment. In this case, the information is insufficient to determine compliance with the benthic criteria in Section 227.13(c)(3) (Appendix A) and further evaluation of steady state bioaccumulation in Tier IV is necessary to determine acceptability.

Steady state contaminant concentrations in tissue samples that exceed those of organisms exposed to reference sediment are compared to contaminant concentrations in field-collected benthic organisms (Figure 3.3) as described in Section 11.3.2.4. Field-collected organisms are those collected in the vicinity of the proposed disposal site and provide an indication of steady state body burden of the contaminants of concern around the site. One of the following conclusions is reached:

- The steady state bioaccumulation of contaminants of concern does not statistically exceed the concentration of these contaminants in field collected organisms and therefore the dredged material complies with the bioaccumulation aspects of the benthic criteria in Section 227.13(c)(3) (Appendix A). If so, no further information is necessary to determine compliance with the bioaccumulation regulations, but benthic toxicity effects must also be considered to determine compliance with Section 227.13(c). Potential with column impacts also have to be considered.

- The steady state bioaccumulation of contaminants statistically exceeds that of field organisms. In this

case, it is desirable that the District Engineer and Regional Administrator develop and agree upon case-specific evaluative criteria, based on technical evaluations made with local input, that emphasize the various factors deemed appropriate in each area for determining compliance with the benthic criteria in Section 227.13(c)(3) (Appendix A).

In evaluating bioaccumulation potential to determine compliance with Section 227.13(c) where the steady state bioaccumulation of contaminants of concern exceeds that of field organisms, concern over potential adverse impacts increases in direct relation to the following:

- The number of species in which bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material.
- The number of contaminants for which bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material.
- The magnitude by which bioaccumulation from the dredged material exceeds bioaccumulation from the reference material.
- The toxicological importance of the contaminants with bioaccumulation from the dredged material statistically exceeding their bioaccumulation from the reference material.
- The phylogenetic diversity of the species in which bioaccumulation from the dredged material statistically exceeds bioaccumulation from the reference material.
- The propensity for the contaminants with statistically significant bioaccumulation to biomagnify within aquatic food webs (Biddinger and Gloss, 1984; Kay, 1984).
- The magnitude of toxicity, and number and phylogenetic diversity of species exhibiting greater mortality in the dredged material than in the reference material.
- The magnitude by which contaminants with bioaccumulation from the dredged material exceeding their bioaccumulation from the reference material also exceed the concentrations found in comparable species living in the vicinity of the proposed disposal site.

These and perhaps other factors are complexly interrelated; i.e., the acceptable level of each factor depends on its interaction with all the other factors. These factors have to be considered in developing case-specific criteria (if needed) for dredged material assessed for

bioaccumulation in the final step of Tier IV. After considering these factors, one of the following decisions is reached:

- The dredged material complies with the bioaccumulation aspects of the benthic criteria of Section 227.13(c)(3) (Appendix A). If so, no further information is necessary to determine compliance with bioaccumulation regulations, but toxicity and water column effects also have to be considered to determine compliance with Section 227.13(c).

- The dredged material does not comply with the bioaccumulation aspects of the benthic criteria of Section 227.13(c)(3) (Appendix A). The decision of whether such material might be allowable for ocean disposal under the MPRSA and the applicable regulations, and the procedural steps to be followed in making this determination, are issues which are beyond the scope of the manual.

7.3 REFERENCES

Biddinger, G.R. and Gloss, S.P. 1984. The importance of trophic transfer in the bioaccumulation of chemical contaminants in aquatic ecosystems. Residues Reviews. Vol. 91:104-130.

Kay, S.H. 1984. Potential for biomagnification of contaminants within marine and freshwater food webs, Technical Report D-84-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

PART III

DATA GENERATION

8.0 COLLECTION AND PRESERVATION OF SAMPLES

If it is determined that physical, chemical and biological testing is necessary (certain dredging operations may require no sampling), samples of dredged material, reference sediment, control sediment, organisms, and water will need to be collected. These are used for chemical analysis, bioassays, and bioaccumulation tests. This chapter provides guidance for the development of a sampling plan that will lead to the collection, preservation, and storage of representative sediment, water, and organism tissue samples so that the physical and chemical characteristics and potential toxicity and bioaccumulation of dredged material can be accurately assessed.

Sampling is the foundation upon which all testing rests. Therefore, regional plans have to be carefully developed on a case-by-case basis. So many case-specific factors influence sampling needs that detailed guidance of national scope is impractical. This manual provides general guidance on items of major importance to consider in designing a sampling plan. The guidance focuses on two aspects of sampling design. One is directed toward project managers and administrative personnel that decide what tests are to be run and where and how samples are to be collected, handled, and tested. The second aspect, discussed later in this chapter, concerns the technical details of sample collection and preservation.

8.1 BACKGROUND FOR A SAMPLING PLAN

A well-designed sampling plan is essential for evaluating the potential impact of dredged material discharge upon the marine environment. The sampling plan has to be tailored to meet clearly defined objectives for individual dredging operations before any sampling is initiated. In designing a generalized sampling program, factors such as the availability and content of historical data, the degree of sediment heterogeneity, the number and geographical distribution of sample collection sites, the procedures for collection, preservation, storage, and tracking of samples, and the necessity for adequate quality assurance and quality control have to be carefully considered. The magnitude of the dredging operation and its time and budgetary constraints should also be considered.

An acceptable sampling plan should be in place before sampling begins so that the amount of material to be collected can be determined. An

adequate amount of material should be collected to conduct all evaluations at all tiers. This strategy should eliminate the need to remobilize field equipment and support crews if anomalous results or inadequate data are obtained for any analysis. In cases where there is valid reason to believe the dredged material might be tested extensively, it might be desirable in the long run to be liberal in the amount of samples taken, but this decision has to be made on a case-by-case basis.

The importance of sampling is underscored by the fact that any evaluation is only as complete and reliable as the sampling (and sample handling and storage) upon which it is based. Thus, inadequacies or biases in sampling will manifest themselves by limiting the accuracy and/or the appropriateness of the study results.

The objective is to obtain samples to characterize the dredging and disposal area. Sample size should be small enough to be conveniently handled and transported and yet sufficient to meet the requirements for all planned analyses. The quality of the information obtained through the testing process is impacted by the following three factors:

- Collecting representative samples
- Using appropriate sampling techniques
- Protecting or preserving the samples until they are tested.

Ideally, the importance of each of the three factors will be fully understood and appropriately implemented for each study. In practice, however, this is not always the case. There may be occasions when study needs, time, or other resource constraints will limit the amount of information that should or can be gathered. When this occurs, each of these factors have to be carefully considered in light of specific study purposes when designing a sampling plan.

An important component of any field sampling program is a preproject meeting with all concerned personnel. Attendance may include management, field personnel, laboratory personnel, data management/analysis personnel, and representatives of the regulators and the dredging proponent. The purposes of the meeting include (1) defining the objectives of the sampling program and (2) ensuring communication between participating groups.

Samples are collected and tested or analyzed to gain information. To be most useful, the information generated through a sampling program has to be directed at a specific need. The purposes of defining the objectives of

a sampling program should be to clarify the information needed and to match these needs with the specific tests that supply the required information.

The stated objectives of a testing program should be more specific than "an environmental evaluation of a proposed dredged material disposal operation." Although an environmental assessment may be the overall objective, the objectives of the testing program should be stated as specific tasks such as the following:

- Compare one or more sites in the dredging area with the reference area.
- Determine the bioavailability of contaminants in the dredged material.
- Determine the kind and/or distribution of chemical contaminants in the sediments of a dredging area.
- Determine potential sediment toxicity.
- Determine bioaccumulation potential.

The more explicitly the goals of a testing program can be stated, the easier it will be to design an appropriate sampling plan. When the sampling plan is completed all sampling procedures should be clearly defined, sample volumes should be clearly established, all logistical concerns should be fully addressed, and target analytes should be identified to class of compound in order to select appropriate methods of preservation.

8.2 COMPONENTS OF A SAMPLING PLAN

A sampling plan that meets the stated objectives has to cover certain issues. The following steps are a guideline to ensure that all essential information is provided:

- Review the engineering specifications for the dredging, including the dimensions of the dredging area, the dredging depth(s), and the volume of sediment for disposal.
- Evaluate the prior history and the existing database for the area. Identify relevant data and the need for additional data. Identify areas of potential environmental concern within the confines of the dredging operation.
- If appropriate, subdivide the dredging area into project segments on the basis of an assessment of level of environmental concern within the dredging area. This may be an iterative process that

starts before sampling using existing information, and is refined after sampling based on new data.

- Determine the number of samples to be collected and select sampling locations. Choose methods and equipment for positioning vessels at established stations.
- Determine what sampling methods will be used.
- Define procedures for sample handling, preservation, and storage.
- Identify potential logistical problems and define safety precautions.
- Prepare a quality assurance/quality control plan.

The sections that follow discuss each of these steps, providing general guidance for their conduct. Supplemental guidance on basic sampling considerations generally applicable to dredged material is discussed from a quality assurance perspective in EPA (1987).

8.2.1 Review of Dredging Specifications

A review of the engineering specifications for the dredging operation provides a general overview to serve as a basis for designing a sampling plan. Information on the volume of material to be dredged and method of dredging is important to determine the number of samples required. Knowledge of the thickness and physical characteristics of the material to be dredged will help determine the kind of sampling equipment required. The boundaries of the dredging area have to be known to ensure that the number and location of samples are appropriate.

8.2.2 Historical Data

In developing a sampling plan, it is important to review all relevant information about the dredging site. Use of existing information to determine project segments and station locations within the dredging area can produce significant cost savings. Review of historical data is the first step in determining whether sediment might be contaminated. If the review identifies possible point sources of contamination, skewing the sampling effort toward these areas may be justified for thorough characterization of the potentially contaminated areas. On the other hand, increasing the proportion of samples in contaminated areas relative to other areas may lead to the conclusion that the "average" contamination is

higher than it really is. To reduce problems in areas of unequally distributed contamination, the total sampling effort should be increased. The information gathered for the Tier I evaluation discussed in Section 4.1 should be reviewed for assistance in designing the sampling plan. A review of historical information should include the following:

- Geotechnical, geochemical, and hydrodynamic data: The grain size, specific density, water content, and identification of sediment horizons are helpful in making operational decisions. Areas of high tidal currents and high wave energy tend to have larger grain sized sediments than quieter areas. Contaminants have a greater affinity for clay and silt than for sand. The horizontal and vertical particle size distribution should be examined from existing data.

- Quality and age of existing data: The value of the existing data should be critically examined. Existing high-quality data might lower costs by reducing the number of analytes measured or tests required for the proposed dredging operation. Even data that do not meet all current quality assurance standards can sometimes provide useful general information about the operation. For example, there may have been significant improvements in sampling and analytical methods since the original study, or the original chain-of-custody or documentation procedures may have been inadequate. Information from such studies might be helpful in identifying areas of contamination, but not in accurately assessing the degree of contamination.

- Spill data: Evidence of a contaminant spill within or near the area of the dredging may be an important consideration in identifying areas for sampling.

- Dredging history: Knowledge of prior dredging may dramatically affect sampling plans. If the area is frequently dredged (every 1-2 years) or if the sediments are subject to frequent mixing by wave action or ship traffic, the sediments are likely to be relatively homogenous. Assuming there are no major contaminant inputs, the sampling effort may be minimal. However, if information regarding possible contamination exists, a more extensive sampling effort may be indicated. New excavations of material unaffected by anthropogenic inputs may require less intensive sampling for contaminants than maintenance dredging.

8.2.3 Subdivision of Dredging Area

Sediment characteristics are likely to vary substantially within the limits of the area to be dredged as a result of geographical and hydrological features in the area. Areas of low hydraulic energy will be characterized by fine sediments that have a greater tendency to accumulate contaminants than coarser grained sediments. Sediments in heavily urban-

ized or industrialized areas are more likely to accumulate contaminants than sediments farther removed from direct contaminant inputs.

Many dredging operations can be subdivided into project segments for sampling. A project segment is an area expected to have relatively consistent characteristics that differ substantially from the characteristics of adjacent segments. Project segments may be sampled with different intensities, and if warranted by objectives of the study and test results, dredged material from various segments could be managed differently during dredging and disposal. When the sampling plan is developed, project segments can be designated based on historical data, sediment characteristics, geographical configuration, depth of cut, sampling or dredging equipment limitations, results of pilot studies, known or suspected contaminant concentrations, etc. Surface sediments might be considered as a separate project segment from subsurface sediments at the same location if vertical stratification of contamination is expected. Large dredging operations located within industrialized areas might require subdivision into several project segments horizontally and one or more segments vertically. A dredging operation characterized by relatively uniform distribution of sediment type in a nonindustrialized location, might be considered as a single project segment. Areas of rapid shoaling or high sediment mixing by ship scour or other means are likely to be relatively homogenous vertically, and vertical subdivisions are usually not appropriate. Vertical subdivisions smaller than about 2-3 ft are impractical because a dredge operator cannot reliably make a cut that size. If analytical data or test results for two or more project segments turn out to be similar, these segments should be treated as one large segment when considering disposal options. If the analytical and test results demonstrate important differences between project segments, an alternative disposal option may be necessary for a portion of the total sediment volume.

Any established sampling program should be sufficiently flexible to allow changes based on field observations. Certain characteristics of the sediments, such as color or texture, can provide the field crew chief with an indication of patchiness. The greater the patchiness, the larger the number of samples that will be required to define the area. The project manager can refine a sampling program based on historical data and/or a preliminary sampling survey of the dredging area.

8.2.4 Selection of Sampling Sites and Number of Samples

The method of dredging, volume of sediment to be removed, and its horizontal and vertical heterogeneity are key to determining station locations and the number of samples to be collected for the total dredging operation and for each project segment. Samples may be composited prior to analysis, bearing in mind the discussion later in this section, when appropriate for testing objectives. The appropriate number of samples and proper use of compositing has to be determined for each operation on a case-by-case basis.

The following seven factors should be considered in sampling site selection:

- Objectives of the testing program
- Accessibility
- Flows
- Mixing
- Source locations
- Available personnel and facilities
- Other physical characteristics.

The actual sampling pattern to be used is by necessity dependent on the site, because major point sources, land use activities, hydrologic conditions, and sample variability fluctuate from area to area.

The pattern should consider contaminant sources in each project segment and currents that could be critical to the pattern of sediment distribution. Station locations within the dredging area should include areas downstream from major point sources and in quiescent areas, such as turning basins, side channels, and inside channel bends, where fine-grained sediments are most likely to settle. Project segments selected on the basis of suspected high contamination cannot be considered representative of the contaminant distribution in the entire dredging area. Therefore, project segments representing the proportion of the overall dredging area expected to be less contaminated have to also be sampled representatively.

Several characteristics have been established to help define the representative-ness of a sample:

- The project segment being sampled is clearly defined.

- The sampling locations are randomly distributed within each project segment.
- More than one sample should be collected from each sampling location if sample variability is suspected.
- If sediment variability is unknown, it may be necessary to conduct a preliminary survey of the dredging area to better define the final sampling program.

Sediment composition can vary in the vertical dimension as well as in the horizontal dimension. Thus, samples should be collected over the entire depth to be excavated unless the sediments are known to be vertically homogeneous or there is adequate data demonstrating that contamination does not extend throughout the depth to be excavated. The easiest task in establishing a sampling program is to locate the areas of maximum concentrations that generally are found near major sources and/or areas of quiescent settling. However, results from these sampling locations may not represent the range of concentrations in the total dredging area. Therefore, additional sampling has to be conducted in any areas for which inadquate data are available.

In relation to sample representativeness, it is possible to define two populations: (1) the actual composition of the area and (2) the composition of the samples obtained from the area. Ideally, these populations would be the same but, in practice, differences often exist because of bias in the sampling program. Many factors contribute to bias, including disproportionate intensity of sampling in different parts of the dredging area and equipment limitations (i.e., extrapolating surface grab sample results to subsurface sediments).

It may be useful to develop a sampling grid for each project segment. The horizontal dimensions of each project segment are subdivided into grid cells of equal size, which are numbered sequentially within each project segment. Cells are then randomly selected for sampling. It may be important to collect more than the minimum number of samples required, especially in areas suspected of having high or highly variable contamination. Extra samples may be collected and archived in case reexamination of a particular project segment(s) is warranted.

In some cases it may be advisable to consider varying the level of sampling effort between project segments. Project segments suspected of containing environmentally important contaminants should be targeted for an increased level of effort so that the boundaries and characteristics of the contamination can be identified. A weighting approach can be applied

whereby project segments are ranked in increasing order of concern. The weights can be used as factors when determining the number of samples within each project segment relative to other project segments. A project segment of low environmental concern will require fewer samples per unit volume of sediment than will similar sized project segments of higher concern.

One of the more important tasks is determining the number of samples that should be collected within each project segment. In general, the number of samples required is inversely proportional to the amount of known information and proportional to the level of confidence that is desired in the results and the suspected level of contamination. No specific guidance can be provided, but several general concepts are presented: (1) the greater the number of samples collected, the better the area will be defined; (2) the means of several measurements at each station within a project segment generally are less variable than individual measurements at each station would be; (3) statistics require replication because single measurements are inadequate to describe variability; and (4) the necessary number of samples is proportional to the heterogeneity of the sediment and the statistical power desired in the tests based on the sampling.

The above factors suggest that replicate samples should be collected at each location. However, they do not help determine the total number of samples needed because the number depends on site-specific heterogeneity and the desired level of definition. Thus, other factors will have to determine the number of samples collected.

One factor that can be used to estimate the number of samples needed is the level of statistical reliability or confidence that is desired in the results. When a random sample is to be taken, sample size can be calculated as follows for any parameter of interest:

$$n_o = \frac{t^2 s^2}{d^2}$$

where

n_o = number of samples required given the following three values:

t^2 = student's t distribution value. This value depends on the confidence desired in the estimate of the population mean, e.g., 95 percent.

s^2 = population variance. This value is often obtained from historical data or a preliminary survey.

d^2 = statement of margin of error. This is the acceptable margin around the estimate of the mean, e.g., mean ± x percent of the mean.

This method will most likely lead to different numbers of samples being required for each parameter, and tradeoffs have to be made in selecting the final number of samples to collect. Because of the inherent heterogeneity of sediments, one should be prepared to accept large values for n_o and/or d when using this approach. In other words, for small values of d, the margin of error, the investigator can expect a large number of samples to be required. If fewer samples have to be taken, the investigator can expect a broader confidence interval around the results.

This approach requires a knowledge of historical data and/or an examination of the dredging area. It can be used to estimate the total number of samples (n_o) needed for a dredging operation after stating the confidence desired in the final data (to determine t), knowing the expected variability (s^2) in the parameter values and deciding on an acceptable margin of error (d). This approach is also frequently used after completion of a sampling program, when n_o and s^2 are known, to calculate the level of confidence (the power) that can be placed in the final statistical analysis.

In all cases the goal is to obtain sufficient information to evaluate the environmental impacts of a dredging operation within the constraints of the operation. Although such constraints do not justify inadequate environmental evaluation, the reality of time and funding constraints have to be recognized. Possible responses to such constraints have been discussed by Higgins (1988). If the original sampling design does not seem to fit time or funding constraints, several options are available:

- Reduce the number of replicates at each station. This provides a more synoptic survey of distribution patterns in the project segment, but makes statistical comparisons of individual stations less powerful. This may be the easiest approach, but is not necessarily the most desirable.

- Maintain replicates but reduce the number of sampling stations. This results in less detailed definition of the project segment, but maintains the power of station-to-station comparisons.

- Reduce the number of project segments into which the project is divided, but maintain the same total number of samples. This also results in less detailed definition of each project segment, but maintains the power of station-to-station comparisons.

- Maintain (or even increase) the number of stations sampled, and composite multiple samples from within a project segment so that a lower number of analyses are performed per project segment.

Regardless of the number of sampling stations finally selected, consideration should be given to collecting samples in excess of the minimum number needed for analysis. The extra samples do not have to be scheduled for analysis and may even be discarded later without analysis. However, sediments can be highly heterogeneous as discussed earlier and, should sample analysis indicate anomalous results, it is easier to analyze additional samples on hand than to remobilize a field crew. Should additional analysis be necessary, this approach avoids the variable of different sampling times, but adds the variable of potential change due to storage.

Regardless of the final decision on project segments and the number of sample stations and replicates per project segment, stations within each segment should be randomly distributed. Expected degree of contamination will be the dominant factor in initially describing the proposed project segments. If there are likely to be important variables in potential dredged material impact within a project segment, it may be advisable to use a stratified random sampling approach or to redefine project segment boundaries. Once the data from the sampling are available, it may be advisable to redefine the boundaries of the project segments to be used in the actual dredging to maximize the homogeneity within segments.

In decisions regarding compositing of samples, the objective of obtaining an accurate representation and definition of the dredging area has to be satisfied. Compositing provides a way to analyze sediments from more stations at the same cost, or the same number of stations at lower cost. However, compositing results in a less detailed description of the area sampled than would individual analysis of each station. If, for example, 5 analyses can be performed to characterize a project segment, increased coverage afforded by collecting 15 individual samples and compositing sets of three into 5 composite samples for analysis may justify the increased time and cost of collecting the extra 10 samples. Compositing can provide the large sample volumes required for some biological tests. Composite samples represent the "average" of the characteristics of the individual samples making up the composite, and can closely represent the overall characteristics of the entire volume of material to be dredged.

When a sediment collection device is brought on board, a decision has to be made as to whether the entire sediment volume is to be considered the sample, or the sediment volume represents separate samples (i.e., based on observed stratification, the top 2-3 ft of a core might be considered a separate sample from the remainder of the core). After the sediment to be considered a sample is identified, it has to be thoroughly homogenized. If the sediment is to be part of a composite, it is split after it is homogenized. Half the original sediment is stored as representative of the individual station in case later analysis of the individual sample is required, and the other half is combined with parts of other samples. These are thoroughly homogenized, producing the composite sample.

8.2.5 Sample Collection Methods

Sample collection requires an experienced crew, an adequate vessel equipped with precise navigational equipment and winches, and non-contaminating sampling apparatus capable of obtaining relatively undisturbed and representative samples. The major sampling effort for a proposed dredging operation is oriented toward the collection of sediment samples for physical and chemical characterization or for biological tests. Collection of water samples might also be required to evaluate potential water column impacts. Collection of organisms near the disposal site might be necessary if there is a need to characterize indigenous populations at these locations or to assess concentrations of contaminants in tissues. Organisms for use in biological effects and bioaccumulation tests may also be field collected.

Guidance is provided in this section regarding the selection and use of some equipment associated with sediment, water, or organism samples. In general, a hierarchy for sample collection should be established to prevent contamination from the previous sample, especially when using the same sampling apparatus. At a station where water and sediments are to be collected, water samples should be collected prior to sediment samples. The vessel should be positioned downwind or downcurrent of the sampling device. When lowering sampling devices, care should be taken to avoid visible surface slicks. The deck and sample handling area should be kept clean to help reduce the possibility of contamination.

EPA (1987) contains useful sampling guidance from a quality assurance viewpoint, and may be followed on all points not in conflict with the

guidance in this manual. Higgins and Lee (1987) provide perspective on sediment collection and analysis as commonly practiced in CE Districts.

8.2.5.1 Sediment Sample Collection

Sediment samples should be collected to the planned depth of excavation, unless the sediments are known to be vertically homogenous or the deepest sediments to be excavated are known to be uncontaminated. Care should be taken to avoid contamination of sediment samples during collection and handling. Samples designated for trace metal analyses should not come into contact with metal surfaces, and samples designated for organic analyses should not come into contact with plastic surfaces. Samples for biological tests may be stored in clean polypropylene containers. Subsamples for particular groups of analytes may be removed from areas of the sample not in physical contact with the collecting instrument.

A coring device is recommended whenever sampling to depth is required. The choice of corer design depends upon the objectives of the sampling program, the sediment type, water depth, sediment depth, and currents. A gravity corer may be limited to cores of 1-2 m in depth depending upon sediment grain size, degree of sediment compactness, and velocity of the drop. For penetration greater than 2 m, a vibratory corer or a piston corer may be preferable. The length of core that can be collected generally is limited to 10 core diameters in sand substrate and 20 core diameters in clay substrate. Longer cores can be obtained but substantial sample disturbance results from internal friction between the sample and the core liner.

Freefall cores can cause compaction of the vertical structure of sediment samples. Therefore, if the vertical stratification in a core sample is of interest, a piston corer should be used. These devices utilize both gravity and hydrostatic pressure. As the cutting edge penetrates the sediments, an internal piston remains at the level of the sediment-water interface, preventing sediment compression and overcoming internal friction. If samples will not be sectioned prior to analysis, compaction is an academic problem, and freefall corers are a suitable alternative.

Corers are the samplers of preference in most cases because of the variation in contamination with depth that can occur in sediment deposits. Substantial variation with depth is unlikely in areas that have frequent

ship traffic and from which sediments are dredged at short intervals. In these situations, accumulating sediments are resuspended and mixed semi-continuously by ship scour and turbulence, effectively preventing stratification. In such cases grab samples can be representative of the mixed sediment column, and corers should be necessary only if excavation of infrequently disturbed sediments below the mixed layer is planned.

Grab samplers are acceptable for collecting samples of reference or control sediments. A grab can be Teflon-coated to prevent potential contamination of trace metal samples. The sampling device should be rinsed with clean water between samples.

8.2.5.2 Water Sample Collection

If water samples are necessary, they should be collected with a noncontaminating pump or, if only a small volume of water is required, with a discrete collection bottle. When sampling with a pump, the potential for contamination can be minimized by using a peristaltic or a magnetically coupled impeller design pump. The system should be flushed with the equivalent of 10 times the volume of the collection tubing. Also, any components within 5 m of the sample intake should be noncontaminating (i.e., sheathed in polypropylene or epoxy-coated).

A discrete water sampler should be of the close/open/close type so that only the target water sample comes into contact with internal sampler surfaces. Seals should be Teflon-coated whenever possible. Water sampling devices should be acid-rinsed prior to use for collection of trace metal samples and rinsed with hexane (or other appropriate solvent) prior to collection of samples for organic analyses.

8.2.5.3 Organism Collection

If collection of epibenthic macrofauna is necessary, they may be collected with a trawl. Infaunal organisms may be collected with a benthic grab or a box corer. If organisms are to be maintained alive, they should be transferred immediately to containers with clean, well-oxygenated flowing seawater. Care should be taken to prevent organisms from coming into contact with potentially contaminated areas or fuels, oils, brass, copper, lead, galvanized metal, cast iron, or natural rubber.

8.2.6 Sample Handling, Preservation, and Storage

Detailed procedures for the handling, preservation, and storage of samples should be addressed in standard operating procedures or protocols developed for each dredging operation. Precautions should be taken to avoid contaminating or diluting the sample in any way. The elapsed time between sample collection and analysis should be kept to a minimum; recommended storage duration times are given in Table 8.1, as well as references which should be consulted for more detailed information. A sample is subject to chemical, biological, and physical changes as soon as it is collected; therefore, handling, preservation, and storage techniques have to be designed to minimize alteration of the representativeness of the sample by retarding chemical and/or biological activity. Because the first few hours are the most critical to changes in the sample, preservation steps should be taken immediately upon sediment collection. There is no universal preservation or storage technique. A technique for one group of analyses may interfere with other analyses. This problem can be overcome by collecting sufficient sample volume to utilize specific preservation or storage techniques for specific analytes or tests. Proper labeling and sample-tracking procedures are of utmost importance. Labels have to withstand soaking, drying, and freezing without becoming detached or illegible. The labeling system should be tested prior to use in the field.

Generally, samples to be analyzed for trace metals should not come into contact with metals, and samples to be analyzed for organic compounds should not come into contact with plastics. Sediment samples should completely fill the storage container, leaving no air space. If the sample is to be frozen, just enough space for expansion should be allowed. Containers for samples should be appropriately cleaned (acid-rinsed for analysis of metals; solvent-rinsed for analysis of organic compounds). Preservation, whether by refrigeration, freezing, or addition of chemicals, should be accomplished onboard whenever possible. If preservation is delayed until after delivery to the laboratory, the sample should be temporarily stored to preserve the integrity of the sample. Onboard refrigeration is easily accomplished with coolers and ice; however, samples should be segregated from melting ice or cooling water. Samples that are to be frozen on-board may simply be placed in a cooler with dry ice. Additional information regarding collection, volume requirements, container specifications, preservation techniques, and storage conditions for

TABLE 8.1. SUMMARY OF RECOMMENDED PROCEDURES FOR SAMPLE COLLECTION, PRESERVATION, AND STORAGE[a]

Analysis or Test	Collection Method	Amount Required	Container	Preservation Technique	Storage Conditions	Storage Duration[b]
SEDIMENT						
Chemical/Physical Analysis						
Bulk metals	Grab/corer	200 mL	Precleaned pre-weighed poly-styrene jar[c]	Dry ice[c]	≤-20°C[c]	Hg-30 days Other-6 mo[f]
Bulk organics (PCBs, pesti-cides, HMW hydrocarbons)	Grab/corer	475 mL	Solvent-rinsed glass Teflon jar[c]	Dry ice[c]	≤-20°C[c]/dark[f]	10 days[f]
Particle size	Grab/corer	75 mL	Whirl-pac bag[c]	Dry ice[c]	≤-20°C[c]	Undetermined
TOC	Grab/corer	3 L	Heat treated glass vials-lined lids[c]	Dry ice[c]	≤-20°C[c]	Undetermined
Sediment from which elutriate is prepared	Grab/corer	Depends on tests being performed	Glass with Teflon-lined lid	Completely fill & refrigerate	4°C/dark/airtight	Undetermined
Biological Tests						
Dredged material	Grab/corer	12-15 L per sample	Plastic bag or container[i]	Completely fill & refrigerate; sieve	4°C/dark airtight	2 wk[h]
Reference sediment	Grab/corer	45-50 L per test	Plastic bag or container[i]	Completely fill & refrigerate; sieve	4°C/dark airtight	2 wk[h]
Control sediment	Grab/corer	21-25 L per test	Plastic bag or container[i]	Completely fill & refrigerate; sieve	4°C/dark airtight	2 wk[h]
WATER AND ELUTRIATE						
Particulate Analysis	Discrete sampler or pump	500-2,000 mL	Plastic or glass	Lugols solution & refrigerate	4°C	Undetermined
Metals	Discrete sampler or pump	1 L	Acid-rinsed polyethylene or glass jar[d]	pH <2 with HNO_3[d]	4°C ±2°C[d]	Hg - 2 wk Others - 6 mo[e]
Total Kjeldahl Nitrogen	Discrete sampler or pump	100-200 mL	Plastics or glass[e]	H_2SO_4 to pH <2; refrigerate[e]	4°C[e]	24 hr[e]

TABLE 8.1 (Cont.) [a]

Analysis or Test	Collection Method	Amount Required	Container	Preservation Technique	Storage Conditions	Storage Duration [b]
COD	Discrete sampler or pump	200 L	Plastic or glass [e]	H_2SO_4 to pH <2; refrigerate [e]	4°C [e]	7 days [e]
TOC	Discrete sampler or pump	100 mL	Plastic or glass [e]	H_2SO_4 to pH <2; refrigerate [e]	4°C [e]	<48 hr [e]
TIC	Discrete sampler or pump	100 mL	Plastic or glass [e]	Airtight seal; refrigerate [e]	4°C [e]	6 mo [e]
Phenolics	Discrete sampler or pump	1 L	Glass [e]	0.1-1.0g $CuSO_4$; H_3PO_4 to pH <4; refrigerate [e]	4°C [e]	24 hr [e]
Soluble reactive Phosphates	Discrete sampler or pump	--	Plastic or glass [e]	Filter, refrigerate [e]	4°C [e]	24 hr [e]
Organics	Discrete sampler or pump	4 L	Amber glass bottle [d]	Airtight seal; refrigerate	4°C ±2°C [d]	5 days [d]
Volatile Organics	Discrete sampler or pump	80 mL	Glass vial [d]	HCL preservation in airtight completely filled container [d]	4°C ±2°C [d]	5 days [d]
Total phosphorus	Discrete sampler or pump	--	Plastic or glass [e]	Refrigerate	4°C [e]	7 days [e]
Total solids	Discrete sampler or pump	200 mL	Plastic or glass [e]	Refrigerate	4°C [e]	7 days [e]
Volatile solids	Discrete sampler or pump	200 mL	Plastic or glass [e]	Refrigerate	4°C [e]	7 days [e]
Sulfides	Discrete sampler or pump	--	Plastic or glass [e]	2 mL ZnOAc [e]	Ambient [e]	24 hr [e]
TISSUE						
Trace metals	Trawl/Teflon-coated grab	30 g	Double Ziploc [c]	Handle w/nonmetallic forceps; plastic gloves; Dry ice [c]	≤-20°C [c]	Hg-28 days Others-6 mo [g]
PCBs and chlorinated pesticides	Trawl/Teflon-coated grab	100 g	Hexane-rinsed double aluminum foil and double Ziploc [c]	Handle w/hexane rinsed stainless steel forceps; Dry ice [c]	≤-20°C [c]	10 days [g]

TABLE 8.1 (Cont.)[a]

Analysis or Test	Collection Method	Amount Required	Container	Preservation Technique	Storage Conditions	Storage Duration[b]
Volatile Organics	Trawl/Teflon-coated grab	50 g	Heat cleaned aluminum foil and watertight plastic bag[g]	Covered ice chest[g]	-20°C[g]	10 days[g]
PAHs	Trawl/Teflon-coated grab	50 g	Hexane-rinsed double aluminum foil and double Ziploc[c]	Handle w/hexane rinsed stainless steel forceps; Dry ice[c]	≤-20°C[c]	10 days[g]
Lipids	Trawl/Teflon-coated grab	50 g	Hexane-rinsed aluminum foil	Handle w/hexane rinsed stainless steel forceps; quick freeze	-20°C	Undetermined

(a) This table contains only a summary of collection, preservation and storage procedures for samples. The cited references should be consulted for a more detailed description of these procedures.
(b) These are holding times for sediment, water and tissue. References should be consulted if holding times for sample extracts are desired.
(c) NOAA (1989)
(d) EPA (1988)
(e) Plumb (1981)
(f) Tetra Tech (1986a)
(g) Tetra Tech (1986b)
(h) EPA/CE (1977)
(i) Polypropylene should be used if phalate bioaccumulation is of concern.

sediment, water, and tissue samples is provided in Table 8.1. EPA (1987) provides useful guidance on QA/QC.

Sediment for bioassays should be stored at 4°C, never frozen or dried. Living organisms should be removed from the sediment before it is used in toxicity tests. This can be accomplished by sieving the sediments through a 1.0 mm mesh screen using the smallest amount of seawater possible. Allow the rinse-water to settle for 6 hr, then siphon off the water and combine the settled material with the sediment sample. Avoid using large volumes of water if at all possible; this may dilute or reduce the concentration of some sediment associated contaminants. Prior to use in bioassays, all sediments should be thoroughly homogenized.

8.2.7 Logistical Considerations and Safety Precautions

A number of frustrations in sample collection and handling can be minimized by carefully thinking through the process and requirements before going to the field. Only well trained and experienced crews should be used. Backup equipment and sampling gear and appropriate repair parts are advisable. A surplus of sampling containers and field data sheets should be available. Sufficient ice and ice chest capacity should be provided, and the necessity of replenishing ice before reaching the laboratory should be considered. A vessel with adequate deck space is safer and allows more efficient work than an overcrowded vessel. Unforeseeable circumstances are to be expected in field sampling, and time to adequately deal with the unforeseen has to be included in sampling schedules. Appropriate safety precautions have to be observed during field sampling activities. Field crews should be well trained and experienced.

Samples have to be properly disposed when no longer needed. Ordinary sample disposal methods are usually acceptable, and special precautions are seldom appropriate. According to the Characterization and Assessment Division of the U.S. EPA Office of Solid Waste and Emergency Response, under 40 CFR 261.4(d)(1) even the most contaminated samples, if collected for the sole purpose of testing, are not subject to requirements of the Federal hazardous waste management regulations. In addition, under 40 CFR 261.5(a), if the waste generated is less than 100 kg per month, the generator is conditionally exempt as a small quantity generator and may accumulate up to 1000 kg of waste on the property without being subject to the requirements of Federal hazardous waste regulations. When samples have

to be shipped, 49 CFR 100-177 should be consulted for current Department of Transportation regulations on packing and shipping.

8.2.8 Quality Control

Although Chapter 13 is devoted to quality assurance/quality control (QA/QC) practices, it is appropriate to discuss QA/QC issues specific to the collection and preservation of samples at this point. An effective quality control program has to be an integral part of a dredging evaluation from initiation of field collections. Potential for sample deterioration and/or contamination occurs during sample collection, handling, preservation, and storage. Approved protocols and standard operating procedures should be followed, and experienced personnel should be responsible for maintaining the integrity and identity of samples from collection through laboratory analysis. EPA (1987) should be consulted for additional guidance generally appropriate to dredged material.

The following areas should receive special attention relative to quality control.

8.2.8.1 Documentation

A complete record of all field procedures should be maintained including station locations, sampling methods, sample handling, preservation, and storage procedures. Dates and times of collection, preservation, and storage should be recorded. A sample inventory log and sample tracking log should be maintained. Any circumstances potentially affecting sampling procedures should be documented.

8.2.8.2 Standard Operating Procedures

Written standard operating procedures should be available for routine procedures performed during field collections. Personnel should be thoroughly familiar with these procedures before sampling is initiated.

8.2.8.3 Sample Labels

At a minimum, the following information should be included on a sample label:

- Unique identifying code
- Location (station number) and depth
- Analysis or test to be performed
- Preservation and/or storage method
- Date/time of collection
- Special remarks if appropriate
- Initials of person collecting the sample.

8.2.8.4 Sample Tracking

A procedure for tracking samples from collection through completion of analysis and sample disposal has to be in place. This procedure should incorporate a system for monitoring the condition of the sample during transport and storage. Appropriate personnel should be assigned responsibility for sample tracking and sample custody.

8.2.8.5 Archived Samples

A sample storage bank containing replicates or subsamples of analyzed samples or extra unanalyzed samples may be beneficial, especially if anomalous results are found from analyzed samples or if additional information or analyses are needed to better define sediment characteristics. Archived samples should be properly stored and inventoried.

8.3 REFERENCES

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9.0 PHYSICAL ANALYSES OF SEDIMENT AND CHEMICAL ANALYSES OF SEDIMENT, WATER AND TISSUE SAMPLES

This chapter provides guidance on the selection of chemical and physical parameters to aid in evaluating the acceptability of dredged material for proposed ocean disposal, and the methods used to analyze these parameters.

Methods cited in this chapter may be used to develop the chemical information required. However, other methods may provide similar results, and the final choice of analytical procedures depends upon the needs of each evaluation. In all cases, state-of-the-art methods should be used.

Any dredged material from estuarine or marine areas contain salt. The salt can interfere with the results obtained from some analytical methods. Any methods proposed for the determination of parameters in sediment and water from estuarine or marine environments have to explicitly address steps taken to control salt interferences.

9.1 PHYSICAL ANALYSES OF SEDIMENT

Ocean dumping evaluations require that the physical characteristics of the dredged material be determined and used to help assess the impacts of dumping on the benthic environment and the water column. The physical analysis of sediment samples is the first step in the overall process of sediment characterization. The physical analyses provide general information on the physical characteristics of the dredged material and can be used to assess the behavior of these sediments after disposal. These data are also valuable in helping to identify appropriate control and reference sediments for biological tests. In addition, the physical parameters can be helpful in evaluating the chemical measurements that are made as a later step in the characterization process.

The general analyses that are recommended are (1) grain size, (2) total organic carbon (TOC), and (3) total solids/specific gravity.

Grain size analysis is a measure of the frequency distribution of the size ranges of the particles that make up the sediment (Plumb, 1981; Folk, 1980). The general size classes of gravel, sand, silt, and clay are the

most useful in describing the size distribution of particles in dredged material samples.

The total organic carbon content of sediment is a measure of the total amount of oxidizable organic material in a sample. The TOC method should be based on high temperature combustion, rather than chemical oxidation. Some classes of organic compounds are not fully degraded by chemical/UV techniques. The volatile and nonvolatile organic components make up the total organic carbon of a sample. Because inorganic carbon (e.g., carbonates and bicarbonates) can be a significant proportion of the total carbon in some sediment, the sample has to be treated with acid to remove the inorganic carbon prior to TOC analysis. The method of Plumb (1981) recommends HCl as the acid. An alternative choice might be sulfuric acid since it is nonvolatile, is used as the preservative, and does not add to the chloride burden of the sample. Whatever acid is used, it has to be demonstrated on sodium chloride blanks, that there is no interference generated from the combined action of acid and salt in the sample. The EPA Region II Laboratory at Edison, New Jersey, has also developed an acceptable method for TOC analysis available from U.S. Environmental Protection Agency, Region II, Surveillance and Monitoring Branch, Woodbridge Avenue, Edison, NJ 08837.

Total solids is a gravimetric determination of the organic and inorganic material remaining in a sample after it has been dried at a specific temperature. The total solids values are generally used to convert concentrations of the chemical parameters from a wet-weight to a dry-weight basis. The specific gravity of a sample is the ratio of the mass of a given volume of material to an equal volume of distilled water at the same temperature (Plumb, 1981). Because the specific gravity analysis requires a dry sample, it is usually performed in conjunction with the total solids determination. The specific gravity of a dredged material sample can be used to help predict the dispersal and settling characteristics of dredged material upon ocean disposal.

Quality control (QC) procedures for the general characterization of sediments are necessary to ensure that the data meet acceptable criteria for precision and accuracy. At a minimum, one triplicate analysis should be performed for every 20 samples analyzed except for TOC where all samples should be run in triplicate. In addition, one procedural blank per 20

samples should be run and the results reported for TOC analysis. Standards used for TOC determinations have to be verified using independent check standards to verify the accuracy of the results. Quality control limits have to be agreed upon for each analytical procedure, and have to be consistent with the overall quality control plan. Standard reference materials are not available for the determination of the physical parameters in sediments; however, where possible, laboratory standards should be analyzed with the same frequency as the triplicate analyses. Quality assurance (QA) is discussed in Chapter 13.

9.2 DETECTION LIMITS

The selection of appropriate method detection limits (MDLs) is important. MDLs should be lower than the appropriate values to which the data are to be compared for interpretation. The detection limits for an analyte should be no greater than one-third (one-half log unit) of the appropriate value for the analyte and matrix of concern. An MDL of one-fifth to one-tenth the appropriate value is desirable and sufficient in most cases. This is necessary to evaluate whether the concentration of the analyte is approaching the value critical to the decision-making process.

Further, the MDL has to be sufficiently below the appropriate value so that there is a diminished variability in numerical values in the vicinity of the appropriate value. Since no conclusion can be more certain than the least certain measurement, excessively low MDLs will not contribute to conclusions if sampling error is the dominant variable factor. For some contaminants such as dioxin, every effort has to be made to achieve consistent quantitation at the lowest possible level. The detection limits have to be documented and reported for all analyses.

9.3 CHEMICAL ANALYSES OF SEDIMENT

9.3.1 Selection of Analytical Targets (Sediment)

Chemical analysis provides information about the chemicals present in the dredged material that, if biologically available, could cause toxicity and/or be bioaccumulated. This information is valuable for exposure

assessment and for deciding which of the contaminants present in the dredged material to measure in tissue samples.

If the historical review conducted in Tier I (Section 4.1) fails to produce sufficient information to develop a suitable list of potential contaminants, a list of target chemicals has to be compiled.

There are many chemicals that could be included as target analytes. Target analytes should be selected from the priority pollutant list (Table 9.1) and the information obtained from the historical review. In the context of the regulations, analysis of PAH in dredged material should focus on those PAH compounds on the priority pollutant list (Clarke and Gibson, 1987). In addition, the target list should be expanded to include other contaminants that historical information or commercial and/or agricultural applications suggest could be present at a specific dredging site; for example, dioxins where industrial fires have occurred, and tributyltin near ships on which these compounds have been used.

9.3.2 Selection of Chemical Analytical Techniques (Sediments)

Once the list of target analytes for sediments has been established, the analytical methods for the analytes have to be determined. The methods will, to some degree, dictate the amount of sediment sample required for each analysis. However, guidelines for the amount of sample to be collected are presented in Table 9.2. These general sample sizes take into consideration that more than one analysis may be required for each group of analytes. The amount of sample used in an analysis affects the detection limits attainable using a particular method.

For priority pollutants in sediments, the method detection limits (MDL) provided by EPA (1986a) may be used as general guidelines. These detection limits are analytical goals rather than requirements. Site- or operation-specific objectives may make lower or higher detection limits appropriate. If lower MDLs are required, the analysis may require more sensitive instrumentation, larger sample sizes or additional cleanup/concentration steps. For most coastal sediments, suitable analytical methodology will control interferences such that required detection limits will be reached. A discussion of sediment MDL values is

TABLE 9.1. PRIORITY POLLUTANTS AND 301(h) PESTICIDES LISTED ACCORDING TO STRUCTURAL COMPOUND CLASS

Structural Compound Class	PP[a]	Pollutant
Phenols	65	phenol
	34	2,4-dimethylphenol
Substituted Phenols	21	2,4,6-trichlorophenol
	22	para-chloro-meta-cresol
	24	2-chlorophenol
	31	2,4-dichlorophenol
	57	2-nitrophenol
	58	4-nitrophenol
	59	2,4-dinitrophenol
	60	4,6-dinitro-o-cresol
	64	pentachlorophenol
Organonitrogen Compounds	5	benzidine
	28	3,3'-dichlorobenzidine
	35	2,4-dinitrotoluene
	36	2,6-dinitrotoluene
	37	1,2-diphenylhydrazine
	56	nitrobenzene
	61	N-nitrosodimethylamine
	62	N-nitrosodiphenylamine
	63	N-nitrosodipropylamine
Low Molecular Weight Polynuclear Aromatic Hydrocarbons (PAH)	1	acenaphthene
	55	naphthalene
	77	acenaphthylene
	78	anthracene
	81	phenanthrene
	80	fluorene
High Molecular Weight PAH	39	fluoranthene
	72	benzo(a)anthracene
	73	benzo(a)pyrene
	74	benzo(b)fluoranthene
	75	benzo(k)fluoranthene
	76	chrysene
	79	benzo(ghi)perylene
	82	dibenzo(a,h)anthracene
	83	ideno(1,2,3-cd)pyrene
	84	pyrene
Chlorinated Aromatic Hydrocarbons	8	1,2,4-trichlorobenzene
	9	hexachlorobenzene
	20	2-chloronaphthalene
	25	1,2-dichlorobenzene
	26	1,3-dichlorobenzene
	27	1,4-dichlorobenzene
Chlorinated Aliphatic Hydrocarbons	52	hexachlorobutadiene
	12	hexachloroethane
	53	hexachlorocyclopentadiene
Halogenated Ethers	18	bis(2-chloroethyl)ether
	40	4-chlorophenyl ether
	41	4-bromophenyl ether
	42	bis(2-chloroisopropyl)ether
	43	bis(2-chlorethoxy)methane
Phthalates	66	bis(2-ethylhexy)phthalate
	67	butyl benzyl phthalate
	68	di-n-butyl phthalate
	69	di-n-octyl phthalate
	70	diethyl phthalate
	71	dimethyl phthalate
Polychlorinated Biphenyls (PCB) as arochlors	106	PCB-1242
	107	PCB-1254
	108	PCB-1221
	109	PCB-1232
	110	PCB-1248
	111	PCB-1260
	112	PCB-1016
Miscellaneous Oxygenated Compounds	129	TCDD (dioxin)
	54	isophorone
Pesticides	89	aldrin
	90	dieldrin
	91	chlordane
	92	DDT [b]
	95	endosulfan [c]
	98	endrin
	99	endrin aldehyde
	100	heptachlor
	101	heptachlor epoxide
	102	alpha-hexachlorocyclohexane
	103	beta-hexachlorocyclohexane
	104	delta-hexachlorocyclohexane
	105	gamma-hexachlorocyclohexane
	113	toxaphene
	--	mirex [d]
	--	methoxychlor [d]
	--	parathion [e]
	--	malathion [e]
	--	guthion [e]
	--	demeton [e]
Volatile Halogenated Alkanes	6	tetrachloromethane
	10	1,2-dichloroethane
	11	1,1,1-trichloroethane
	13	1,1-dichloroethane
	14	1,1,2-trichloroethane
	15	1,1,2,2-tetrachloroethane
	16	chloroethane
	23	chloroform
	32	1,2-dichloropropane
	44	dichloromethane
	45	chloromethane
	46	bromomethane
	47	bromoform
	48	dichlorobromoethane
	49	fluorotrichloromethane (removed)
	50	dichlorodifluoromethane (removed)
	51	chlorodibromomethane

TABLE 9.1. (Continued)

Structural Compound Class	PP[a]	Pollutant
Volatile Halogenated Alkenes	29	1,1-dichlorethylene
	30	1,2-trans-dichlorethylene
	33	trans-1,3-dichloropropene
	33	cis-1,3-dichloropropene
	85	tetrachlorethene
	87	trichlorethene
	88	vinyl chloride
Volatile Aromatic Hydrocarbons	4	benzene
	38	ethylbenzene
	86	toluene
Volatile Chlorinated Aromatic Hydrocarbons	7	chlorobenzene
Volatile Unsaturated Carbonyl Compounds	2	acrolein
	3	acrylonitrile
Volatile Ethers	19	2-chlorethylvinylether
		bis(chloromethyl)ether (Removed)
Metals	114	antimony
	115	arsenic
	117	beryllium
	118	cadmium
	119	chromium
	120	copper
	122	lead
	123	mercury
	124	nickel
	125	selenium
	126	silver
	127	thallium
	128	zinc
Miscellaneous	121	cyanide
	116	asbestos

(a) PP = Priority Pollutant
(b) Includes DDT, DDD, and DDE
(c) Includes alpha-endosulfan, beta-endosulfan, and endosulfan sulfate.
(d) Chlorinated 301(h) pesticides that are not on the priority pollutant list.
(e) Organophosphorus 301(h) pesticides that are not on the priority pollutant list.

TABLE 9.2. SEDIMENT SAMPLE SIZE REQUIREMENTS FOR CHEMICAL AND PHYSICAL ANALYSES

Analytical Parameter	Sediment Sample Size (g, wet wt.) Delivered to Laboratory
Organics	250
Metals	100
Miscellaneous	50[a]
Grain size	100
Total organic carbon	50
Total solids/specific gravity	50

(a) Miscellaneous sample size should be increased if auxiliary analytes that cannot be included as part of the organic or metal analyses are added to the target list.

presented in Tetra Tech (1986a) and EPA (1986a). In any event, quality control data should corroborate the detection limits reached, and any discrepancies has to be justified by the data.

The recommended method for the analysis of semivolatile and volatile priority pollutants in sediment is available from Tetra Tech (1986a). Analyses for organics should always use capillary column gas chromatography (GC) or gas chromatography/mass spectrometry (GC/MS) techniques. These methods provide analytically sound techniques that yield accurate data on the concentrations of chemicals in the sediment matrix. The analytical techniques for semivolatile organic compounds generally involve the solvent extraction of the organic constituents from the sediment matrix and subsequent analysis, after clean-up, using gas chromatography (GC) or gas chromatography/mass spectrometry (GC/MS). The extensive clean-up is necessitated by the likelihood of (1) biological macromolecules, (2) sulfur from sediments with low or no oxygen, and (3) oil and/or grease in the sediment. The analysis of volatile organic compounds incorporates purge and trap techniques with analysis by either GC or GC/MS. If dioxin analysis is being performed, the methods of Kuehl et al. (1987) or Smith et al. (1984) should be consulted.

For many metals analyses, the concentration of salt may be much greater than the analyte of interest, and cause unacceptable interferences in certain analytical techniques. In such cases, the freshwater approach of acid digestion followed by inductively coupled plasma or graphite furnace atomic absorption spectroscopy needs to be coupled with appropriate techniques for controlling this interference. Further, it has to be remembered that Cr, Se, Sn, Sb, and As generally occur as anions with several possible oxidation states, while the elements Fe, Zn, Pb, Ni, Cd, and Cu occur as hydrated cations (also with different oxidation states possible). The Hg method in EPA (1986a) may be used for sediment analysis. For quantitation at lower levels, the gold amalgamation methods may be necessary. Tributyltin is analyzed by the method of Rice et al. (1987), and selenium and arsenic by the method of EPRI (1986).

The techniques for the analysis of chemical constituents have some inherent limitations for sediment samples. Interferences encountered as part of the sediment matrix, particularly in samples from heavily polluted areas, may limit the ability of a method to detect or quantify some

analytes. Consequently, the most selective methods using GC/MS techniques are recommended for all nonchlorinated organic compounds, because GC/MS analysis can often avoid problems due to matrix interferences. Gas chromatography/electron capture detector (GC/ECD) methods are recommended as the primary analytical tool for all polychlorinated biphenyl (PCB) and pesticide analyses because GC/ECD analysis will result in lower detection limits. Two-column GC/ECD confirmation of all analytes is recommended. Alternatively, GC/MS using selected ion monitoring (SIM) can be used for PCB and pesticide analysis. A total extraction of metal ions is not necessary. The standard aqua regia extraction yields consistent and reproducible results. A total extraction of the metals can only be achieved by acid fluoride, or flux fusion methods.

The traditional methods for the analysis of PCB quantify PCB as aroclor mixtures, which can result in errors in determining concentrations (Brown et al., 1984). The mixture of PCB congeners making up the aroclors changes due to physical, chemical and/or biological processes altering the distribution of individual congeners in the environment after release. Techniques that rely on quantification of PCB by aroclor assume that the distributions of PCB congeners found in environmental samples are identical to industrial formulations. This is not the case. In addition, aroclor determinations do not yield information on the potential biological significance of the PCBs (McFarland and Clarke, 1989). The most toxic PCB congeners fall mainly within the tetra-, penta-, and hexa-chlorobiphenyl isomer groups (McFarland et al., 1986). More meaningful biological and toxicological information about PCB concentrations and more accurate analytical chemistry data can be obtained by analyzing and quantifying PCBs as individual congeners or isomer classes (Cl_1-Cl_{10}). Total PCBs can be determined by the sum of the individual congeners. This summation more accurately represents the PCB concentration in samples as shown in the National Oceanic and Atmospheric Administration's Mussel Watch Program (NOAA, 1989). PCB congener analytical methods are recommended for all analyses of PCB in sediments. Table 9.3 lists the congeners recommended for analysis based on environmental abundance, persistence, and biological importance (McFarland and Clarke, 1989). The preparation for analysis should follow the techniques described in Tetra Tech (1986a) or EPA (1986a), but the instrumental analysis and quantification of the PCBs

TABLE 9.3. POLYCHLORINATED BIPHENYL (PCB) CONGENERS RECOMMENDED FOR QUANTITATION AS POTENTIAL CONTAMINANTS OF CONCERN

PCB Congener[a]	Congener Number[b]		
	Summation[c]	Highest Priority[d]	Second Priority[e]
2,4′ diCB	8		
2,2′,5 triCB	18		18
2,4,4′ triCB	28		
3,4,4′ triCB			37
2,2′,3,5′ tetraCB	44		44
2,2′,4,5′ tetraCB			99
2,2′,5,5′ tetraCB	52		52
2,3′,4,4′ tetraCB	66		
2,3′,4′,5 tetraCB			70
2,4,4′,5 tetraCB			74
3,3′,4,4′ tetraCB	77	77	
3,4,4′,5 tetraCB			81
2,2′,3,4,5′ pentaCB		87	
2,2′,3,4′,5 pentaCB		49	
2,2′,4,5,5′ pentaCB	101	101	
2,3,3′,4,4′ pentaCB	105	105	
2,3,4,4′,5 pentaCB			114
2,3′,4,4′,5 pentaCB	118	118	
2,3′,4,4′,6 pentaCB			119
2′,3,4,4′,5 pentaCB			123
3,3′,4,4′,5 pentaCB	126	126	
2,2′,3,3′,4,4′ hexaCB	128	128	
2,2′,3,4,4′,5′ hexaCB	138	138	
2,2′,3,5,5′,6 hexaCB			151
2,2′,4,4′,5,5′ hexaCB	153	153	
2,3,3′,4,4′,5 hexaCB		156	
2,3,3′,4,4′,5 hexaCB			157
2,3,3′,4,4′,6 hexaCB			158

Table 9.3 (Cont.)

PCB Congener[a]	Congener Number[b]		
	Summation[c]	Highest Priority[d]	Second Priority[e]
2,3′,4,4′,5,5′ hexaCB			167
2,3′,4,4′,5′,6 hexaCB			168
3,3′,4,4′,5,5′ hexaCB	169	169	
2,2′,3,3′,4,4′,5 heptaCB	170	170	
2,2′,3,4,4′,5,5′ heptaCB	180	180	
2,2′,3,4,4′,5′,6 heptaCB		183	
2,2′,3,4,4′,6,6′ heptaCB		184	
2,2′,3,4′,5,5′,6 heptaCB	187		187
2,3,3′,4,4′,5,5′ heptaCB			189
2,2′,3,3′,4,4′,5,6 octaCB	195		
2,2′,3,3′,4,5,5′,6′ octaCB			201
2,2′,3,3′,4,4′,5,5′,6 nonaCB	206		
2,2′,3,3′,4,4′,5,5′,6,6′ decaCB	209		

(a) PCB congeners recommended for quantitation, from dichlorobiphenyl (diCB) through decachlorobiphenyl (decaCB).

(b) Congeners are identified by their International Union of Pure and Applied Chemistry (IUPAC) number, as referenced in Ballschmiter and Zell (1980) and Mullen et al. (1984).

(c) These congeners are summed to determine total PCB concentration following the approach in NOAA (1989).

(d) PCB congeners having highest priority for potential environmental importance based on potential for toxicity, frequency of occurrence in environmental samples, and relative abundance in animal tissues (McFarland and Clarke, 1989).

(e) PCB congeners having second priority for potential environmental importance based on potential for toxicity, frequency of occurrence in environmental samples, and relative abundance in animal tissues (McFarland and Clarke, 1989).

should be performed using standard capillary GC columns, on individual PCB isomers according to the methods in NOAA (1989) (see also Stalling, 1987; Dunn, 1984; Schwartz, 1984; Mullin, 1984). Based on quantitation of the congeners listed in Table 9.3, PCB concentrations should also be summed to give total PCBs in the sample according to the NOAA (1989) methods.

As stated earlier, the list of target analytes should include compounds that background and historical information suggest may be present. To further ensure that toxic compounds not included in the priority pollutant list are not overlooked in the chemical characterization of the dredged material, the analytical results should also be scrutinized by trained personnel for additional analytes that are not on the target list. The presence of persistent major "unknown" analytes on gas chromatograms (GC) or reconstructed ion chromatograms (GC/MS) should be noted. In such a case, methods involving GC/MS techniques for organic compounds are recommended for the identification of unknown chemicals.

9.3.3 Quality Control

Although Chapter 13 presents general quality control/quality assurance considerations, the EPA methods for the analysis of priority pollutants include detailed quality control procedures and requirements that are appropriate for discussion here. These guidelines should be followed rigorously throughout the chemical analyses. General quality control procedures should include the analysis of a procedural blank and a matrix spike along with every 10 - 20 samples processed. To measure analytical precision, one sample should be analyzed in triplicate for every 10 - 20 samples analyzed. The standard deviation and coefficient of variation should be reported. In addition, recoveries of surrogate spikes should be documented and all analytical instruments calibrated at least daily. All calibration data should be submitted for review.

Standard reference materials (SRM) should also be routinely analyzed, if available, to determine analytical accuracy. Standard reference materials may be obtained from the organizations listed in Table 9.4. One SRM sample should be analyzed with every batch of 10 to 20 samples. Some samples of SRMs for organic analytes include National Research Council of

TABLE 9.4. MARINE REFERENCE MATERIALS AND STANDARDS

Reference Material Needed	Inorganic Constituents	Organic Constituents
Addresses	Marine Anaytical Chemistry Standards Program National Research Council of Canada Division of Chemistry Montreal Road Ottawa, Ontario, Canada K1A0R9 Telephone: (613) 993-2359	Marine Analytical Chemistry Standards Program National Research Council of Canada Atlantic Research Laboratory 1411 Oxford Street Halifax, Nova Scotia, Canada B3H3Z1 Telephone: (902) 426-8280
	U.S. Department of Commerce National Institute for Standards and Technology Office of Standard Reference Materials Room B3111 Chemistry Bldg. Gaithersburg, MD 20899	U.S. Department of Commerce National Institute for Standards and Technology Office of Standard Reference Materials Room B3111 Chemistry Bldg. Gaithersburg, MD 20899

Canada (NRC) marine sediment HS-1 and HS-2 for PCB; NRC marine sediment HS-3, HS-4, HS-5, and HS-6 for PAH; and National Institute for Standards and Technology (NIST) SRM #1647 and SRM #1597 for PAH. SRMs for metals analyses include NBS estuarine sediment (SRM #1646); NRC marine sediments MESS-1, BCSS-1, and PACS-1; and International Atomic Energy Agency (IAEA) marine sediment SD-N-1/2(TM). Since new SRMs are appearing continuously, current listings of appropriate agencies should be consulted frequently. The QA program has to document the ability of the methods selected to cope with the high salt content of sediments.

9.4 CHEMICAL ANALYSES OF WATER

9.4.1 Recommended Analytical Targets (Water)

Analysis of seawater to determine the potential release of dissolved chemical constituents from the dredged material (standard elutriate) may be necessary to determine compliance with the regulations. Elutriate tests (Section 10.1.2.1) involve mixing dredged material with seawater and allowing the mixture to settle. The portion of the dredged material that is considered to have the potential to impact the water column is the supernatant remaining after undisturbed settling. Chemical analysis of the elutriate allows a direct comparison of the data to applicable marine water quality criteria. Analysis of seawater samples from the disposal site may be necessary to help interpret interaction between the water and sediment during disposal of the dredged material. When collecting samples for elutriate testing, consideration should be given to the large volumes of water and sediment required to prepare triplicate samples for analysis. In some instances when poor settling occurs, the elutriate preparation has to be performed successively several times to accumulate enough water for testing.

In selecting target analytes for water analyses, historical water quality information from the dredging site should be evaluated along with data obtained from the chemical analysis of sediment samples. The data from the chemical evaluation of the dredged material provide a known list of constituents that might affect the water column. All target analytes identified in the sediment chemical analyses should be initially considered

potential targets for water analysis. Nonpriority-pollutant chemical components that are found in measurable concentrations in the sediments should be included as targets for the water analyses if review of the literature indicates that these analytes have the potential to bioaccumulate in animals (i.e., have high Kows or BCFs) and are of toxicological concern.

9.4.2 Selection of Analytical Techniques (Water)

In contrast to freshwaters, there are generally not EPA approved methods for analysis of saline waters. Application of the freshwater methods to seawater will frequently result in much higher method detection limits (MDLs) than are common for freshwater unless care is taken to control the effects of salt on the analytical signal. It is therefore extremely important to ascertain a laboratory's ability to execute methods and attain acceptable MDLs in matrices containing up to three percent sodium chloride.

Once the list of target analytes for water is established, the methods for analysis should be selected. The water volume delivered to the laboratory for specific analytical methods may vary. A minimum of 1 L of elutriate should be delivered to the laboratory for metals analysis (as little as 100 mL may be analyzed). One liter of elutriate should be analyzed for organic compounds. For water samples from the dredging or disposal sites, 10 L water samples should be analyzed for organic analytes and 1 L water samples should be delivered for metals analyses. Additional water samples might be required for any supplemental target compounds that cannot be determined as part of the analyses for metal or organic priority pollutants. The size of the sample is one of the limiting factors in determining the detection limits for the water analyses. In some cases, the 10 L seawater volume for organic analysis will provide MDLs below the applicable marine water quality criteria. This will allow a direct comparison of the seawater field data to the water quality criteria. MDLs for these water analyses should be established on the assumption that the seawater MDLs should be lower than the water quality criteria concentrations. Laboratories participating in this program should routinely report MDLs achieved for a given analyte.

Many of the methods cited below for priority pollutants correspond to the methods established by EPA for fresh water analyses. Modifications or substitute methods (e.g., additional extract concentration steps, larger sample sizes, or concentration of extracts to smaller volumes) might be necessary to properly determine analyte concentration in seawater or to meet the desired MDLs.

Detailed methods for the analysis of organic and inorganic priority pollutants in water are referenced in the Federal Register (1984, Vol. 49, No. 209) and "Methods for Chemical Analysis of Water and Wastes" (EPA, 1982). Additional approved methods can be found in "U.S. EPA Contract Lab Program" (EPA, 1986b), APHA "Standard Methods for the Analysis of Water and Wastewater" (1989), ASTM "Annual Book of Standards, Part 31, Water" (1980), and Tetra Tech (1985). Most of these methods will require modification to achieve low MDLs in seawater. Analysis of the semivolatile organic priority pollutants involves a solvent extraction of water with an optional sample cleanup procedure and analysis using GC or GC/MS Tetra Tech (1986). The volatile priority pollutants are determined using purge and trap techniques and analyzed by either GC or GC/MS. If dioxin analysis is necessary, methods of Mehrle et al. (1988) should be consulted.

Other methods available for metals are: cadmium, copper, lead, iron, zinc, silver (Danielson et al., 1978); arsenic (EPRI, 1986); selenium and antimony (Sturgeon et al., 1985); very low levels of mercury (Bloom et al., 1983); tributyltin (Rice 1987).

A primary requirement of the analysis of seawater for inorganic and organic priority pollutants is obtaining detection limits that will result in usable, quantitative data that can subsequently be compared to applicable marine water quality criteria to determine compliance with the LPC. Many existing EPA methods for fresh water analysis need to be adapted to achieve environmentally meaningful detection limits in seawater. Particularly of concern are procedural blanks and matrix interferences caused by the salt in seawater. Some modifications to the analytical methods for organic compounds might be required to sufficiently lower the MDLs. For example, it is recommended that sample extracts be concentrated to the lowest possible volume prior to instrumental analysis, and that instrumental injection volumes be increased in order to lower the limits of detection for the analytical methods used. All PCB and pesticide analytes

should be analyzed by GC/ECD, since the GC/ECD methods are more sensitive to these compounds and will lower the detection limits. PCB should be quantified as specific congeners (Mullin et al., 1984; Stalling et al., 1987) and as total PCB based on the summation of particular congeners. Methods for specific PCB congener analysis are available from NOAA (1989). The congener method is accurate, provides lower detection limits, and is less subject to matrix interferences based on the selection of the individual PCB congeners used to quantify PCB.

The analysis of metals in seawater is subject to matrix interferences from sea salts, particularly sodium and chloride ions, when the samples are concentrated prior to instrumental analysis. The presence of salts in seawater samples might require the use of alternate analytical approaches to the EPA approved freshwater methods to achieve the desired MDLs. The gold amalgamation method with cold vapor Atomic Absorption Spectrophotemetry (AAS) analysis is recommended to eliminate seawater matrix interferences for mercury analysis. Methods using solvent extraction and AAS analysis might be required to reduce seawater matrix interferences for the analysis of other target metals. Graphite furnace AAS techniques after extraction are recommended for the analysis of metals with the exception of mercury. Appropriate techniques should be used on the instruments to reduce salt interferences.

9.4.3 Quality Control

Chapter 13 presents a general discussion of appropriate quality assurance and control practices. The methods recommended for the analysis of priority pollutants in water include detailed quality control procedures and requirements. These guidelines should be followed closely throughout the chemical analyses. Minimum quality control procedures should include the analysis of a procedural blank and a matrix spike along with every 10 - 20 samples processed. Triplicate analysis of one sample and analysis of appropriate standard reference materials should be conducted with the same frequency as the blanks and matrix spikes. Standard reference materials for organic priority pollutants are not currently available for seawater, but reference materials for inorganics may be obtained from the organizations listed in Table 9.4. Seawater matrix spikes of target

analytes (e.g., seawater spiked with NIST SRM 1647 for PAH), should be used to fulfill analytical accuracy requirements. Some available standard reference materials for priority pollutant metals in seawater are NRC seawater CASS-1 and NRC seawater NASS-2.

Since many MDL goals might be well below what current freshwater methods are able to do, it is necessary that an appropriate part of the QA program require laboratories to establish their own MDLs and provide data to support their detection limits. It is also incumbent on participating laboratories to show that modifications of existing methods are adequately precise, accurate, and free of salt interference from sea water.

9.5 CHEMICAL ANALYSES OF TISSUES

9.5.1 Recommended Analytical Targets (Biota)

Bioaccumulation is evaluated by analyzing the tissue of the test organisms for contaminants that are selected from the list of target analytes as being of contaminants of concern for a specific dredged material. Sediment chemistry data and available information on the bioaccumulation potential of those analytes has to be interpreted to establish which compounds are contaminants of concern in the tissues of biota.

The n-octanol/water partition coefficient (K_{ow}) has traditionally been used to estimate the bioconcentration factors (BCFs) of many chemicals, including the priority pollutants, in organism/water systems (Chiou et al., 1977; Kenaga and Goring, 1980; Veith et al., 1980; Mackay, 1982).

When identifying organic contaminants of concern for bioaccumulation, a useful rule of thumb is that the potential for bioaccumulation increases as K_{ow} increases. This general relationship is often true for compounds with log K_{ow} less than approximately 6. Above this value there is less of a tendency for bioaccumulation potential to increase with increasing K_{ow}. Consequently, the relative potential for bioaccumulation of organic compounds can be estimated from the K_{ow} of the compounds. EPA (1985) recommends that compounds for which the log K_{ow} is greater than 3.5 be flagged for consideration for further evaluation of bioaccumulation potential. Based on the existing data, the organic compound classes of

priority pollutants with the greatest potential to bioaccumulate are polynuclear aromatic hydrocarbons (PAH), PCBs, pesticides, and some phthalate esters. Generally, the volatile organic, phenol, and organonitrogen priority pollutants are not readily bioaccumulated. Some exceptions might be the chlorinated benzenes and the chlorinated phenols. Table 9.5 indicates the relative bioaccumulation potential of organic priority pollutants based on K_{ow}. If PCBs or PAHs are identified for analysis in tissues, the guidance on selection of specific analytical target compounds in Sections 9.3.1 and 9.3.2 should be followed.

The priority pollutant metals that might tend to bioaccumulate based on available BCF data are mercury, copper, arsenic, cadmium, zinc, lead, and chromium. Table 9.6 ranks the bioaccumulation potential of the priority pollutant metals based on calculated BCFs. Tables 9.5 and 9.6 have to be used with caution, because they are based on calculated bioconcentration from water. Sediment bioaccumulation tests, in contrast, are concerned with accumulation from a complex medium via all possible routes of uptake. The appropriate use of the tables is to help in selecting contaminants of concern for bioaccumulation analyses by providing a general indication of the relative potential for various chemicals to accumulate in tissues.

The strategy for selecting contaminants of concern for the chemical analysis of tissue of organisms should include three criteria: (1) the target analyte is present at levels of potential concern in the sediment as determined by sediment chemical analyses, (2) the target analyte has a high potential to accumulate and persist in tissues, and (3) the target analyte is of toxicological concern.

Analytes that might have a lower potential to bioaccumulate, but which are present at very high concentrations in the sediments, should also be included in the target list because the bioavailability of the compound might increase as organisms encounter high levels in sediments. In addition, compounds of a high accumulation potential and of high toxicological concern should be considered, even if present at low concentrations in the sediment.

Nonpriority-pollutant chemical components that are found in measurable concentrations in the sediments should be included as targets for the

TABLE 9.5. POTENTIAL FOR BIOACCUMULATION OF ORGANIC PRIORITY POLLUTANTS AND 301(h) PESTICIDES BASED ON OCTANOL/WATER PARTITION COEFFICIENTS (K_{ow})[a]

Pollutant	Octanol/Water Partition Coefficients (log K_{ow})
Di-n-octyl phthalate	9.2
Indeno(1,2,3-cd)pyrene	7.7
Benzo(ghi)perylene	7.0
PCB-1260	6.9
Mirex[b]	6.9
Benzo(k)fluoranthene	6.8
Benzo(b)fluoranthene	6.6
PCB-1248	6.1
2,3,7,8-TCDD (dioxin)	6.1
Benzo(a)pyrene	6.0
Chlordane	6.0
PCB-1242	6.0
4,4'-DDD	6.0
Dibenzo(a,h)anthracene	6.0
PCB-1016	5.9
4,4'-DDT	5.7
4,4'-DDE	5.7
Benzo(a)anthracene	5.6
Chrysene	5.6
Endrin aldehyde	5.6
Fluoranthene	5.5
Hexachlorocyclopentadiene	5.5
Dieldrin	5.5
Heptachlor	5.4
Heptachlor epoxide	5.4
Hexachlorobenzene	5.2
Di-n-butyl phthalate	5.1
4-Bromophenyl phenyl ether	5.1
Pentachlorophenol	5.0
4-Chlorophenyl phenyl ether	4.9
Pyrene	4.9
2-Chloronaphthalene	4.7
Endrin	4.6
PCB-1232	4.5
Phenanthrene	4.5
Fluorene	4.4
Anthracene	4.3
Methoxychlor[b]	4.3
Hexachlorobutadiene	4.3

TABLE 9.5. (Continued)

Pollutant	Octanol/Water Partition Coefficients (log K_{ow})
1,2,4-trichlorobenzene	4.2
Bis(2-ethylhexyl)phthalate	4.2
Acenaphthylene	4.1
Butyl benzyl phthalate	4.0
PCB-1221	4.0
Hexachloroethane	3.9
Acenaphthene	3.9
α-hexachlorocyclohexane	3.8
δ-hexachlorocyclohexane	3.8
β-hexachlorocyclohexane	3.8
γ-hexachlorocyclohexane	3.8
Parathion[b]	3.8
Chlorobenzene	3.8
2,4,6-trichlorophenol	3.7
β-endosulfan	3.6
Endosulfan sulfate	3.6
α-endosulfan	3.6
Naphthalene	3.6
Fluorotrichloromethane[c]	3.5
1,4-dichlorobenzene	3.5
1,3-dichlorobenzene	3.4
1,2-dichlorobenzene	3.4
Toxaphene	3.3
Ethylbenzene	3.1
N-nitrosodiphenylamine	3.1
P-chloro-m cresol	3.1
2,4-dichlorophenol	3.1
3,3'-dichlorobenzene	3.0
Aldrin	3.0
1,2-diphenylhydrazine	2.9
4-nitrophenol	2.9
Malathion[b]	2.9
Tetrachloroethene	2.9
4,6-dinitro-o-cresol	2.8
Tetrachloroethene	2.6
Bis(2-chloroisopropyl)ether	2.6
1,1,1-trichloroethane	2.5
Trichloroethene	2.4
2,4-dimethylphenol	2.4
1,1,2,2-tetrachloroethane	2.4
Bromoform	2.3
1,2-dichloropropane	2.3
Toluene	2.2

TABLE 9.5. (Continued)

Pollutant	Octanol/Water Partition Coefficients (log K_{ow})
1,1,2-trichloroethane	2.2
Guthion[b]	2.2
Dichlorodiflouromethane[c]	2.2
2-chlorophenol	2.2
Benzene	2.1
Chlorodibromomethane	2.1
2,4-dinitrotoluene	2.1
2,6-dinitrotoluene	2.0
Trans-1,2-dichloropropene	2.0
Cis-1,3-dichloropropene	2.0
Demeton[b]	1.9
Chloloform	1.9
Dichlorobromomethane	1.9
Nitrobenzene	1.9
Benzidine	1.8
1,1-dichloroethane	1.8
2-nitrophenol	1.8
Isophorone	1.7
Dimethyl phthalate	1.6
Chloroethane	1.5
2,4-dinitrophenol	1.5
1,1-dichloroethylene	1.5
Phenol	1.5
1,2-dichloroethane	1.4
Diethyl phthalate	1.4
N-nitrosodipropylamine	1.3
Dichloromethane	1.3
2-chloroethylvinylether	1.3
Bis(2-chloroethoxy)methane	1.3
Acrylonitrile	1.2
Bis(2-chloroethyl)ether	1.1
Bromomethane	1.0
Acrolein	0.9
Chloromethane	0.9
Vinyl chloride	0.6
N-nitrosodimethylamine	0.6

(a) Adapted from Tetra Tech (1985).
(b) 301(h) pesticides not on the priority pollutant list.
(c) No longer on priority pollutant or 301(h) list.

TABLE 9.6. POTENTIAL FOR BIOACCUMULATION OF TRACE METAL PRIORITY POLLUTANTS BASED ON EMPIRICAL MEAN BIOCONCENTRATION FACTORS (BCF)[a]

Pollutant	log BCF[b]
Methylmercury	4.6
Phenylmercury	4.6
Mercuric acetate	3.5
Copper	3.1
Zinc	2.8
Arsenic	2.5
Cadmium	2.5
Lead	2.2
Chromium IV	2.1
Chromium III	2.1
Mercury	2.0
Nickel	1.7
Thallium	1.2
Antimony	ND
Cyanide	ND
Asbestos	ND
Silver	ND
Selenium	ND
Beryllium	ND

(a) Adapted from Tetra Tech (1986b).

(b) ND = no data.

tissue analyses if review of the literature indicates that these analytes have the potential to bioaccumulate in animals (i.e., have high K_{ow}s or BCFs) and persist in animal tissues, and are of toxicological concern.

9.5.2 Selection of Analytical Chemical Techniques (Biota)

At present, formally approved standard methods for the analysis of priority pollutants in tissues are not available. However, several studies conducted for EPA and other agencies have developed analytical methods capable of identifying and quantifying most organic and inorganic priority pollutants in tissues. The amount of tissue required for analysis is somewhat dependent on the analytical procedure. As a general guideline, 25 g (wet weight) of tissue should be delivered to the laboratory for organic analysis and 10 g delivered for metals analysis; an additional 25 g may be necessary for supplemental analyte determinations.

The detection limits achieved for target analytes in tissue depend on the sample size as well as the specific analytical procedure. The MDL presented in a particular analytical method should serve as goals for priority pollutant tissue analyses. MDLs should be determined for all analytes according to guidance in 40 CFR 136; Appendix A. Detection limits have to be specified based on the intended use of the data and specific needs of each evaluation.

The existing methods for the analysis of priority pollutants in tissue involve two separate procedures: one for organic compounds and another for metals. The recommended methods for the analysis of semivolatile organic pollutants are described in "Extractable Toxic Organic Compounds, Standard Analytical Procedures of the NOAA National Analytical Facility" (NOAA, 1989). These methods are currently being used in the NOAA National Status and Trends Program. The procedure involves serial extraction of homogenized tissue samples with methylene chloride, followed by alumina and gel permeation column cleanup procedures that remove coextracted lipids. An automated gel permeation procedure described by Krahn et al. (1988) is recommended for rapid, efficient, and reproducible sample cleanup. The methylene chloride extract is concentrated and analyzed for semivolatile

organic pollutants using gas chromatography with capillary fused-silica columns to achieve sufficient analyte resolution.

Chlorinated hydrocarbons (e.g., PCBs and chlorinated pesticides) should be analyzed by gas chromatography/electron capture detection (GC/ECD). It is recommended that PCBs be quantitated as specific congeners (Mullin et al., 1984; Stalling et al., 1987) and not by industrial formulations (e.g., arochlors) because the levels of PCBs in tissues result from complex processes including selective accumulation and metabolism. See the discussion of PCB in Section 9.3.2. Lower detection limits and positive identification of PCBs and pesticides can be obtained using chemical ionization mass spectrometry if necessary.

The same tissue extract is analyzed for other semivolatile pollutants (e.g., PAHs phthalate esters, nitrosamines, phenols, etc.) using gas chromatography/mass spectrometry (GC/MS) as described in NOAA (1989), Battelle (1985), and Tetra Tech (1986b). These GC/MS methods are similar to EPA Method 8270 for solid wastes and soils (EPA, 1986). The lowest detection limits are achieved by operating the mass spectrometer in the selected ion monitoring (SIM) mode. Decisions to perform analysis of nonchlorinated hydrocarbons and the interpretation of resulting data should consider that many of these analytes are readily metabolized by most fish and many marine invertebrates.

If analysis of tissue samples for volatile priority pollutants is necessary, analytical methods are cited in Tetra Tech (1986b). The lipid content of the biological material is of importance in the interpretation of bioaccumulation information. A lipid determination should be performed on all biota submitted for organic analyses and the method of Bligh and Dyer (1959) is recommended. If other methods are used, they should be referenced to results from Bligh and Dyer's method. If dioxin analysis is being performed, methods by Mehrle et al. (1988), Smith et al. (1984), or Kuehl et al. (1987) should be consulted.

The analysis for priority pollutant metals involves a nitric acid or nitric acid/perchloric acid digestion of the tissue sample and subsequent analysis of the acid extract using AAS or Inductively Coupled Plasma (ICP) techniques. Procedures for the digestion of tissue samples for priority pollutant metals can be found in Tetra Tech (1986b). The methods used in the NOAA Status and Trends Program (NOAA, 1989) may also be used and are

recommended when very low detection levels are required. Microwave technology may be used for tissue digestion to reduce contamination and improve recovery of metals (Nakashima et al., 1988). This methodology is consistent with tissue analyses performed for the NOAA Status and Trends Program except for the microwave heating steps. Mercury analysis requires the use of cold vapor AAS methods. The matrix interferences encountered in analysis of metals in tissue might require case-specific techniques for overcoming interference problems. If tributyltin analysis is being performed, the methods of Rice et al. (1987) or Uhler et al. (1989) should be consulted.

9.5.3 Quality Control

Chapter 13 presents a general discussion of appropriate quality assurance and control practices for tissue analysis. A procedural blank (to measure potential contamination from laboratory procedures) and a matrix spike (to measure the recoveries of the target analytes from a sample matrix) should be performed with each 10 - 20 samples. Triplicate analysis of one sample (to measure analytical precision) and appropriate standard reference materials (to measure analytical accuracy) should be performed with the same frequency as the blanks and matrix spikes. Standard reference materials for organic priority pollutants in tissues are currently not available. The National Institute for Standards and Technology (NIST) is presently developing standard reference materials (SRM) for organic analytes. Tissue matrix spikes of target analytes should be used to fulfill analytical accuracy requirements for organic analyses. Standard reference materials for priority pollutant metals include NRC dogfish liver tissue (DOLT-1), dogfish muscle tissue (DORM-1), and lobster hepatopancreas reference tissue (TORT-1); and IAEA fish flesh MA-A-2(TM) and mussel tissue MAM-2(TM). Marine reference materials and standards for inorganic constituents in tissue may be obtained from the organizations listed in Table 9.4.

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10.0 GUIDANCE FOR PERFORMING BIOLOGICAL EFFECTS TESTS

Biological effects tests with the dredged material may be necessary if Tiers I and II evaluations suggest that the dredged material contains contaminants that might result in an unacceptable adverse impact to the benthic environment and/or the water column. Bioassays with deposited dredged material are used to determine the effects on benthic (bottom-dwelling) organisms; bioassays with suspensions/solutions of dredged material are conducted to determine the effects on water column organisms. Bioassays should be conducted only in the tiers appropriate to provide the information necessary and sufficient for decisions.

The objective of water column bioassays (if they are necessary) is to determine the potential impact of dissolved and suspended contaminants on organisms in the water column, after considering initial mixing. Test organisms should be representative of sensitive water column organisms occurring in the vicinity of the disposal site.

The objective of benthic bioassays is to determine the potential impact of the settleable fraction of the dredged material on benthic organisms at and beyond the boundaries of the disposal site. The organisms used in testing should be representative of sensitive infaunal or epifaunal organisms occurring in the vicinity of the disposal site. Benthic bioassays are intended to determine the potential toxicity of a dredged material as distinct from its physical effects. In tests similar to those described here, some animals are known to be affected by differences in sediment textures or absence of sediments (DeWitt et al., 1988; McFarland, 1981). It is important, therefore, that test organisms and control and reference sediments are selected to minimize the artifactual effects of differences in grain size. If the sediment texture varies considerably between the dredged material and the control or reference sediments, organisms sensitive to grain size effects have to either not be used, or the effects of grain size have to be determined and considered when designing benthic bioassays and evaluating the test results.

10.1 TIER II: WATER COLUMN EFFECTS

10.1.1 Determination of the Need for Additional Water Column Testing

The initial step of the Tier II water column evaluation determines the need for additional testing by considering the bulk concentration of contaminants in the dredged material, the initial mixing at the disposal site, and applicable marine water quality criteria. If the need for additional testing is not demonstrated, the potential for water column impacts is considered to be in compliance with the regulations. If additional testing is needed, it is conducted according to the guidance in Section 10.1.2 or 10.2.1 as appropriate.

10.1.1.1 Chemical Analysis

Analytical procedures for specific constituents in water are presented Section 9.4.2.

10.1.1.2 Need for Additional Testing

The determination of the need for additional water column testing involves determination that the limiting permissible concentration (LPC) would be met if the bulk concentration of contaminants were to be dissolved in the water at the disposal site upon dumping. This is determined using the appropriate numerical computer model described in Appendix B. Versions of the models for use on IBM compatible microcomputers and example applications are found on the floppy disk in the pocket inside the back cover of this manual.

The disk contains models appropriate to instantaneous discharges, continuous discharges, and hopper dredge discharges, as described in Appendix B. The appropriate model for the proposed operation under consideration has to be selected according to the guidance in Appendix B. Within that model the application for determination of need for additional testing is selected.

The model need only be run for the contaminant of concern that would require the greatest dilution. If this contaminant would meet the LPC, all

others requiring lesser dilution would also meet the LPC. The contaminant that would require the greatest dilution is determined by calculating the dilution that would be required to meet the applicable marine quality criterion. To determine the dilution (D) the following equation is solved for each contaminant of concern:

$$D = C_o / C_{WQ}$$

where C_o = bulk sediment concentration of the contaminant in µg/kg

C_{WQ} = applicable marine water quality criterion for the contaminant in µg/L

A data analysis routine is available in the dispersion models to perform these calculations and identify the contaminant of concern that would require the greatest dilution.

The concentration of the contaminant that would require the greatest dilution is then modeled. The key parameter derived from the dispersion model is the maximum concentration of the contaminant in the water column outside the boundary of the disposal site after the 4 hr initial mixing period. If this concentration is below the applicable marine water quality criterion, no additional testing is required and the water column evaluation complies with the regulations. If this concentration exceeds the applicable marine water quality criterion, additional testing is necessary. Since the model calculations at this stage are based on bulk concentrations which will not totally dissolve upon discharge, if further testing is indicated the procedures described in Section 10.1.2 or 10.2.1 have to be used. The procedure described above cannot be used to evaluate water column impacts; it can be used <u>only</u> to determine whether additional testing for potential water column impacts as described in Section 10.1.2. or 10.2.1 is necessary.

10.1.2 Testing for Potential Water Column Impacts

The potential for impacts in the water column can be evaluated in Tier II if there are applicable marine water quality criteria for all contaminants of concern and synergistic effects are not suspected (see Section 227.13(c)(1) of the regulations). Even though this Tier II

evaluation utilizes chemical rather than biological testing, it is placed in the chapter on biological testing because the results are used to evaluate biological effects by comparison to water quality criteria, which are based on biological tests.

The Tier II water column evaluation considers dissolved concentrations (in contrast to bulk concentrations used in Section 10.1.1) of contaminants of concern from the dredged material, after allowance for initial mixing, compared with applicable marine water quality criteria.

10.1.2.1 Dredged Material Preparation (Standard Elutriate)

Prior to use, all glassware should be thoroughly cleaned. Glassware should be washed with detergent, rinsed 5 times with tap water, placed in a clean 10 percent HCl acid bath for a minimum of 4 hr, rinsed 5 times with tap water, and then thoroughly flushed with distilled or deionized water.

The dredged material may be prepared using seawater collected from the disposal site, clean seawater, or artificial sea salt mixtures.

Subsample approximately 1 L of the dredged material from the well-mixed original sample. Combine the dredged material and unfiltered water in a sediment-to-water ratio of 1:4 on a volume basis at room temperature (22° ± 2°C). This is best accomplished by volumetric displacement. After the correct ratio is achieved, mix vigorously for 30 min with a magnetic stirrer. Also stir the flasks manually at 10 min intervals to ensure complete mixing. After the 30 min mixing period, allow the mixture to settle for 1 hr. Siphon off the supernatant and/or centrifuge filter through a 0.45 µm filter to remove particulates.

10.1.2.2 Chemical Analysis

Analytical procedures for specific constituents in water are presented in Section 9.4.2.

10.1.2.3 Determination of Compliance

The Tier II water column effects evaluation involves running a numerical computer model to determine compliance with the LPC. A

description of the model is contained in Appendix B, and the models are found on the floppy disk in the pocket inside the back cover of this manual.

The disk contains models appropriate to instantaneous discharges, continuous discharges, and hopper dredge discharges, as described in Appendix B. The appropriate model for the proposed operation under consideration has to be selected according to the guidance in Appendix B. Within that model the Tier II application for comparison to water quality criteria is selected.

The model need only be run for the contaminant of concern requiring the greatest dilution. If this contaminant meets the LPC, all others requiring lesser dilution will also meet the LPC. The contaminant requiring the greatest dilution is determined by calculating the value of dilution required to meet the applicable marine water quality criterion for every contaminant of concern. To determine the dilution (D) the following equation is solved for each contaminant of concern:

$$D = (C_o - C_{BG}) \ / \ (C_{WQ} - C_{BG})$$

where C_o = concentration of the dissolved contaminant in the standard elutriate in µg/L

C_{BG} = background concentration of the dissolved contaminant in the disposal site water in µg/L

C_{WQ} = applicable marine water quality criterion for the contaminant in µg/L

A data analysis routine is available in the dispersion models to perform these calculations and identify the contaminant of concern requiring the greatest dilution.

The concentration of the contaminant requiring the greatest dilution is then modeled. The key parameters derived from the model are the maximum concentration of the contaminant outside the boundary of the disposal site during the 4 hr initial mixing period and the maximum concentration anywhere in the marine environment after the 4 hr initial mixing period. These values are compared with applicable marine water quality criteria according to the guidance in Section 5.1.2 to determine compliance with the regulations.

10.2 TIER III: BIOASSAYS

10.2.1 Water Column Bioassays

Tests to determine the impact of the dredged material on water column organisms involve exposing organisms to a dilution series containing both dissolved and suspended components of the dredged material. The test organisms are added to the exposure chambers and exposed for prescribed period of time (usually 96 hr). Tests with zooplankton and larvae may be run for shorter periods. The surviving organisms are examined at specified intervals to determine if the test material is producing an effect. An introductory guide to general toxicity testing is presented in part 8000 of Standard Methods (1989). Biological testing aspects of the Standard Methods guidelines may be followed as long as they do not conflict with the guidelines in this manual.

10.2.1.1 Species Selection

Section 227.27(c) of the regulations defines appropriate sensitive water column marine organism to mean at least one species each representative of phytoplankton or zooplankton, crustacean or mollusc, and fish. It is recommended that the test organisms be fish, crustaceans, and zooplankton. The test species may be from healthy laboratory cultures or may be collected from the vicinity of the disposal site or in an area of similar water quality and substrate sedimentology, but not within the influence of former or active disposal sites or other discharges. Ideally the test species should be the same or closely related to those species that naturally dominate biological assemblages in the vicinity of the disposal site. Characteristics and examples of some appropriate species for water column testing are presented in Figure 10.1. With reasonable care test organisms can be collected from wild populations and maintained in the laboratory under controlled conditions with low mortality. If the proposed test species has not been used previously, a preliminary study should be conducted to assess the ability of the field collected species to acclimate to laboratory conditions.

CHARACTERISTICS[a]

- Comply with Section 227.27(c)
- Readily available year-round
- Tolerate handling and laboratory conditions
- Consistent, reproducible response to toxicants
- Related phylogenetically and/or ecological requirements to species characteristic of the water column of the disposal site area in the season of the proposed disposal
- Can be readily tested as juveniles or larvae to increase sensitivity
- Important ecologically, economically, and/or recreationally

EXAMPLES[a]

Crustaceans

Mysids

**Mysidopsis* sp.

**Neomysis* sp.

**Holmesimysis* sp.

Grass Shrimp, *Palaemonetes* sp.

Commercial shrimp, *Penaeus* sp.

Oceanic shrimp, *Pandalus* sp.

Blue crab, *Callinectes sapidus*

Cancer crab, *Cancer* sp.

Fish

*Silversides, *Menidia sp.*

*Shiner perch, *Cymatogaster aggregata*

Pinfish, *Lagodon rhomboides*

Spot, *Leiostomus xanthurus*

Zooplankton

*Copepods, *Acartia* sp.

*Larvae of:

mussels, *Mytilus edulis*
oysters, *Crassostrea virginica*
Ostrea sp.
recommended crustacean species

[a]Neither characteristics nor examples are presented in order of importance, except that the first characteristic is mandatory and recommended species are marked by an asterisk.

FIGURE 10.1. CHARACTERISTICS AND EXAMPLES OF APPROPRIATE SPECIES FOR DETERMINING POTENTIAL WATER COLUMN IMPACTS OF DREDGED MATERIAL DISPOSAL. THE LISTS ARE ILLUSTRATIVE BUT NOT EXHAUSTIVE.

In addition to species occurring at the disposal site, other representative commercially available species or sensitive life stages of economically important species may be used. Mysids of the genera *Mysidopsis, Neomysis,* or *Holmesimysis* are highly recommended as test species. Embryo-larval stages of crustaceans, molluscs, or fish are also appropriate sensitive marine organisms. Adult fish and molluscs and large crustaceans are not recommended for water column testing because of their generally greater resistance to contaminants.

Regardless of their source, test organisms should be collected and handled as gently as possible. Transport field collected animals to the laboratory in seawater of the same salinity and temperature as the water from which they were obtained. Hold them in the laboratory no longer than necessary, preferably no more than 2 wk, before they are used. During this period they have to be gradually acclimated to the salinity and temperature at which the test will be conducted. Animals from established laboratory cultures can be held indefinitely but may also need to be gradually acclimated to the test temperature and salinity if test conditions differ from holding conditions.

10.2.1.2 Apparatus

Water column bioassays are generally run as static exposures for a period of 96 hr. The exposures should be conducted in glass chambers equipped with covers to minimize evaporation. The size of the chambers depends on the size of the test species. All glassware has to extremely clean. Before use, glassware should be washed with detergent, rinsed 5 times with tap water, placed in a clean 10 percent HCl acid bath for a minimum of 4 hr, rinsed 5 times with tap water, and then thoroughly flushed with distilled or deionized water.

Equipment and facilities have to be available to provide acceptable lighting requirements and temperature control. An environmental incubator or a water bath system that allows temperature control within $\pm 1°C$ is recommended. A waterproof light box or table is recommended for observing zooplankton and larvae.

10.2.1.3 Experimental Conditions

Water column bioassays should be conducted under conditions known to be nonstressful to the test organisms. Salinity should be stable within +2°/oo and temperature within ±2°C throughout the exposure period. Dissolved oxygen concentration should not be allowed to fall below 4 mg/L. The temperature, salinity, dissolved oxygen, and pH in the test containers should be measured and recorded daily.

10.2.1.4 Experimental Procedures

(1) Dredged Material Preparation

Prior to use, all glassware should be thoroughly cleaned. Glassware should be washed with detergent, rinsed 5 times with tap water, placed in a clean 10 percent HCl acid bath for a minimum of 4 hr, rinsed 5 times with tap water, and then thoroughly flushed with distilled or deionized water. Seawater collected from the disposal site may be used to prepare the dredged material suspension and as dilution water in the test. If disposal site water is not used, clean seawater or artificial sea salt mixtures adjusted to the test salinity may be used instead.

Subsample approximately 1 L of the dredged material from the well-mixed original sample. Combine the dredged material and unfiltered water in a volumetric sediment-to-water ratio of 1:4 at room temperature (22° ±2°C). This is best accomplished by volumetric displacement. After the correct ratio is achieved, mix vigorously for 30 min with a magnetic stirrer. Also stir the flasks manually at 10 min intervals to ensure complete mixing. After the 30 min mixing period, allow the mixture to settle for 1 hr. The liquid plus the material remaining in suspension after the settling period represents the 100 percent liquid plus suspended particulate phase. Carefully siphon the supernatant, without disturbing the settled material, and immediately use it for testing. With some very fine-grained dredged materials, it may be necessary to centrifuge the supernatant for a short time. The suspension should be clear enough at the first observation time for the organisms to be visible.

(2) Test Design

The number of replicate exposure chambers per treatment and the number of organisms per exposure chamber should be determined according to the guidance in Section 12.1. A minimum of 5 replicates per treatment and 10 organisms per replicate are recommended unless Section 12.1 indicates otherwise. In all cases the single most important concern is that the organisms not be stressed by overcrowding. At least 3 concentrations of dredged material suspension should be tested; recommended minimum test concentrations are 100, 50, and 10 percent. If disposal site water is used, both 100 percent disposal site water and water of the type in which the animals were held prior to testing should be included as control treatments.

Assign test organisms randomly to the different treatments, using animals of approximately equal size. Zooplankton and larvae are usually transferred with the aid of a pipette. Take care that air is not trapped on or under the animals during the transfer process. Larger animals may be transferred in fine-mesh nets. Discard any animals that are dropped, physically abused, or exhibit abnormal behavior.

Cover the test chambers and place them in an incubator or water bath. Randomize placement of the test containers. During the exposure period, do not replace the test medium, do not supply aeration (unless necessary to keep dissolved oxygen concentration above 4 mg/L), and do not stir the test solutions. Some species of crustaceans, particularly larval forms, will require feeding during the test.

Recommended test duration is 48 hr for zooplankton and larvae, and 96 hr for other organisms. At 0, 4, 24, 48, (and perhaps 72 and 96) hr, record the number of live animals in each chamber. Use a light box or dissecting microscope, taking care to minimize the stress to the animal. Always count the number living, not the number dead. An animal is judged dead if it does not move after the water is gently swirled or after a sensitive part of its body is gently touched with a probe. At each observation, use a pipette or forceps to remove dead organisms, molted exoskeletons, and food debris.

10.2.1.5 Data Analysis

(1) Data Presentation

Present the data for each test species in separate tables that include the following information: the scientific name of the test species, the number of animals in each treatment at the start of the test, the number of animals alive at each observation period, the number of animals alive from each chamber at the end of the test, and any additional information such as behavioral abnormalities.

(2) Statistical Analysis

It is possible that no mortality will be observed in any treatments or that survival in the dredged material will be equal to or higher than survival in the controls. In either of these situations, there is no need for statistical analyses and no indication of adverse effects due to the dredged material. If survival in the controls is greater than 90 percent and is higher than in the dredged material treatments, the data have to be evaluated statistically to determine whether there is a significant difference in survival between the control and any dredged material sample. If greater than 50 percent mortality occurs in any of the dredged material treatments, it might be possible to calculate an LC50 value (lethal concentration to 50 percent of the sample). If less than 50 percent mortality occurs in any of the dredged material treatments it is not possible to calculate an LC50. In such cases the LC50 is considered to be 100 percent suspension in determining compliance as discussed in Section 10.2.1.6. Statistical procedures recommended for analyzing the test data are described in detail in Sections 12.2.1 and 12.2.2.

10.2.1.6 Determination of Compliance

The Tier III water column effects evaluation involves running a numerical model to determine compliance with the LPC. A description of the

models is contained in Appendix B, and the models are found on the floppy disk in the pocket inside the back cover of this manual.

The disk contains models appropriate to instantaneous discharges, continuous discharges, and hopper dredge discharges, as described in Appendix B. The appropriate model for the proposed operation under consideration has to be selected according to the guidance in Appendix B. Within that model the Tier III water column bioassay application is selected. The key parameters derived from the model for evaluating water column toxicity in Tier III are the maximum concentration of dredged material in the water column outside the boundary of the disposal site during the 4 hr initial mixing period, and the maximum concentration in the water column anywhere in the marine environment after the 4 hr initial mixing period.

Compliance with the LPC is evaluated by constructing a time-concentration acute mortality curve from the bioassay data, which is compared graphically to the time-concentration dilution curve as determined by the model. A time-concentration acute mortality curve is constructed from the bioassay data by calculating the LC50 for each observation time and plotting the LC50 estimates for each observation against time, as in Figure 10.2. This illustrates the relationship of concentration and exposure time causing acute mortality in the bioassay.

To determine whether the LPC might be exceeded in the field, this time-concentration mortality curve is graphically compared to the expected dilution curve from the model, as in Figure 10.2. To accomplish this, the data in the final table of the model output are utilized. The maximum concentration outside the site boundaries is plotted against time on the same plot as the acute mortality data (Figure 10.2). If the model outputs of maximum concentrations inside and outside the site have not converged by 4 hr, the dilution curve is plotted using concentration outside the site during the first 4 hr and inside the site from 4 hr until the outputs converge.

To determine whether or not the proposed discharge complies with the LPC requirement that a concentration of 0.01 of the acutely toxic concentration not be exceeded outside the site boundaries during the first 4 hr and at any point after 4 hr, the two curves on this plot are compared. This comparison is easier if a curve representing 0.01 of the mortality

curve is plotted, as illustrated in Figure 10.2. Determination of compliance is made in accordance with the guidance in Chapter 6.1.

Figure 10.2 is a hypothetical case illustrating a situation where the LPC would not be met. This hypothetical illustration is only to illustrate the procedure for determination of compliance with the LPC; the typical plot might frequently resemble Figure 10.3 more than Figure 10.2. In Figure 10.2 the LPC would be exceeded after the 4 hr initial mixing period and at 8 and 24 hr because the concentration predicted by the dilution curve is greater than 0.01 of the time-concentration mortality curve. At 48 hr, the LPC would be satisfied, since the predicted concentration is less than 0.01 of the toxic concentration. However, at 72 hr, the LPC would again be exceeded. Both the 4 hr and long-term considerations of the LPC have to be met to satisfy the criteria. Therefore, this hypothetical situation would not meet the LPC.

Figure 10.3 is also a hypothetical case, illustrating a situation where the LPC would be met. In Figure 10.3, both the 4 hr and long-term requirements of the LPC are met. After 4 hr, the toxic concentration cannot be precisely specified but is greater than 100 percent of the original concentration, and during the 4 hr initial mixing period the predicted dilution is to a concentration far less than 0.01 of the acutely toxic concentration. Since the dilution curve and mortality curve continue to diverge, the LPC requirement that a concentration of 0.01 of the acutely toxic concentration shall not be exceeded is met both at the end of and beyond the 4 hr initial mixing period.

10.2.1.7 Quality Control Considerations

If less than 10 percent mortality (20 percent for zooplankton and larvae) occurs in the control treatment for a particular test species, the data for that species may be evaluated. Unacceptably high control mortality indicates that the organisms are being affected by important stresses other than contamination in the material being tested. These stresses may be due to injury or disease, unfavorable physical or chemical conditions in the test containers, improper handling or acclimation, or possibly unsuitable or contaminated water. Species selection and the potential effects of these and other variables should be carefully

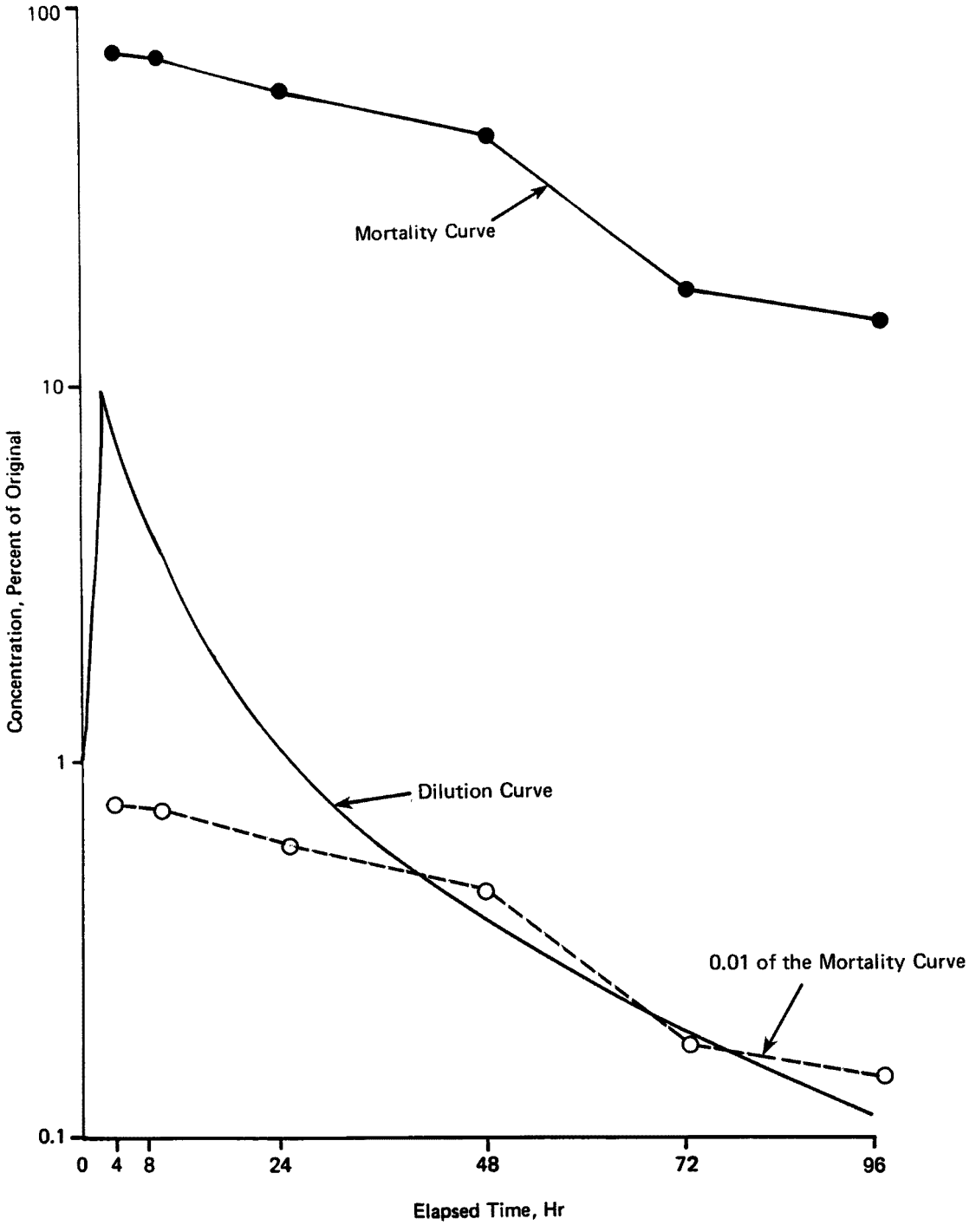

Figure 10-2. Comparison of hypothetical time-concentration mortality curve with hypothetical dilution curve illustrating non-compliance with the LPC.

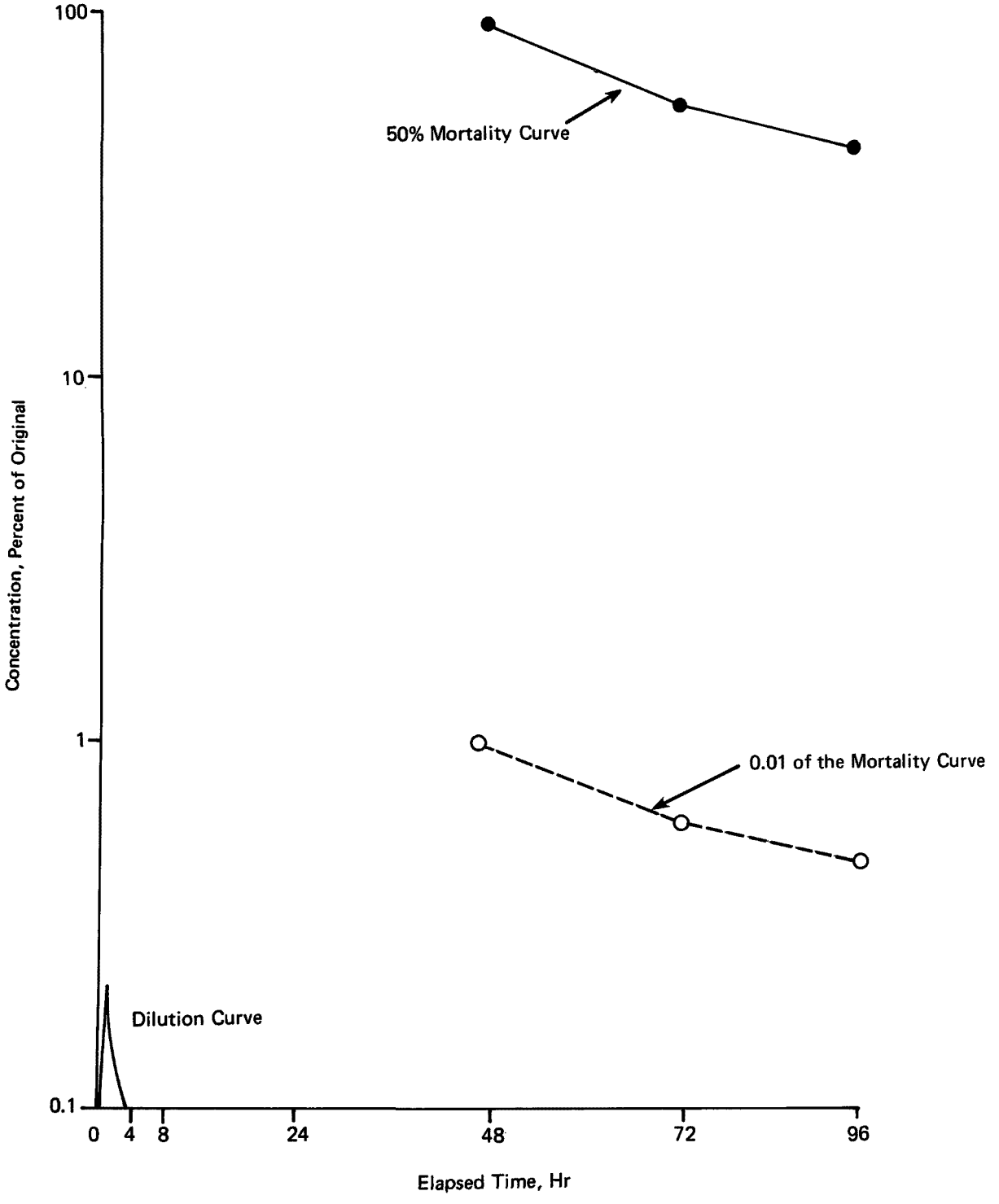

Figure 10-3. Comparison of typical time-concentration mortality curve with typical dilution curve illustrating compliance with the LPC.

examined in an attempt to reduce unacceptably high mortality if the test is repeated.

Reference toxicant tests should be performed routinely on all groups of organisms used in dredged material testing in order to determine their relative health and vigor. Many chemicals may be used satisfactorily as reference toxicants (Lee, 1980). Reference toxicant tests are performed in the absence of sediment. A geometric dilution series of 5 unreplicated concentrations is used. Nominal (rather than measured) concentrations are usually sufficient for reference toxicant tests. The concentration range should be selected to give greater than 50 percent mortality in at least one concentration and less than 50 percent mortality in at least one concentration. An initial pilot test using a very wide range of concentrations may be necessary to determine the proper concentration range for reference toxicant tests. Test duration is 24 hr. Ten organisms per exposure chamber are sufficient. Reference toxicant tests are usually conducted under static conditions. For each species mortality is determined and the LC50 is calculated as described in Section 12.2.2.

When data for a particular reference toxicant have been generated on at least 5 groups of organisms of a species, two standard deviations above and below the mean is established as the bounds of acceptability. When the next group of organisms of this species is tested with this reference toxicant, if the LC50 is within the bounds of acceptability, the group of organisms may be used for dredged material testing. If not, their response is atypical of the population, and that group of organisms should not be used for testing. The data from each reference toxicant test are added to the database and the bounds of acceptability are recalculated after each test in order to continuously improve the characterization of the typical response of the species. Reference toxicant tests should be conducted at least monthly on each species cultured in-house, and should be performed on each lot of purchased or field-collected organisms. The basic concept and application of reference toxicant tests is discussed by Lee (1980).

General quality assurance (QA) considerations applicable to biological tests are discussed in Chapter 13.

10.2.2 Benthic Bioassays

Bioassays with deposited dredged material are designed to determine whether the material is likely to produce unacceptable adverse effects on appropriate sensitive benthic marine organisms. The test animals are exposed to the test sediments for a specified period of time, and the number of survivors is recorded.

10.2.2.1 Species Selection

Benthic bioassays have to be conducted with appropriate sensitive benthic marine organisms. Section 227.27(d) of the regulations defines this to mean at least one species each representing filter-feeding, deposit-feeding, and burrowing species chosen from among the most sensitive species accepted by EPA and CE as being reliable test organisms to determine the potential for benthic impacts. Among these three groups, great differences in sensitivity to sediment associated contaminants have been demonstrated by research on contaminated sediments (e.g., Gentile, et al., 1988; Rogerson, et al., 1985) and experience under the MPRSA since biological testing of dredged material began in 1977. Infaunal amphipods are commonly the most sensitive of the three groups (Swartz et al., 1979; Mearns and Word, 1982; Rogerson, et al., 1985; Gentile, et al, 1988) in short-term toxicity tests with deposited sediment. Therefore, toxicity testing is best done with infaunal amphipods, and they are used in this manual as surrogates for the others in compliance with the requirement to test appropriate sensitive benthic marine organisms.

The test species should be related as closely as possible phylogenetically and ecologically to appropriate sensitive benthic marine organisms expected in the area of the disposal site at the time of the proposed operation. Commercially important benthic species occurring in the vicinity of the disposal site may also be used as test species. Characteristics and examples of some appropriate species for benthic testing are presented in Figure 10.4.

Because the sediment grain size is likely to vary considerably between the dredged material, the reference sediment, and the control sediment, any species selected for testing should first be evaluated for sensitivity to

CHARACTERISTICS[a]

- Comply with Section 227.27(d)
- Readily available year-round
- Ingest sediments
- Tolerate grain sizes of dredged material and control and reference sediments equally well
- Consistent, reproducible response to toxicants
- Tolerate handling and laboratory conditions
- Related phylogenetically and/or ecological requirements to species characteristic of the disposal site area
- Can be readily tested as juveniles to increase sensitivities
- Important ecologically, economically, and/or recreationally

EXAMPLES[a]

Infaunal amphipods

* *Rhepoxynius* sp.
* *Ampelisca* sp.
* *Eohaustorius* sp.

Burrowing Polychaetes

* *Neanthes* sp.
* *Nereis* sp.

Nephthys sp.
Glycera sp.
Arenicola sp.
Abarenicola sp.

Crustaceans

Mysids-*Mysidopsis* sp.
Neomysis sp.
Holmesimysis sp.
Commercial shrimp, *Penaeus* sp.
Grass shrimp, *Palaemonetes* sp.
Sand shrimp, *Crangon* sp.
Ocean shrimp, *Pandalus* sp.
Blue crab, *Callinectes sapidus*
Cancer crab, *Cancer* sp.

Molluscs

Yoldia limatula
Macoma sp.

[a]Neither characteristics nor examples are presented in order of importance, except that the first characteristic is mandatory and recommended species are marked by an asterisk.

FIGURE 10.4. CHARACTERISTICS AND EXAMPLES OF APPROPRIATE SPECIES FOR DETERMINING POTENTIAL BENTHIC IMPACTS OF DREDGED MATERIAL DISPOSAL. THE LISTS ARE ILLUSTRATIVE BUT NOT EXHAUSTIVE.

the effects of grain size (DeWitt, et al., 1988; McFarland, 1981). If sensitivity of a candidate test species to the different grain sizes of the dredged material, control, and reference sediments to be used in a particular test is great enough to be of concern, other species shown to tolerate the range of grain sizes represented by the dredged material, reference, and control sediments should be considered. It is also possible to conduct the test and mathematically account for any grain size effects by a method similar to that used by DeWitt et al. (1988) for the amphipod *Rhepoxynius abronius*. The data these authors present can be used directly to describe the relationship between survival and sediment grain size in *R. abronius* bioassays compatible with their method. A data analysis approach similar to that of DeWitt et al. (1988) can be used in conjunction with an experimental design patterned after McFarland (1981) to determine the relationship between sediment grain size and survival for other species. In addition to the sediment tests, all species will also be tested with a standard reference toxicant to determine the relative health of the test animals as part of the quality control program discussed in Section 10.2.2.7.

The number of animals of each species in each replicate exposure chamber should be determined according to the guidance in Section 12.1. A minimum of 20 animals are recommended unless Section 12.1 indicates fewer are sufficient. In all cases the single most important concern is that the organisms not be stressed by overcrowding. Juvenile forms of molluscs or large crustaceans are recommended because they are generally more sensitive than adults. The identity of all species should be verified by experienced taxonomists, particularly for animals collected in the field. If the bioassay animals are also to be used in estimating bioaccumulation potential, the factors discussed in Section 11.2.1 for species selection should also be considered.

Handle the animals as gently as possible, placing them in buckets containing about 3 cm of sediment and several liters of seawater. Transport the animals to the laboratory in well aerated water from the collection site. Benthic animals should be held in the laboratory in aquaria with a 5 cm layer of control sediment. This sediment should be sieved and contain no organisms which would adversely affect test results.

Animals from established laboratory cultures can be held indefinitely. Animals collected from the field should be held no longer than necessary, preferably for no more than 10 days, before they are used in testing. During this period, they have to be gradually acclimated, if necessary, to the temperature and salinity at which the toxicity test will be conducted.

10.2.2.2 Apparatus

The test system described by Swartz et al. (1985) for the phoxocephalid amphipod *Rhepoxynius abronius* is recommended for bioassays with this and other amphipod species. Some amphipods do not survive well under static conditions and, therefore, should be tested using only a continuous flow or static renewal test design. The American Society for Testing and Materials or ASTM, (ASTM Headquarters, 1916 Race St., Philadelphia, PA 19013) is preparing standardized guidance on conducting sediment bioassays with amphipods. The guidance will consist of a generic test design and species-specific appendices. When released by ASTM, this guidance for testing all species of amphipod may be followed on all points that do not conflict with this manual.

Larger aquaria ($\geq$20 L) are recommended for larger species. Tests with large aquaria should be run under continuous flow conditions with 90 percent of the water volume replaced at least once every 4 hr. If a continuous flow seawater supply is not available, the animals may be tested using a static renewal design. Seventy-five percent of the water in each exposure chamber should be renewed 1 and 48 hr after test initiation and at 48 hr intervals thereafter. Care should be taken to minimize resuspension of the sediments during water changes. The frequency of water changes should be increased if acceptable water quality cannot be maintained.

All glassware has to be extremely clean. Before use, glassware should be washed with detergent, rinsed 5 times with tap water, placed in a clean 10 percent HCl acid bath for a minimum of 4 hr, rinsed 5 times with tap water, and then thoroughly flushed with distilled or deionized water.

The dilution water used in both flow-through and static renewal tests should be of a temperature, salinity, and dissolved oxygen concentration known to be nonstressful to the test organisms, and should be stable throughout the exposure period. The seawater should be filtered (20 µm)

and the flow to the exposure chamber should be directed to achieve good mixing without disturbing the sediment on the bottom of the chamber. Static renewal tests should be conducted in a water bath or environmental chamber to maintain the temperature within ±1°C of the test temperature.

The procedures for collecting sediments (and animals and water if appropriate) are described in Chapter 8. The sediment samples should be stored as indicated in Table 8.1. The bioassay will include a reference sediment and a control sediment (as discussed in Section 3.1), and one or more dredged material samples.

The bioassays should be initiated as soon as possible, preferably within 1 wk after sediments and animals are collected. The number of replicate exposure chambers for the dredged material, reference, and control should be determined according to the guidance in Section 12.1. A minimum of 5 replicates are recommended unless Section 12.1 indicates otherwise.

The quantity of sediment needed for the benthic tests depends on the size of the exposure chambers to be used. The test is conducted with a layer of dredged material or reference sediment or control sediment on the bottom of each exposure chamber. This layer has to be deep enough to meet the biological needs of the test organisms, i.e., allow organisms to burrow in their normal position, etc. In any case it should be at least 2 cm deep.

10.2.2.3 Experimental Conditions

Benthic bioassays should be conducted under conditions known to be nonstressful to the test organisms. Salinity should be stable within ±2°/oo and temperature within ±2°C throughout the exposure period. Dissolved oxygen should be maintained above 4 mg/L by gentle aeration if necessary, being careful not to resuspend deposited sediment. The water used in the test may be collected from the disposal site or uncontaminated seawater or artificial sea salt mixtures may be used. The amphipod bioassay (Swartz, et al., 1985) employs a 96 hr exposure period. Tests with other species are 10 days in duration.

10.2.2.4 Experimental Procedure

The reference and control sediments, as well as the dredged material being tested, may contain live organisms. Remove macroinvertebrates by wet sieving the sediments, using the smallest amount of seawater possible, through a 1.0 mm mesh screen. Retain the water and sediment in a settling container. Gently transfer the material that remains on the screen to a sorting tray, remove the animals, and return the remainder to the settling container. After the sediments have settled for a minimum of 6 hr, decant the seawater from the settling container without disturbing the sediment surface, and then mix the sediment thoroughly. Return the sieved dredged material to its storage container and hold it at 4°C. Use the sieved reference and control sediments as soon as possible after the macroinvertebrates are removed.

Follow the experimental procedure described in Swartz et al. (1985) for preparing the exposure chambers for amphipod bioassays. For larger exposure chambers use the following procedure. Place reference and control sediment and dredged material in their respective aquaria deep enough to meet the needs of the test organisms but at least 2 cm deep on the bottom of the empty exposure chambers. Start the flow of seawater to each exposure chamber, directing the flow to minimize the resuspension of sediment. Introduce the test organisms to the exposure chambers as soon as the chambers are full of water.

The use of flow-through exposure systems is preferred to minimize the chances that stressful artifacts of experimental procedures will affect the results; static renewal systems may be acceptable. If static renewal systems are used, the exposure design should include replacement of 75 percent of the water volume every 48 hr. When water is changed, be very careful not to resuspend settled material or test organisms.

Animals that have been collected in the field and kept in holding tanks with sediment can be recaptured by gently siphoning the sediment through a 1.0 mm screen. Handle the animals as little as possible and with the utmost care. Do not use any animals that are dropped, physically abused during capture or transfer, or exhibit unusual behavior. Specific handling requirements for amphipods are described in Swartz et al. (1985).

Divide the test animals randomly among finger bowls, or other suitable intermediate containers, equal in number to the number of exposure chambers in the test. Randomly place 20 individuals of each species in each container with water of the same temperature and salinity and from the same source as the water being used in the test. After 30 min remove any dead animals or animals exhibiting unusual behavior and replace them with healthy individuals. If obvious mortalities exceed 10 percent during this period, discontinue the test and begin a new one. Reexamine species selection, collection, and holding techniques in an effort to reduce the unacceptably high mortality in the new test.

During the exposure period, record daily observations of obvious mortalities, emergence of infaunal organisms, formation of tubes or burrows, and any unusual behavior. Also keep a daily record of water quality parameters (e.g., dissolved oxygen, salinity, temperature, pH) in each exposure chamber; in static renewal systems, also measure ammonia concentrations. Water quality parameters may be kept within acceptable bounds by increasing the flow rate or frequency of water changes. Gentle aeration may also be used to keep dissolved oxygen concentration above 4 mg/L.

After the exposure period, siphon the sediment in the exposure chambers through a 0.5 mm screen. Gently rinse the material retained on the screen with seawater and search it thoroughly for animals. Animals that show any response to gentle probing of sensitive parts should be considered alive. Specimens not recovered have to be considered dead. Always count living animals, because dead animals may decompose or be eaten. If animals from the benthic bioassay are to be used in estimating bioaccumulation potential, gently and rapidly count the surviving specimens and treat them as described in Chapter 11.

10.2.2.5 Data Analysis

(1) Data Presentation

Present the data for each test species in separate tables that include the following information: the scientific name of the test species, the number of animals in each treatment at the start of the test, the percent

of animals recovered alive from each chamber at the end of the test, and any additional information regarding emergence, burrowing, tube building, or other behavioral abnormalities. Present the water quality data for each test chamber for each day in a separate table.

(2) Statistical Analysis

If less than 10 percent mean mortality occurs in the control, the data may be evaluated statistically. It is possible that no mortality will be observed in any treatments or that the total survival in the dredged material will be equal to or higher than survival in the reference or control sediments. In either of these situations, there is no need for statistical analyses and no indication of adverse effects due to the dredged material. If survival in the reference sediment is higher than in the dredged material treatments, the data have to be analyzed statistically to determine whether there is a significant difference in survival between the reference material and any dredged material sample. Statistical procedures recommended for analyzing benthic bioassay data are described in detail in Section 12.2.3.

10.2.2.6 Determination of Compliance

Guidance on the use of the results to reach a decision is provided in Section 6.2.

10.2.2.7 Quality Control Considerations

If less than 10 percent mortality occurs in the control treatment for a particular test species, the data for that species may be evaluated. Unacceptably high control mortality indicates that the organisms are being affected by important stresses other than contamination in the material being tested and the test has to be repeated. These stresses may be due to injury or disease, unfavorable physical or chemical conditions in the test containers, improper handling or acclimation, or possibly unsuitable sediment grain size. Species selection and the potential effects of these

and other variables should be carefully reexamined in an attempt to reduce unacceptably high mortality when the test is repeated.

Reference toxicant tests should be performed routinely on all groups of organisms used in dredged material testing in order to determine their relative health and vigor. Many chemicals may be used satisfactorily as reference toxicants (Lee, 1980). Reference toxicant tests are performed in the absence of sediment, even for animals to be used in benthic bioassays. The idea is to use short-term response to a standardized exposure as an indication of the relative health of the organisms. Sediment is unnecessary in the short reference toxicant tests and, if used, would sorb the toxicant and invalidate the reference toxicant test. A geometric dilution series of 5 unreplicated concentrations is used. Nominal (rather than measured) concentrations are usually sufficient for reference toxicant tests. The concentration range should be selected to give greater than 50 percent mortality in at least one concentration and less than 50 percent mortality in at least one concentration. An initial pilot test using a very wide range of concentrations may be necessary to determine the proper concentration range for the reference toxicant tests. Test duration is 24 hr. Ten organisms per exposure chamber are sufficient. Reference toxicant tests are usually conducted under static conditions. For each species, mortality is determined and the LC50 is calculated as described in Section 12.2.2.

When data for a particular reference toxicant have been generated on at least 5 groups of organisms of a species, two standard deviations above and below the mean is established as the bounds of acceptability. When the next group of organisms of this species is tested with this reference toxicant, if the LC50 is within the bounds of acceptability, the group of organisms may be used for dredged material testing. If not, their response is atypical of the population, and that group of organisms should not be used for testing. The data from each reference toxicant test are added to the database and the bounds of acceptability are recalculated after each test in order to continuously improve the characterization of the typical response of the species. Reference toxicant tests should be conducted at least monthly on each species cultured in-house, and should be performed on each lot of purchased or field-collected organisms. The basic concept and application of reference toxicant tests is discussed by Lee (1980).

General quality assurance (QA) guidance applicable to bioassays is presented in Chapter 13.

10.3 TIER IV: CASE-SPECIFIC TESTS

Under certain circumstances, as discussed in Chapter 7, it might be necessary to assess the chronic effects of the dredged material on sensitive benthic organisms. There are no routine methods available for assessing the chronic effects (i.e., effects on growth or reproductive processes) of contaminated sediments on benthic marine or estuarine organisms. However, a number of tests are under development or could be developed for this purpose.

Biological tests in Tier IV should be used only in situations that warrant special investigative procedures. In such cases, test procedures have to be tailored to the specific situation, and general guidance cannot be offered. Such studies have to be selected, designed, and evaluated as the need arises, with the assistance of administrative and scientific expertise from headquarters of CE and EPA, and other sources if appropriate.

Ideally Tier IV tests would measure reproductive effects on a sensitive sediment-ingesting, infaunal animal. A number of species of polychaetes and amphipods and certain species of bivalve mollusc (e.g., *Macoma* sp., *Yoldia limatula*) could be used. The primary disadvantage of this approach is that most species of infaunal polychaetes, amphipods, and molluscs have relatively long life cycles and a test of several months or longer would be needed to accurately assess reproductive effects. It might be possible, however, to measure effects on growth that correlate with reproductive effects within a shorter exposure period. It might also be possible to measure bioenergetic alterations that correlate with reproductive suppression without conducting a full life-cycle test, as has been demonstrated with mysids (Carr et al., 1985).

In some cases the potential for chronic benthic impacts may be determined from properly designed and conducted field studies. The use of field studies for predictive purposes is valid only where there is a true historical precedent for the proposed operation being evaluated. That is, it can be used only for maintenance dredging where the quality of the

sediment to be dredged can be shown not to have deteriorated or become more contaminated since the last dredging and disposal operation. In addition, the disposal has to be proposed for the site at which the dredged material in question has been previously disposed, or for a site with similar sediment type supporting a similar biological community. Under these conditions field studies can provide very realistic predictions of effect because benthic animals have been exposed throughout their life cycles to the chemical, physical, and biological conditions prevailing at the disposal site. Although field assessments are frequently of limited usefulness because of the above constraints, when the constraints are met, field assessments can be valuable.

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11.0 GUIDANCE FOR PERFORMING BIOACCUMULATION TESTS

Bioaccumulation refers to the accumulation of contaminants in the tissues of organisms through any route, including respiration, ingestion, or direct contact with contaminated sediment or water. The regulations require that bioaccumulation be considered as part of the environmental evaluation of dredged material proposed for ocean dumping. This consideration involves predicting whether there will be a cause and effect relationship between an animal's presence in the area influenced by the dredged material and an environmentally important elevation of its tissue content or body burden of contaminants above that in similar animals not influenced by the disposal of the dredged material. That is, it has to be predicted whether an animal's exposure to the influence of the dredged material is likely to cause a meaningful elevation of contaminants in its body.

The bioaccumulation evaluation may be conducted at Tiers II, III, and/or IV, as appropriate. The tiered approach uses resources efficiently by testing only as intensively as is necessary to reach a decision in each case.

- **Tier II** provides an evaluation of the theoretical bioaccumulation potential (TBP) of nonpolar organic contaminants if the dredged material in question is the only source of contaminants to the organism. It is based on solubility partitioning between sediments and tissues. If the theoretical bioaccumulation potential calculated in Tier II can be judged acceptable under the guidance discussed in Section 5.2, no further bioaccumulation testing of these compounds is needed. If it is not possible to make a decision at Tier II, further evaluation in Tier III or IV is necessary.

- **Tier III** bioaccumulation evaluation consists of measurement of bioaccumulation potential after a 10 or 28 day exposure to the dredged material. These exposure periods do not provide information on concentrations that would actually be accumulated by organisms after prolonged exposure to the dredged material, but do indicate bioavailability, i.e., whether there is a real potential for bioaccumulation to occur. If the acceptability of the bioaccumulation potential can be determined following the guidance discussed in Section 6.3, no further bioaccumulation testing is needed. If this is not the case, further evaluation in Tier IV is necessary.

- **Tier IV** provides a determination of steady state bioaccumulation from exposure to the dredged material. It is based on field data or laboratory exposure with time-sequence sampling of the organisms. The acceptability of the bioaccumulation indicated at Tier IV has to be determined under the guidance discussed in Section 7.2; no further bioaccumulation testing is available.

Many marine organisms are capable of metabolizing some types of organic compounds to varying degrees, and the ability of each species to metabolize the specific contaminant(s) of concern influences the tissue concentration of those chemicals. Organic contaminants such as PCBs and other synthetic compounds can accumulate to high levels in animal tissues because they are highly resistant to metabolic degradation. Many PAHs, on the other hand, are readily taken up by many organisms, but might not be found in high concentrations in tissue because some of the parent compounds are rapidly metabolized. The metabolites are not easily quantified by standard analytical methods, but in many cases are potent toxicants that can adversely affect the organisms in which they occur. Relatively low concentrations of organic chemicals in tissues may thus suggest either low bioavailability and therefore low bioaccumulation, or that bioaccumulation was followed by metabolization. Therefore, it is important to evaluate PAH bioaccumulation in species that have only limited ability to metabolize them. Bivalve molluscs are generally considered to satisfy this requirement. For purposes of regulation, analyses of PAH in dredged material and organisms exposed to it should focus on the PAH on the priority pollutant list. The rationale for this recommendation is provided by Clarke and Gibson (1987).

11.1 TIER II: THEORETICAL BIOACCUMULATION POTENTIAL (TBP) OF NONPOLAR ORGANIC CHEMICALS

TBP is an approximation of the equilibrium concentration in tissues if the dredged material in question were the only source of contaminant to the organisms. At present the TBP calculation can be performed only for nonpolar organic chemicals (such as PCBs), although methods for making the calculation with metals and polar organic compounds are under development and may be added to this manual in the future. Therefore, a particular dredged material may contain contaminants of concern for which it is

inappropriate to calculate TBP (e.g., polar organic compounds, organometals, and metals), and bioaccumulation evaluations of such dredged materials will require testing in Tiers III or IV as appropriate. However, even if the dredged material contains other contaminants of concern in addition to nonpolar organic contaminants of concern, it is still useful to calculate TBP. TBP provides an indication of the magnitude of bioaccumulation of nonpolar organics that may be encountered in Tier III and/or Tier IV testing. Additionally, if the TBP of the nonpolar organics meets the decision guidance, the calculation may eliminate the need for further evaluation of these compounds and thereby reduce efforts in Tier III and/or IV.

For the purposes of Tier II, nonpolar organic chemicals include all organic compounds that do not dissociate or form ions. This includes the chlorinated hydrocarbon pesticides; many other halogenated hydrocarbons; PCB, many PAHs including all the priority pollutant PAHs, dioxins, furans, etc. It does not include organic acids or salts, or organometallic complexes such as tributyltin or methyl mercury. Metals and metal compounds are not included.

The distribution in the environment of nonpolar organic chemicals is controlled largely by their solubility in various media. Therefore in sediments they tend to occur primarily in association with organic matter (Karickhoff, 1981), and in organisms are found primarily in the body fats or lipids (Konemann and van Leeuwen, 1980; Geyer et al., 1982; Mackay, 1982). Therefore, bioaccumulation of nonpolar organic compounds from dredged material can be estimated from the organic carbon content of the material, the lipid content of the organism, and the relative affinities of the chemical for sediment organic carbon and animal lipid content.

The calculation of TBP assumes that various lipids in different organisms and organic carbon in different sediments are similar and have similar distributional properties. Other simplifying assumptions are that chemicals are freely exchanged between the sediments and tissues and that compounds behave conservatively. In reality, compound size and structure may influence accumulation, and portions of organic compounds present on suspended particulates may have kinetic or structural barriers to availability. Two important assumptions implicit in the TBP calculations

are: (1) there is no metabolic degradation or biotransformation of the chemical, and (2) the sediment-associated chemical is totally bioavailable to the organism. Calculations based on these assumptions present the theoretical bioaccumulation potential if the dredged material in question is the only source of the contaminant to the organism.

It is possible to relate concentration of a chemical in one phase of a two-phase system to concentration in the second phase when the system is in equilibrium. In calculating TBP, interest is focused on the equilibrium distribution of a chemical between the dredged material or reference sediment and the organism. By normalizing nonpolar organic chemical concentration data for lipid content in organisms and organic carbon in dredged material or reference sediment, it is possible to estimate the preference of a chemical for either phase. Using this approach based on the work of Konemann and van Leeuwen (1980) and Karickhoff (1981), McFarland (1984) calculated the equilibrium concentration of nonpolar organic chemicals that the lipids of an organism could accumulate as a result of exposure to dredged material would be about 1.7 times the organic carbon-normalized concentration of the chemical in the dredged material. Concentrations are directly proportional to the lipid content of the organism and the contaminant content of the dredged material or reference sediment, and inversely proportional to the organic carbon content of the dredged or reference material (Lake et al. 1987).

This means that the chemical concentration that could result in an organism's lipids (lipid bioaccumulation potential--LBP) would theoretically be 1.7 times the concentration of that chemical in the sediment organic carbon. Rubinstein et al. (1987) have shown, based on field studies, that an value of 4 for calculating LBP is appropriate, and this is the value used in this manual. LBP represents the potential contaminant concentration in lipid if the sediment is the only source of that contaminant to the organism. It is generally desirable to convert LBP to whole body bioaccumulation potential for a particular organism of interest. This is done by multiplying LBP by that organism's lipid content, as determined by lipid analysis or from reported data. Therefore, theoretical bioaccumulation potential (TBP) can be calculated as

$$TBP = 4\ (C_s/\%TOC)\ \%L$$

where

TBP is expressed on a whole body wet weight basis in the same units of concentration as C_s

C_s = concentration of nonpolar organic chemical in the dredged material or reference sediment (any units of concentration may be used)

%TOC = organic carbon content of the dredged material or reference sediment expressed as a decimal fraction (i.e., 2% = 0.02)

%L = organism lipid content expressed as a decimal fraction (i.e., 3% = 0.03) of whole body wet weight

This calculation is based on McFarland and Clarke (1987), who also developed the nomograph in Figure 11.1 by which TBP can be determined graphically. Using the nomograph, it is possible to quickly estimate TBP for organisms of various lipid contents, providing the contaminant concentration C_s and organic carbon content %TOC of the dredged material or reference sediment are known. Even though the nomograph does not provide as precise an answer as the equation, it is sufficient for Tier II applications. Because TBP does not predict expected environmental concentrations but indicates the upper range, exact evaluation is not necessary. The procedure for using the nomograph is as follows:

Step 1. Determine the lipid content of an organism of interest, either from previously reported values or from laboratory analysis, and express the lipid content as percent of whole-body wet weight, rather than as decimal fraction.

Step 2. Locate the value on the right hand vertical axis that corresponds most closely to that lipid content.

Step 3. Follow the sloped line until it intersects the dredged material or reference sediment concentration C_s. C_s may be expressed in any units of concentration and may be selected from any of the four ranges: 0.1-1.0; 1-10; 10-100; or 100-1000.

Step 4. From that point, read across to the left hand vertical axis and select the TBP value from the appropriate sediment organic carbon column expressed as percent of sediment dry weight.

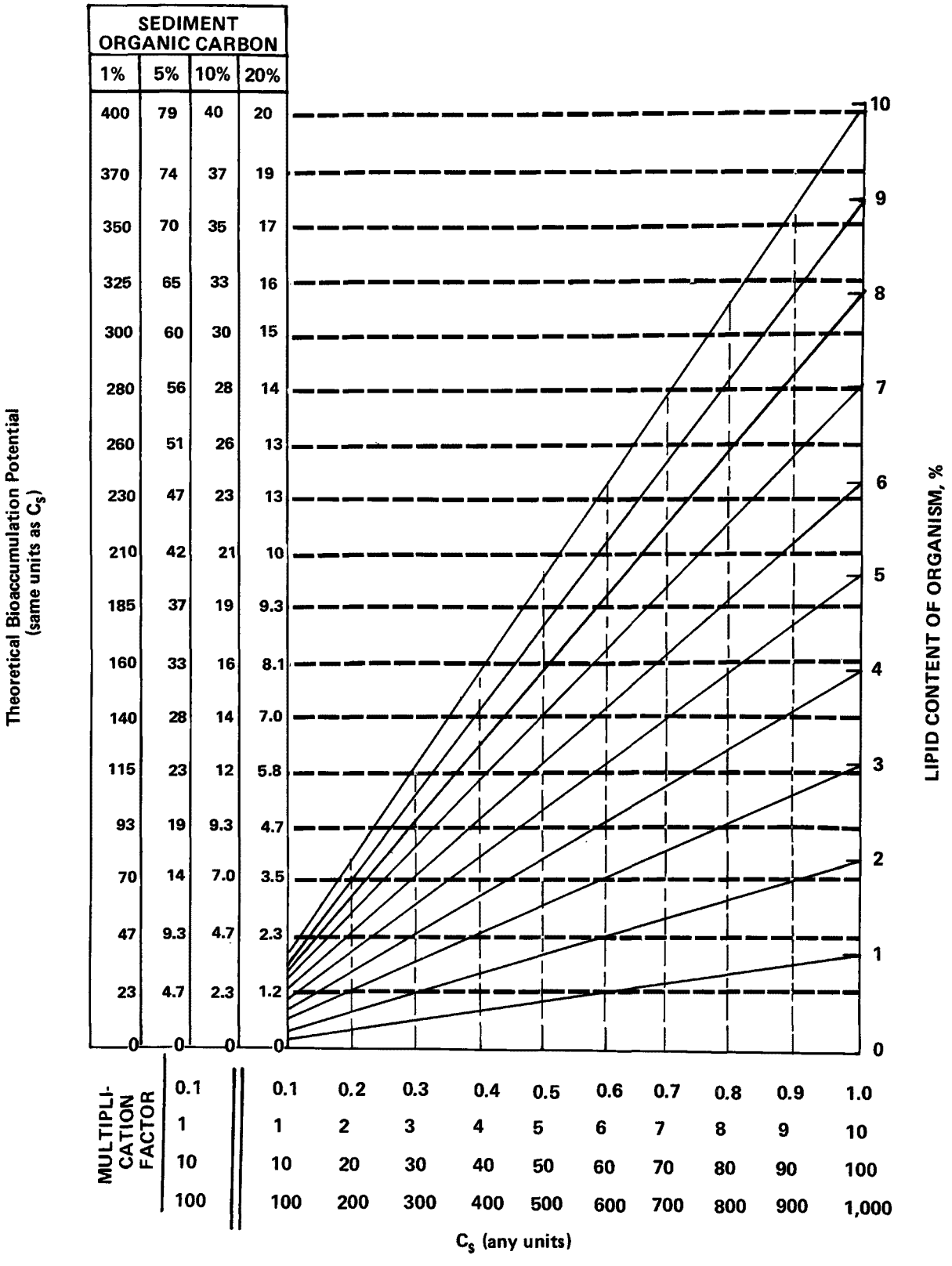

Figure 11.1. Nomograph for determining theoretical bioaccumulation potential.

Step 5. Multiply TBP by the factor (0.1, 1, 10, 100) corresponding to the selected C_s range. The TBP will then be in the same units of concentration as C_s.

The lipid scale and the C_s scale of the nomograph can be changed by orders of magnitude by adjusting the TBP scale in the same manner. For example, if the organism of interest is a mussel having 0.3 percent lipid content, one would simply follow the 3 percent lipid line and divide the appropriate resulting theoretical bioaccumulation value by 10. If the dredged material or reference sediment concentration C_s of a contaminant lies above or below the C_s ranges shown on the nomograph, the units of concentration can be changed (e.g., change 0.02 parts per million to 20 parts per billion). Interpolation between lipid lines or between organic carbon columns is straightforward because all relationships are proportional. For example, for dredged material or reference sediment with an organic carbon content of 3 percent, TBP would be 1/3 the TBP at 1 percent carbon, 5/3 the TBP at 5 percent organic carbon, 10/3 the TBP value at 10 percent organic carbon, or 20/3 the TBP at 20 percent organic carbon.

The following illustration of the use of the nomograph determines the TBP of total PCB by a fish of 6 percent lipid content exposed to a sediment containing 4 ppm PCB and 4.6 percent total organic carbon. Follow the 6 percent lipid line to a C_s value of 4 and then read across to the 5 percent organic carbon column to obtain a TBP of about 19 x 1 or 19 ppm. Because the organic carbon content of the sediment is actually 4.6 percent rather than 5 percent, a more precise estimate can be made by multiplying 19 by 5/4.6 to obtain a TBP of 20.6 ppm. This would be evaluated under guidance in Section 5.2 to determine whether a decision could be reached or further testing was necessary.

11.2 TIER III: DETERMINATION OF BIOAVAILABILITY

Bioavailability tests are designed to evaluate the potential of benthic organisms to bioaccumulate contaminants of concern from the proposed dredged material. The "Guidance Manual: Bedded Sediment Bioaccumulation Tests," by Lee et al. (1989), discusses bioaccumulation methodology in detail and may be followed on any matter that does not

conflict with this manual. Tier III bioavailability tests are based on analysis of tissues of organisms after 10 or 28 days of exposure. The 10 day exposure test is appropriate when all contaminants of concern are metals, whereas 28 day exposure tests should be used when any contaminant of concern is organic or organometallic (i.e., not an element). As discussed in Section 6.3, even though concentrations of these contaminants may not be at steady state after 10 or 28 days, these tests determine the potential for bioaccumulation and provide the information for decision making in the Tier III bioaccumulation evaluation.

11.2.1 Species Selection and Apparatus

Bioaccumulation tests have to be conducted with appropriate sensitive benthic marine organisms. Section 227.27(d) of the regulations defines this to mean at least one species each representing filter-feeding, deposit-feeding, and burrowing species chosen from among the most sensitive species accepted by EPA and CE as being reliable test organisms to determine the anticipated benthic impact. These are broad overlapping general categories, and it is recommended that the species be selected to include a burrowing polychaete and a deposit-feeding bivalve mollusc. As discussed at the beginning of this chapter, many species can metabolize PAH, thus giving a misleading indication of bioaccumulation potential. Therefore, it is essential that bioaccumulation studies include one or more species with very low ability to metabolize PAH. Bivalve molluscs are widely accepted as meeting this requirement. Characteristics and examples of appropriate species for bioaccumulation testing are presented in Figure 11.2.

A minimum of several grams of tissue have to be available to allow measurement of chemical concentrations. In samples that do not contain sufficient tissue, it will be impossible to quantify the amount of contaminant present. Because data in the form of "concentration below detection limits" are not quantitative, it is vital that sufficient tissue to allow definitive measurement of concentration be collected for each species.

Characteristics[a]

- Comply with Section 227.27(d)
- Readily available year-round
- Provide adequate biomass for analysis
- Ingest sediments
- Tolerate grain sizes of dredged material and control and reference sediments equally well
- Tolerate handling and laboratory conditions
- Related phylogenetically and/or by ecological requirements to species characteristic of the disposal site area
- Important ecologically, economically, and/or recreationally
- Inefficient metabolizers of contaminants, particularly PAH

EXAMPLES[a]

Polychaetes	Molluscs
* *Neanthes* sp.	* Macoma clam, *Macoma* sp.
* *Nereis* sp.	* Yoldia clam, *Yoldia limatula*
Nephthys sp.	Nucula clam, *Nucula* sp.
Arenicola sp.	
Abarenicola sp.	

[a]Neither characteristics nor examples are presented in order of importance, except that the first characteristic is mandatory and recommended species are marked by an asterisk.

FIGURE 11.2. CHARACTERISTICS AND EXAMPLES OF APPROPRIATE SPECIES FOR DETERMINING BIOACCUMULATION FROM DEPOSITED DREDGED MATERIAL. THE LISTS ARE ILLUSTRATIVE BUT NOT EXHAUSTIVE.

The apparatus to be used are those described for benthic bioassays in Section 10.2.2.2. In addition, aquaria with clean, sediment-free water are necessary to hold the organisms during the period required to void their digestive tracts. If the biological needs of the organisms require the presence of sediment, control sediment should be used.

11.2.2 Experimental Conditions

The test conditions are those described in Sections 10.2.2.3 and 10.2.2.4 for benthic bioassays. Animals should not be provided food or additional sediment during the test. Animals to be used to evaluate bioavailability are taken from the dredged material samples after 10 or 28 days of exposure. In addition, a sample of each species taken from the animal holding tanks at the time the test is initiated is also analyzed.

It is necessary to empty or remove the digestive tracts of the animals immediately after sampling. Sediment in the digestive tracts may contain inert constituents and the contaminants of concern in forms that do not become biologically available during passage through the digestive tract.

If animals are large enough to make it practical, the best procedure is to excise the digestive tracts as soon as possible after sampling. However, test organisms are seldom large enough to allow this, and most organisms have to be allowed to excrete the material. Organisms are placed in separate aquaria in clean, sediment-free water to purge their digestive tracts. Some polychaetes will pass material through the digestive tract only if more material is ingested. These animals have to be purged in aquaria with clean sand. Animals are not fed during the purging period. Fecal material is siphoned from the aquaria twice during the 24 hr purging period. To minimize the possibility of loss of contaminants from the tissues, purging for longer periods is not recommended. The shells or exoskeletons of molluscs or crustaceans are removed and not included in the analysis. These structures generally contain low levels of contaminants and would contribute weight but little contaminants to the analysis. This would give an artificially low indication of bioavailability.

11.2.3 Chemical Analysis

Contaminants of concern to be assessed for bioavailability are those identified in Sections 4.2 and 9.5.1. Analytical procedures for contaminants of concern in tissue are presented in Section 9.5.2.

11.2.4 Data Analysis

The data should be presented in a table that lists the tissue concentration of each contaminant of concern measured in the organisms exposed to the dredged material and reference sediment.

To determine whether there is an indication of bioaccumulation potential, the tissue concentrations in animals in the reference sediment have to be statistically compared with FDA Action Levels for Poisonous or Deleterious Substances in Fish or Shellfish for Human Consumption. Depending on the outcome of this comparison, tissue concentrations may also be statistically compared with those in animals exposed to the dredged material. Recommended statistical methods are presented in Section 12.3.1. If mortality is 25 percent or more for animals exposed to either dredged material or reference sediment, it is recommended that the test be considered invalid. In some cases the mean tissue concentration in animals exposed to one or more of the dredged material samples may be less than or equal to that in animals exposed to the reference sediment. This in no way reflects adversely on the quality of the evaluation, but simply gives no indication of bioaccumulation potential for the contaminant, species, and dredged material sample in question.

The sample of animals taken at the initiation of the exposure can be useful in interpreting results. It can add perspective to the magnitude of uptake during the exposure period, and in some cases has shown that elevated body burdens were not due to the dredged material or reference sediment, but were already present in the organisms at the start of the test.

11.2.5 Determination of Compliance

Guidance on the use of the results of the determination of bioavailability in relation to FDA limits and bioavailability from reference sediment to reach a decision in Tier III is presented in Section 6.3.

11.2.6 Quality Control Considerations

Reference toxicant tests should be performed routinely on all groups of organisms used in dredged material bioaccumulation testing in order to determine their relative health and vigor. Many chemicals may be used satisfactorily as reference toxicants (Lee, 1980). Reference toxicant tests are performed in the absence of sediment, even for animals to be used in benthic bioaccumulation testing. The idea is to use short-term response to a standardized exposure as an indication of the relative health of the organisms. Sediment is unnecessary in the short reference toxicant tests and, if used, would sorb the toxicant and invalidate the reference toxicant test. A geometric dilution series of 5 unreplicated concentrations is used. Nominal (rather than measured) concentrations are usually sufficient for reference toxicant tests. The concentration range should be selected to give greater than 50 percent mortality in at least one concentration and less than 50 percent mortality in at least one concentration. An initial pilot test using a very wide range of concentrations may be necessary to determine the proper concentration range for the reference toxicant tests. Test duration is 24 hr. Ten organisms per exposure chamber are sufficient. Reference toxicant tests are usually conducted under static conditions. For each species, mortality is determined and the LC50 is calculated as described in Section 12.2.2.

When data for a particular reference toxicant have been generated on at least 5 groups of organisms of a species, two standard deviations above and below the mean is established as the bounds of acceptability. When the next group of organisms of this species is tested with this reference toxicant, if the LC50 is within the bounds of acceptability, the group of organisms may be used for dredged material bioaccumulation testing. If

not, their response is atypical of the population, and that group of organisms should not be used for testing. The data from each reference toxicant test are added to the database and the bounds of acceptability are recalculated after each test in order to continuously improve the characterization of the typical response of the species. Reference toxicant tests should be conducted at least monthly on each species cultured in-house, and should be performed on each lot of purchased or field-collected organisms. The basic concept and application of reference toxicant tests is discussed by Lee (1980).

General quality assurance (QA) guidance applicable to bioaccumulation testing is presented in Chapter 13.

11.3 TIER IV: DETERMINATION OF STEADY STATE BIOACCUMULATION

Bioaccumulation evaluation at Tier IV provides for determination, either by laboratory testing or by collection of field samples, of the steady state concentrations of constituents in organisms exposed to the dredged material as compared with organisms exposed to the reference material. Steady state concentrations determined in the laboratory or in the field are used in the same way to make Tier IV decisions according to the guidance in Section 7.2.

11.3.1 Laboratory Assessment of Steady State Bioaccumulation

Tier IV laboratory bioaccumulation testing is based on the American Society for Testing and Materials (ASTM) standard practice for conducting bioconcentration tests with fishes and saltwater bivalve molluscs (ASTM, 1984). The Tier IV test is a 28 day exposure to deposited dredged material from which steady state concentration of contaminants in organism tissues is calculated based on time-series sampling.

11.3.1.1 Species Selection and Apparatus

The necessary species and apparatus are those indicated in Section 11.2.1 for Tier III bioaccumulation testing.

11.3.1.2 Experimental Conditions

Experimental conditions are the same as those described in Section 11.2.2 for determination of bioavailability. A series of tissue samples taken during the exposure period provides the basis for determining the rate of uptake and elimination of contaminants by the organism. From these rate data, the steady state concentration of contaminants in the tissues can be calculated, even though steady state might not have been reached during the actual exposure. Steady state is defined for the purposes of this test as the concentration of contaminant that would occur in tissue after the organisms were exposed to the dredged or reference material for a very long time under constant exposure conditions.

At the time the animals are placed in the aquaria to begin the exposure phase, an initial time 0 sample of each species is collected for tissue analysis. Additional tissue samples are collected from each of the five replicate reference and dredged material aquaria at intervals of 2, 4, 7, 10, 18, and 28 days after exposure begins. Calculation of steady state as described in Section 12.3.2 requires that the data describe the inflection in the uptake curve. This might not require analysis of the samples collected at the later time intervals given above. If logistically practical, it may be cost-effective to submit the day 2, 4, 7, and 10 samples to the laboratory for analysis and continue the experiment to collect the day 18 and 28 samples. If the data from the first sampling times clearly include the inflection of the uptake curve, analysis of the samples from later intervals may not be necessary.

11.3.1.3 Chemical Analysis

Contaminants of concern to be assessed for bioaccumulation are those identified in Sections 4.2 and 9.5.1. Analytical procedures for contaminants of concern in tissues are presented in Section 9.5.2. As described in Section 11.2.2, sediment has to be removed from the digestive tracts of the animals before they are preserved.

11.3.1.4 Data Analysis

Complete tissue concentration data for all tissue samples should be presented in a table. As in Tier III bioavailability tests, if the mortality of animals exposed to dredged material or reference sediment is greater than or equal to 25 percent, the test should be considered invalid. Recommended statistical methods for fitting a curve to the data to determine steady state concentration in the tissue are presented in Section 12.3.2. The statistical procedures use an iterative curve-fitting process to determine the key variables (k_1C_s, the uptake rate constant times the contaminant concentration in the sediment, and k_2, the depuration rate constant). An initial value for C_s has to be supplied. When the sediment concentration of the contaminant of concern is used, the ratio of k_1/k_2 is the sediment bioaccumulation factor or BAF (Lake et al. 1987; Rubinstein et al., 1987), the ratio of steady state tissue concentration to sediment concentration.

11.3.1.5 Determination of Compliance

Decisions are based on the magnitude of bioaccumulation from the dredged material, and its comparison with FDA limits, steady state bioaccumulation from the reference sediment, and the body burden of reference organisms. Guidance for making decisions in Tier IV based on these comparisons is presented in Section 7.2.

11.3.1.6 Other Considerations

Although procedures for performing bioavailability and steady state bioaccumulation tests have been discussed separately, it may be practical to combine these procedures in practice. This can be done by following the steady state bioaccumulation procedure, but initially analyzing only the 10 or 28 day sample. If the use of the data from this analysis as part of the Tier III bioavailability evaluation does not provide for decision-making,

then the remaining time-series samples may be analyzed and used in the Tier IV steady state bioaccumulation evaluation.

11.3.1.7 Quality Control Considerations

Guidance on quality control considerations for bioaccumulation testing is provided in Section 11.2.6.

11.3.2 Field Assessment of Steady State Bioaccumulation

Field sampling programs overcome difficulties related to quantitatively considering field exposure conditions in the interpretation of test results, since the animals are exposed to the conditions of mixing and sediment transport actually occurring at the disposal site in question. Difficulties related to the time required to conduct laboratory bioaccumulation studies are also overcome if organisms already living at the disposal site are used in the field bioaccumulation studies. The use of this approach for predictive purposes is technically valid only where there is a true historical precedent for the proposed operation being evaluated. That is, it can be used only in maintenance dredging where the quality of the sediment to be dredged can be shown not to have deteriorated or become more contaminated since the last dredging and disposal operation. In addition, the disposal has to be proposed for the site at which the dredged material in question has been previously disposed or for a site of similar sediment type supporting a similar biological community. Field assessments are frequently of limited usefulness because of these constraints, but when they can be met, field assessments can be valuable. Knowledge of the organisms contaminant body burden living around the proposed disposal site is used in evaluating bioaccumulation results in Tier IV (Section 7.2).

11.3.2.1 Apparatus

The following is a general description of the major items required for field assessment of bioaccumulation potential. Additional miscellaneous equipment will have to be furnished.

- A vessel capable of operating at the disposal site and equipped to handle benthic sampling devices. Navigation equipment has to be sufficient to allow precise positioning.
- Sampling devices such as a box corer, Smith-MacIntyre or other benthic grab. Corers are less satisfactory because they sample a smaller surface area and have a greater penetration than is needed.
- Stainless steel screens of 1 mm mesh to remove animals from the sediment.
- Tanks for transporting the animals to the laboratory in collection site water.
- Laboratory facilities for holding the animals prior to analysis.
- Chemical and analytical facilities as required for the desired analyses.

11.3.2.2 Species Selection

The species selected for analysis have to occur in sufficient numbers for collection of an adequate sample at all stations. The same species have to be collected at all stations because bioaccumulation cannot be compared across species lines.

For each species at each station, a minimum of several grams of tissue has to be collected to allow measurement of chemical concentrations. In samples that do not contain sufficient tissue, it will be impossible to quantify the amount of contaminant present. Because data in the form of "concentration below detection limits" are not quantitative, it is vital that sufficient tissue to allow definitive measurement of concentration be collected for each species at each station. The ability to obtain sufficient tissue is a critical factor in selecting species for use in bioaccumulation studies, and in determining the practicality of the field assessment approach.

If possible, several samples of sufficient size for analysis should be collected at each sampling station in order to provide a statistical estimate of variability in tissue content of the contaminants of concern. Collection of more than one sample per station, however, may prove

impractical if a composite of many small organisms have to be used or if suitable organisms are not abundant at the disposal site.

To minimize the numbers and collection effort required, it is desirable to select the largest appropriate species. However, highly mobile epifauna (such as crabs, lobsters, shrimp, and fish) should not be used, because a cause-and-effect relationship cannot be established between their location when collected and their body burden at the time of collection. Therefore, relatively immobile species that are fairly large, such as bivalves, some gastropods, large polychaetes, etc., are the most desirable organisms. Any relatively immobile species collectable in sufficient numbers at all stations may be used, but the required collection effort increases sharply as organism size decreases.

As discussed at the beginning of this chapter, many species can metabolize PAH, thus giving a misleading indication of bioaccumulation potential. Therefore, it is essential that bioaccumulation studies include one or more species with very low ability to metabolize PAH. Bivalve molluscs are widely accepted as meeting this requirement.

11.3.2.3 Sampling Design and Conduct

Sufficient tissue to obtain definitive body burden values has to be collected from each of at least three stations within the disposal site boundaries. It is mandatory that several stations be sampled, rather than collecting all of the animals at one station. This will provide a measure of the variability that exists in tissue concentrations in the animals in the area. Samples from all stations should be collected on the same day if possible, and, in any case, within 4 days.

11.3.2.4 Basis for Evaluation of Bioaccumulation

Tier IV bioaccumulation, whether based on laboratory or field assessment, is evaluated (Section 7.2) by comparison to contaminant concentrations in field organisms living around, but not affected by, the disposal site. This is very similar to the reference area approach (Section 3.1.2.1). To generate these data, at least three stations have to

be located in an uncontaminated sediment sedimentologically similar to that within the disposal site, in a direction perpendicular to the net bottom transport. Data from these sites will provide the level of contaminants in tissues to which those levels found in organisms exposed to the dredged material may be compared. If the direction of net bottom transport is not known, at least six stations surrounding the disposal site should be established in sediments sedimentologically similar to those within the disposal site.

In all cases it is mandatory that several stations be sampled, rather than collecting all of the animals at one station. This will provide a measure of the variability that exists in tissue concentrations in the animals in the area. Samples from all stations should be collected on the same day if possible, and, in any case, within 4 days.

11.3.2.5 Sample Collection and Handling

When the collection vessel has been positioned, make repeated collections at the same spot until an adequate tissue volume is obtained. Gently wash the sediment obtained by the sampler through 1 mm stainless steel screens, and place the retained organisms of the desired species in holding tanks. Never retain an animal that shows any indication of injury.

Label the samples clearly and return the animals to the laboratory, being careful to keep them separated and to maintain nonstressful levels of temperature and dissolved oxygen. In the laboratory, maintain the samples in clean water in separate containers. Do not place any sediment in the containers and do not feed the animals. Immediately discard any organisms that die.

It is necessary to remove sediment from the digestive tracts of the animals because it may contain inert constituents and the contaminants of concern in forms that do not become biologically available during passage through the digestive tract. If the animals are large enough to make it practical, the best procedure is to excise the digestive tracts as soon as possible after collection. However, animals are seldom large enough to allow this, and most organisms have to be allowed to excrete the material. Surviving organisms are placed in separate aquaria in clean, sediment-free

water to purge their digestive tracts. Some polychaetes will pass material through the digestive tract only if more material is ingested. These animals have to be purged in aquaria with clean sand. Animals are not fed during the purging period. Siphon fecal material from the aquaria twice during the 24 hr purging period. Purging for longer periods of time is not recommended to minimize the possibility of loss of contaminants from the tissues.

Also remove the shells or exoskeletons of molluscs or crustaceans. These structures generally contain low levels of contaminants and would contribute weight but few contaminants if they were included in the analysis. This would give an artificially low indication of bioaccumulation.

11.3.2.6 Chemical Analysis

The contaminants of concern to be assessed for bioaccumulation are those identified in Sections 4.2 and 9.5.1. Analytical procedures for specific constituents are presented in Section 9.5.2.

11.3.2.7 Data Analysis

Complete tissue concentration data for all samples should be presented in table format. Recommended statistical methods are presented in Section 12.3.

11.3.2.8 Determination of Compliance

Decisions are based on the magnitude of bioaccumulation in organisms collected within the boundaries of the disposal site, and its comparison with bioaccumulation in organisms living around the disposal site, but not affected by the site. Guidance for making regulatory decisions based on this comparison is presented in Section 7.2.

11.4 REFERENCES

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12.0 STATISTICAL METHODS

This chapter presents the appropriate statistical methods for analyzing the data from bioassays and bioaccumulation tests. The methodology is not intended to be exhaustive, nor is it intended to be a "cook-book" approach to data analysis. Statistical analyses are only routine under ideal experimental conditions. The methods presented here will usually be adequate for the tests conducted under the conditions specified in this document. An experienced applied statistician should be consulted whenever any questions arise. The 95 percent confidence level is used for all statistical comparisons in this manual.

The following are examples of departures from ideal experimental conditions that may require additions to or modifications of the straightforward statistical methods presented in this chapter:

- Unequal numbers of experimental animals assigned to each treatment container, or loss of animals during the experiment.
- Unequal numbers of replications of the treatments (i.e., containers or aquaria)
- Measurements scheduled at selected time intervals actually performed at other times
- Different conditions of salinity, pH, dissolved oxygen, temperature, etc. among exposure chambers
- Differences in placement conditions of the testing containers, or in the animals assigned to different treatments.

The following statistical methods will be presented as they apply to a specific test procedure:

- Sample size determinations
- Data scale transformations
- Variance homogeneity tests
- Two-sample t-tests
- Analysis of variance (ANOVA)
- Multiple comparisons among treatment means
- Confidence interval calculations

The statistical methods are illustrated in this manual with example IBM PC computer programs using SAS (Statistical Analysis System) software (SAS Institute, 1985). This does not constitute official endorsement or approval of these commercial hardware or software products. Other equally acceptable hardware and software products are commercially available and may be used to perform the necessary analyses. Although it may be acceptable to write original programs to do the calculations, the appropriateness of the techniques and accuracy of the calculations have to be very carefully verified and documented before use if this approach is chosen.

12.1 SAMPLE SIZE CONSIDERATION

Throughout this document five replications of test containers are recommended as the minimum for each treatment level. Experience has shown this number of replications to be cost-effective and easy to manage. However, it is important to consider the statistical implications of this recommendation.

In the simplest case, the goal is to determine whether the effect of exposure to a dredged material is significantly greater than the effect of exposure to the reference sediment. This situation can be viewed as a two-sample statistical test where k organisms have been randomly assigned to each of n containers or replicates. The adequacy of the test design is not as sensitive to the value of k as it is to n. In Chapters 10 and 11, where guidance for performing the various tests is provided, k has usually been set at 10 or 20 organisms, depending on the test.

Choosing a value for n (i.e., sample size or numbers of replicates) also requires choosing acceptable probabilities for making two kinds of errors. A Type I error occurs if we conclude that effect in the dredged material group is greater than in the reference group when, in fact, the true effect is no greater. On the other hand, a Type II error occurs if we conclude that effect in the dredged material group is no greater than in the reference group when, in fact, the true effect is greater.

Under ideal circumstances the experimenter wants to minimize the probability (β) of Type II error subject to a fixed probability (α) of Type I error. The power of the statistical test is the probability of

concluding that effect is greater in the dredged material group when, in fact, this is true. It is the probability of detecting a difference in effect when there is one. This probability or the power of the test is equal to $1 - \beta$.

Two formal hypotheses underlie the statistical analysis of data from the example just discussed. Simply stated, the null hypothesis (H_0) and the alternative hypothesis (H_1) are as follows:

H_0: $\mu_1 = \mu_2$

There is no difference in effect between the treatment (dredged material) and reference groups of animals.

H_1: $\mu_1 < \mu_2$

There is significantly greater effect among dredged material treated animals than among reference animals. A "one-tailed" test is used because there is little concern about identifying dredged material with less effect than the reference sediment.

where μ_1 is the average effect in the population of reference animals and μ_2 is the average effect in the population of dredged material treated animals.

The power of a statistical test is calculated for a specific difference in effect δ, where $\mu_1 - \mu_2 = \delta$.

Because the power of a statistical test increases with sample size for a fixed α and δ, it is essential to know the power of the statistical test when, for example, the recommended sample size of five containers or replicates is chosen.

We will assume that the difference (δ) we wish to detect is directly proportional to the standard deviation (σ) in effect from replicate to replicate. If the effect is highly variable we are likely to detect only large differences in the true effect between dredged material and reference groups. Conversely, if the effect is less variable we can detect smaller differences in true effect between the dredged material and reference groups. But relative to the variability, the detectable difference in effect is constant; specifically, we will assume that $\delta/\sigma = 1$.

The standard deviation (σ) is often unknown. But suppose we want to detect a difference in the average effect of $\delta = 1\sigma$ using a one-tailed test. With a probability of Type I error of 5 percent (i.e., $\alpha = 0.05$) and

the above assumptions, the power of the example test with five replicates is 0.43. This means that a difference in average effect between the dredged material and reference animals of one standard deviation would be detected 43 percent of the time.

Table 12.1 presents the power calculations (Cohen 1977) for selected sample sizes. For example, in order to detect a true difference in effect of 1σ 80 percent of the time at $\alpha = 0.05$, the number of replicates would have to be approximately 13.

The experimenter should consider this information, the statistical power needed for decision making, and the cost and handling time per container, before choosing the sample size for a test. Five replicates are often considered useful for routine testing purposes.

12.2 BIOLOGICAL EFFECTS

12.2.1 Tier III Water Column Bioassays

The objective of the analysis of Tier III water column toxicity test data is to assess the evidence for reduced survival due to toxicity of suspended plus dissolved dredged material constituents, and to calculate the median lethal concentration (LC50) of the material from the serial dilution experiment described in Section 10.2.1.

At the end of the exposure period, the effects, if any, on the survival of the test organisms should be clearly manifest in the 100 percent concentration (undiluted) test container. If two controls have been used, e.g., seawater from the disposal site and an artificial sea salt mixture, the control using seawater from the disposal site is preferred for the following statistical analyses. The appropriate statistical test for detecting a significant difference in survival between two independent samples, i.e., the control and the 100 percent concentration is the two-sample t-test (Snedecor and Cochran, 1980). The usual *t* statistic for testing the equality of means $\bar{x}_1$ and $\bar{x}_2$ from two independent samples with n_1 and n_2 observations is:

TABLE 12.1. POWER CALCULATIONS FOR ONE TAILED t-TESTS FOR SELECTED SAMPLE SIZES[a] (after Cohen, 1977)

Sample Size	Power(%)[b]
30	99
25	97
20	93
15	86
10	71
9	66
8	62
7	56
6	50
5	43
4	36
3	28
2	20

(a) Where $\alpha = 0.05$ and $\delta/\sigma = 1$.

(b) Power is $(1 - \beta)100$.

$$t = (\bar{x}_1 - \bar{x}_2) / \sqrt{s^2 \ (1/n_1 + 1/n_2)}$$

where s^2, the pooled variance, is calculated as follows:

$$s^2 = \{(n_1 - 1) s_1^2 + (n_2 - 1) s_2^2\} \div (n_1 + n_2 - 2)$$

and where s_1^2 and s_2^2 are the sample variances of the two groups.

The use of this t statistic depends on the assumption that the variances of the two groups are equivalent. This assumption can be tested using the folded F statistic, F′.

$$F' = (\text{larger of } s_1^2 \ , s_2^2 \ ) \ / \ (\text{smaller of } s_1^2 \ , \ s_2^2 \ )$$

with $n_1 - 1$ and $n_2 - 1$ degrees of freedom

A test of F′ is a two-tailed F test since we do not specify which variance is expected to be larger.

Under the assumption of equal variances, the t statistic is computed with the formula given above, using the pooled variance estimate s^2.

Under the assumption of unequal variances, the t statistic is computed as

$$t = (\bar{x}_1 - \bar{x}_2) \ / \ \sqrt{s_1^2/n_1 + s_2^2/n_2} \ .$$

The formula for Satterthwaites (1946) approximation for the degrees of freedom for use with this t statistic is as follows:

$$df = \frac{(s_1^2/n_1 + s_2^2/n_2)^2}{(s_1^2/n_1)^2/(n_1 - 1) + (s_2^2/n_2)^2/(n_2 - 1)}$$

Table 12.2 contains sample data from a 96 hr water column bioassay using a seawater control and dissolved plus suspended dredged material constituents at four serial dilutions. In this example, mean mortality in the control is less than 10 percent, indicating the acceptability of the test.

Figure 12.1 illustrates a SAS/PC program that will perform a two-sample t-test and a Levene's test of the homogeneity of sample variances. The results from this program are given in Figures 12.2 and 12.3. Figure 12.2 presents a listing of the data produced by the proc print; statement and the two-sample t-test results produced by the statement proc ttest cochran; and the next three statements.

Three t-test results are given: two versions of the t-test for unequal variances, and one for use if the variances in the two treatments are equal.

The F' statistic tests the hypothesis that the sample variances in the control data and 100 percent concentration data are equal (Steel and Torrie, 1980). The F' test in this example is significant at the 0.064 level, indicating that if the variances in the two groups are equal, then we will obtain the data we did or data with still more unequal variances only 6.4 percent of the time; i.e., the data suggest that variances in the two groups are not equal. The test is on the verge of being significant, if we are judging significance at the 0.05 level. In such cases it is usually prudent to use the t-test for unequal variances. Choosing this approach, the t-test, assuming unequal variances, indicates a significant difference (Prob>|T| = 0.0001) in survival between these two treatments. Significance probabilities for all of the t-tests in the SAS results are two-tailed probabilities. For this application we are concerned about dredged material samples with an effect greater than the control, and it is not important to detect dredged material samples that have less effect than the control. To obtain the one-tailed or directional probabilities which we want here, divide the two-tailed probabilities and consider the sign of

TABLE 12.2. NUMBER OF SURVIVORS IN A HYPOTHETICAL WATER COLUMN BIOASSAY AFTER 96 HOURS.

		Concentrations[c]			
Replicate[a]	Control[b]	100	50	25	12.5
1	20	6	8	12	17
2	19	7	8	18	17
3	20	9	9	15	18
4	20	5	10	14	16
5	19	8	11	13	18
Total	98	35	46	72	86

(a) 20 organisms per replicate at initiation of the test.
(b) Control = seawater.
(c) Percent concentrations of dissolved plus suspended dredged material constituents:

100% = 1 part suspension and 0 part seawater.
50% = 1 part suspension and 1 part seawater.
25% = 1 part suspension and 3 parts seawater.
12.5% = 1 part suspension and 7 parts seawater.

```
*++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*
*  This is an example SAS/PC program for a two-sample t-test of re-  *
*  sults from a 96-hour water column bioassay.  The t-test compares  *
*  the number of surviving organisms in the control (seawater)       *
*  to the number of surviving organisms in the 100% concentration.   *
*++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*;
options nodate pagesize=60;

data susphase;
        input trtmnt num_sviv @@;
        cards;
1 20 1 19 1 20 1 20 1 19 2 6 2 7 2 9 2 5 2 8
;
proc print;
        title1 'Water Column Bioassay Data and t-test Results';
proc sort;
        by trtmnt;

* The following two-sample t-test procedure will provide a t-statistic
  for each of two conditions, viz., when the sample variances are equal
  and when the sample variances are not equal.  An F' test is also
  provided which tests the hypothesis that the sample variances are,
  in fact, equal;
proc ttest cochran;
        class trtmnt;
        var num_sviv;
        label trtmnt='Control or 100% Concentration'
              num_sviv='Number of surviving animals';

* The following program performs a Levene's (1960) test for the
  equality of two sample variances;
proc sort;
        by trtmnt;
proc means noprint;   /*Calculate treatment Means */;
        by trtmnt;
        var num_sviv;
        output out=meanout mean=average;

* Next, merge treatment means with survival data;
data sustwo;
        merge susphase meanout;
        by trtmnt;
        deviatns=abs(num_sviv-average);
        drop _type_ _freq_;
proc print;
        title1 'Levene''s Test on Water Column Bioassay Data';

* Levene's test consists of an analysis of variance (ANOVA) on
  the absolute deviations of each observation from its respective
  sample mean;
proc anova;
        label deviatns='Absolute Deviations from Mean';
        class trtmnt;
        model deviatns=trtmnt;
run;
```

Figure 12-1. Example SAS/PC program to perform two-sample t-test and Leven's Homogeneity of Variance Test for a hypothetical water column bioassay from data in Table 12-2.

Water Column Bioassay Data and t-test Results

OBS	TRTMNT	NUM_SVIV
1	1	20
2	1	19
3	1	20
4	1	20
5	1	19
6	2	6
7	2	7
8	2	9
9	2	5
10	2	8

Water Column Bioassay Data and t-test Results 10

TTEST PROCEDURE

Variable: NUM_SVIV Number of surviving animals

TRTMNT	N	Mean	Std Dev	Std Error
1	5	19.60000000	0.54772256	0.24494897
2	5	7.00000000	1.58113883	0.70710678

Variances	T	Method	DF	Prob>|T|
Unequal	16.8375	Satterthwaite	4.9	0.0001
		Cochran	4.0	0.0001
Equal	16.8375		8.0	0.0000

For H0: Variances are equal, F' = 8.33 DF = (4,4) Prob>F' = 0.0640

Figure 12-2. Example data listing and SAS/PC program for a t-test between treatments based on hypothetical water column bioassay data in Table 12-2.

Levene's Test on Water Column Bioassay Data

OBS	TRTMNT	NUM_SVIV	AVERAGE	DEVIATNS
1	1	20	19.6	0.4
2	1	19	19.6	0.6
3	1	20	19.6	0.4
4	1	20	19.6	0.4
5	1	19	19.6	0.6
6	2	6	7.0	1.0
7	2	7	7.0	0.0
8	2	9	7.0	2.0
9	2	5	7.0	2.0
10	2	8	7.0	1.0

Levene's Test on Water Column Bioassay Data

Analysis of Variance Procedure

Dependent Variable: DEVIATNS Absolute Deviations from Mean

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1.29600000	1.29600000	3.64	0.0928
Error	8	2.84800000	0.35600000		
Corrected Total	9	4.14400000			

R-Square	C.V.	Root MSE	DEVIATNS Mean
0.312741	71.03064	0.596657	0.84000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRTMNT	1	1.29600000	1.29600000	3.64	0.0928

Figure 12-3. Example data listing and SAS/PC program output for a Levene's Test of Variance Homogeneity for hypothetical water column bioassay data in Table 12-2.

the t statistic. Here we are comparing the response in the control to the response in the 100 percent concentration. In this case the control meanis greater than the mean of the 100 percent concentration group, and therefore, the t statistic is positive. Considering the t-test for unequal variances, the results are significant ($p = 0.00005$) and in the direction we consider important, i.e., there is statistically significant increased mortality in the 100 percent concentration.

The F′ test of equality of variances is sensitive to departures from the assumption that these samples have been taken from populations with an underlying normal probability distribution. Figure 12.3 presents the results of a Levene's test, which is not sensitive to this assumption for reasonable samples sizes. This test is based on an ANOVA of the absolute deviations from the mean. Larger sample variances indicate larger absolute deviations. These results show that there is weaker evidence ($Pr > F = 0.093$) than in the F′ test discussed above favoring the conclusion that the sample variances are unequal. That is, there is almost a 10 percent chance of being wrong if we reject the null hypothesis and say the variances are unequal. In this example, the t-test shows that there is a statistically significant difference between the mean number surviving in the control and 100 percent concentration groups whether equal variances are assumed for the two groups or not.

12.2.2 Calculating Median Lethal Concentration

In the Tier III water column bioassays it is recommended (Section 10.2.1.5) that the median lethal concentration (LC50) be calculated for each observation time of the experiment. These values and their upper and lower 95 percent confidence limits are used to assess whether the toxicity of the dredged material exceeds the limiting permissible concentration (LPC). It is not possible to calculate LC50s unless at least 50 percent of the test organisms die in at least one of the serial dilutions. Experience indicates that often this does not occur for earlier time periods, and in such cases, it is only possible to calculate LC50s for later time periods. If it is not possible to calculate an LC50, then the LC50 is assumed to be 100 percent.

LC50 calculations are also recommended for reference toxicant tests to determine the relative health of the organisms used in bioassay and bioaccumulation testing.

Table 12.2 gives examples of data from a 96 hr water column bioassay. We see from these data that intermediate concentrations of the dredged material show intermediate proportions of surviving test organisms. The aim, therefore, is to apply some statistical method to these data to estimate the LC50 concentration at which 50 percent of the animals in the population would die. Calculating a 95 percent confidence interval using the sample LC50 signifies that there is only a 5 percent probability that the true LC50 of the population of test organisms lies outside of this interval.

Because opinions vary about the most appropriate statistical method for calculating the LC50, this implementation manual recommends using two or more of the procedures in the following citations to calculate the LC50. Stephan (1977) and Gelber et al. (1985) provide careful reviews of LC50 estimation procedures. In addition, EPA (1985) discusses in detail the mechanics of calculating LC50s using current methods and contains, as an appendix, computer programs for each statistical method.

Compliance with the regulations is determined according to the Tier III guidance in Section 6.1.

12.2.3 Tier III Benthic Bioassays

The objective of a statistical analysis of Tier III benthic bioassay data is to determine the strength of the evidence for concluding that the dredged material samples are significantly more toxic to marine benthic infauna than are the reference sediment samples. The test procedure is described in Section 10.2.2.

This objective can be accomplished using an analysis of variance (ANOVA) procedure and an associated multiple comparison procedure known as the Dunnett's test. These statistical techniques are discussed in Sokal and Rohlf (1981), Snedecor and Cochran (1980), Steele and Torrie (1980), SAS Institute (1985), and Dunnett (1964).

Table 12.3 presents survival data from a hypothetical benthic bioassay. In this example, mean mortality in the control is less than 10 percent, indicating the acceptability of the test. The ANOVA procedure assumes that the survival responses are independently and normally distributed with a common variance among treatment levels. That is:

$$X_{ij} \sim N(\mu_i, \sigma_i)$$

where X_{ij} is the number of survivors at the ith treatment level and the jth replicate. For the ith treatment level, X_{ij} is sampled from a normally distributed population with a mean μ_i and variance σ^2. In other words, the treatment levels can have different means but all levels have the same variance. The assumptions of normality and constant variance are not always met. Although ANOVA is fairly robust to deviations from these assumptions when sample sizes are equal, a test of the validity of these assumptions is recommended before performing the ANOVA. Bartlett's test (Snedecor and Cochran, 1980), the F' test (Section 12.2.1), or Levene's test (12.2.1) may be used to test for homogeneity of variances. If the raw data do not satisfy these assumptions, a mathematical transformation can sometimes be applied to the data which will confer a more normal distribution to the transformed data and will stabilize the variance among treatment levels (Natrella, 1963). For example, a common transformation for proportions (such as percent survival) is:

$$Y_{ij} = arcsine \sqrt{p_{ij}}$$

where p_{ij} is the proportion of survivors at the ith treatment level and for the jth replicate, i.e., $p_{ij} = X_{ij}/n$. We recommend that the survival proportion be used as the treatment response for analysis. If the data do not satisfy the ANOVA assumptions of normality and constant variance, we recommend that the arcsine/square root transformation be used prior to performing the ANOVA, although any transformation that increases normality and stabilizes variance among treatments may be used.

Another common transformation used to stabilize the variance is the logarithmic transformation. It is used when the standard deviation increases in direct proportion to the mean, i.e., when those treatments with

TABLE 12.3. NUMBER OF SURVIVORS IN THE HYPOTHETICAL BENTHIC BIOASSAY

	Treatments				
			Dredged Material Locations		
Replicate[a]	Reference	Control	Station 1	Station 2	Station 3
1	20	20	17	15	17
2	20	19	16	16	12
3	19	20	18	13	10
4	19	20	17	17	16
5	20	20	15	11	13

(a) 20 animals per replicate at initiation of test.

larger means also have larger standard deviations. The transformation is simply:

$$Y_{ij} = \log(X_{ij})$$

Either natural or base 10 logarithms are commonly used.

Figure 12.4 illustrates a SAS/PC program that performs an ANOVA on the transformed survival proportions calculated from Table 12.3. In addition to the ANOVA, this program includes an analysis of the total number of survivors using a nonparametric Kruskal-Wallis test (Daniel, 1978) for comparison. The nonparametric test is often performed when the assumptions of the commensurate parametric test, such as the ANOVA, cannot be verified. The nonparametric test can actually be more powerful in detecting differences among treatment levels depending on the underlying parametric probability distribution model.

The output from the program is given in Figures 12.5-12.9. Figure 12.5 presents the data on the number of survivors for each treatment, the proportion of survivors, and the arcsine/square root transformed proportions. This output was produced by the proc print; statement in the program.

Figure 12.6 presents the arithmetic means and standard deviations of these variables. Note that the survival (NUM-SVIV) is more variable (i.e., standard deviations are larger) in the Station treatment groups than in the reference sediment treatment groups. Note also that the variability among treatment groups is more stable for the transformed variable (TRN-SVIV). Output in Figure 12.6 is produced by the proc means; statement and the two following statements in the program.

Figure 12.7 contains the ANOVA results. These results were produced by the proc anova; statement and subsequent statements. The F Value is the statistic of interest in these tables, where:

$$F = MST/MSE$$

```
*++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
*                                                                     *
*  This is an example SAS/PC program for an analysis of variance     *
*                                                                     *
*  using hypothetical benthic bioassay data.                          *
*                                                                     *
*++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*;
options nodate pagesize=60;

data solphase;
        input trtmnt num_sviv @@;
* The following variable prp_sviv is the proportion of survivors.
  It is transformed to a different scale to stabilize the variance
  within each trtmnt level using arcsine of the square root
  transformation. This new variable is trn_sviv;
        prp_sviv=num_sviv/20;
        trn_sviv=arsin(sqrt(prp_sviv));
        cards;
1 20 1 20 1 19 1 19 1 20 2 20 2 19 2 20 2 20 2 20 3 17 3 16 3 18
3 17 3 15 4 15 4 16 4 13 4 17 4 11 5 17 5 12 5 10 5 16 5 13
;
proc print;

* Obtain the mean number of survivors per reference, control, or
  station sample and the mean percent survival;
proc sort;
        by trtmnt;
proc means;
        by trtmnt;
        var num_sviv prp_sviv trn_sviv;

* A one-way ANOVA follows with provisions for a Dunnett's multiple
  comparison test of each sampling station mean versus the control
  mean:  trtmnt=1 is the reference sediment sample, trtmnt=2 is the
  control sediment sample;
proc anova;
        label trtmnt='Controls/Sampling Stations'
              num_sviv='Number of surviving animals'
              prp_sviv= 'Proportion of surviving animals'
              trn_sviv= 'Transformed survivorship proportion';
        class trtmnt;
        model num_sviv trn_sviv=trtmnt;
        means trtmnt/ dunnettl;
        title1 'Benthic Bioassay ANOVA Results';

* A nonparametric analysis of variance of the same data follow for
  comparison;
proc npar1way wilcoxon;
        class trtmnt;
        var num_sviv;
        title1 'Benthic Bioassay Nonparametric Analysis Results';
run;
```

Figure 12-4. An example SAS/PC program for analyzing survival proportion from the hypothetical benthic bioassay data in Table 12-3.

SAS

OBS	TRTMNT	NUM_SVIV	PRP_SVIV	TRN_SVIV
1	1	20	1.00	1.57080
2	1	20	1.00	1.57080
3	1	19	0.95	1.34528
4	1	19	0.95	1.34528
5	1	20	1.00	1.57080
6	2	20	1.00	1.57080
7	2	19	0.95	1.34528
8	2	20	1.00	1.57080
9	2	20	1.00	1.57080
10	2	20	1.00	1.57080
11	3	17	0.85	1.17310
12	3	16	0.80	1.10715
13	3	18	0.90	1.24905
14	3	17	0.85	1.17310
15	3	15	0.75	1.04720
16	4	15	0.75	1.04720
17	4	16	0.80	1.10715
18	4	13	0.65	0.93774
19	4	17	0.85	1.17310
20	4	11	0.55	0.83548
21	5	17	0.85	1.17310
22	5	12	0.60	0.88608
23	5	10	0.50	0.78540
24	5	16	0.80	1.10715
25	5	13	0.65	0.93774

Figure 12-5. Example data listing from a SAS/PC program showing the treatment level (TRN, number of survivors)(NUM_SVIV), survival proportional (PRP_SVIV), and the transformed proportions (TRN_sviv0 from the hypothetical data given in Table 12-3.

SAS

TRTMNT=1

N Obs	Variable	N	Minimum	Maximum	Mean	Std Dev
5	NUM_SVIV	5	19.0000000	20.0000000	19.6000000	0.5477226
	PRP_SVIV	5	0.9500000	1.0000000	0.9800000	0.0273861
	TRN_SVIV	5	1.3452829	1.5707963	1.4805910	0.1235188

TRTMNT=2

N Obs	Variable	N	Minimum	Maximum	Mean	Std Dev
5	NUM_SVIV	5	19.0000000	20.0000000	19.8000000	0.4472136
	PRP_SVIV	5	0.9500000	1.0000000	0.9900000	0.0223607
	TRN_SVIV	5	1.3452829	1.5707963	1.5256936	0.1008527

TRTMNT=3

N Obs	Variable	N	Minimum	Maximum	Mean	Std Dev
5	NUM_SVIV	5	15.0000000	18.0000000	16.6000000	1.1401754
	PRP_SVIV	5	0.7500000	0.9000000	0.8300000	0.0570088
	TRN_SVIV	5	1.0471976	1.2490458	1.1499172	0.0762914

TRTMNT=4

N Obs	Variable	N	Minimum	Maximum	Mean	Std Dev
5	NUM_SVIV	5	11.0000000	17.0000000	14.4000000	2.4083189
	PRP_SVIV	5	0.5500000	0.8500000	0.7200000	0.1204159
	TRN_SVIV	5	0.8354819	1.1730969	1.0201339	0.1347090

TRTMNT=5

N Obs	Variable	N	Minimum	Maximum	Mean	Std Dev
5	NUM_SVIV	5	10.0000000	17.0000000	13.6000000	2.8809721
	PRP_SVIV	5	0.5000000	0.8500000	0.6800000	0.1440486
	TRN_SVIV	5	0.7853982	1.1730969	0.9778931	0.1596151

Figure 12-6. Example of SAS/PC listing of arithmetic means and standard deviations for hypothetical benthic bioassay data given in Table 12-3.

Benthic Bioassay ANOVA Results

Analysis of Variance Procedure

Dependent Variable: NUM_SVIV Number of surviving animals

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	164.4000000	41.1000000	12.92	0.0001
Error	20	63.6000000	3.1800000		
Corrected Total	24	228.0000000			

R-Square	C.V.	Root MSE	NUM_SVIV Mean
0.721053	10.61462	1.783255	16.8000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRTMNT	4	164.4000000	41.1000000	12.92	0.0001

Benthic Bioassay ANOVA Results

Analysis of Variance Procedure

Dependent Variable: TRN_SVIV Transformed survivorship proportion

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	1.32120960	0.33030240	22.06	0.0001
Error	20	0.29948815	0.01497441		
Corrected Total	24	1.62069775			

R-Square	C.V.	Root MSE	TRN_SVIV Mean
0.815210	9.941941	0.122370	1.23084575

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRTMNT	4	1.32120960	0.33030240	22.06	0.0001

Figure 12-7. Example SAS/PC program output showing ANOVA results for hypothetical benthic bioassay data given in Table 12-3.

Benthic Bioassay ANOVA Results

Analysis of Variance Procedure

Dunnett's One-tailed T tests for variable: NUM_SVIV

NOTE: This tests controls the type I experimentwise error for comparisons of all treatments against a control.

Alpha= 0.05 Confidence= 0.95 df= 20 MSE= 3.18
Critical Value of Dunnett's T= 2.304
Minimum Significant Difference= 2.599

Comparisons significant at the 0.05 level are indicated by '***'.

TRTMNT Comparison		Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
2	- 1	-2.399	0.200	2.799	
3	- 1	-5.599	-3.000	-0.401	***
4	- 1	-7.799	-5.200	-2.601	***
5	- 1	-8.599	-6.000	-3.401	***

Benthic Bioassay ANOVA Results

Analysis of Variance Procedure

Dunnett's One-tailed T tests for variable: TRN_SVIV

NOTE: This tests controls the type I experimentwise error for comparisons of all treatments against a control.

Alpha= 0.05 Confidence= 0.95 df= 20 MSE= 0.014974
Critical Value of Dunnett's T= 2.304
Minimum Significant Difference= 0.1783

Comparisons significant at the 0.05 level are indicated by '***'.

TRTMNT Comparison		Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
1	- 2	-0.2234	-0.0451	0.1332	
3	- 2	-0.5541	-0.3758	-0.1974	***
4	- 2	-0.6839	-0.5056	-0.3272	***
5	- 2	-0.7261	-0.5478	-0.3695	***

Figure 12-8. Example SAS/PC program output showing Dunnett's Test for hypotehtical benthic bioassay given in Table 12-3.

Benthic Bioassay Nonparametric Analysis Results

N P A R 1 W A Y P R O C E D U R E

Wilcoxon Scores (Rank Sums) for Variable NUM_SVIV
Classified by Variable TRTMNT

TRTMNT	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
1	5	100.000000	65.0	14.5028733	20.0000000
2	5	105.000000	65.0	14.5028733	21.0000000
3	5	55.500000	65.0	14.5028733	11.1000000
4	5	34.500000	65.0	14.5028733	6.9000000
5	5	30.000000	65.0	14.5028733	6.0000000

Average Scores were used for Ties

Kruskal-Wallis Test (Chi-Square Approximation)
CHISQ= 19.286 DF= 4 Prob > CHISQ= 0.0007

Figure 12-9. Example SAS/PC program output showing non-parametric (Kruskal-Wallis) test results for hypothetical benthic bioassay data given in Table 12-3.

MST is the mean square (variance) for differences among treatment level means (41.1 in this example with NUM_SIV as the dependent variable) and MSE is the mean square for differences among replicates (3.18 in this same example). If survival is unaffected by the treatment levels, F is approximately equal to 1.0. If survival is less among treatments levels, F > 1.0. The probability of obtaining an F statistic as large or larger than the one calculated for the transformed data (i.e., F = 22.06) is 0.0001. That is, if there is no difference in survival among the stations and controls, we would expect to observe survival data like those given in Table 12.3, only 1 in 10,000. Thus we reject the hypothesis of equal survival rates at the 0.0001 level of significance.

In this example there is strong evidence for concluding that there are significant differences in survival among the reference sediment and dredged material treatment groups. This conclusion would have been reached regardless of whether the data are transformed or not (Figure 12.7). It is also important to know which sampling stations differed significantly from the reference. The results of an appropriate multiple comparison analysis known as the Dunnett's test (Dunnett, 1964) are given in Figure 12.8. This test was requested in the SAS statements specifying the ANOVA, and the results show that there is no difference in survival between the control group and the reference sediment group either for transformed or untransformed data. With only a 5 percent chance of being wrong, we can also conclude from these results that survival in each dredged material treatment group is significantly less than in the reference sediment group.

In this example, all comparisons are made to trtmnt=1 which is the reference sediment. The Dunnett's test in SAS compares all subsequent treatment groups to the first group in the dataset, which in this case is the reference sediment. **If other software is used, care has to be taken to see that comparisons are made to reference, not control, data.**

Finally, because the number of survivors in each treatment group is not always normally distributed, a nonparametric test that does not require the assumption of normality can be performed. Figure 12.9 shows the results from a nonparametric Kruskal-Wallis test which was generated by the <u>proc npar1way wilcoxon</u>; statement. This test is a counterpart to the parametric ANOVA procedure. It is based on the sum of the ranks for all

observations in each treatment group. If survival is consistently lower in the station treatment groups, the sum of the ranks will be smaller. The Kruskal-Wallis statistic is approximately distributed as a chi square. Hence, the probability of obtaining this much or more evidence (CHISQ = 19.286) in favor of a difference in survival among the reference and station treatment groups when, in fact, there is no difference is 0.0007, or about 7 times in 10,000. This very small probability is strong evidence that sediments from the proposed dredging site in our hypothetical example truly are more toxic than the reference sediment.

Compliance with the regulations is determined according to the Tier III guidance in Section 6.2.

12.3 BIOACCUMULATION

Bioaccumulation tests described in Chapter 11 are employed to determine whether an organism's exposure to the dredged material is likely to cause an elevation of contaminants in its body, i.e., is bioaccumulation likely to occur in organisms exposed to the dredged material. Bioaccumulation tests conducted in the laboratory or in the field require statistical analysis as described in Sections 12.3.1-3.

12.3.1 Tier III 10 or 28 Day Single Time Point Laboratory Study

The Tier III single time point laboratory bioaccumulation test produces tissue concentration measurements for each contaminant of concern. Table 12.4 presents the results from a hypothetical laboratory test. Chemical analysis of the tissue samples from each replicate shows varying concentrations of the example contaminant. Data, which are not shown here, attest that mortality did not exceed 25 percent in any of the replicates for the control or for any of the dredged material samples, indicating that the test is acceptable.

The appropriate statistical test for these data is similar to that given for benthic bioassays (Section 12.2.3), with several exceptions. In

TABLE 12.4. RESULTS FROM A HYPOTHETICAL SINGLE TIME POINT BIOACCUMULATION TEST SHOWING AVERAGE CONTAMINANT CONCENTRATIONS (ug/g dry weight) IN TISSUES OF ANIMALS EXPOSED TO DIFFERENT TREATMENTS.

Replicate[a]	Reference	Control	Dredged Material Samples 1	2	3
1	0.06	0.04	0.16	0.24	0.13
2	0.05	0.03	0.19	0.10	0.05
3	0.05	0.09	0.18	0.13	0.17
4	0.08	0.04	0.22	0.18	0.08
5	0.09	0.05	0.31	0.30	0.22
n	5		5	5	5
mean	0.066		0.212	0.190	0.130
standard error	0.008		0.026	0.036	0.030
upper 95%, one-sided confidence limit	0.083				
lower 95%, one-sided confidence limit			0.156	0.113	0.065

(a) 20 animals per replicate

evaluating the results of Tier III bioaccumulation tests, average contaminant concentration in tissues of organisms exposed to dredged material samples is compared to FDA action limits (when FDA limits exist), as well as being statistically compared to average concentration in tissues of organisms exposed to reference sediments. A second difference is that in the benthic bioassays, we were concerned when survival was less in the organisms exposed to dredged material than in those exposed to the reference sediment. In bioaccumulation tests, we are concerned when the effect (bioaccumulation as measured by tissue concentration of contaminants) is greater in the organisms exposed to dredged material than in those exposed to the reference sediment.

12.3.1.1 Confidence Interval Approach

Statistical comparison of the dredged material results to the FDA action limits and the reference sediment results involves calculation of confidence limits. If the confidence limits of a dredged material sample overlap the FDA limit or the confidence limits of the reference sediment, there is no statistically significant difference between the dredged material sample and the FDA action limit or the reference sediment. Conversely, if there is no overlap of confidence limits, the dredged material is statistically significantly different from the FDA action limit or the reference sediment. One-sided confidence limits are appropriate since there is concern if the effect in the dredged material is greater than in the reference sediment. There is little concern if the effect in the dredged material is less than in the reference sediment.

In benthic bioassays, survival in the dredged material is considered statistically significantly different from the reference sediments when the upper 95 percent, one-sided confidence limit of survival in the dredged material is less than the lower 95 percent, one-sided confidence limit of survival the reference material. If the upper confidence limit for survival in the dredged material is greater than the lower confidence limit for survival in the reference sediment, then the confidence intervals overlap, and there is no statistically significant difference between survival in the dredged material and the reference sediment.

Bioaccumulation from the dredged material is considered statistically significantly greater than the FDA limit or bioaccumulation from the reference sediment when the lower 95 percent, one-sided confidence limit of the dredged material samples is greater than the FDA limit or the upper 95 percent, one-sided confidence limit of the reference material samples. If the lower confidence limit for the dredged material is less than the FDA limit or the upper confidence limit for the reference sediment, then the confidence intervals overlap and the difference between bioaccumulation from the dredged material and the FDA limit or bioaccumulation from the reference sediment is not considered statistically significant.

12.3.1.2 Confidence Internal Formulae

The statistics needed for the calculation of confidence limits include the mean and the standard error. These calculations are simple, especially with a small sample size, and can be calculated with paper and pencil. Many calculators include programmed mean and standard deviation calculations. The sequence of calculations necessary for the statistical analysis is given in the following:

n = number of observations

x_n = the nth observation, e.g., x_2 is the second observation

Σx = sum of the x's = $x_1 + x_2 + x_3 + \ldots + x_n$

Σx^2 = sum of the squared x's = $(x_1)(x_1) + (x_2)(x_2) + \ldots + (x_n)(x_n)$

mean = $\Sigma x / n$

variance = $[\Sigma x^2 - (\Sigma x)^2/n] / [n-1]$

standard deviation = $\sqrt{\text{variance}}$

standard error = standard deviation / $\sqrt{n}$

upper 95%, one-sided confidence limit = mean + $(t_{0.10,n-1})$(std. error)

lower 95%, one-sided confidence limit = mean - $(t_{0.10,n-1})$(std. error)

The t-value ($t_{0.10,n-1}$ above) is a value from the t-distribution. The t-distribution resembles the normal distribution in that it is bell-shaped.

This distribution, rather than the normal distribution, is used in situations when the population variance of the distribution is not known and is estimated from the sample values. Tables of the t-distribution can be found in many statistical texts and references. The correct t-value to use depends on two parameters, alpha (α is the probability of a type I error) and the number of degrees of freedom. In the application presented here, the number of degrees of freedom is always one less than the number of observations, i.e., $n - 1$. The value of α depends on the probability desired in the tails of the distribution, i.e., the probability of obtaining a larger value than the t-value used. Here we are interested in a 95 percent, one-sided confidence limit, i.e., we want 5 percent of the probability in one tail or the other of the distribution. To obtain a one-tailed probability of 0.05, an α value of 0.10 is found in standard tables of the two-tailed t-distribution. This value gives 5 percent of the probability in each tail of the distribution, and we use either the upper or the lower tail as needed. Table 12.5 gives an abbreviated t-distribution table. The t-value which will give 95 percent, one-sided confidence limits for five observations is 2.132 ($\alpha = 0.10$ with $n - 1 = 4$ degrees of freedom).

The bioaccumulation data in Table 12.4 can be analyzed using either the confidence interval approach or the SAS/PC program given in Section 12.2.3. The confidence interval approach using the formulas above is used when bioaccumulation from reference sediment samples using the reference area approach has been determined previous to the determination of bioaccumulation from dredged material samples. The statistics calculated in this way are included in Table 12.4 and the confidence intervals are illustrated in Figure 12.10. If dredged material and reference sediment tests are run concurrently using the reference point approach, the program in Figure 12.4 can be used by labeling the reference sediment data as treatment = 1 and the dredged material samples as treatments 2,3, and 4. The Dunnett's test compares bioaccumulation from each dredged material sample to bioaccumulation from the reference sediment.

Figure 12.10 shows the relationship of bioaccumulation in the various dredged material samples to both the reference sediment bioaccumulation and the FDA action limit. Average tissue concentration in dredged material

TABLE 12.5. SELECTED VALUES OF THE TWO-TAILED t-DISTRIBUTION

Degrees of Freedom	Value of t-distribution[a]
1	6.314
2	2.920
3	2.353
4	2.132
5	2.015
6	1.943
7	1.895
8	1.860
9	1.833
10	1.812

(a) Two-tailed probability = 0.10; one-tailed probability = 0.05

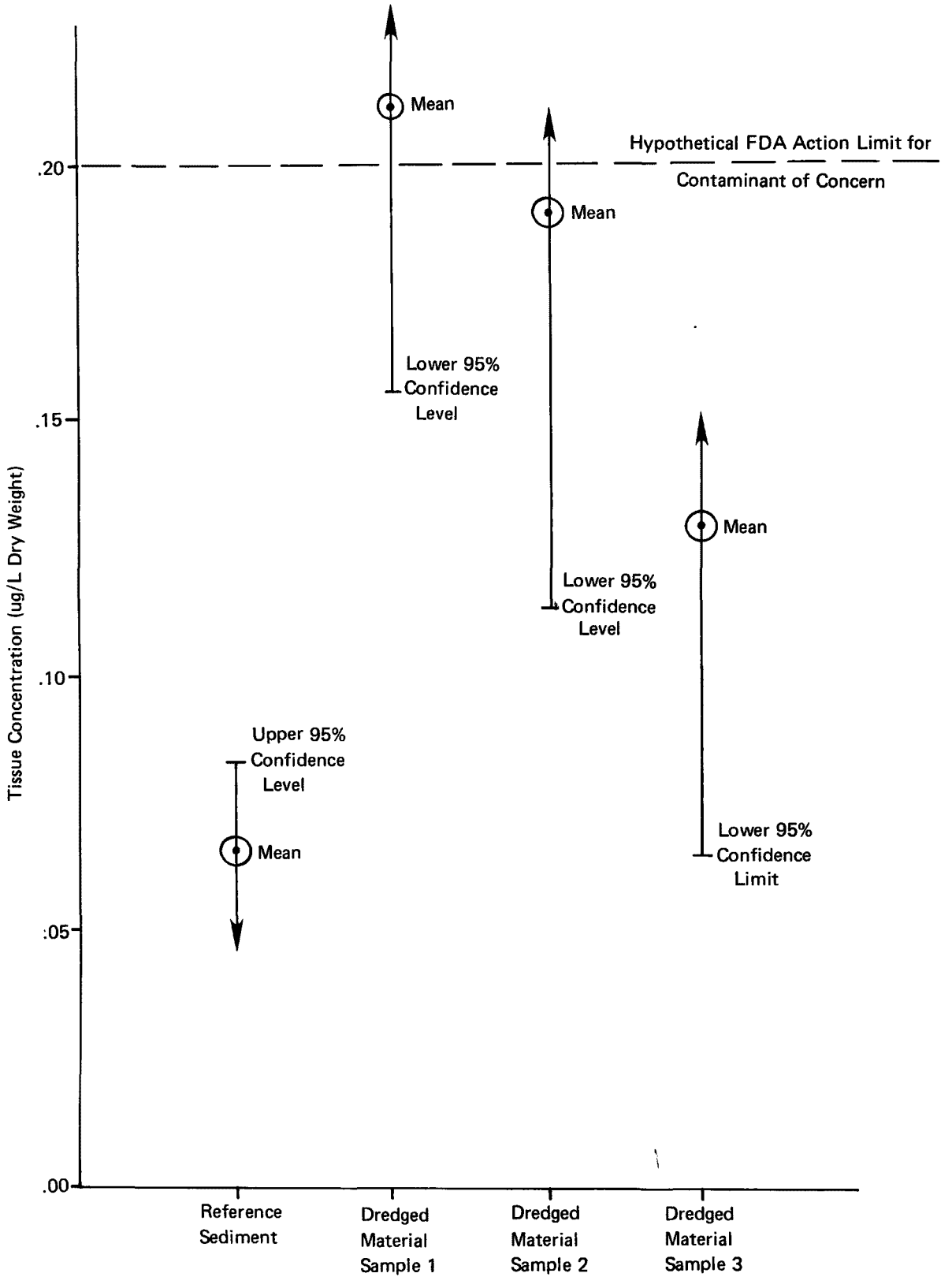

Figure 12-10. **Mean tissue concentration with 95 percent one-sided confidence intervals calculated on hypothetical single time point bioaccumulation data given in Table 12-4.**

sample number 1 is numerically higher than the FDA action limit, but the concentration cannot be considered statistically different at the 95 percent level from the FDA limit since the lower 95 percent confidence limit overlaps the FDA limit. The average tissue concentration in dredged material sample 2 is below the FDA action limit, but the dredged material is statistically significantly greater than the reference sediment; i.e., there is no overlap between the confidence intervals of the reference sediment and dredged material sample 2. The average concentration in dredged material sample 3 is less than the FDA action limit, and the bioaccumulation from the dredged material does not statistically exceed bioaccumulation from the reference sediment, i.e., the confidence limits of sample 3 and the reference sediment overlap.

Compliance with the regulations is determined according to the Tier III bioaccumulation guidance in Section 6.3.

12.3.2 Tier IV Time-Series Laboratory Bioaccumulation Study

The 28 day time-series laboratory bioaccumulation test in Tier IV is designed to detect differences, if any, between steady state bioaccumulation in organisms exposed to the dredged material and steady state bioaccumulation in organisms exposed to reference sediment. If organisms are exposed to biologically available contaminants under constant conditions for a sufficient period of time, bioaccumulation will eventually reach a steady state in which maximum bioaccumulation has occurred, and the net exchange of the contaminant between sediment or dredged material and the organism is zero.

A simple kinetic model (McFarland et. al., 1986; McFarland and Clarke, 1987) can be used with data collected over a relatively short period of constant exposure to project tissue concentrations at steady state. This model integrated for constant exposure is:

$$C_t = \frac{k_1 C_w}{k_2}(1 - e^{-k_2 t})$$

where

C_t = concentration of a compound in tissues of an organism at time t
k_1 = uptake rate constant
C_w = exposure concentration of the compound
k_2 = elimination rate constant
t = time

As duration of exposure increases, the exponential term in the model approaches zero, and the tissue concentration at steady state (i.e., infinite exposure) is calculated as follows:

$$C_t = \frac{k_1 C_w}{k_2} = C_{ss}$$

where C_{ss} is an estimate of the whole-body concentration of the compound at steady state (i.e., after infinitely long constant exposure).

Table 12.6 presents tissue concentrations resulting from a hypothetical 28 day time series laboratory bioaccumulation test on three dredged material samples. There are five replicates of each treatment, and tissue samples were analyzed on days 2, 4, 7, 10, 18, and 28 of the test. Mortality in all replicates did not exceed 25 percent, and therefore the test is acceptable.

These data can be used with iterative nonlinear regression methods such as those in the SAS NLIN procedure to solve for the parameters in the model above. Then C_{ss}, the steady state concentration, is simply the ratio of the estimated nonlinear regression parameters k_1 and k_2 together with C_w. In this iterative calculation method, the contaminant concentration in the sediment is used as C_w. Figure 12.11 provides a SAS/PC program to carry out these calculations. Iterative curve fitting techniques will provide better

TABLE 12.6. AVERAGE TISSUE CONCENTRATION RESULTING FROM A HYPOTHETICAL 28-DAY TIME-SERIES BIOACCUMULATION TEST, SHOWING DIFFERENT CONTAMINANT CONCENTRATIONS IN TISSUES OF ANIMALS EXPOSED TO DIFFERENT TREATMENTS.[a]

Day	Replicate	Reference	Dredged Material Samples A	B	C
2	1	0.054	0.159	0.869	0.745
2	2	0.163	0.292	0.726	1.703
2	3	0.391	0.428	0.394	2.045
2	4	0.734	0.558	1.232	1.855
2	5	0.634	0.256	0.977	1.135
4	1	0.441	0.516	0.838	1.316
4	2	0.797	0.158	0.633	0.930
4	3	0.203	0.743	0.452	2.141
4	4	0.564	0.324	0.728	1.150
4	5	0.018	0.126	1.314	1.621
7	1	0.687	0.881	1.246	1.583
7	2	0.177	0.317	0.816	2.715
7	3	0.862	0.270	0.897	1.016
7	4	0.413	0.562	1.639	2.221
7	5	0.029	0.095	0.688	2.134
10	1	0.037	0.278	1.767	1.578
10	2	0.549	0.485	1.272	2.268
10	3	0.884	0.051	1.003	1.756
10	4	0.787	0.909	1.158	2.899
10	5	0.294	0.718	1.415	0.890
18	1	0.856	0.904	1.631	2.822
18	2	0.598	1.300	1.877	2.607
18	3	0.016	0.671	1.487	3.414
18	4	0.806	0.234	1.216	1.319
18	5	0.119	0.337	1.280	1.866
28	1	0.514	0.172	1.178	1.295
28	2	0.839	1.049	1.721	2.964
28	3	0.793	0.476	1.366	2.109
28	4	0.099	0.712	1.513	2.820
28	5	0.226	1.245	1.843	3.325
mean sediment concentration		0.45	4.0	33.0	44.0

(a) Total contaminant concentration in µg/g dry weight.
Reference Sediment Statistics
Steady state mean tissue concentration = 0.473 µg/g
Steady state upper 95%, one-sided confidence limit 0.590
Hypothetical FDA action level = 2 µg/g

```
*+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*
*  This is an example SAS/PC program which performs nonlinear        *
*  regression analysis on hypothetical 28-day bioaccumulation        *
*  laboratory test data.                                             *
*+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*;
options pagesize=60 linesize=80 nodate;

data bioaccum;
        retain trtmnt t_days conc_sed;
        input trtmnt $ t_days @;
        if trtmnt='R' then conc_sed = 0.45;
           else if trtmnt='A' then conc_sed = 4.0;
           else if trtmnt='B' then conc_sed = 33.;
           else if trtmnt='C' then conc_sed = 44.;
        do rep = 1 to 5;
           input conc_tis @@;
           output;  end;
        if t_days = 28 then do;
           t_days = 999;  rep = 1;  conc_tis=.;  output;  end;
cards;
R  2 0.054 0.163 0.391 0.734 0.634  R  4 0.441 0.797 0.203 0.564 0.018
R  7 0.687 0.177 0.862 0.413 0.029  R 10 0.037 0.549 0.884 0.787 0.294
R 18 0.856 0.598 0.016 0.806 0.119  R 28 0.514 0.839 0.793 0.099 0.226
A  2 0.159 0.292 0.428 0.558 0.256  A  4 0.516 0.158 0.743 0.324 0.126
A  7 0.881 0.317 0.270 0.562 0.095  A 10 0.278 0.485 0.051 0.909 0.718
A 18 0.904 1.300 0.671 0.234 0.337  A 28 0.172 1.049 0.476 0.712 1.245
B  2 0.869 0.726 0.394 1.232 0.977  B  4 0.838 0.633 0.452 0.728 1.314
B  7 1.246 0.816 0.897 1.639 0.688  B 10 1.767 1.272 1.003 1.158 1.415
B 18 1.631 1.877 1.487 1.216 1.280  B 28 1.178 1.721 1.366 1.513 1.843
C  2 0.745 1.703 2.045 1.855 1.136  C  4 1.316 0.930 2.141 1.150 1.621
C  7 1.583 2.715 1.016 2.221 2.134  C 10 1.578 2.268 1.756 2.899 0.890
C 18 2.822 2.607 3.414 1.319 1.866  C 28 1.295 2.964 2.109 2.820 3.325
;

proc print  data=bioaccum;
        title1 '28-Day Bioaccumulation Data';

* The following procedure performs a nonlinear regression analysis
  using a simple kinetic model on 28-day bioaccumulation laboratory
  test data;
proc nlin  data=bioaccum  method=marquardt;
        by trtmnt  notsorted;
        parameters  k1 = 0.1  k2 = 0.5;
        kicks = k1 * conc_sed /k2;
        exp_term = exp(-k2 * t_days);
        model  conc_tis = kicks * (1-exp_term);
        der.k1 = (conc_sed / k2) * (1-exp_term);
        der.k2 = kicks * (-1/k2 + exp_term/k2 + t_days*exp_term);
        output  out=results  p=pred_ct  l95m=lo_95_2s  u95m=up_95_2s;

* This data step calculates the 95%, 1-sided confidence limits from
  the 95%, 2-sided limits produced by SAS.  The t-values used here
  must be changed if the sample size changes;
data results2;
        set results;
        drop rep conc_tis lo_95_2s up_95_2s;
        if rep=1;
        lo_95_1s = pred_ct - (up_95_2s-pred_ct)*1.701/2.048;
        up_95_1s = pred_ct + (up_95_2s-pred_ct)*1.701/2.048;
proc print  data=results2;
```

Figure 12-11. Example SAS/PC program to perform nonlinear regression analysis using hypothetical 28 day time-series bioaccumulation data.

fits to some data than to others. If difficulties are encountered, approaches such as those discussed by SCI (1989) and Draper and Smith (1981) should be considered. The advice of an applied statistician might be appropriate.

Figures 12.12-12.17 present the results of the SAS program shown in Figure 12.11. Figure 12.12 is a list of the data used in the program. Figures 12.13 - 12.16 give the nonlinear regression analyses for the reference and dredged materials A, B, and C, respectively. Results of the regression analyses are listed in Figure 12.17.

In the data listing in Figure 12.12, a value of 999 days is used to represent time infinity at which steady state concentrations would have occurred.

The confidence limits calculated by the SAS nonlinear regression procedure are 95 percent, two-sided confidence limits. A one-sided confidence limit is calculated from the two-sided limits in the SAS statements in the last data step of the program. The SAS statement incorporate t-values for two-sided limits (t-value = 2.048, p-level = 0.05 with 28 degrees of freedom) and for one-sided limits (t-value = 1.701, Figure 12.12 p-level = 0.10 with 28 degrees of freedom). If other than five replicates on each of six days (resulting in 30 observations included in the nonlinear regression analysis) are used, these t-values have to be altered to reflect the correct number of degrees of freedom which is two less than the total number of observations.

The summary in Figure 12.17 gives the value of the tissue concentration (pre_ct) predicted by nonlinear regression for each day of the test and for steady state (estimated at 999 days). The summary also includes the corresponding upper and lower 95 percent, one-sided confidence limits (up_95_1s and lo_95_1s). The predicted steady state concentrations and their lower confidence limits are compared to FDA action limits and to the upper confidence limit calculated on steady state reference sediment bioaccumulation.

Figure 12.18 graphically displays the results of the nonlinear regressions of tissue concentration over time for the four treatments. The nonlinear regression line for each treatment is shown with the lower 95 percent one-sided confidence bounds on the sample means. The regression

28-Day Bioaccumulation Data

OBS	TRTMNT	T_DAYS	CONC_SED	REP	CONC_TIS
1	R	2	0.45	1	0.054
2	R	2	0.45	2	0.163
3	R	2	0.45	3	0.391
4	R	2	0.45	4	0.734
5	R	2	0.45	5	0.634
6	R	4	0.45	1	0.441
7	R	4	0.45	2	0.797
8	R	4	0.45	3	0.203
9	R	4	0.45	4	0.564
10	R	4	0.45	5	0.018
11	R	7	0.45	1	0.687
12	R	7	0.45	2	0.177
13	R	7	0.45	3	0.862
14	R	7	0.45	4	0.413
15	R	7	0.45	5	0.029
16	R	10	0.45	1	0.037
17	R	10	0.45	2	0.549
18	R	10	0.45	3	0.884
19	R	10	0.45	4	0.787
20	R	10	0.45	5	0.294
21	R	18	0.45	1	0.856
22	R	18	0.45	2	0.598
23	R	18	0.45	3	0.016
24	R	18	0.45	4	0.806
25	R	18	0.45	5	0.119
26	R	28	0.45	1	0.514
27	R	28	0.45	2	0.839
28	R	28	0.45	3	0.793
29	R	28	0.45	4	0.099
30	R	28	0.45	5	0.226
31	R	999	0.45	1	.
32	A	2	4.00	1	0.159
33	A	2	4.00	2	0.292
34	A	2	4.00	3	0.428
35	A	2	4.00	4	0.558
36	A	2	4.00	5	0.256
37	A	4	4.00	1	0.516
38	A	4	4.00	2	0.158
39	A	4	4.00	3	0.743
40	A	4	4.00	4	0.324
41	A	4	4.00	5	0.126
42	A	7	4.00	1	0.881
43	A	7	4.00	2	0.317
44	A	7	4.00	3	0.270
45	A	7	4.00	4	0.562
46	A	7	4.00	5	0.095
47	A	10	4.00	1	0.278
48	A	10	4.00	2	0.485
49	A	10	4.00	3	0.051
50	A	10	4.00	4	0.909
51	A	10	4.00	5	0.718
52	A	18	4.00	1	0.904
53	A	18	4.00	2	1.300
54	A	18	4.00	3	0.671
55	A	18	4.00	4	0.234
56	A	18	4.00	5	0.337

Figure 12-12. Example data listing from SAS/PC program showing sediment concenration (CON_SED), treatment level (TRTMNT), time in days (T_DAYS), and tissue concentration (CONC_TIS) for hypothetical 28 day bioaccumulation laboratory test data.

28-Day Bioaccumulation Data

OBS	TRTMNT	T_DAYS	CONC_SED	REP	CONC_TIS
57	A	28	4	1	0.172
58	A	28	4	2	1.049
59	A	28	4	3	0.476
60	A	28	4	4	0.712
61	A	28	4	5	1.245
62	A	999	4	1	.
63	B	2	33	1	0.869
64	B	2	33	2	0.726
65	B	2	33	3	0.394
66	B	2	33	4	1.232
67	B	2	33	5	0.977
68	B	4	33	1	0.838
69	B	4	33	2	0.633
70	B	4	33	3	0.452
71	B	4	33	4	0.728
72	B	4	33	5	1.314
73	B	7	33	1	1.246
74	B	7	33	2	0.816
75	B	7	33	3	0.897
76	B	7	33	4	1.639
77	B	7	33	5	0.688
78	B	10	33	1	1.767
79	B	10	33	2	1.272
80	B	10	33	3	1.003
81	B	10	33	4	1.158
82	B	10	33	5	1.415
83	B	18	33	1	1.631
84	B	18	33	2	1.877
85	B	18	33	3	1.487
86	B	18	33	4	1.216
87	B	18	33	5	1.280
88	B	28	33	1	1.178
89	B	28	33	2	1.721
90	B	28	33	3	1.366
91	B	28	33	4	1.513
92	B	28	33	5	1.843
93	B	999	33	1	.
94	C	2	44	1	0.745
95	C	2	44	2	1.703
96	C	2	44	3	2.045
97	C	2	44	4	1.855
98	C	2	44	5	1.136
99	C	4	44	1	1.316
100	C	4	44	2	0.930
101	C	4	44	3	2.141
102	C	4	44	4	1.150
103	C	4	44	5	1.621
104	C	7	44	1	1.583
105	C	7	44	2	2.715
106	C	7	44	3	1.016
107	C	7	44	4	2.221
108	C	7	44	5	2.134
109	C	10	44	1	1.578
110	C	10	44	2	2.268
111	C	10	44	3	1.756
112	C	10	44	4	2.899

Figure 12-12. Cont.

28-Day Bioaccumulation Data

OBS	TRTMNT	T_DAYS	CONC_SED	REP	CONC_TIS
113	C	10	44	5	0.890
114	C	18	44	1	2.822
115	C	18	44	2	2.607
116	C	18	44	3	3.414
117	C	18	44	4	1.319
118	C	18	44	5	1.866
119	C	28	44	1	1.295
120	C	28	44	2	2.964
121	C	28	44	3	2.109
122	C	28	44	4	2.820
123	C	28	44	5	3.325
124	C	999	44	1	

Figure 12-12. Cont.

28-Day Bioaccumulation Data

---------- TRTMNT=R ----------

Non-Linear Least Squares Iterative Phase
Dependent Variable CONC_TIS Method: Marquardt

Iter	K1	K2	Sum of Squares
0	0.100000	0.500000	6.887855
1	0.685462	1.283176	4.167862
2	0.974848	0.687322	3.452842
3	0.785682	0.730668	2.755431
4	0.802025	0.761427	2.753115
5	0.811932	0.772154	2.753084
6	0.815045	0.775362	2.753082
7	0.815940	0.776284	2.753082
8	0.816195	0.776546	2.753082

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics Dependent Variable CONC_TIS

Source	DF	Sum of Squares	Mean Square
Regression	2	6.1793341786	3.0896670893
Residual	28	2.7530818214	0.0983243508
Uncorrected Total	30	8.9324160000	
(Corrected Total)	29	2.7815808000	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K1	0.8161949523	0.72854762039	-.67615585015	2.3085457547
K2	0.7765458839	0.74248899959	-.74436232210	2.2974540900

Asymptotic Correlation Matrix

Corr	K1	K2
K1	1	0.9899643378
K2	0.9899643378	1

Figure 12-13. Example results from SAS/PC program showing nonlinear regression analysis for reference treatment level from 28 day bioaccumulation test.

28-Day Bioaccumulation Data

---------- TRTMNT=A ----------

Non-Linear Least Squares Iterative Phase
Dependent Variable CONC_TIS Method: Marquardt

Iter	K1	K2	Sum of Squares
0	0.100000	0.500000	4.511244
1	0.032072	0.283014	3.513831
2	0.032303	0.157206	3.041152
3	0.029106	0.164033	2.856415
4	0.029372	0.167118	2.856061
5	0.029488	0.168038	2.856044
6	0.029522	0.168305	2.856043
7	0.029532	0.168382	2.856043
8	0.029534	0.168404	2.856043

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics Dependent Variable CONC_TIS

Source	DF	Sum of Squares	Mean Square
Regression	2	8.249353153	4.124676577
Residual	28	2.856042847	0.102001530
Uncorrected Total	30	11.105396000	
(Corrected Total)	29	3.377693467	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K1	0.0295344074	0.01095794141	0.00708825264	0.05198056222
K2	0.1684037645	0.08228376939	-.00014561487	0.33695314391

Asymptotic Correlation Matrix

Corr	K1	K2
K1	1	0.9540322074
K2	0.9540322074	1

Figure 12-14. Example results from SAS/PC program showing nonlinear regression analysis for Treatment Level A from 28 day bioaccumulation test.

28-Day Bioaccumulation Data

---------- TRTMNT=B ----------

Non-Linear Least Squares Iterative Phase
Dependent Variable CONC_TIS Method: Marquardt

Iter	K1	K2	Sum of Squares
0	0.100000	0.500000	717.141922
1	0.010591	0.448632	10.506473
2	0.013544	0.250922	4.997893
3	0.010636	0.240108	2.892513
4	0.010558	0.235466	2.888916
5	0.010522	0.234465	2.888869
6	0.010514	0.234235	2.888867
7	0.010512	0.234181	2.888867
8	0.010512	0.234169	2.888867

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics Dependent Variable CONC_TIS

Source	DF	Sum of Squares	Mean Square
Regression	2	43.269707380	21.634853690
Residual	28	2.888866620	0.103173808
Uncorrected Total	30	46.158574000	
(Corrected Total)	29	4.913541467	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K1	0.0105115591	0.00190839085	0.00660242738	0.01442069084
K2	0.2341690260	0.05242599994	0.12678004972	0.34155800218

Asymptotic Correlation Matrix

Corr	K1	K2
K1	1	0.9631505062
K2	0.9631505062	1

Figure 12-15. Example results from SAS/PC program showing nonlinear regression analysis for Treatment Level B from 28 day bioaccumulation test.

28-Day Bioaccumulation Data

---------- TRTMNT=C ----------

Non-Linear Least Squares Iterative Phase
Dependent Variable CONC_TIS Method: Marquardt

Iter	K1	K2	Sum of Squares
0	0.100000	0.500000	1140.748958
1	0.018868	0.469395	17.304428
2	0.018655	0.346769	13.625363
3	0.017113	0.332761	13.308116
4	0.016869	0.326314	13.305225
5	0.016752	0.323591	13.304758
6	0.016701	0.322416	13.304669
7	0.016679	0.321905	13.304653
8	0.016670	0.321683	13.304649
9	0.016666	0.321586	13.304649
10	0.016664	0.321544	13.304649

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics Dependent Variable CONC_TIS

Source	DF	Sum of Squares	Mean Square
Regression	2	116.06029440	58.03014720
Residual	28	13.30464860	0.47516602
Uncorrected Total	30	129.36494300	
(Corrected Total)	29	16.29004137	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K1	0.0166638672	0.00451720105	0.00741087069	0.02591686376
K2	0.3215436613	0.10241876561	0.11174992542	0.53133739719

Asymptotic Correlation Matrix

Corr	K1	K2
K1	1	0.9717431252
K2	0.9717431252	1

Figure 12-16. Example results from SAS/PC program showing nonlinear regression analysis for Treatment Level C from 28 day bioaccumulation test.

Nonlinear Regression Results: 28-Day Bioaccumulation Data

OBS	TRTMNT	T_DAYS	CONC_SED	PRED_CT	LO_95_1S	UP_95_1S
1	R	2	0.45	0.37290	0.15110	0.59469
2	R	4	0.45	0.45180	0.34211	0.56149
3	R	7	0.45	0.47092	0.36228	0.57955
4	R	10	0.45	0.47278	0.35700	0.58855
5	R	18	0.45	0.47298	0.35591	0.59004
6	R	28	0.45	0.47298	0.35591	0.59005
7	R	999	0.45	0.47298	0.35591	0.59005
8	A	2	4.00	0.20060	0.09895	0.30225
9	A	4	4.00	0.34384	0.20600	0.48168
10	A	7	4.00	0.48570	0.34973	0.62167
11	A	10	4.00	0.57130	0.45161	0.69099
12	A	18	4.00	0.66766	0.52438	0.81094
13	A	28	4.00	0.69523	0.50702	0.88344
14	A	999	4.00	0.70151	0.49310	0.90993
15	B	2	33.00	0.55396	0.42615	0.68176
16	B	4	33.00	0.90075	0.74901	1.05250
17	B	7	33.00	1.19375	1.06633	1.32116
18	B	10	33.00	1.33888	1.22659	1.45117
19	B	18	33.00	1.45945	1.31046	1.60844
20	B	28	33.00	1.47923	1.30878	1.64967
21	B	999	33.00	1.48133	1.30695	1.65571
22	C	2	44.00	1.08161	0.74408	1.41914
23	C	4	44.00	1.65018	1.31374	1.98662
24	C	7	44.00	2.04014	1.79589	2.28438
25	C	10	44.00	2.18876	1.94614	2.43137
26	C	18	44.00	2.27329	1.96056	2.58602
27	C	28	44.00	2.28000	1.95334	2.60667
28	C	999	44.00	2.28028	1.95269	2.60788

Figure 12-17. Example results from SAS/PC program showing data listing of nonlinear regression results for 28 day bioaccumulation test. Output includes predicted tissue concentration, i.e., bioaccumulation (PRED_CT), and Upper (UP_CL) and lower (LOW_CL) 95 percent confidence bounds on the observation.

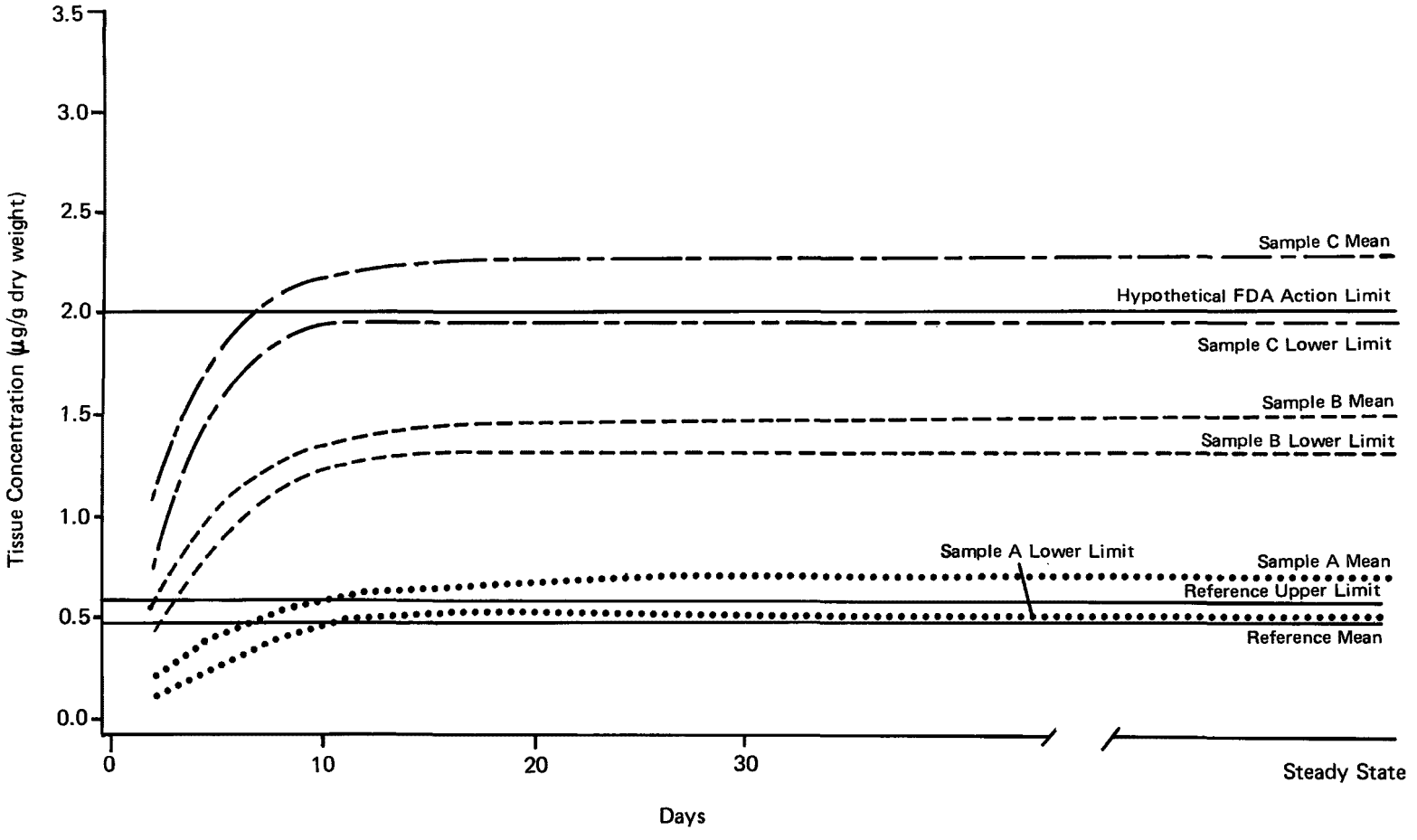

Figure 12.18. Non-linear regression lines with 95% one-sided confidence bounds on bioaccumulation data.

line and confidence bounds for the reference treatment are solid lines. The lines for treatment A are dotted, for treatment B are dashed, and for treatment C are long and short dashes. Because the endpoint of interest isthe steady state concentration, the regression lines and confidence bounds have been drawn beyond the time frame of the laboratory test (28 days) to illustrate the steady state tissue concentration. The hypothetical FDA action limit is shown on Figure 12.18 for comparison.

From Figure 12.18 it can be seen that at steady state bioaccumulation from dredged material sample A does not differ from the reference sediment, i.e., the 95 percent one-sided confidence interval of treatment A overlaps the confidence interval of the reference sediment. At steady state, the lower bound of sample A is less than the upper bound of the reference sediment. Figure 12.18 also illustrates that the steady state tissue concentration of sample A is less than the FDA action limit. For samples B and C, the lower 95 percent one-sided confidence bounds on concentration at steady state are completely above the confidence bounds of the reference sediment. Since there is no overlap of confidence bounds at steady state, samples B and C differ from the reference sediment at the statistical significance level of 0.05.

The mean tissue concentration at steady state for dredged material sample B is less than the FDA action limits. Steady state bioaccumulation in sample B is statistically greater than steady state bioaccumulation in the reference sediment because there is no overlap of confidence limits. The predicted steady state tissue concentration in dredged material sample C is not statistically different from the FDA action limit, as demonstrated by the lower 95 percent one-sided confidence bound being lower than the action limit.

Compliance with the regulations is determined in accordance with the Tier IV bioaccumulation guidance in Section 7.2.

12.3.3 Steady State Bioaccumulation from Field Data

The field bioaccumulation test is designed to show differences, if any, between organisms living at the proposed disposal site and organisms

living in the sediments in the reference area. This approach is valid only under the specific conditions described in Section 11.3.2.

The mean tissue concentration in field organisms collected at the disposal site is calculated along with lower 95 percent one-sided confidence limits using the formulas given in Section 12.3.1. This mean and confidence limit are compared to the mean and upper 95 percent one-sided confidence limit calculated at steady state for organisms collected from the reference area. Bioaccumulation in two groups of organisms is considered to be statistically different if the 95 percent, one-sided confidence intervals do not overlap.

Compliance with the regulations is determined in accordance with Tier IV bioaccumulation guidance in Section 7.2.

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13.0 QUALITY ASSURANCE CONSIDERATIONS

The purpose of a quality assurance program in a dredging study is to ensure that the data produced by the study are of known and documented quality. This is accomplished by ensuring that proper quality control procedures are built into the study at the beginning and by verifying that the procedures are followed during the study.

The distinction between quality assurance (QA) and quality control (QC) is that the former is a management tool and the latter is a series of procedures designed to implement that tool by measuring precision, accuracy, comparability, completeness and representativeness. QA activities insure that QC procedures have been implemented and documented. QA reports to the upper management and operates independently of activities involved with conduct of the tests. QC operates as an integral part of the study and includes measurements of data quality using blanks, spikes, and control test groups to which test results can be compared.

A complete QA effort in a dredging study has two components: a QA program implemented by the responsible governmental agency (the data user) and QA programs implemented by the laboratories performing the tests (the data generators).

13.1 STRUCTURE OF QA PROGRAMS

The organization of the QA effort for a dredging study and the responsibilities of each component are discussed in this section.

13.1.1 Government (Data User) QA Program

The function of the government QA program is to ensure that laboratories contracted for the dredging studies comply with the procedures in this manual or with other specified guidelines. Oversight of the QA effort for a dredging study should be the responsibility of a QA Coordinator to be established in the Corps of Engineers District Office, working in conjunction with the EPA Regional QA Officer. District QA Coordinators should be responsible for ensuring that data submitted with permit applications and laboratories under contract to their Districts comply with the QA needs of the regulations and guidelines governing dredged material studies. This responsibility should be carried out in three ways: pre-award inspections, inter-laboratory comparisons, and routine inspections during conduct of the studies. Data quality objectives should be established for testing. The

QA program should be designed with the assistance of administrative and scientific expertise from headquarters of CE and EPA, and other qualified sources as appropriate. Some QA considerations in contractor selection are discussed by Sturgis (1990).

13.1.1.1 Pre-award Inspections

Before a government contract is awarded, it is strongly recommended that the District QA Coordinator inspect the laboratories seeking to work on the study. This pre-award inspection assesses the laboratory's capabilities, personnel, and equipment. It establishes the groundwork necessary to ensure that tests will be conducted properly, provides the initial contact between government and laboratory staff, and emphasizes the importance that the government places on quality assurance.

This inspection is designed to establish that the laboratory has implemented the following measures:

- An independent QA program
- Written work plans for each test
- Technically sound written standard operating procedures (SOPs) for all study activities.

13.1.1.2 Interlaboratory Comparison

In dredging studies it is important for data collected and processed at various laboratories to be comparable. To ensure this comparability, proficiency testing of a laboratory is recommended before a contract is signed and yearly thereafter. Each laboratory taking part in a proficiency test analyzes samples, prepared to a known concentration, of a standard from the National Institute for Standards and Technology or other recognized source of Standard Reference Material (SRM) (refer to Table 9.4 for sources of reference material and standards). Results are compared with predetermined criteria of acceptability. Proficiency testing programs already established by EPA or CE may be used, or a program may be designed specifically for dredging evaluations.

13.1.1.3 Routine Inspections

The purpose of routine surveillance inspections during conduct of contract work is to ensure that laboratories are complying with the QA

Plan. It is suggested that the District QA Coordinator develop checklists for review of training records, equipment specifications, quality control procedures for analytical tasks, management organization, etc. The QA Coordinator should also establish laboratory review files for quick assessment of the laboratory's activity on a study, and to aid in monitoring of the overall quality of the laboratory. Procedures for inspections by the District QA Coordinator are similar to systems audits (Section 13.3.4) conducted by the laboratories themselves.

13.1.2 Data Generator QA Program

Ideally, each laboratory participating in a dredged material study should have a written QA Program Plan that describes the organization's QA program, including its policies, areas of application, and authorities. Individuals involved in the QA program should be identified, and their responsibilities clearly stated. For any given study, QA personnel should be entirely independent of the technical personnel engaged in the study to ensure unbiased assessments of the work performed.

Where possible, the laboratory should have a QA Manager or Coordinator who is responsible for the development, implementation, and administration of the QA program. For dredging studies, the QA Manager/Coordinator should ensure that the appropriate QA planning documents exist for each study (Section 13.2.8); routine procedures that impact data quality are described in SOPs; sufficiently detailed audits are conducted at frequent enough intervals to ensure conformance with approved study plans and SOPs and to identify deficiencies; and appropriate corrective actions are implemented in a timely manner.

13.2 GENERAL COMPONENTS OF ALL QA PROGRAMS

A well-structured QA program defines the criteria data have to meet to be acceptable. The procedures for collecting and analyzing those data should be an integral part of the overall study plan. A good QA program sets standards for personnel qualifications, facilities, equipment, services, data generation, recordkeeping, and data quality assessments.

13.2.1 Organization

The QA program plan should describe the lines of authority and responsibilities for technical personnel, including those responsible for

quality assurance. Procedures should be available to describe the qualifications, training, job descriptions, etc. for all field and laboratory personnel.

13.2.2 Personnel Qualifications

All personnel performing tasks and functions related to data quality have to be appropriately qualified and adequately trained. It is generally the responsibility of the contractor's QA staff to ensure that personnel are qualified and trained. Records of qualifications and training of personnel should be kept current, so that training can be verified by internal quality assurance personnel or by CE and EPA.

13.2.3 Facilities

The QA program plan should provide a description of the physical layout of the laboratory, define space for each area of testing, describe traffic flow patterns, and document special laboratory needs.

13.2.4 Equipment and Supplies

The QA program plan should describe how field and laboratory equipment essential to the performance of environmental measurements will be maintained in proper working order. This is demonstrated through records that document the reliability and performance characteristics of the equipment. Such equipment should be subject to regular inspection and preventive maintenance procedures to ensure proper working order. Instruments should have periodic calibration and preventive maintenance performed by qualified technical personnel, and a permanent record kept of calibrations, problems diagnosed, and corrective actions applied. An acceptance testing program for key materials used in the performance of environmental measurements (chemical and biological materials) should be applied prior to their use.

13.2.5 Test Methods and Procedures

All methods and procedures used in the field and laboratory should be in written form, authorized, and readily available to all personnel. There should be a mechanism to describe the circumstances under which non-stan-

dard methods or procedures may be used, and the appropriate approval and documentation should be described.

13.2.6 Sample Handling and Tracking

Sample custody is a part of any good field or laboratory operation. Where samples may be needed for potential litigation, chain of custody procedures should be used. Sample custody is important for both parts of the dredged material evaluation process - the field (sample collection) and the laboratory (receipt, analysis and reporting). More detailed sample handling guidance is provided in Sections 8.2.6 through 8.2.8.

13.2.7 Documentation and Recordkeeping

Records should be maintained to ensure that all aspects of the field and laboratory work are documented. It is important to record all the events that are associated with a sample so that the scope and validity of the resulting data may be properly interpreted. A document trail is generated to show the course of the sample from the field through the laboratory.

All data should be recorded directly, promptly, legibly, and indelibly, so that data are easily traceable. Data entries should be dated on the date of entry and signed or initialed by the person making the measurement and the person entering the data. Changes on entries should be made so as not to obscure the original entry, and should indicate the reason for the change, the person making the change, and the date of change. In computer-driven data collection systems, the person responsible for direct data input should be identified at the time of input.

13.2.8 Quality Assurance Study Plan

It is good practice for the government to require that QA study plans be developed by the contractor for all dredged material evaluations. These study plans may be developed in accordance with CE (1985) or EPA (1984). EPA (1987) contains QA guidance that is generally applicable to sample collection and laboratory aspects of dredged material evaluations and should be considered in QA study plan development. Topics covered in these documents include provisions for (1) name of the study, (2) what agency requested it, (3) date of the request, (4) date of initiation, (5) program officer, (6) quality assurance officer, (7) study description, (8) fiscal

information, (9) schedule of tasks and products, (10) organization and responsibilities, (11) data quality requirements and assessments, (12) sampling and analytical procedures, (13) sample custody procedures, (14) equipment calibration and maintenance procedures, (15) documentation, data reduction and reporting, (16) data validation, (17) performance and systems audits, (18) corrective action, and (19) reports.

QA study plans are valuable documents because they provide in one place an overall plan for conducting work, including standards of data quality that have to be maintained. QA study plans are particularly useful for work that involves many people or that lasts over a long time period. When many people are involved, the plan ensures that everyone has a thorough understanding of the goals and procedures of the program. When work is conducted over a long period of time, the plan provides a basis of continuity, ensuring that procedures do not slowly change over time without the persons involved in the program evaluating the nature of the changes and their possible impacts on data quality.

13.2.9 Standard Operating Procedures (SOP)

Standard operating procedures (SOP) are documents describing routine study methods and procedures which affect data quality and integrity. Like QA study plans, standard operating procedures (SOP) ensure that all persons conducting work are following the same procedures and that the procedures do not change over time. SOPs should be prepared for use of equipment and facilities, measurements, and other aspects of work that impact data quality.

13.3 DATA QUALITY ASSESSMENT

13.3.1 Data Validation

Data validation involves all procedures used to accept or reject data after collection and prior to use, including editing, screening, checking, auditing, verifying, and reviewing. Data validation procedures ensure that the standards for data accuracy and precision were met, that data were generated in accordance with the QA study plan and SOPs, and that data are traceable and defensible. It is important for all reported data to be properly validated following standardized procedures to ensure that data are of consistent and documented quality.

13.3.2 Chemical Quality Control

Chemical quality control specifications are the ranges considered acceptable for instrument calibration, analyte recovery, data accuracy, and data precision. Instrument calibration involves determining a linear response over the range of data to be collected. Recovery is determined by analyzing a sample spiked with a known amount of chemical. Procedural accuracy is established by including a series of spiked and blank samples in each analysis. Precision is established by analyzing replicate samples. Quality control procedures are discussed in more detail for sediment, water and tissue analyses in Sections 9.3.3, 9.4.3, and 9.5.3, respectively.

The CE District QA Coordinator or management authority for the program may require that certain samples be submitted on a routine basis to government laboratories for analysis, and EPA or CE may participate in some studies. These activities provide an independent quality assurance check on activities being performed and on data being generated.

13.3.3 Biological Quality Control (Reference Toxicant Testing)

Biological quality control involves periodic reference toxicant tests conducted with all stocks of organisms to be used in the dredged material tests to determine the relative health of the test organisms. The application and benefits of reference toxicant tests are discussed by Lee (1980). Detailed assistance in establishing a biological quality control program can be provided by scientists from headquarters of CE and EPA. When sufficient reference toxicant data have been generated for a particular species, it may be possible to stipulate an acceptable LC50 range for that species with the reference toxicant.

13.3.4 Performance and System Audits

Performance and system audits are an essential part of the field and laboratory quality assurance program. A performance audit independently collects measurement data using performance evaluation (PE) samples, field blanks, trip blanks, duplicate samples and spiked samples. A systems audit consists of a review of the total data production process which includes on-site reviews of field and laboratory operational systems. The purpose of these inspections is to verify that (1) appropriate standard operating procedures are in place, (2) training of the staff is appropriate and documented, (3) all equipment is properly calibrated and maintained, (4)

approved analytical procedures are being followed, and (5) all aspects of the study are on schedule.

13.3.5 Management of Nonconformance Events

One purpose of any QA program is to identify a nonconformance event as quickly as possible. A nonconformance event is defined as any event that does not follow defined methods, procedures, protocols, or any occurrence that may affect the quality of the data or study. A QA program should have a corrective action plan to provide feedback channels to the appropriate management authority defining how all nonconformance events were corrected.

13.3.6 Archiving of Data and Samples

A procedure should be established for the retention of all appropriate field and laboratory records, specimens and samples as various tasks or phases are completed. The archival procedure should indicate the storage requirements, location, indexing codes, retention time, security and environmental measures needed to preserve the data and samples.

13.4 REFERENCES

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APPENDIX A

Title 40, Code of Federal Regulations, Parts 220-228

SUBCHAPTER H—OCEAN DUMPING

PART 220—GENERAL

Sec.
220.1 Purpose and scope.
220.2 Definitions.
220.3 Categories of permits.
220.4 Authorities to issue permits.

AUTHORITY: 33 U.S.C. 1412 and 1418.

SOURCE: 42 FR 2468, Jan. 11, 1977, unless otherwise noted.

§ 220.1 Purpose and scope.

(a) *General.* This Subchapter H establishes procedures and criteria for the issuance of permits by EPA pursuant to section 102 of the Act. This Subchapter H also establishes the criteria to be applied by the Corps of Engineers in its review of activities involving the transportation of dredged material for the purpose of dumping it in ocean waters pursuant to section 103 of the Act. Except as may be authorized by a permit issued pursuant to this Subchapter H, or pursuant to section 103 of the Act, and subject to other applicable regulations promulgated pursuant to section 108 of the Act:

(1) No person shall transport from the United States any material for the purpose of dumping it into ocean waters;

(2) In the case of a vessel or aircraft registered in the United States or flying the United States flag or in the case of a United States department, agency, or instrumentality, no person shall transport from any location any material for the purpose of dumping it into ocean waters; and

(3) No person shall dump any material transported from a location outside the United States:

(i) Into the territorial sea of the United States; or

(ii) Into a zone contiguous to the territorial sea of the United States, extending to a line twelve nautical miles seaward from the base line from which the breadth of the territorial sea is measured, to the extent that it may affect the territorial sea or the territory of the United States.

(b) *Relationship to international agreements.* In accordance with section 102(a) of the Act, the regulations and criteria included in this Subchapter H apply the standards and criteria binding upon the United States under the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter to the extent that application of such standards and criteria do not relax the requirements of the Act.

(c) *Exclusions*—(1) *Fish wastes.* This Subchapter H does not apply to, and no permit hereunder shall be required for, the transportation for the purpose of dumping or the dumping in ocean waters of fish wastes unless such dumping occurs in:

(i) Harbors or other protected or enclosed coastal waters; or

(ii) Any other location where the Administrator finds that such dumping may reasonably be anticipated to endanger health, the environment or ecological systems.

(2) *Fisheries resources.* This Subchapter H does not apply to, and no permit hereunder shall be required for, the placement or deposit of oyster shells or other materials for the purpose of developing, maintaining or harvesting fisheries resources; provided, such placement or deposit is regulated under or is a part of an authorized State or Federal program certified to EPA by the agency authorized to enforce the regulation, or to administer the program, as the case may be; and provided further, that the National Oceanic and Atmospheric Administration, the U.S. Coast Guard, and the U.S. Army Corps of Engineers concur in such placement or deposit as it may affect their responsibilities and such concurrence is evidenced by letters of concurrence from these agencies.

(3) *Vessel propulsion and fixed structures.* This Subchapter H does not apply to, and no permit hereunder shall be required for:

(i) Routine discharges of effluent incidental to the propulsion of vessels or the operation of motor-driven equipment on vessels; or

(ii) Construction of any fixed structure or artificial island, or the intentional placement of any device in

ocean waters or on or in the submerged land beneath such waters, for a purpose other than disposal when such construction or such placement is otherwise regulated by Federal or State law or made pursuant to an authorized Federal or State program certified to EPA by the agency authorized to enforce the regulations or to administer the program, as the case may be.

(4) *Emergency to safeguard life at sea.* This Subchapter H does not apply to, and no permit hereunder shall be required for, the dumping of material into ocean waters from a vessel or aircraft in an emergency to safeguard life at sea to the extent that the person owning or operating such vessel or aircraft files timely reports required by § 224.2(b).

§ 220.2 Definitions.

As used in this Subchapter H:

(a) "Act" means the Marine Protection, Research, and Sanctuaries Act of 1972, as amended (33 U.S.C. 1401);

(b) "FWPCA" means the Federal Water Pollution Control Act, as amended (33 U.S.C. 1251);

(c) "Ocean" or "ocean waters" means those waters of the open seas lying seaward of the baseline from which the territorial sea is measured, as provided for in the Convention on the Territorial Sea and the Contiguous Zone (15 UST 1606; TIAS 5639); this definition includes the waters of the territorial sea, the contiguous zone and the oceans as defined in section 502 of the FWPCA.

(d) "Material" means matter of any kind or description, including, but not limited to, dredged material, solid waste, incinerator residue, garbage, sewage, sewage sludge, munitions, radiological, chemical, and biological warfare agents, radioactive materials, chemicals, biological and laboratory waste, wreck or discarded equipment, rock, sand, excavation debris, industrial, municipal, agricultural, and other waste, but such term does not mean sewage from vessels within the meaning of section 312 of the FWPCA. Oil within the meaning of section 311 of the FWPCA shall constitute "material" for purposes of this Subchapter H only to the extent that it is taken on board a vessel or aircraft for the primary purpose of dumping.

(e) "Dumping" means a disposition of material: *Provided,* That it does not mean a disposition of any effluent from any outfall structure to the extent that such disposition is regulated under the provisions of the FWPCA, under the provisions of section 13 of the River and Harbor Act of 1899, as amended (33 U.S.C. 407), or under the provisions of the Atomic Energy Act of 1954, as amended (42 U.S.C. 2011), nor does it mean a routine discharge of effluent incidental to the propulsion of, or operation of motor-driven equipment on, vessels: *Provided further,* That it does not mean the construction of any fixed structure or artificial island nor the intentional placement of any device in ocean waters or on or in the submerged land beneath such waters, for a purpose other than disposal, when such construction or such placement is otherwise regulated by Federal or State law or occurs pursuant to an authorized Federal or State program; And provided further, That it does not include the deposit of oyster shells, or other materials when such deposit is made for the purpose of developing, maintaining, or harvesting fisheries resources and is otherwise regulated by Federal or State law or occurs pursuant to an authorized Federal or State program.

(f) "Sewage Treatment Works" means municipal or domestic waste treatment facilities of any type which are publicly owned or regulated to the extent that feasible compliance schedules are determined by the availability of funding provided by Federal, State, or local governments.

(g) "Criteria" means the criteria set forth in Part 227 of this Subchapter H.

(h) "Dredged Material Permit" means a permit issued by the Corps of Engineers under section 103 of the Act (see 33 CFR 209.120) and any Federal projects reviewed under section 103(e) of the Act (see 33 CFR 209.145).

(i) Unless the context otherwise requires, all other terms shall have the meanings assigned to them by the Act.

§ 220.3 Categories of permits.

This § 220.3 provides for the issuance of general, special, emergency, interim and research permits for ocean dumping under section 102 of the Act.

(a) *General permits.* General permits may be issued for the dumping of certain materials which will have a minimal adverse environmental impact and are generally disposed of in small quantities, or for specific classes of materials that must be disposed of in emergency situations. General permits may be issued on application of an interested person in accordance with the procedures of Part 221 or may be issued without such application whenever the Administrator determines that issuance of a general permit is necessary or appropriate.

(b) *Special permits.* Special permits may be issued for the dumping of materials which satisfy the Criteria and shall specify an expiration date no later than three years from the date of issue.

(c) *Emergency permits.* For any of the materials listed in § 227.6, except as trace contaminants, after consultation with the Department of State with respect to the need to consult with parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter that are likely to be affected by the dumping, emergency permits may be issued to dump such materials where there is demonstrated to exist an emergency requiring the dumping of such materials, which poses an unacceptable risk relating to human health and admits of no other feasible solution. As used herein, "emergency" refers to situations requiring action with a marked degree of urgency, but is not limited in its application to circumstances requiring immediate action. Emergency permits may be issued for other materials, except those prohibited by § 227.5, without consultation with the Department of State when the Administrator determines that there exists an emergency requiring the dumping of such materials which poses an unacceptable risk to human health and admits of no other feasible solution.

(d) *Interim permits.* Prior to April 23, 1978, interim permits may be issued in accordance with Subpart A of Part 227 to dump materials which are not in compliance with the environmental impact criteria of Subpart B of Part 227, or which would cause substantial adverse effects as determined in accordance with the criteria of Subpart D or E of Part 227 or for which an ocean disposal site has not been designated on other than an interim basis pursuant to Part 228 of this Subchapter H; provided, however, no permit may be issued for the ocean dumping of any materials listed in § 227.5, or for any of the materials listed in § 227.6, except as trace contaminants; provided further that the compliance date of April 23, 1978, does not apply to the dumping of wastes by existing dumpers when the Regional Administrator determines that the permittee has exercised his best efforts to comply with all requirements of a special permit by April 23, 1978, and has an implementation schedule adequate to allow phasing out of ocean dumping or compliance with all requirements necessary to receive a special permit by December 31, 1981, at the latest. No interim permit will be granted for the dumping of waste from a facility which has not previously dumped wastes in the ocean from a new facility, or for the dumping of an increased amount of waste from the expansion or modification of an existing facility, after the effective date of these regulations (except when the facility is operated by a municipality now dumping such wastes). No interim permit will be issued for the dumping of any material in the ocean for which an interim permit had previously been issued unless the applicant demonstrates that he has exercised his best efforts to comply with all provisions of the previously issued permits. Interim permits shall specify an expiration date no later than one year from the date of issue.

(e) *Research permits.* Research permits may be issued for the dumping of any materials, other than materials specified in § 227.5 or for any of the materials listed in § 227.6 except as trace contaminants, unless subject to the exclusion of § 227.6(g), into the ocean as part of a research project when it is determined that the scien-

tific merit of the proposed project outweighs the potential environmental or other damage that may result from the dumping. Research permits shall specify an expiration date no later than 18 months from the date of issue.

(f) *Permits for incineration at sea.* Permits for incineration of wastes at sea will be issued only as research permits or as interim permits until specific criteria to regulate this type of disposal are promulgated, except in those cases where studies on the waste, the incineration method and vessel, and the site have been conducted and the site has been designated for incineration at sea in accordance with the procedures of § 228.4(b). In all other respects the requirements of Parts 220 through 228 apply.

[42 FR 2468, Jan. 11, 1977; 43 FR 1071, Jan. 6, 1978]

§ 220.4 Authorities to issue permits.

(a) *Determination by Administrator.* The Administrator, or such other EPA employee as he may from time to time designate in writing, shall issue, deny, modify, revoke, suspend, impose conditions on, initiate and carry out enforcement activities and take any and all other actions necessary or proper and permitted by law with respect to general, special, emergency, interim, or research permits.

(b) *Authority delegated to Regional Administrators.* Regional Administrators, or such other EPA employees as they may from time to time designate in writing, are delegated the authority to issue, deny, modify, revoke, suspend, impose conditions on, initiate and carry out enforcement activities, and take any and all other actions necessary or proper and permitted by law with respect to special and interim permits for:

(1) The dumping of material in those portions of the territorial sea which are subject to the jurisdiction of any State within their respective Regions, and in those portions of the contiguous zone immediately adjacent to such parts of the territorial sea; and in the oceans with respect to approved waste disposal sites designated pursuant to Part 228 of this Subchapter H, and

(2) Where transportation for dumping is to originate in one Region and dumping is to occur at a location within another Region's jurisdiction conferred by order of the Administrator, the Region in which transportation is to originate shall be responsible for review of the application and shall prepare the technical evaluation of the need for dumping and alternatives to ocean dumping. The Region having jurisdiction over the proposed dump site shall take all other actions required by this Subchapter H with respect to the permit application, including without limitation, determining to issue or deny the permit, specifying the conditions to be imposed, and giving public notice. If both Regions do not concur in the disposition of the permit application, the Administrator will make the final decision on all issues with respect to the permit application, including without limitation, issuance or denial of the permit and the conditions to be imposed.

(c) *Review of Corps of Engineers Dredged Material Permits.* Regional Administrators have the authority to review, to approve or to disapprove or to propose conditions upon Dredged Material Permits for ocean dumping of dredged material at locations within the respective Regional jurisdictions. Regional jurisdiction to act under this paragraph (c) of § 220.4 is determined by the Administrator in accordance with § 228.4(e).

PART 221—APPLICATIONS FOR OCEAN DUMPING PERMITS UNDER SECTION 102 OF THE ACT

Sec.
221.1 Applications for permits.
221.2 Other information.
221.3 Applicant.
221.4 Adequacy of information in application.
221.5 Processing fees.

AUTHORITY: 33 U.S.C. 1412 and 1418.

SOURCE: 42 FR 2470, Jan. 11, 1977, unless otherwise noted.

§ 221.1 Applications for permits.

Applications for general, special, emergency, interim and research permits under section 102 of the Act may

be filed with the Administrator or the appropriate Regional Administrator, as the case may be, authorized by § 220.4 to act on the application. Applications shall be made in writing and shall contain, in addition to any other material which may be required, the following:

(a) Name and address of applicant;

(b) Name of the person or firm transporting the material for dumping, the name of the person(s) or firm(s) producing or processing all materials to be transported for dumping, and the name or other identification, and usual location, of the conveyance to be used in the transportation and dumping of the material to be dumped, including information on the transporting vessel's communications and navigation equipment;

(c) Adequate physical and chemical description of material to be dumped, including results of tests necessary to apply the Criteria, and the number, size, and physical configuration of any containers to be dumped;

(d) Quantity of material to be dumped;

(e) Proposed dates and times of disposal;

(f) Proposed dump site, and in the event such proposed dump site is not a dump site designated in this Subchapter H, detailed physical, chemical and biological information relating to the proposed dump site and sufficient to support its designation as a site according to the procedures of Part 228 of this Subchapter H;

(g) Proposed method of releasing the material at the dump site and means by which the disposal rate can be controlled and modified as required;

(h) Identification of the specific process or activity giving rise to the production of the material;

(i) Description of the manner in which the type of material proposed to be dumped has been previously disposed of by or on behalf of the person(s) or firm(s) producing such material;

(j) A statement of the need for the proposed dumping and an evaluation of short and long term alternative means of disposal, treatment or recycle of the material. Means of disposal shall include without limitation, landfill, well injection, incineration, spread of material over open ground; biological, chemical or physical treatment; recovery and recycle of material within the plant or at other plants which may use the material, and storage. The statement shall also include an analysis of the availability and environmental impact of such alternatives; and

(k) An assessment of the anticipated environmental impact of the proposed dumping, including without limitation, the relative duration of the effect of the proposed dumping on the marine environment, navigation, living and non-living marine resource exploitation, scientific study, recreation and other uses of the ocean.

§ 221.2 Other information.

In the event the Administrator, Regional Administrator, or a person designated by either to review permit applications, determines that additional information is needed in order to apply the Criteria, he shall so advise the applicant in writing. All additional information requested pursuant to this § 221.2 shall be deemed part of the application and for purposes of applying the time limitation of § 222.1, the application will not be considered complete until such information has been filed.

§ 221.3 Applicant.

Any person may apply for a permit under this Subchapter H even though the proposed dumping may be carried on by a permittee who is not the applicant; provided however, that the Administrator or the Regional Administrator, as the case may be, may, in his discretion, require that an application be filed by the person or firm producing or processing the material proposed to be dumped. Issuance of a permit will not excuse the permittee from any civil or criminal liability which may attach by virtue of his having transported or dumped materials in violation of the terms or conditions of a permit, notwithstanding that the permittee may not have been the applicant.

§ 221.4 Adequacy of information in application.

No permit issued under this Subchapter H will be valid for the transportation or dumping of any material which is not accurately and adequately described in the application. No permittee shall be relieved of any liability which may arise as a result of the transportation or dumping of material which does not conform to information provided in the application solely by virtue of the fact that such information was furnished by an applicant other than the permittee.

§ 221.5 Processing fees.

(a) A processing fee of $1,000 will be charged in connection with each application for a permit for dumping in an existing dump site designated in this Subchapter H.

(b) A processing fee of an additional $3,000 will be charged in connection with each application for a permit for dumping in a dump site other than a dump site designated in this Subchapter H.

(c) Notwithstanding any other provision of this § 221.5, no agency or instrumentality of the United States or of a State or local government will be required to pay the processing fees specified in paragraphs (a) and (b) of this section.

PART 222—ACTION ON OCEAN DUMPING PERMIT APPLICATIONS UNDER SECTION 102 OF THE ACT

Sec.
222.1 General.
222.2 Tentative determinations.
222.3 Notice of applications.
222.4 Initiation of hearings.
222.5 Time and place of hearings.
222.6 Presiding Officer.
222.7 Conduct of public hearing.
222.8 Recommendations of Presiding Officer.
222.9 Issuance of permits.
222.10 Appeal to adjudicatory hearing.
222.11 Conduct of adjudicatory hearings.
222.12 Appeal to Administrator.
222.13 Computation of time.

AUTHORITY: 33 U.S.C. 1412 and 1418.

SOURCE: 42 FR 2471, Jan. 11, 1977, unless otherwise noted.

§ 222.1 General.

Decisions as to the issuance, denial, or imposition of conditions on general, special, emergency, interim and research permits under section 102 of the Act will be made by application of the criteria of Parts 227 and 228. Final action on any application for a permit will, to the extent practicable, be taken within 180 days from the date a complete application is filed.

§ 222.2 Tentative determinations.

(a) Within 30 days of the receipt of his initial application, an applicant shall be issued notification of whether his application is complete and what, if any, additional information is required. No such notification shall be deemed to foreclose the Administrator or the Regional Administrator, as the case may be, from requiring additional information at any time pursuant to § 221.2.

(b) Within 30 days after receipt of a completed permit application, the Administrator or the Regional Administrator, as the case may be, shall publish notice of such application including a tentative determination with respect to issuance or denial of the permit. If such tentative determination is to issue the permit, the following additional tentative determinations will be made:

(1) Proposed time limitations, if any;

(2) Proposed rate of discharge from the barge or vessel transporting the waste;

(3) Proposed dumping site; and

(4) A brief description of any other proposed conditions determined to be appropriate for inclusion in the permit in question.

§ 222.3 Notice of applications.

(a) *Contents.* Notice of every complete application for a general, special, interim, emergency and research permit shall, in addition to any other material, include the following:

(1) A summary of the information included in the permit application;

(2) Any tentative determinations made pursuant to paragraph (b) of § 222.2;

(3) A brief description of the procedures set forth in § 222.5 for request-

ing a public hearing on the application including specification of the date by which requests for a public hearing must be filed;

(4) A brief statement of the factors considered in reaching the tentative determination with respect to the permit and, in the case of a tentative determination to issue the permit, the reasons for the choice of the particular permit conditions selected; and

(5) The location at which interested persons may obtain further information on the proposed dumping, including copies of any relevant documents.

(b) *Publication*—(1) *Special, interim and research permits.* Notice of every complete application for special, interim and research permits shall be given by:

(i) Publication in a daily newspaper of general circulation in the State in closest proximity to the proposed dump site; and

(ii) Publication in a daily newspaper of general circulation in the city in which is located the office of the Administrator or the Regional Administrator, as the case may be, giving notice of the permit application.

(2) *General permits.* Notice of every complete application for a general permit or notice of action proposed to be taken by the Administrator to issue a general permit, without an application, shall be given by publication in the FEDERAL REGISTER.

(3) *Emergency permits.* Notice of every complete application for an emergency permit shall be given by publication in accordance with paragraphs (b)(1)(i) and (ii) of this section; *Provided, however,* That no such notice and no tentative determination in accordance with § 222.2 shall be required in any case in which the Administrator determines:

(i) That an emergency, as defined in paragraph (c) of § 220.3 exists;

(ii) That the emergency poses an unacceptable risk relating to human health;

(iii) That the emergency admits of no other feasible solution; and

(iv) That the public interest requires the issuance of an emergency permit as soon as possible.

Notice of any determination made by the Administrator pursuant to this paragraph (b)(3) shall be given as soon as practicable after the issuance of the emergency permit by publication in accordance with paragraphs (b)(1)(i) and (ii) and with paragraphs (a), (c) through (i) of this section.

(c) *Copies of notice sent to specific persons.* In addition to the publication of notice required by paragraph (b) of this section, copies of such notice will be mailed by the Administrator or the Regional Administrator, as the case may be, to any person, group or Federal, State or local agency upon request. Any such request may be a standing request for copies of such notices and shall be submitted in writing to the Administrator or to any Regional Administrator and shall relate to all or any class of permit applications which may be acted upon by the Administrator or such Regional Administrator, as the case may be.

(d) *Copies of notice sent to States.* In addition to the publication of notice required by paragraph (b) of this section, copies of such notice will be mailed to the State water pollution control agency and to the State agency responsible for carrying out the Coastal Zone Management Act, if such agency exists, for each coastal State within 500 miles of the proposed dumping site.

(e) *Copies of notice sent to Corps of Engineers.* In addition to the publication of notice required by paragraph (b) of this section, copies of such notice will be mailed to the office of the appropriate District Engineer of the U.S. Army Corps of Engineers for purposes of section 106(c) of the Act, (pertaining to navigation, harbor approaches, and artificial islands on the outer continental shelf).

(f) *Copies of notice sent to Coast Guard.* In addition to the publication of notice required by paragraph (b) of this section, copies of such notice will be sent to the appropriate district office of the U.S. Coast Guard for review and possible suggestion of additional conditions to be included in the permit to facilitate surveillance and enforcement.

(g) *Fish and Wildlife Coordination Act.* The Fish and Wildlife Coordination Act, Reorganization Plan No. 4 of 1970, and the Act require that the Ad-

ministrator or the Regional Administrator, as the case may be, consult with appropriate regional officials of the Departments of Commerce and Interior, the Regional Director of the NMFS-NOAA, and the agency exercising administrative jurisdiction over the fish and wildlife resources of the States subject to any dumping prior to the issuance of a permit under this Subchapter H. Copies of the notice shall be sent to the persons noted in paragraph (g) of this section.

(h) *Copies of notice sent to Food and Drug Administration.* In addition to the publication of notice required by paragraph (b) of this section, copies of such notice will be mailed to Food and Drug Administration, Shellfish Sanitation Branch (HF-417), 200 C Street SW., Washington, DC 20204.

(i) *Failure to give certain notices.* Failure to send copies of any public notice in accordance with paragraphs (c) through (h) of this section shall not invalidate any notice given pursuant to this section nor shall such failure invalidate any subsequent administrative proceeding.

(j) *Failure of consulted agency to respond.* Unless advice to the contrary is received from the appropriate Federal or State agency within 30 days of the date copies of any public notice were dispatched to such agency, such agency will be deemed to have no objection to the issuance of the permit identified in the public notice.

§ 222.4 Initiation of hearings.

(a) In the case of any permit application for which public notice in advance of permit issuance is required in accordance with paragraph (b) of § 222.3, any person may, within 30 days of the date on which all provisions of paragraph (b) of § 222.3 have been complied with, request a public hearing to consider the issuance or denial of, or the conditions to be imposed upon, such permit. Any such request for a public hearing shall be in writing, shall identify the person requesting the hearing, shall state with particularity any objections to the issuance or denial of, or to the conditions to be imposed upon, the proposed permit, and shall state the issues which are proposed to be raised by such person for consideration at a hearing.

(b) Whenever (1) a written request satisfying the requirements of paragraph (a) of this section has been received and the Administrator or Regional Administrator, as the case may be, determines that such request presents genuine issues, or (2) the Administrator or Regional Administrator, as the case may be, determines in his discretion that a public hearing is necessary or appropriate, the Administrator or the Regional Administrator, as the case may be, will set a time and place for a public hearing in accordance with § 222.5, and will give notice of such hearing by publication in accordance with § 222.3.

(c) In the event the Administrator or the Regional Administrator, as the case may be, determines that a request filed pursuant to paragraph (a) of this section does not comply with the requirements of such paragraph (a) of this section or that such request does not present substantial issues of public interest, he shall advise, in writing, the person requesting the hearing of his determination.

§ 222.5 Time and place of hearings.

Hearings shall be held in the State in closest proximity to the proposed dump site, whenever practicable, and shall be set for the earliest practicable date no less than 30 days after the receipt of an appropriate request for a hearing or a determination by the Administrator or the Regional Administrator, as the case may be, to hold such a hearing without such a request.

§ 222.6 Presiding Officer.

A hearing convened pursuant to this Subchapter H shall be conducted by a Presiding Officer. The Administrator or Regional Administrator, as the case may be, may designate a Presiding Officer. For adjudicatory hearings held pursuant to § 222.11, the Presiding Officer shall be an EPA employee who has had no prior connection with the permit application in question, including without limitation, the performance of investigative or prosecuting functions or any other functions, and who is not employed in the Enforce-

ment Division or any Regional enforcement office.

[42 FR 2471, Jan. 11, 1977; 42 FR 6583, Feb. 3, 1977]

§ 222.7 Conduct of public hearing.

The Presiding Officer shall be responsible for the expeditious conduct of the hearing. The hearing shall be an informal public hearing, not an adversary proceeding, and shall be conducted so as to allow the presentation of public comments. When the Presiding Officer determines that it is necessary or appropriate, he shall cause a suitable record, which may include a verbatim transcript, of the proceedings to be made. Any person may appear at a public hearing convened pursuant to § 222.5 whether or not he requested the hearing, and may be represented by counsel or any other authorized representative. The Presiding Officer is authorized to set forth reasonable restrictions on the nature or amount of documentary material or testimony presented at a public hearing, giving due regard to the relevancy of any such information, and to the avoidance of undue repetitiveness of information presented.

§ 222.8 Recommendations of Presiding Officer.

Within 30 days following the adjournment of a public hearing convened pursuant to § 222.5, or within such additional period as the Administrator or the Regional Administrator, as the case may be, may grant to the Presiding Officer for good cause shown, and after full consideration of the comments received at the hearing, the Presiding Officer will prepare and forward to the Administrator or to the Regional Administrator, as the case may be, written recommendations relating to the issuance or denial of, or conditions to be imposed upon, the proposed permit and the record of the hearing, if any. Such recommendations shall contain a brief statement of the basis for the recommendations including a description of evidence relied upon. Copies of the Presiding Officer's recommendations shall be provided to any interested person on request, without charge. Copies of the record will be provided in accordance with 40 CFR Part 2.

[42 FR 2471, Jan. 11, 1977; 42 FR 6583, Feb. 3, 1977]

§ 222.9 Issuance of permits.

(a) Within 30 days following receipt of the Presiding Officer's recommendations or, where no hearing has been held, following the close of the 30-day period for requesting a hearing as provided in § 222.4, the Administrator or the Regional Administrator, as the case may be, shall make a determination with respect to the issuance, denial, or imposition of conditions on, any permit applied for under this Subchapter H and shall give notice to the applicant and to all persons who registered their attendance at the hearing by providing their name and mailing address, if any, by mailing a letter stating the determination and stating the basis therefor in terms of the Criteria.

(b) Any determination to issue or deny any permit after a hearing held pursuant to § 222.7 shall take effect no sooner than:

(1) 10 days after notice of such determination is given if no request for an adjudicatory hearing is filed in accordance with § 222.10(a); or

(2) 20 days after notice of such determination is given if a request for an adjudicatory hearing is filed in accordance with paragraph (a) of § 222.10 and the Administrator or the Regional Administrator, as the case may be, denies such request in accordance with paragraph (c) of § 222.10; or

(3) The date on which a final determination has been made following an adjudicatory hearing held pursuant to § 222.11.

(c) The Administrator or Regional Administrator, as the case may be, may extend the term of a previously issued permit pending the conclusion of the proceedings held pursuant to §§ 222.7 through 222.9.

(d) A copy of each permit issued shall be sent to the appropriate District Office of the U.S. Coast Guard.

§ 222.10 Appeal to adjudicatory hearing.

(a) Within 10 days following the receipt of notice of the issuance or

denial of any permit pursuant to § 222.9 after a hearing held pursuant to § 222.7, any interested person who participated in such hearing may request that an adjudicatory hearing be held pursuant to § 222.11 for the purpose of reviewing such determination, or any part thereof. Any such request for an adjudicatory hearing shall be filed with the Administrator or the Regional Administrator, as the case may be, and shall be in writing, shall identify the person requesting the adjudicatory hearing and shall state with particularity the objections to the determination, the basis therefor and the modification requested.

(b) Whenever a written request satisfying the requirements of paragraph (a) of this section has been received and the Administrator or Regional Administrator, as the case may be, determines that an adjudicatory hearing is warranted, the Administrator or the Regional Administrator, as the case may be, will set a time and place for an adjudicatory hearing in accordance with § 222.5, and will give notice of such hearing by publication in accordance with § 222.3.

(c) Prior to the conclusion of the adjudicatory hearing and appeal process, the Administrator or the Regional Administrator, as the case may be, in his discretion may extend the duration of a previously issued permit until a final determination has been made pursuant to § 222.11 or § 222.12.

(d) In the event the Administrator or the Regional Administrator, as the case may be, determines that a request filed pursuant to paragraph (a) of this section does not comply with the requirements of such paragraph (a) of this section or that such request does not present substantial issues of public interest, he shall advise, in writing, the person requesting the adjudicatory hearing of his determination.

(e) Any person requesting an adjudicatory hearing or requesting admission as a party to an adjudicatory hearing shall state in his written request, and shall by filing such request consent, that he and his employees and agents shall submit themselves to direct and cross-examination at any such hearing and to the taking of an oath administered by the Presiding Officer.

§ 222.11 Conduct of adjudicatory hearings.

(a) *Parties.* Any interested person may at a reasonable time prior to the commencement of the hearing submit to the Presiding Officer a request to be admitted as a party. Such request shall be in writing and shall set forth the information which would be required to be submitted by such person if he were requesting an adjudicatory hearing. Any such request to be admitted as a party which satisfies the requirements of this paragraph (a) shall be granted and all parties shall be informed at the commencement of the adjudicatory hearing of the parties involved. Any party may be represented by counsel or other authorized representative. EPA staff representing the Administrator or Regional Administrator who took action with respect to the permit application shall be deemed a party.

(b) *Filing and service.* (1) An original and two (2) copies of all documents or papers required or permitted to be filed shall be filed with the Presiding Officer.

(2) Copies of all documents and papers filed with the Presiding Officer shall be served upon all other parties to the adjudicatory hearing.

(c) *Consolidation.* The Administrator, or the Regional Administrator in the case of a hearing arising within his Region and for which he has been delegated authority hereunder, may, in his discretion, order consolidation of any adjudicatory hearings held pursuant to this section whenever he determines that consolidation will expedite or simplify the consideration of the issues presented. The Administrator may, in his discretion, order consolidation and designate one Region to be responsible for the conduct of any hearings held pursuant to this section which arise in different Regions whenever he determines that consolidation will expedite or simplify the consideration of the issues presented.

(d) *Pre-hearing conference.* The Presiding Officer may hold one or more prehearing conferences and may issue a prehearing order which may include

without limitation, requirements with respect to any or all of the following:

(1) Stipulations and admissions;

(2) Disputed issues of fact;

(3) Disputed issues of law;

(4) Admissibility of any evidence;

(5) Hearing procedures including submission of oral or written direct testimony, conduct of cross-examination, and the opportunity for oral arguments;

(6) Any other matter which may expedite the hearing or aid in disposition of any issues raised therein.

(e) *Adjudicatory hearing procedures.*

(1) The burden of going forward with the evidence shall:

(i) In the case of any adjudicatory hearing held pursuant to § 222.10(b)(1), be on the person filing a request under § 222.10(a) as to each issue raised by the request; and

(ii) In the case of any adjudicatory hearing held pursuant to § 223.2 or pursuant to Part 226, be on the Environmental Protection Agency.

(2) The Presiding Officer shall have the duty to conduct a fair and impartial hearing, to take action to avoid unnecessary delay in the disposition of proceedings, and to maintain order. He shall have all powers necessary or appropriate to that end, including without limitation, the following:

(i) To administer oaths and affirmations;

(ii) To rule upon offers of proof and receive relevant evidence;

(iii) To regulate the course of the hearing and the conduct of the parties and their counsel;

(iv) To consider and rule upon all procedural and other motions appropriate to the proceedings; and

(v) To take any action authorized by these regulations and in conformance with law.

(3) Parties shall have the right to cross-examine a witness who appears at an adjudicatory hearing to the extent that such cross-examination is necessary or appropriate for a full disclosure of the facts. In multi-party proceedings the Presiding Officer may limit cross-examination to one party on each side if he is satisfied that the cross-examination by one party will adequately protect the interests of other parties.

(4) When a party will not be unfairly prejudiced thereby, the Presiding Officer may order all or part of the evidence to be submitted in written form.

(5) Rulings of the Presiding Officer on the admissibility of evidence, the propriety of cross-examination, and other procedural matters, shall be final and shall appear in the record.

(6) Interlocutory appeals may not be taken.

(7) Parties shall be presumed to have taken exception to an adverse ruling.

(8) The proceedings of all hearings shall be recorded by such means as the Presiding Officer may determine. The original transcript of the hearing shall be a part of the record and the sole official transcript. Copies of the transcript shall be available from the Environmental Protection Agency in accordance with 40 CFR Part 2.

(9) The rules of evidence shall not apply.

(f) *Decision after adjudicatory hearing.* (1) Within 30 days after the conclusion of the adjudicatory hearing, or within such additional period as the Administrator or the Regional Administrator, as the case may be, may grant to the Presiding Officer for good cause shown, the Presiding Officer shall submit to the Administrator or the Regional Administrator, as the case may be, proposed findings of fact and conclusions of law, his recommendation with respect to any and all issues raised at the hearing, and the record of the hearing. Such findings, conclusions and recommendations shall contain a brief statement of the basis for the recommendations. Copies of the Presiding Officer's proposed findings of fact, conclusions of law and recommendations shall be provided to all parties to the adjudicatory hearing on request, without charge.

(2) Within 20 days following submission of the Presiding Officer's proposed findings of fact, conclusions of law and recommendations, any party may submit written exceptions, no more than 30 pages in length, to such proposed findings, conclsions and recommendations and within 30 days following the submission of the Presiding Officer's proposed findings, conclusions and recommendations any party may file written comments, no more

than 30 pages in length, on another party's exceptions. Within 45 days following the submission of the Presiding Officer's proposed findings, conclusions and recommendations, the Administrator or the Regional Administrator, as the case may be, shall make a determination with respect to all issues raised at such hearing and shall affirm, reverse or modify the previous or proposed determination, as the case may be. Notice of such determination shall set forth the determination for each such issue, shall briefly state the basis therefor and shall be given by mail to all parties to the adjudicatory hearing.

§ 222.12 Appeal to Administrator.

(a) Within 10 days following receipt of the determination of the Regional Administrator pursuant to paragraph (f)(2) of § 222.11, any party to an adjudicatory hearing held in accordance with § 222.11 may appeal such determination to the Administrator by filing a written notice of appeal, or the Administrator may, on his own initiative, review any prior determination.

(b) The notice of appeal shall be no more than 40 pages in length and shall contain:

(1) The name and address of the person filing the notice of appeal;

(2) A concise statement of the facts on which the person relies and appropriate citations to the record of the adjudicatory hearing;

(3) A concise statement of the legal basis on which the person relies;

(4) A concise statement setting forth the action which the person proposes that the Administrator take; and

(5) A certificate of service of the notice of appeal on all other parties to the adjudicatory hearing.

(c) The effective date of any determination made pursuant to paragraph (f)(2) of § 222.11 may be stayed by the Administrator pending final determination by him pursuant to this section upon the filing of a notice of appeal which satisfies the requirements of paragraph (b) of this section or upon initiation by the Administrator of review of any determination in the absence of such notice of appeal.

(d) Within 20 days following the filing of a notice of appeal in accordance with this section, any party to the adjudicatory hearing may file a written memorandum, no more than 40 pages in length, in response thereto.

(e) Within 45 days following the filing of a notice of appeal in accordance with this section, the Administrator shall render his final determination with respect to all issues raised in the appeal to the Administrator and shall affirm, reverse, or modify the previous determination and briefly state the basis for his determination.

(f) In accordance with 5 U.S.C. section 704, the filing of an appeal to the Administrator pursuant to this section shall be a prerequisite to judicial review of any determination to issue, deny or impose conditions upon any permit, or to modify, revoke or suspend any permit, or to take any other enforcement action, under this Subchapter H.

§ 222.13 Computation of time.

In computing any period of time prescribed or allowed in this part, except unless otherwise provided, the day on which the designated period of time begins to run shall not be included. The last day of the period so computed is to be included unless it is a Saturday, Sunday, or a legal holiday in which the Environmental Protection Agency is not open for business, in which event the period runs until the end of the next day which is not a Saturday, Sunday, or legal holiday. Intermediate Saturdays, Sundays and legal holidays shall be excluded from the computation when the period of time prescribed or allowed is seven days or less.

PART 223—CONTENTS OF PERMITS; REVISION, REVOCATION OR LIMITATION OF OCEAN DUMPING PERMITS UNDER SECTION 104(d) OF THE ACT

Subpart A—Contents of Ocean Dumping Permits Issued Under Section 102 of the Act

Sec.

223.1 Contents of special, interim, emergency, general and research permits; posting requirements.

Subpart B—Procedures for Revision, Revocation or Limitation of Ocean Dumping Permits Under Section 104(d) of the Act

223.2 Scope of these rules.
223.3 Preliminary determination; notice.
223.4 Request for, scheduling and conduct of public hearing; determination.
223.5 Request for, scheduling and conduct of adjudicatory hearing; determination.

AUTHORITY: Secs. 102, 104, 107, 108, Marine Protection Research, and Sanctuaries Act of 1972, as amended (33 U.S.C. 1412, 1414, 1417, 1418).

SOURCE: 42 FR 60702, Nov. 28, 1977, unless otherwise noted.

Subpart A—Contents of Ocean Dumping Permits Issued Under Section 102 of the Act

§ 223.1 Contents of special, interim, emergency, general and research permits; posting requirements.

(a) All special, interim, emergency and research permits shall be displayed on the vessel engaged in dumping and shall include the following:

(1) Name of permittee;

(2) Means of conveyance and methods and procedures for release of the materials to be dumped;

(3) The port through or from which such material will be transported for dumping;

(4) A description of relevant physical and chemical properties of the materials to be dumped;

(5) The quantity of the material to be dumped expressed in tons;

(6) The disposal site;

(7) The times at which the permitted dumping may occur and the effective date and expiration date of the permit;

(8) Special provisions which, after consultation with the Coast Guard, are deemed necessary for monitoring or surveillance of the transportation or dumping;

(9) Such monitoring relevant to the assessment of the impact of permitted dumping activities on the marine environment at the disposal site as the Administrator or Regional Administrator, as the case may be, determine to be necessary or appropriate; and

(10) Any other terms and conditions determined by the Administrator, or Regional Administrator, as the case may be, to be necessary or appropriate, including, without limitation, release procedures and requirements for the continued investigation or development of alternatives to ocean dumping.

(b) General permits shall contain such terms and conditions as the Administrator deems necessary or appropriate.

(c) Interim permits shall, in addition to the information required or permitted to be included in the permit pursuant to paragraph (a) of this section, include terms and conditions which satisfy the requirements of §§ 220.3(d) and 227.8.

Subpart B—Procedures for Revision, Revocation or Limitation of Ocean Dumping Permits Under Section 104(d) of the Act

§ 223.2 Scope of these rules.

(a) These rules of practice shall govern all proceedings under Section 104(d) of the Marine Protection, Research, and Sanctuaries Act of 1972, as amended (33 U.S.C. 1414(d)), to revise, revoke or limit the terms and conditions of any permit issued pursuant to section 102 of the Act. Section 104(d) provides that "the Administrator * * * may limit or deny the issuance of permits, or he may alter or revoke partially or entirely the terms of permits issued by him under this title, for the transportation for dumping, or for the dumping, or both of specified materials or classes of materials, where he finds that such materials cannot be dumped consistently with the criteria and other factors required to be applied in evaluating the permit application."

(b) In the absence of specific provisions in these rules, and where appropriate, questions arising at any stage of the proceedings shall be resolved at the discretion of the Presiding Officer, the Regional Administrator, or the Administrator, as appropriate.

§ 223.3 Preliminary determination; notice.

(a) *General.* Any general, special, emergency, interim or research permit issued pursuant to section 102 of the Act shall be subject to revision, revoca-

tion or limitation, in whole or in part, as the result of a determination by the Administrator or Regional Administrator that:

(1) The cumulative impact of the permittee's dumping activities or the aggregate impact of all dumping activities at the dump site designated in the permit should be categorized as Impact Category I, as defined in § 228.10(c)(1) of this subchapter; or

(2) There has been a change in circumstances relating to the management of the disposal site designated in the permit; or

(3) The dumping authorized by the permit would violate applicable water quality standards; or

(4) The dumping authorized by the permit can no longer be carried out consistent with the criteria set forth in Parts 227 and 228.

(b) *Preliminary determination.* Whenever any person authorized by the Administrator or Regional Administrator to (1) periodically review permits pursuant to section 104(d) of the Act or (2) otherwise assess the need for revision, revocation or limitation of a permit makes any of the determinations listed in paragraph (a) of this section with respect to a permit issued pursuant to section 102 of the Act, and additionally determines that revision, revocation or limitation of such permit is warranted, the Administrator or Regional Administrator, as the case may be, shall provide notification of such proposed revision, revocation or limitation to the permittee named in the permit, if any, the public, and any cognizant Federal/State agencies pursuant to paragraph (c) of this section.

(c) *Form of notification.* Notice of any proposed revision, revocation or limitation of a permit shall be sent to the permittee by certified mail, return receipt requested, and shall be published and otherwise disseminated in the manner described in § 222.3(b) through (h).

(d) *Contents of notice.* The notice of any proposed revision, revocation or limitation of a permit issued pursuant to paragraph (b) of this section shall include, in addition to any other materials, the following:

(1) A brief description of the contents of the permit, as set forth in § 223.1;

(2) A description of the proposed revision, revocation, or limitation;

(3) A statement of the reason for such proposed revision, revocation, or limitation; and

(4) A statement that within thirty (30) days of the date of dissemination of the notice, any person may request a public hearing on the proposed revision, revocation or limitation.

§ 223.4 Request for, scheduling and conduct of public hearing; determination.

(a) *Request for hearing.* Within thirty (30) days of the date of the dissemination of any notice required by § 223.2(b), any person may request the Administrator or Regional Administrator, as appropriate, to hold a public hearing on the proposed revision, revocation or limitation by submitting a written request containing the following:

(1) Identification of the person requesting the hearing and his interest in the proceeding;

(2) A statement of any objections to the proposed revision, revocation or limitation or to any facts or reasons identified as supporting such revision, revocation or limitation; and

(3) A statement of the issues which such person proposes to raise for consideration at such hearing.

(b) *Grant or denial of hearing; notification.* Whenever (1) a written request satisfying the requirements of paragraph (a) of this section has been received, and the Administrator or Regional Administrator, as appropriate, determines that such request presents genuine issues, or (2) the Administrator or Regional Administrator, as the case may be, determines in his discretion that a public hearing is necessary or appropriate, the Administrator or Regional Administrator, as the case may be, will set a time and place for a public hearing in accordance with paragraph (c) of this section and will give notice of such hearing by publication in accordance with § 223.3(c). In the event the Administrator or the Regional Administrator, as the case may be, determines that a request filed

pursuant to paragraph (a) of this section does not comply with the requirements of paragraph (a) or that such request does not present genuine issues, he shall advise, in writing, the person requesting the hearing of his determination.

(c) *Time and place of hearing.* Any hearing authorized pursuant to this Section by the Administrator or Regional Administrator, as the case may be, shall be held in the city in which the Environmental Protection Agency Regional Office which issued the permit is located, whenever practicable, and shall be set for the earliest practicable date, but in no event less than thirty (30) days after the receipt of an appropriate request for a hearing or a determination by the Administrator or the Regional Administrator, as the case may be, to hold such a hearing without such a request.

(d) *Presiding Officer.* Any hearing convened pursuant to this part shall be conducted by a Presiding Officer, who shall be either a Regional Judicial Officer or a person having the qualifications of a Judicial Officer assigned by the Administrator or Regional Administrator, as appropriate. Such person shall be an attorney who is a permanent or temporary employee of the Agency, who is not employed by the Region's or Headquarter's Water Programs Division, Surveillance and Analysis Division, or Enforcement Division, and who has had no connection with the preparation or presentation of evidence for any hearing in which he participates as Judicial Officer.

(e) *Conduct of the public hearing.* The Presiding Officer shall be responsible for the expeditious conduct of the hearing. The hearing shall be an informal public hearing, not an adversary proceeding, and shall be conducted so as to allow the presentation of public comments. When the Presiding Officer determines that it is necessary or appropriate, he shall cause a suitable record, which may include a verbatim transcript, of the proceedings to be made. Any person may appear at a public hearing convened pursuant to this section whether or not he requested the hearing, and may be represented by counsel or any other authorized representative. The Presiding Officer is authorized to set forth reasonable restrictions on the nature or amount of documentary material or testimony presented at a public hearing, giving due regard to the relevancy of any such information, and to the avoidance of undue repetitiveness of information presented.

(f) *Recommendations of Presiding Officer.* Within 30 days following the adjournment of a public hearing convened pursuant to this section or within such additional period as the Administrator or the Regional Administrator, as the case may be, may grant to the Presiding Officer for good cause shown, and after full consideration of the comments received at the hearing, the Presiding Officer will prepare and forward to the Administrator or to the Regional Administrator, as the case may be, written recommendations relating to the revision, revocation or limitation of the permit and the record of the hearing, if any. Such recommendations shall contain a brief statement of the basis therefor, including a description of evidence relied upon (1) to support any finding made pursuant to § 223.3(a); (2) to justify any proposed revision, revocation or limitation of the permit; and (3) to justify any proposed revision, revocation or limitation which differs from that set forth in the notice issued pursuant to § 223.3(b). Copies of the Presiding Officer's recommendations shall be provided to any interested person on request, without charge. Copies of the record will be provided in accordance with 40 CFR Part 2.

(g) *Determination of the Administrator or Regional Administrator.* Upon receipt of the Presiding Officer's recommendations or, where no hearing has been held, upon termination of the thirty (30)-day period for requesting a hearing provided in paragraph (a) of this section, the Administrator or the Regional Administrator, as the case may be, shall make a determination with respect to the modification, revocation or suspension of the permit. Such determination shall include a description of the permit revision, revocation or limitation, the basis therefor, and the effective date. A copy of such determination shall be mailed to the permittee and each

person who registered his attendance at the hearing by providing his name and mailing address.

§ 223.5 Request for, scheduling and conduct of adjudicatory hearing; determination.

Within ten (10) days following the receipt of the Administrator's or Regional Administrator's determination issued pursuant to § 223.4(g), any person who participated in the public hearing held pursuant to § 223.4 may request that an adjudicatory hearing be held for the purpose of reviewing such determination or any part thereof. Such request shall be submitted and disposed of, and any adjudicatory hearing convened shall be conducted in accordance with the procedures set forth in §§ 222.10(a), (b), (d), and (e) and 222.11.

PART 224—RECORDS AND REPORTS REQUIRED OF OCEAN DUMPING PERMITTEES UNDER SECTION 102 OF THE ACT

Sec.
224.1 Records of permittees.
224.2 Reports.

AUTHORITY: 33 U.S.C. 1412 and 1418.

§ 224.1 Records of permittees.

Each permittee named in a special, interim, emergency or research permit under section 102 of the Act and each person availing himself of the privilege conferred by a general permit, shall maintain complete records of the following information, which will be available for inspection by the Administrator, Regional Administrator, the Commandant of the U.S. Coast Guard, or their respective designees:

(a) The physical and chemical characteristics of the material dumped pursuant to the permit;

(b) The precise times and locations of dumping;

(c) Any other information required as a condition of a permit by the Administrator or the Regional Administrator, as the case may be.

[42 FR 2474, Jan. 11, 1977]

§ 224.2 Reports.

(a) *Periodic reports.* Information required to be recorded pursuant to § 224.1 shall be reported to the Administrator or the Regional Administrator, as the case may be, for the periods indicated within 30 days of the expiration of such periods:

(1) For each six-month period, if any, following the effective date of the permit;

(2) For any other period of less than six months ending on the expiration date of the permit; and

(3) As otherwise required in the conditions of the permit.

(b) *Reports of emergency dumping.* If material is dumped without a permit pursuant to paragraph (c)(4) of § 220.1, the owner or operator of the vessel or aircraft from which such dumping occurs shall as soon as feasible inform the Administrator, Regional Administrator, or the nearest Coast Guard district of the incident by radio, telephone, or telegraph and shall within 10 days file a written report with the Administrator or Regional Administrator containing the information required under § 224.1 and a complete description of the circumstances under which the dumping occurred. Such description shall explain how human life at sea was in danger and how the emergency dumping reduced that danger. If the material dumped included containers, the vessel owner or operator shall immediately request the U.S. Coast Guard to publish in the local Notice to Mariners the dumping location, the type of containers, and whether the contents are toxic or explosive. Notification shall also be given to the Food and Drug Administration, Shellfish Sanitation Branch, Washington, DC 20204, as soon as possible.

[42 FR 2474, Jan. 11, 1977]

PART 225—CORPS OF ENGINEERS DREDGED MATERIAL PERMITS

Sec.
225.1 General.
225.2 Review of Dredged Material Permits.
225.3 Procedure for invoking economic impact.
225.4 Waiver by Administrator.

AUTHORITY: 33 U.S.C. 1412 and 1418.

SOURCE: 42 FR 2475, Jan. 11, 1977, unless otherwise noted.

§ 225.1 General.

Applications and authorizations for Dredged Material Permits under section 103 of the Act for the transportation of dredged material for the purpose of dumping it in ocean waters will be evaluated by the U.S. Army Corps of Engineers in accordance with the criteria set forth in Part 227 and processed in accordance with 33 CFR 209.120 with special attention to § 209.120(g)(17) and 33 CFR 209.145.

§ 225.2 Review of Dredged Material Permits.

(a) The District Engineer shall send a copy of the public notice to the appropriate Regional Administrator, and set forth in writing all of the following information:

(1) The location of the proposed disposal site and its physical boundaries;

(2) A statement as to whether the site has been designated for use by the Administrator pursuant to section 102(c) of the Act;

(3) If the proposed disposal site has not been designated by the Administrator, a statement of the basis for the proposed determination why no previously designated site is feasible and a description of the characteristics of the proposed disposal site necessary for its designation pursuant to Part 228 of this Subchapter H;

(4) The known historical uses of the proposed disposal site;

(5) Existence and documented effects of other authorized dumpings that have been made in the dumping area (e.g., heavy metal background reading and organic carbon content);

(6) An estimate of the length of time during which disposal will continue at the proposed site;

(7) Characteristics and composition of the dredged material; and

(8) A statement concerning a preliminary determination of the need for and/or availability of an environmental impact statement.

(b) The Regional Administrator will within 15 days of the date the public notice and other information required to be submitted by paragraph (a) of § 225.2 are received by him, review the information submitted and request from the District Engineer any additional information he deems necessary or appropriate to evaluate the proposed dumping.

(c) Using the information submitted by the District Engineer, and any other information available to him, the Regional Administrator will within 15 days after receipt of all requested information, make an independent evaluation of the proposed dumping in accordance with the criteria and respond to the District Engineer pursuant to paragraph (d) or (e) of this section. The Regional Administrator may request an extension of this 15 day period to 30 days from the District Engineer.

(d) When the Regional Administrator determines that the proposed dumping will comply with the criteria, he will so inform the District Engineer in writing.

(e) When the Regional Administrator determines that the proposed dumping will not comply with the criteria he shall so inform the District Engineer in writing. In such cases, no Dredged Material Permit for such dumping shall be issued unless and until the provisions of § 225.3 are followed and the Administrator grants a waiver of the criteria pursuant to § 225.4.

§ 225.3 Procedure for invoking economic impact.

(a) When a District Engineer's determination to issue a Dredged Material Permit for the dumping of dredged material into ocean waters has been rejected by a Regional Administrator upon application of the Criteria, the District Engineer may determine whether, under section 103(d) of the Act, there is an economically feasible alternative method or site available other than the proposed dumping in ocean waters. If the District Engineer makes any such preliminary determination that there is no economically feasible alternative method or site available, he shall so advise the Regional Administrator setting forth his reasons for such determination and shall submit a report of such determination to the Chief of Engineers in ac-

cordance with 33 CFR 209.120 and 209.145.

(b) If the decision of the Chief of Engineers is that ocean dumping at the designated site is required because of the unavailability of feasible alternatives, he shall so certify and request that the Secretary of the Army seek a waiver from the Administrator of the Criteria or of the critical site designation in accordance with § 225.4.

§ 225.4 Waiver by Administrator.

The Administrator shall grant the requested waiver unless within 30 days of his receipt of the notice, certificate and request in accordance with paragraph (b) of § 225.3 he determines in accordance with this section that the proposed dumping will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas. Notice of the Administrator's final determination under this section shall be given to the Secretary of the Army.

PART 227—CRITERIA FOR THE EVALUATION OF PERMIT APPLICATIONS FOR OCEAN DUMPING OF MATERIALS

Subpart A—General

Sec.
227.1 Applicability.
227.2 Materials which satisfy the environmental impact criteria of Subpart B.
227.3 Materials which do not satisfy the environmental impact criteria set forth in Subpart B.

Subpart B—Environmental Impact

227.4 Criteria for evaluating environmental impact.
227.5 Prohibited materials.
227.6 Constituents prohibited as other than trace contaminants.
227.7 Limits established for specific wastes or waste constituents.
227.8 Limitations on the disposal rates of toxic wastes.
227.9 Limitations on quantities of waste materials.
227.10 Hazards to fishing, navigation, shorelines or beaches.
227.11 Containerized wastes.
227.12 Insoluble wastes.
227.13 Dredged materials.

Subpart C—Need for Ocean Dumping

227.14 Criteria for evaluating the need for ocean dumping and alternatives to ocean dumping.
227.15 Factors considered.
227.16 Basis for determination of need for ocean dumping.

Subpart D—Impact of the Proposed Dumping on Esthetic, Recreational and Economic Values

227.17 Basis for determination.
227.18 Factors considered.
227.19 Assessment of impact.

Subpart E—Impact of the Proposed Dumping on Other Uses of the Ocean

227.20 Basis for determination.
227.21 Uses considered.
227.22 Assessment of impact.

Subpart F—Special Requirements for Interim Permits Under Section 102 of the Act

227.23 General requirement.
227.24 Contents of environmental assessment.
227.25 Contents of plans.
227.26 Implementation of plans.

Subpart G—Definitions

227.27 Limiting permissible concentration (LPC).
227.28 Release zone.
227.29 Initial mixing.
227.30 High-level radioactive waste.
227.31 Applicable marine water quality criteria.
227.32 Liquid, suspended particulate, and solid phases of a material.

AUTHORITY: 33 U.S.C. 1412 and 1418.

SOURCE: 42 FR 2476, Jan. 11, 1977, unless otherwise noted.

Subpart A—General

§ 227.1 Applicability.

(a) Section 102 of the Act requires that criteria for the issuance of ocean disposal permits be promulgated after consideration of the environmental effect of the proposed dumping operation, the need for ocean dumping, alternatives to ocean dumping, and the effect of the proposed action on esthetic, recreational and economic values and on other uses of the ocean.

This Parts 227 and 228 of this Subchapter H together constitute the criteria established pursuant to section 102 of the Act. The decision of the Administrator, Regional Administrator or the District Engineer, as the case may be, to issue or deny a permit and to impose specific conditions on any permit issued will be based on an evaluation of the permit application pursuant to the criteria set forth in this Part 227 and upon the requirements for disposal site management pursuant to the criteria set forth in Part 228 of this Subchapter H.

(b) With respect to the criteria to be used in evaluating disposal of dredged materials, this section and Subparts C, D, E, and G apply in their entirety. To determine whether the proposed dumping of dredged material complies with Subpart B, only §§ 227.4, 227.5, 227.6, 227.9, 227.10 and 227.13 apply. An applicant for a permit to dump dredged material must comply with all of Subparts C, D, E, G and applicable sections of B, to be deemed to have met the EPA criteria for dredged material dumping promulgated pursuant to section 102(a) of the Act. If, in any case, the Chief of Engineers finds that, in the disposition of dredged material, there is no economically feasible method or site available other than a dumping site, the utilization of which would result in noncompliance with the criteria established pursuant to Subpart B relating to the effects of dumping or with the restrictions established pursuant to section 102(c) of the Act relating to critical areas, he shall so certify and request that the Secretary of the Army seek a waiver from the Administrator pursuant to Part 225.

(c) The Criteria of this Part 227 are established pursuant to section 102 of the Act and apply to the evaluation of proposed dumping of materials under Title I of the Act. The Criteria of this Part 227 deal with the evaluation of proposed dumping of materials on a case-by-case basis from information supplied by the applicant or otherwise available to EPA or the Corps of Engineers concerning the characteristics of the waste and other considerations relating to the proposed dumping.

(d) After consideration of the provisions of §§ 227.28 and 227.29, no permit will be issued when the dumping would result in a violation of applicable water quality standards.

§ 227.2 Materials which satisfy the environmental impact criteria of Subpart B.

(a) If the applicant satisfactorily demonstrates that the material proposed for ocean dumping satisfies the environmental impact criteria set forth in Subpart B, a permit for ocean dumping will be issued unless:

(1) There is no need for the dumping, and alternative means of disposal are available, as determined in accordance with the criteria set forth in Subpart C; or

(2) There are unacceptable adverse effects on esthetic, recreational or economic values as determined in accordance with the criteria set forth in Subpart D; or

(3) There are unacceptable adverse effects on other uses of the ocean as determined in accordance with the criteria set forth in Subpart E.

(b) If the material proposed for ocean dumping satisfies the environmental impact criteria set forth in Subpart B, but the Administrator or the Regional Administrator, as the case may be, determines that any one of the considerations set forth in paragraph (a)(1), (2) or (3) of this section applies, he will deny the permit application; provided however, that he may issue an interim permit for ocean dumping pursuant to paragraph (d) of § 220.3 and Subpart F of this Part 227 when he determines that:

(1) The material proposed for ocean dumping does not contain any of the materials listed in § 227.5 or listed in § 227.6, except as trace contaminants; and

(2) In accordance with Subpart C there is a need to ocean dump the material and no alternatives are available to such dumping; and

(3) The need for the dumping and the unavailability of alternatives, as determined in accordance with Subpart C, are of greater significance to the public interest than the potential for adverse effect on esthetic, recre-

ational or economic values, or on other uses of the ocean, as determined in accordance with Subparts D and E, respectively.

§ 227.3 Materials which do not satisfy the environmental impact criteria set forth in Subpart B.

If the material proposed for ocean dumping does not satisfy the environmental impact criteria of Subpart B, the Administrator or the Regional Administrator, as the case may be, will deny the permit application; provided however, that he may issue an interim permit pursuant to paragraph (d) of § 220.3 and Subpart F of this Part 227 when he determines that:

(a) The material proposed for dumping does not contain any of the materials listed in § 227.6 except as trace contaminants, or any of the materials listed in § 227.5;

(b) In accordance with Subpart C there is a need to ocean dump the material; and

(c) Any one of the following factors is of greater significance to the public interest than the potential for adverse impact on the marine environment, as determined in accordance with Subpart B:

(1) The need for the dumping, as determined in accordance with Subpart C; or

(2) The adverse effects of denial of the permit on recreational or economic values as determined in accordance with Subpart D; or

(3) The adverse effects of denial of the permit on other uses of the ocean, as determined in accordance with Subpart E.

Subpart B—Environmental Impact

§ 227.4 Criteria for evaluating environmental impact.

This Subpart B sets specific environmental impact prohibitions, limits, and conditions for the dumping of materials into ocean waters. If the applicable prohibitions, limits, and conditions are satisfied, it is the determination of EPA that the proposed disposal will not unduly degrade or endanger the marine environment and that the disposal will present:

(a) No unacceptable adverse effects on human health and no significant damage to the resources of the marine environment;

(b) No unacceptable adverse effect on the marine ecosystem;

(c) No unacceptable adverse persistent or permanent effects due to the dumping of the particular volumes or concentrations of these materials; and

(d) No unacceptable adverse effect on the ocean for other uses as a result of direct environmental impact.

§ 227.5 Prohibited materials.

The ocean dumping of the following materials will not be approved by EPA or the Corps of Engineers under any circumstances:

(a) High-level radioactive wastes as defined in § 227.30;

(b) Materials in whatever form (including without limitation, solids, liquids, semi-liquids, gases or organisms) produced or used for radiological, chemical or biological warfare;

(c) Materials insufficiently described by the applicant in terms of their compositions and properties to permit application of the environmental impact criteria of this Subpart B;

(d) Persistent inert synthetic or natural materials which may float or remain in suspension in the ocean in such a manner that they may interfere materially with fishing, navigation, or other legitimate uses of the ocean.

§ 227.6 Constituents prohibited as other than trace contaminants.

(a) Subject to the exclusions of paragraphs (f), (g) and (h) of this section, the ocean dumping, or transportation for dumping, of materials containing the following constituents as other than trace contaminants will not be approved on other than an emergency basis:

(1) Organohalogen compounds;

(2) Mercury and mercury compounds;

(3) Cadmium and cadmium compounds;

(4) Oil of any kind or in any form, including but not limited to petroleum, oil sludge, oil refuse, crude oil, fuel oil, heavy diesel oil, lubricating

oils, hydraulic fluids, and any mixtures containing these, transported for the purpose of dumping insofar as these are not regulated under the FWPCA;

(5) Known carcinogens, mutagens, or teratogens or materials suspected to be carcinogens, mutagens, or teratogens by responsible scientific opinion.

(b) These constituents will be considered to be present as trace contaminants only when they are present in materials otherwise acceptable for ocean dumping in such forms and amounts in liquid, suspended particulate, and solid phases that the dumping of the materials will not cause significant undesirable effects, including the possibility of danger associated with their bioaccumulation in marine organisms.

(c) The potential for significant undesirable effects due to the presence of these constituents shall be determined by application of results of bioassays on liquid, suspended particulate, and solid phases of wastes according to procedures acceptable to EPA, and for dredged material, acceptable to EPA and the Corps of Engineers. Materials shall be deemed environmentally acceptable for ocean dumping only when the following conditions are met:

(1) The liquid phase does not contain any of these constituents in concentrations which will exceed applicable marine water quality criteria after allowance for initial mixing; provided that mercury concentrations in the disposal site, after allowance for initial mixing, may exceed the average normal ambient concentrations of mercury in ocean waters at or near the dumping site which would be present in the absence of dumping, by not more than 50 percent; and

(2) Bioassay results on the suspended particulate phase of the waste do not indicate occurrence of significant mortality or significant adverse sublethal effects including bioaccumulation due to the dumping of wastes containing the constituents listed in paragraph (a) of this section. These bioassays shall be conducted with appropriate sensitive marine organisms as defined in § 227.27(c) using procedures for suspended particulate phase bioassays approved by EPA, or, for dredged material, approved by EPA and the Corps of Engineers. Procedures approved for bioassays under this section will require exposure of organisms for a sufficient period of time and under appropriate conditions to provide reasonable assurance, based on consideration of the statistical significance of effects at the 95 percent confidence level, that, when the materials are dumped, no significant undesirable effects will occur due either to chronic toxicity or to bioaccumulation of the constituents listed in paragraph (a) of this section; and

(3) Bioassay results on the solid phase of the wastes do not indicate occurrence of significant mortality or significant adverse sublethal effects due to the dumping of wastes containing the constituents listed in paragraph (a) of this section. These bioassays shall be conducted with appropriate sensitive benthic marine organisms using benthic bioassay procedures approved by EPA, or, for dredged material, approved by EPA and the Corps of Engineers. Procedures approved for bioassays under this section will require exposure of organisms for a sufficient period of time to provide reasonable assurance, based on considerations of statistical significance of effects at the 95 percent confidence level, that, when the materials are dumped, no significant undesirable effects will occur due either to chronic toxicity or to bioaccumulation of the constituents listed in paragraph (a) of this section; and

(4) For persistent organohalogens not included in the applicable marine water quality criteria, bioassay results on the liquid phase of the waste show that such compounds are not present in concentrations large enough to cause significant undesirable effects due either to chronic toxicity or to bioaccumulation in marine organisms after allowance for initial mixing.

(d) When the Administrator, Regional Administrator or District Engineer, as the case may be, has reasonable cause to believe that a material proposed for ocean dumping contains compounds identified as carcinogens, mutagens, or teratogens for which criteria have not been included in the ap-

plicable marine water quality criteria, he may require special studies to be done prior to issuance of a permit to determine the impact of disposal on human health and/or marine ecosystems. Such studies must provide information comparable to that required under paragraph (c)(3) of this section.

(e) The criteria stated in paragraphs (c)(2) and (3) of this section will become mandatory as soon as announcement of the availability of acceptable procedures is made in the FEDERAL REGISTER. At that time the interim criteria contained in paragraph (e) of this section shall no longer be applicable.

NOTE: The remainder of this paragraph has been made inapplicable by the notice of "Availability of Implementation Manual, 'Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters,'" Federal Register, Vo. 42, NO. 7, 7 September 1977, page 44835.

(f) The prohibitions and limitations of this section do not apply to the constituents identified in paragraph (a) of this section when the applicant can demonstrate that such constituents are (1) present in the material only as chemical compounds or forms (e.g., inert insoluble solid materials) non-toxic to marine life and non-bioaccumulative in the marine environment upon disposal and thereafter, or (2) present in the material only as chemical compounds or forms which, at the time of dumping and thereafter, will be rapidly rendered non-toxic to marine life and non-bioaccumulative in the marine environment by chemical or biological degradation in the sea; provided they will not make edible marine organisms unpalatable; or will not endanger human health or that of domestic animals, fish, shellfish, or wildlife.

(g) The prohibitions and limitations of this section do not apply to the constituents identified in paragraph (a) of this section for the granting of research permits if the substances are rapidly rendered harmless by physical, chemical or biological processes in the sea; provided they will not make edible marine organisms unpalatable and will not endanger human health or that of domestic animals.

(h) The prohibitions and limitations of this section do not apply to the constituents identified in paragraph (a) of this section for the granting of permits for the transport of these substances for the purpose of incineration at sea if the applicant can demonstrate that the stack emissions consist of substances which are rapidly rendered harmless by physical, chemical or biological processes in the sea. Incinerator operations shall comply with requirements which will be established on a case-by-case basis.

[42 FR 2476, Jan. 11, 1977; 43 FR 1071, Jan. 6, 1978]

§ 227.7 Limits established for specific wastes or waste constituents.

Materials containing the following constituents must meet the additional limitations specified in this section to be deemed acceptable for ocean dumping:

(a) Liquid waste constituents immiscible with or slightly soluble in seawater, such as benzene, xylene, carbon disulfide and toluene, may be dumped only when they are present in the waste in concentrations below their solubility limits in seawater. This provision does not apply to materials which may interact with ocean water to form insoluble materials;

(b) Radioactive materials, other than those prohibited by § 227.5, must be contained in accordance with the provisions of § 227.11 to prevent their direct dispersion or dilution in ocean waters;

(c) Wastes containing living organisms may not be dumped if the organisms present would endanger human health or that of domestic animals, fish, shellfish and wildlife by:

(1) Extending the range of biological pests, viruses, pathogenic microorganisms or other agents capable of infesting, infecting or extensively and permanently altering the normal populations of organisms;

(2) Degrading uninfected areas; or

§ 227.7 Limits established for specific wastes or waste constituents.

Materials containing the following constituents must meet the additional limitations specified in this section to be deemed acceptable for ocean dumping:

(a) Liquid waste constituents immiscible with or slightly soluble in seawater, such as benzene, xylene, carbon disulfide and toluene, may be dumped only when they are present in the waste in concentrations below their solubility limits in seawater. This provision does not apply to materials which may interact with ocean water to form insoluble materials;

(b) Radioactive materials, other than those prohibited by § 227.5, must be contained in accordance with the provisions of § 227.11 to prevent their direct dispersion or dilution in ocean waters;

(c) Wastes containing living organisms may not be dumped if the organisms present would endanger human health or that of domestic animals, fish, shellfish and wildlife by:

(1) Extending the range of biological pests, viruses, pathogenic microorganisms or other agents capable of infesting, infecting or extensively and permanently altering the normal populations of organisms;

(2) Degrading uninfected areas; or

(3) Introducing viable species not indigenous to an area.

(d) In the dumping of wastes of highly acidic or alkaline nature into the ocean, consideration shall be given to:

(1) The effects of any change in acidity or alkalinity of the water at the disposal site; and

(2) The potential for synergistic effects or for the formation of toxic compounds at or near the disposal site. Allowance may be made in the permit conditions for the capability of ocean waters to neutralize acid or alkaline wastes; provided, however, that dumping conditions must be such that the average total alkalinity or total acidity of the ocean water after allowance for initial mixing, as defined in § 227.29, may be changed, based on stoichiometric calculations, by no more than 10 percent during all dumping operations at a site to neutralize acid or alkaline wastes.

(e) Wastes containing biodegradable constituents, or constituents which consume oxygen in any fashion, may be dumped in the ocean only under conditions in which the dissolved oxygen after allowance for initial mixing, as defined in § 227.29, will not be depressed by more than 25 percent below the normally anticipated ambient conditions in the disposal area at the time of dumping.

§ 227.8 Limitations on the disposal rates of toxic wastes.

No wastes will be deemed acceptable for ocean dumping unless such wastes can be dumped so as not to exceed the limiting permissible concentration as defined in § 227.27; *Provided*, That this § 227.8 does not apply to those wastes for which specific criteria are established in § 227.11 or § 227.12. Total quantities of wastes dumped at a site may be limited as described in § 228.8.

§ 227.9 Limitations on quantities of waste materials.

Substances which may damage the ocean environment due to the quantities in which they are dumped, or which may seriously reduce amenities, may be dumped only when the quantities to be dumped at a single time and place are controlled to prevent long-term damage to the environment or to amenities.

§ 227.10 Hazards to fishing, navigation, shorelines or beaches.

(a) Wastes which may present a serious obstacle to fishing or navigation may be dumped only at disposal sites and under conditions which will insure no unacceptable interference with fishing or navigation.

(b) Wastes which may present a hazard to shorelines or beaches may be dumped only at sites and under conditions which will insure no unacceptable danger to shorelines or beaches.

§ 227.11 Containerized wastes.

(a) Wastes containerized solely for transport to the dumping site and ex-

pected to rupture or leak on impact or shortly thereafter must meet the appropriate requirements of §§ 227.6, 227.7, 227.8, 227.9, and 227.10.

(b) Other containerized wastes will be approved for dumping only under the following conditions:

(1) The materials to be disposed of decay, decompose or radiodecay to environmentally innocuous materials within the life expectancy of the containers and/or their inert matrix; and

(2) Materials to be dumped are present in such quantities and are of such nature that only short-term localized adverse effects will occur should the containers rupture at any time; and

(3) Containers are dumped at depths and locations where they will cause no threat to navigation, fishing, shorelines, or beaches.

§ 227.12 Insoluble wastes.

(a) Solid wastes consisting of inert natural minerals or materials compatible with the ocean environment may be generally approved for ocean dumping provided they are insoluble above the applicable trace or limiting permissible concentrations and are rapidly and completely settleable, and they are of a particle size and density that they would be deposited or rapidly dispersed without damage to benthic, demersal, or pelagic biota.

(b) Persistent inert synthetic or natural materials which may float or remain in suspension in the ocean as prohibited in paragraph (d) of § 227.5 may be dumped in the ocean only when they have been processed in such a fashion that they will sink to the bottom and remain in place.

§ 227.13 Dredged materials.

(a) Dredged materials are bottom sediments or materials that have been dredged or excavated from the navigable waters of the United States, and their disposal into ocean waters is regulated by the U.S. Army Corps of Engineers using the criteria of applicable sections of Parts 227 and 228. Dredged material consists primarily of natural sediments or materials which may be contaminated by municipal or industrial wastes or by runoff from terrestrial sources such as agricultural lands.

(b) Dredged material which meets the criteria set forth in the following paragraphs (b)(1), (2), or (3) of this section is environmentally acceptable for ocean dumping without further testing under this section:

(1) Dredged material is composed predominantly of sand, gravel, rock, or any other naturally occurring bottom material with particle sizes larger than silt, and the material is found in areas of high current or wave energy such as streams with large bed loads or coastal areas with shifting bars and channels; or

(2) Dredged material is for beach nourishment or restoration and is composed predominantly of sand, gravel or shell with particle sizes compatible with material on the receiving beaches; or

(3) *When:* (i) The material proposed for dumping is substantially the same as the substrate at the proposed disposal site; and

(ii) The site from which the material proposed for dumping is to be taken is far removed from known existing and historical sources of pollution so as to provide reasonable assurance that such material has not been contaminated by such pollution.

(c) When dredged material proposed for ocean dumping does not meet the criteria of paragraph (b) of this section, further testing of the liquid, suspended particulate, and solid phases, as defined in § 227.32, is required. Based on the results of such testing, dredged material can be considered to be environmentally acceptable for ocean dumping only under the following conditions:

(1) The material is in compliance with the requirements of § 227.6; and

(2)(i) All major constituents of the liquid phase are in compliance with the applicable marine water quality criteria after allowance for initial mixing; or

(ii) When the liquid phase contains major constituents not included in the applicable marine water quality criteria, or there is reason to suspect synergistic effects of certain contaminants, bioassays on the liquid phase of the dredged material show that it can be

discharged so as not to exceed the limiting permissible concentration as defined in paragraph (a) of § 227.27; and

(3) Bioassays on the suspended particulate and solid phases show that it can be discharged so as not to exceed the limiting permissible concentration as defined in paragraph (b) of § 227.27.

(d) For the purposes of paragraph (c)(2) of this section, major constituents to be analyzed in the liquid phase are those deemed critical by the District Engineer, after evaluating and considering any comments received from the Regional Administrator, and considering known sources of discharges in the area.

Subpart C—Need for Ocean Dumping

§ 227.14 Criteria for evaluating the need for ocean dumping and alternatives to ocean dumping.

This Subpart C states the basis on which an evaluation will be made of the need for ocean dumping, and alternatives to ocean dumping. The nature of these factors does not permit the promulgation of specific quantitative criteria of each permit application. These factors will therefore be evaluated if applicable for each proposed dumping on an individual basis using the guidelines specified in this Subpart C.

§ 227.15 Factors considered.

The need for dumping will be determined by evaluation of the following factors:

(a) Degree of treatment useful and feasible for the waste to be dumped, and whether or not the waste material has been or will be treated to this degree before dumping;

(b) Raw materials and manufacturing or other processes resulting in the waste, and whether or not these materials or processes are essential to the provision of the applicant's goods or services, or if other less polluting materials or processes could be used;

(c) The relative environmental risks, impact and cost for ocean dumping as opposed to other feasible alternatives including but not limited to:

(1) Land fill;

(2) Well injection;

(3) Incineration;

(4) Spread of material over open ground;

(5) Recycling of material for reuse;

(6) Additional biological, chemical, or physical treatment of intermediate or final waste streams;

(7) Storage.

(d) Irreversible or irretrievable consequences of the use of alternatives to ocean dumping.

§ 227.16 Basis for determination of need for ocean dumping.

(a) A need for ocean dumping will be considered to have been demonstrated when a thorough evaluation of the factors listed in § 227.15 has been made, and the Administrator, Regional Administrator or District Engineer, as the case may be, has determined that the following conditions exist where applicable:

(1) There are no practicable improvements which can be made in process technology or in overall waste treatment to reduce the adverse impacts of the waste on the total environment;

(2) There are no practicable alternative locations and methods of disposal or recycling available, including without limitation, storage until treatment facilities are completed, which have less adverse environmental impact or potential risk to other parts of the environment than ocean dumping.

(b) For purposes of paragraph (a) of this section, waste treatment or improvements in processes and alternative methods of disposal are practicable when they are available at reasonable incremental cost and energy expenditures, which need not be competitive with the costs of ocean dumping, taking into account the environmental benefits derived from such activity, including the relative adverse environmental impacts associated with the use of alternatives to ocean dumping.

(c) The duration of permits issued under Subchapter H and other terms and conditions imposed in those permits shall be determined after taking into account the factors set forth in this section. Notwithstanding compliance with Subparts B, D, and E of this Part 227 permittees may, on the basis

of the need for and alternatives to ocean dumping, be required to terminate all ocean dumping by a specified date, to phase out all ocean dumping over a specified period or periods, to continue research and development of alternative methods of disposal and make periodic reports of such research and development in order to provide additional information for periodic review of the need for and alternatives to ocean dumping, or to take such other action as the Administrator, the Regional Administrator, or District Engineer, as the case may be, determines to be necessary or appropriate.

Subpart D—Impact of the Proposed Dumping on Esthetic, Recreational and Economic Values

§ 227.17 Basis for determination.

(a) The impact of dumping on esthetic, recreational and economic values will be evaluated on an individual basis using the following considerations:

(1) Potential for affecting recreational use and values of ocean waters, inshore waters, beaches, or shorelines;

(2) Potential for affecting the recreational and commercial values of living marine resources.

(b) For all proposed dumping, full consideration will be given to such nonquantifiable aspects of esthetic, recreational and economic impact as:

(1) Responsible public concern for the consequences of the proposed dumping;

(2) Consequences of not authorizing the dumping including without limitation, the impact on esthetic, recreational and economic values with respect to the municipalities and industries involved.

§ 227.18 Factors considered.

The assessment of the potential for impacts on esthetic, recreational and economic values will be based on an evaluation of the appropriate characteristics of the material to be dumped, allowing for conservative rates of dilution, dispersion, and biochemical degradation during movement of the materials from a disposal site to an area of significant recreational or commercial value. The following specific factors will be considered in making such an assessment:

(a) Nature and extent of present and potential recreational and commercial use of areas which might be affected by the proposed dumping;

(b) Existing water quality, and nature and extent of disposal activities, in the areas which might be affected by the proposed dumping;

(c) Applicable water quality standards;

(d) Visible characteristics of the materials (e.g., color, suspended particulates) which result in an unacceptable estetic nuisance in recreational areas;

(e) Presence in the material of pathogenic organisms which may cause a public health hazard either directly or through contamination of fisheries or shellfisheries;

(f) Presence in the material of toxic chemical constituents released in volumes which may affect humans directly;

(g) Presence in the material of chemical constituents which may be bioaccumulated or persistent and may have an adverse effect on humans directly or through food chain interactions;

(h) Presence in the material of any constituents which might significantly affect living marine resources of recreational or commercial value.

§ 227.19 Assessment of impact.

An overall assessment of the proposed dumping and possible alternative methods of disposal or recycling will be made based on the effect on esthetic, recreational and economic values based on the factors set forth in this Subpart D, including where applicable, enhancement of these values, and the results of the assessment will be expressed, where possible, on a quantitative basis, such as percentage of a resource lost, reduction in use days of recreational areas, or dollars lost in commercial fishery profits or the profitability of other commercial enterprises.

Subpart E—Impact of the Proposed Dumping on Other Uses of the Ocean

§ 227.20 Basis for determination.

(a) Based on current state of the art, consideration must be given to any possible long-range effects of even the most innocuous substances when dumped in the ocean on a continuing basis. Such a consideration is made in evaluating the relationship of each proposed disposal activity in relationship to its potential for long-range impact on other uses of the ocean.

(b) An evaluation will be made on an individual basis for each proposed dumping of material of the potential for effects on uses of the ocean for purposes other than material disposal. The factors to be considered in this evaluation include those stated in Subpart D, but the evaluation of this Subpart E will be based on the impact of the proposed dumping on specific uses of the ocean rather than on overall esthetic, recreational and economic values.

§ 227.21 Uses considered.

An appraisal will be made of the nature and extent of existing and potential uses of the disposal site itself and of any areas which might reasonably be expected to be affected by the proposed dumping, and a quantitative and qualitative evaluation made, where feasible, of the impact of the proposed dumping on each use. The uses considered shall include, but not be limited to:

(a) Commercial fishing in open ocean areas;

(b) Commercial fishing in coastal areas;

(c) Commercial fishing in estuarine areas;

(d) Recreational fishing in open ocean areas;

(e) Recreational fishing in coastal areas;

(f) Recreational fishing in estuarine areas;

(g) Recreational use of shorelines and beaches;

(h) Commercial navigation;

(i) Recreational navigation;

(j) Actual or anticipated exploitation of living marine resources;

(k) Actual or anticipated exploitation of non-living resources, including without limitation, sand and gravel places and other mineral deposits, oil and gas exploration and development and offshore marine terminal or other structure development; and

(l) Scientific research and study.

§ 227.22 Assessment of impact.

The assessment of impact on other uses of the ocean will consider both temporary and long-range effects within the state of the art, but particular emphasis will be placed on any irreversible or irretrievable commitment of resources that would result from the proposed dumping.

Subpart F—Special Requirements for Interim Permits Under Section 102 of the Act

§ 227.23 General requirement.

Each interim permit issued under section 102 of the Act will include a requirement for the development and implementation, as soon as practicable, of a plan which requires, at the discretion of the Administrator or Regional Administrator, as the case may be, either:

(a) Elimination of ocean disposal of the waste, or

(b) Bringing the waste into compliance with all the criteria for acceptable ocean disposal.

§ 227.24 Contents of environmental assessment.

A plan developed pursuant to this Subpart F must include an environmental assessment of the proposed action, including without limitation:

(a) Description of the proposed action;

(b) A thorough review of the actual need for dumping;

(c) Environmental impact of the proposed action;

(d) Adverse impacts which cannot be avoided should the proposal be implemented;

(e) Alternatives to the proposed action;

(f) Relationship between short-term uses of man's environment and the

maintenance and enhancement of long-term productivity;

(g) Irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented; and

(h) A discussion of problems and objections raised by other Federal, State and local agencies and by interested persons in the review process.

§ 227.25 Contents of plans.

In addition to the environmental assessment required by § 227.24, a plan developed pursuant to this Subpart F must include a schedule for eliminating ocean dumping or bringing the wastes into compliance with the environmental impact criteria of Subpart B, including without limitation, the following:

(a) If the waste is treated to the degree necessary to bring it into compliance with the ocean dumping criteria, the applicant should provide a description of the treatment and a scheduled program for treatment and a subsequent analysis of treated material to prove the effectiveness of the process.

(b) If treatment cannot be effected by post-process techniques the applicant should, determining the offending constituents, examine his raw materials and his total process to determine the origin of the pollutant. If the offending constituents are found in the raw material the applicant should consider a new supplier and provide an analysis of the new material to prove compliance. Raw materials are to include all water used in the process. Water from municipal sources complying with drinking water standards is acceptable. Water from other sources such as private wells should be analyzed for contaminants. Water that has been used in the process should be considered for treatment and recycling as an additional source of process water.

(c) If offending constituents are a result of the process, the applicant should investigate and describe the source of the constituents. A report of this information will be submitted to EPA and the applicant will then submit a proposal describing possible alternatives to the existing process or processes and level of cost and effectiveness.

(d) If an acceptable alternative to ocean dumping or additional control technology is required, a schedule and documentation for implementation of the alternative or approved control process shall be submitted and shall include, without limitation:

(1) Engineering plan;
(2) Financing approval;
(3) Starting date for change;
(4) Completiodate;
(5) Operation starting date.

(e) If an acceptable alternative does not exist at the time the application is submitted, the applicant will submit an acceptable in-house research program or employ a competent research institution to study the problem. The program of research must be approved by the Administrator or Regional Administrator, as the case may be, before the initiation of the research. The schedule and documentation for implementation of a research program will include, without limitation:

(1) Approaches;
(2) Experimental design;
(3) Starting date;
(4) Reporting intervals;
(5) Proposed completion date;
(6) Date for submission of final report.

§ 227.26 Implementation of plans.

Implementation of each phase of a plan shall be initiated as soon as it is approved by the Administrator or Regional Administrator, as the case may be.

Subpart G—Definitions

§ 227.27 Limiting permissible concentration (LPC).

(a) The limiting permissible concentration of the liquid phase of a material is:

(1) That concentration of a constituent which, after allowance for initial mixing as provided in § 227.29, does not exceed applicable marine water quality criteria; or, when there are no applicable marine water quality criteria,

(2) That concentration of waste or dredged material in the receiving

water which, after allowance for initial mixing, as specified in § 227.29, will not exceed a toxicity threshold defined as 0.01 of a concentration shown to be acutely toxic to appropriate sensitive marine organisms in a bioassay carried out in accordance with approved EPA procedures.

(3) When there is reasonable scientific evidence on a specific waste material to justify the use of an application factor other than 0.01 as specified in paragraph (a)(2) of this section, such alternative application factor shall be used in calculating the LPC.

(b) The limiting permissible concentration of the suspended particulate and solid phases of a material means that concentration which will not cause unreasonable acute or chronic toxicity or other sublethal adverse effects based on bioassay results using appropriate sensitive marine organisms in the case of the suspended particulate phase, or appropriate sensitive benthic marine organisms in the case of the solid phase; and which will not cause accumulation of toxic materials in the human food chain. These bioassays are to be conducted in accordance with procedures approved by EPA, or, in the case of dredged material, approved by EPA and the Corps of Engineers.[1]

(c) "Appropriate sensitive marine organisms" means at least one species each representative of phytoplankton or zooplankton, crustacean or mollusk, and fish species chosen from among the most sensitive species documented in the scientific literature or accepted by EPA as being reliable test organisms to determine the anticipated impact of the wastes on the ecosystem at the disposal site. Bioassays, except on phytoplankton or zooplankton, shall be run for a minimum of 96 hours under temperature, salinity, and dissolved oxygen conditions representing the extremes of environmental stress at the disposal site. Bioassays on phytoplankton or zooplankton may be run for shorter periods of time as appropriate for the organisms tested at the discretion of EPA, or EPA and the Corps of Engineers, as the case may be.

(d) "Appropriate sensitive benthic marine organisms" means at least one species each representing filter-feeding, deposit-feeding, and burrowing species chosen from among the most sensitive species accepted by EPA as being reliable test organisms to determine the anticipated impact on the site; provided, however, that until sufficient species are adequately tested and documented, interim guidance on appropriate organisms available for use will be provided by the Administrator, Regional Administrator, or the District Engineer, as the case may be.

[42 FR 2476, Jan. 11, 1977; 43 FR 1071, Jan. 6, 1978]

§ 227.28 Release zone.

The release zone is the area swept out by the locus of points constantly 100 meters from the perimeter of the conveyance engaged in dumping activities, beginning at the first moment in which dumping is scheduled to occur and ending at the last moment in which dumping is scheduled to occur. No release zone shall exceed the total surface area of the dumpsite.

§ 227.29 Initial mixing.

(a) Initial mixing is defined to be that dispersion or diffusion of liquid, suspended particulate, and solid phases of a waste which occurs within four hours after dumping. The limiting permissible concentration shall not be exceeded beyond the boundaries of the disposal site during initial mixing, and shall not be exceeded at any point in the marine environment after initial mixing. The maximum concentration of the liquid, suspended particulate, and solid phases of a dumped material after initial mixing shall be estimated by one of these methods, in order of preference:

(1) When field data on the proposed dumping are adequate to predict ini-

[1] An implementation manual is being developed jointly by EPA and the Corps of Engineers, and announcement of the availability of the manual will be published in the FEDERAL REGISTER. Until this manual is available, interim guidance on the appropriate procedures can be obtained from the Marine Protection Branch, WH-548, Environmental Protection Agency, 401 M Street SW, Washington, DC 20460, or the Corps of Engineers, as the case may be.

tial dispersion and diffusion of the waste, these shall be used, if necessary, in conjunction with an appropriate mathematical model acceptable to EPA or the District Engineer, as appropriate.

(2) When field data on the dispersion and diffusion of a waste of characteristics similar to that proposed for discharge are available, these shall be used in conjunction with an appropriate mathematical model acceptable to EPA or the District Engineer, as appropriate.

(3) When no field data are available, theoretical oceanic turbulent diffusion relationships may be applied to known characteristics of the waste and the disposal site.

(b) When no other means of estimation are feasible.

(1) The liquid and suspended particulate phases of the dumped waste may be assumed to be evenly distributed after four hours over a column of water bounded on the surface by the release zone and extending to the ocean floor, thermocline, or halocline if one exists, or to a depth of 20 meters, whichever is shallower, and

(2) The solid phase of a dumped waste may be assumed to settle rapidly to the ocean bottom and to be distributed evenly over the ocean bottom in an area equal to that of the release zone as defined in § 227.28.

(c) When there is reasonable scientific evidence to demonstrate that other methods of estimating a reasonable allowance for initial mixing are appropriate for a specific material, such methods may be used with the concurrence of EPA after appropriate scientific review.

§ 227.30 High-level radioactive waste.

High-level radioactive waste means the aqueous waste resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated waste from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuels or irradiated fuel from nuclear power reactors.

§ 227.31 Applicable marine water quality criteria.

Applicable marine water quality criteria means the criteria given for marine waters in the EPA publication "Quality Criteria for Water" as published in 1976 and amended by subsequent supplements or additions.

§ 227.32 Liquid, suspended particulate, and solid phases of a material.

(a) For the purposes of these regulations, the liquid phase of a material, subject to the exclusions of paragraph (b) of this section, is the supernatant remaining after one hour undisturbed settling, after centrifugation and filtration through a 0.45 micron filter. The suspended particulate phase is the supernatant as obtained above prior to centrifugation and filtration. The solid phase includes all material settling to the bottom in one hour. Settling shall be conducted according to procedures approved by EPA.

(b) For dredged material, other material containing large proportions of insoluble matter, materials which may interact with ocean water to form insoluble matter or new toxic compounds, or materials which may release toxic compounds upon deposition, the Administrator, Regional Administrator, or the District Engineer, as the case may be, may require that the separation of liquid, suspended particulate, and solid phases of the material be performed upon a mixture of the waste with ocean water rather than on the material itself. In such cases the following procedures shall be used:

(1) For dredged material, the liquid phase is considered to be the centrifuged and 0.45 micron filtered supernatant remaining after one hour undisturbed settling of the mixture resulting from a vigorous 30-minute agitation of one part bottom sediment from the dredging site with four parts water (vol/vol) collected from the dredging site or from the disposal site, as appropriate for the type of dredging operation. The suspended particulate phase is the supernatant as obtained above prior to centrifugation and filtration. The solid phase is considered to be all material settling to

the bottom within one hour. Settling shall be conducted by procedures approved by EPA and the Corps of Engineers.

(2) For other materials, the proportion of ocean water used shall be the minimum amount necessary to produce the anticipated effect (e.g., complete neutralization of an acid or alkaline waste) based on guidance provided by EPA on particular cases, or in accordance with approved EPA procedures. For such materials the liquid phase is the filtered and centrifuged supernatant resulting from the mixture after 30 minutes of vigorous shaking followed by undisturbed settling for one hour. The suspended particulate phase is the supernatant as obtained above prior to centrifugation and filtration. The solid phase is the insoluble material settling to the bottom in that period.

PART 228—CRITERIA FOR THE MANAGEMENT OF DISPOSAL SITES FOR OCEAN DUMPING

Sec.

228.1 Applicability.
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228.5 General criteria for the selection of sites.
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228.7 Regulation of disposal site use.
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228.11 Modification in disposal site use.
228.12 Delegation of management authority for interim ocean dumping sites.
228.13 Guidelines for ocean disposal site baseline or trend assessment surveys under section 102 of the Act.

AUTHORITY: 33 U.S.C. 1412 and 1418.

SOURCE: 42 FR 2482, Jan. 11, 1977, unless otherwise noted.

§ 228.1 Applicability.

The criteria of this Part 228 are established pursuant to section 102 of the Act and apply to the evaluation of proposed ocean dumping under Title I of the Act. The criteria of this Part 228 deal with the evaluation of the proposed dumping of material in ocean waters in relation to continuing requirements for effective management of ocean disposal sites to prevent unreasonable degradation of the marine environment from all wastes being dumped in the ocean. This Part 228 is applicable to dredged material disposal sites only as specified in §§ 228.4(e), 228.9, and 228.12.

§ 228.2 Definitions.

(a) The term "disposal site" means an interim or finally approved and precise geographical area within which ocean dumping of wastes is permitted under conditions specified in permits issued under sections 102 and 103 of the Act. Such sites are identified by boundaries established by (1) coordinates of latitude and longitude for each corner, or by (2) coordinates of latitude and longitude for the center point and a radius in nautical miles from that point. Boundary coordinates shall be identified as precisely as is warranted by the accuracy with which the site can be located with existing navigational aids or by the implantation of transponders, buoys or other means of marking the site.

(b) The term "baseline" or "trend assessment" survey means the planned sampling or measurement of parameters at set stations or in set areas in and near disposal sites for a period of time sufficient to provide synoptic data for determining water quality, benthic, or biological conditions as a result of ocean disposal operations. The minimum requirements for such surveys are given in § 228.13.

(c) The term "disposal site evaluation study" means the collection, analysis, and interpretation of all pertinent information available concerning an existing disposal site, including but not limited to, data and information from trend assessment surveys, monitoring surveys, special purpose surveys of other Federal agencies, public data archives, and social and economic studies and records of affected areas.

(d) The term "disposal site designation study" means the collection, analysis and interpretation of all available pertinent data and information on a proposed disposal site prior to use, in-

cluding but not limited to, that from baseline surveys, special purpose surveys of other Federal agencies, public data archives, and social and economic studies and records of areas which would be affected by use of the proposed site.

(e) The term "management authority" means the EPA organizational entity assigned responsibility for implementing the management functions identified in § 228.3.

(f) "Statistical significance" shall mean the statistical significance determined by using appropriate standard techniques of multivariate analysis with results interpreted at the 95 percent confidence level and based on data relating species which are present in sufficient numbers at control areas to permit a valid statistical comparison with the areas being tested.

(g) "Valuable commercial and recreational species" shall mean those species for which catch statistics are compiled on a routine basis by the Federal or State agency responsible for compiling such statistics for the general geographical area impacted, or which are under current study by such Federal or State agencies for potential development for commercial or recreational use.

(h) "Normal ambient value" means that concentration of a chemical species reasonably anticipated to be present in the water column, sediments, or biota in the absence of disposal activities at the disposal site in question.

§ 228.3 Disposal site management responsibilities.

(a) Management of a site consists of regulating times, rates, and methods of disposal and quantities and types of materials disposed of; developing and maintaining effective ambient monitoring programs for the site; conducting disposal site evaluation and designation studies; and recommending modifications in site use and/or designation (e.g., termination of use of the site for general use or for disposal of specific wastes).

(b) Each site, upon interim or continuing use designation, will be assigned to either an EPA Regional office or to EPA Headquarters for management. These designations will be consistent with the delegation of authority in § 220.4. The designated management authority is fully responsible for all aspects of the management of sites within the general requirements specified in § 220.4 and this section. Specific requirements for meeting the management responsibilities assigned to the designated management authority for each site are outlined in §§ 228.5 and 228.6.

§ 228.4 Procedures for designation of sites.

(a) *General Permits.* Geographical areas or regions within which materials may be dumped under a general permit will be published as part of the promulgation of each general permit.

(b) *Special and Interim Permits.* Areas where ocean dumping is permitted subject to the specific conditions of individual special or interim permits, will be designated by promulgation in this Part 228, and such designation will be made based on environmental studies of each site, regions adjacent to the site, and on historical knowledge of the impact of waste disposal on areas similar to such sites in physical, chemical, and biological characteristics. All studies for the evaluation and potential selection of dumping sites will be conducted in accordance with the requirements of §§ 228.5 and 228.6.

The Administrator may, from time to time, designate specific locations for temporary use for disposal of small amounts of materials under a special permit only without disposal site designation studies when such materials satisfy the Criteria and the Administrator determines that the quantities to be disposed of at such sites will not result in significant impact on the environment. Such designations will be done by promulgation in this Part 228, and will be for a specified period of time and for specified quantities of materials.

(c) *Emergency Permits.* Dumping sites for materials disposed of under an emergency permit will be specified by the Administrator as a permit condition and will be based on an individual appraisal of the characteristics of

the waste and the safest means for its disposal.

(d) *Research Permits.* Dumping sites for research permits will be determined by the nature of the proposed study. Dumping sites will be specified by the Administrator as a permit condition.

(e) *Dredged Material Permits.*

(1) Areas where ocean dumping of dredged material is permitted subject to the specific conditions of Dredged Material permits issued by the U.S. Army Corps of Engineers will be designated by EPA promulgation in this Part 228, and such designation will be made based on environmental studies of each site, regions adjacent to the site, and on historical knowledge of the impact of dredged material disposal on areas similar to such sites in physical, chemical, and biological characteristics. All studies for the evaluation and potential selection of dredged material disposal sites will be conducted in accordance with the appropriate requirements of §§ 228.5 and 228.6, except that:

(i) Baseline or trend assessment requirements may be developed on a case-by-case basis from the results of research, including that now in progress by the Corps of Engineers.

(ii) An environmental impact assessment for all sites within a particular geographic area may be prepared based on complete disposal site designation or evaluation studies on a typical site or sites in that area. In such cases, sufficient studies to demonstrate the generic similarity of all sites within such a geographic area will be conducted.

(2) In those cases where a recommended disposal site has not been designated by the Administrator, or where it is not feasible to utilize a recommended disposal site that has been designated by the Administrator, the District Engineer shall, in consultation with EPA, select a site in accordance with the requirements of §§ 228.5 and 228.6(a). Concurrence by EPA in permits issued for the use of such site for the dumping of dredged material at the site will constitute EPA approval of the use of the site for dredged material disposal only.

(3) Sites designated for the ocean dumping of dredged material in accordance with the procedures of paragraph (e)(1) or (2) of this section shall be used only for the ocean dumping of dredged material under permits issued by the U.S. Army Corps of Engineers.

§ 228.5 General criteria for the selection of sites.

(a) The dumping of materials into the ocean will be permitted only at sites or in areas selected to minimize the interference of disposal activities with other activities in the marine environment, particularly avoiding areas of existing fisheries or shellfisheries, and regions of heavy commercial or recreational navigation.

(b) Locations and boundaries of disposal sites will be so chosen that temporary perturbations in water quality or other environmental conditions during initial mixing caused by disposal operations anywhere within the site can be expected to be reduced to normal ambient seawater levels or to undetectable contaminant concentrations or effects before reaching any beach, shoreline, marine sanctuary, or known geographically limited fishery or shellfishery.

(c) If at any time during or after disposal site evaluation studies, it is determined that existing disposal sites presently approved on an interim basis for ocean dumping do not meet the criteria for site selection set forth in §§ 228.5 through 228.6, the use of such sites will be terminated as soon as suitable alternate disposal sites can be designated.

(d) The sizes of ocean disposal sites will be limited in order to localize for identification and control any immediate adverse impacts and permit the implementation of effective monitoring and surveilance programs to prevent adverse long-range impacts. The size, configuration, and location of any disposal site will be determined as a part of the disposal site evaluation or designation study.

(e) EPA will, wherever feasible, designate ocean dumping sites beyond the edge of the continental shelf and other such sites that have been historically used.

§ 228.6 Specific criteria for site selection.

(a) In the selection of disposal sites, in addition to other necessary or appropriate factors determined by the Administrator, the following factors will be considered:

(1) Geographical position, depth of water, bottom topography and distance from coast;

(2) Location in relation to breeding, spawning, nursery, feeding, or passage areas of living resources in adult or juvenile phases;

(3) Location in relation to beaches and other amenity areas;

(4) Types and quantities of wastes proposed to be disposed of, and proposed methods of release, including methods of packing the waste, if any;

(5) Feasibility of surveillance and monitoring;

(6) Dispersal, horizontal transport and vertical mixing characteristics of the area, including prevailing current direction and velocity, if any;

(7) Existence and effects of current and previous discharges and dumping in the area (including cumulative effects);

(8) Interference with shipping, fishing, recreation, mineral extraction, desalination, fish and shellfish culture, areas of special scientific importance and other legitimate uses of the ocean;

(9) The existing water quality and ecology of the site as determined by available data or by trend assessment or baseline surveys;

(10) Potentiality for the development or recruitment of nuisance species in the disposal site;

(11) Existence at or in close proximity to the site of any significant natural or cultural features of historical importance.

(b) The results of a disposal site evaluation and/or designation study based on the criteria stated in paragraphs (b)(1) through (11) of this section will be presented in support of the site designation promulgation as an environmental assessment of the impact of the use of the site for disposal, and will be used in the preparation of an environmental impact statement for each site where such a statement is required by EPA policy. By publication of a notice in accordance with this Part 228, an environmental impact statement, in draft form, will be made available for public comment not later than the time of publication of the site designation as proposed rulemaking, and a final EIS will be made available at the time of final rulemaking.

§ 228.7 Regulation of disposal site use.

Where necessary, disposal site use will be regulated by setting limitations on times of dumping and rates of discharge, and establishing a disposal site monitoring program.

§ 228.8 Limitations on times and rates of disposal.

Limitations as to time for and rates of dumping may be stated as part of the promulgation of site designation. The times and the quantities of permitted material disposal will be regulated by the EPA management authority so that the limits for the site as specified in the site designation are not exceeded. This will be accomplished by the denial of permits for the disposal of some materials, by the imposition of appropriate conditions on other permits and, if necessary, the designation of new disposal sites under the procedures of § 228.4. In no case may the total volume of material disposed of at any site under special or interim permits cause the concentration of the total materials or any constituent of any of the materials being disposed of at the site to exceed limits specified in the site designation.

§ 228.9 Disposal site monitoring.

(a) The monitoring program, if deemed necessary by the Regional Administrator or the District Engineer, as appropriate, may include baseline or trend assessment surveys by EPA, NOAA, other Federal agencies, or contractors, special studies by permittees, and the analysis and interpretation of data from remote or automatic sampling and/or sensing devices. The primary purpose of the monitoring program is to evaluate the impact of disposal on the marine environment by referencing the monitoring results to a set of baseline conditions. When disposal sites are being used on a continu-

ing basis, such programs may consist of the following components:

(1) Trend assessment surveys conducted at intervals frequent enough to assess the extent and trends of environmental impact. Until survey data or other information are adequate to show that changes in frequency or scope are necessary or desirable, trend assessment and baseline surveys should generally conform to the applicable requirements of § 228.13. These surveys shall be the responsibility of the Federal government.

(2) Special studies conducted by the permittee to identify immediate and short-term impacts of disposal operations.

(b) These surveys may be supplemented, where feasible and useful, by data collected from the use of automatic sampling buoys, satellites or in situ platforms, and from experimental programs.

(c) EPA will require the full participation of permittees, and encourage the full participation of other Federal and State and local agencies in the development and implementation of disposal site monitoring programs. The monitoring and research programs presently supported by permittees may be incorporated into the overall monitoring program insofar as feasible.

§ 228.10 Evaluating disposal impact.

(a) Impact of the disposal at each site designated under section 102 of the Act will be evaluated periodically and a report will be submitted as appropriate as part of the Annual Report to Congress. Such reports will be prepared by or under the direction of the EPA management authority for a specific site and will be based on an evaluation of all data available from baseline and trend assessment surveys, monitoring surveys, and other data pertinent to conditions at and near a site.

(b) The following types of effects, in addition to other necessary or appropriate considerations, will be considered in determining to what extent the marine environment has been impacted by materials disposed of at an ocean disposal site:

(1) Movement of materials into estuaries or marine sanctuaries, or onto oceanfront beaches, or shorelines;

(2) Movement of materials toward productive fishery or shellfishery areas;

(3) Absence from the disposal site of pollution-sensitive biota characteristic of the general area;

(4) Progressive, non-seasonal, changes in water quality or sediment composition at the disposal site, when these changes are attributable to materials disposed of at the site;

(5) Progressive, non-seasonal, changes in composition or numbers of pelagic, demersal, or benthic biota at or near the disposal site, when these changes can be attributed to the effects of materials disposed of at the site;

(6) Accumulation of material constituents (including without limitation, human pathogens) in marine biota at or near the site.

(c) The determination of the overall severity of disposal at the site on the marine environment, including without limitation, the disposal site and adjacent areas, will be based on the evaluation of the entire body of pertinent data using appropriate methods of data analysis for the quantity and type of data available. Impacts will be categorized according to the overall condition of the environment of the disposal site and adjacent areas based on the determination by the EPA management authority assessing the nature and extent of the effects identified in paragraph (b) of this section in addition to other necessary or appropriate considerations. The following categories shall be used:

(1) *Impact Category I*: The effects of activities at the disposal site shall be categorized in Impact Category I when one or more of the following conditions is present and can reasonably be attributed to ocean dumping activities;

(i) There is identifiable progressive movement or accumulation, in detectable concentrations above normal ambient values, of any waste or waste constituent from the disposal site within 12 nautical miles of any shoreline, marine sanctuary designated under Title III of the Act, or critical area

designated under section 102(c) of the Act; or

(ii) The biota, sediments, or water column of the disposal site, or of any area outside the disposal site where any waste or waste constituent from the disposal site is present in detectable concentrations above normal ambient values, are adversely affected by the toxicity of such waste or waste constituent to the extent that there are statistically significant decreases in the populations of valuable commercial or recreational species, or of specific species of biota essential to the propagation of such species, within the disposal site and such other area as compared to populations of the same organisms in comparable locations outside such site and area; or

(iii) Solid waste material disposed of at the site has accumulated at the site or in areas adjacent to it, to such an extent that major uses of the site or of adjacent areas are significantly impaired and the Federal or State agency responsible for regulating such uses certifies that such significant impairment has occurred and states in its certificate the basis for its determination of such impairment; or

(iv) There are adverse effects on the taste or odor of valuable commercial or recreational species as a result of disposal activities; or

(v) When any toxic waste, toxic waste constituent, or toxic byproduct of waste interaction, is consistently identified in toxic concentrations above normal ambient values outside the disposal site more than 4 hours after disposal.

(2) *Impact Category II*: The effects of activities at the disposal site which are not categorized in Impact Category I shall be categorized in Impact Category II.

§ 228.11 Modification in disposal site use.

(a) Modifications in disposal site use which involve the withdrawal of designated disposal sites from use or permanent changes in the total specified quantities or types of wastes permitted to be discharged to a specific disposal site will be made through promulgation of an amendment to the disposal site designation set forth in this Part 228 and will be based on the results of the analyses of impact described in § 228.10 or upon changed circumstances concerning use of the site.

(b) Modifications in disposal site use promulgated pursuant to paragraph (a) of this section shall not automatically modify conditions of any outstanding permit issued pursuant to this Subchapter H, and provided further that unless the EPA management authority for such site modifies, revokes or suspends such permit or any of the terms or conditions of such permit in accordance with the provisions of § 232.2 based on the results of impact analyses as described in § 228.10 or upon changed circumstances concerning use of the site, such permit will remain in force until its expiration date.

(c) When the EPA management authority determines that activities at a disposal site have placed the site in Impact Category I, the Administrator or the Regional Administrator, as the case may be, shall place such limitations on the use of the site as are necessary to reduce the impacts to acceptable levels.

(d) The determination of the Administrator as to whether to terminate or limit use of a disposal site will be based on the impact of disposal at the site itself and on the Criteria.

[42 FR 2482, Jan. 11, 1977; 43 FR 1071, Jan. 6, 1978]

§ 228.12 Delegation of management authority for interim ocean dumping sites.

(a) The following sites are approved for dumping the indicated materials on an interim basis pending completion of baseline or trend assessment surveys and designation for continuing use or termination of use. Management authority for all sites is delegated to the EPA organizational entity under which each site is listed. The sizes and use specifications are based on historical usage and do not necessarily meet the criteria stated in this part.

(1) The following sites for disposal of dredged material under Corps of Engineers permits under section 103 of the Act will remain in force according to the following schedule:

(i) Until such time as formal rulemaking is completed or until December 31, 1988, whichever is sooner:

(A) [Reserved] (See editorial note three at end of section.)

(B) Georgetown, SC.

(C) Pascagoula, MS.

(D) Humboldt Bay, CA.

(E) Long Beach, CA.

(F) San Diego, CA (2 sites).

(G) New Jersey/Long Island Sites (8 sites): Absecon Inlet, NJ; Cold Spring Inlet, NJ; Manasquan Inlet, NJ; East Rockaway, NY; Jones Inlet, NY; Fire Island, NY; Shark River, NJ; and Rockaway Inlet, NY.

(H) [Reserved]

(ii) Until such time as formal rulemaking is completed or until July 31, 1988, whichever is sooner:

(A)-(O) [Reserved] (See editorial note three at end of section.)

(2) The interim designations of the following sites are terminated effective immediately:

(i) Both Region I industrial waste sites.

(ii) Region II wreck site.

(iii) Region III acid wastes site.

(iv) Region IV industrial wastes site.

(v) The Region VI industrial waste site located at 28d 00′ to 28d 10′ N, and 89d 15′ to 89d 30′ W.

(vi) Port Mansfield Channel Disposal Area 1-A.

(3) The interim designations of all other dredged material sites listed in § 228.12(a) and the Region II wood incineration site are extended indefinitely, pending completion of the present studies and determination of the need for continuing use of these sites, the completion of any necessary studies, and evaluation of their suitability. Designation studies for particular sites within this group will begin as soon as feasible after the completion of nearby sites presently being studied.

APPROVED INTERIM DUMPING SITES

Location (latitude, longitude)	EPA region	Primary use
43°33′00″ N., 69°55′00″ W., 1 nautical mile radius	I	Industrial wastes.
42°25′42″ N., 70°35′00″ W., 1 nautical mile radius	I	Do.
40°22′30″ N. to 40°25′00″ N., 73°41′30″ W. to 78°45′00″ W	II	Municipal sewage sludge.
40°16′00″ N. to 40°20′00″ N., 73°36′00″ W. to 73°40′00″ W	II	Acid wastes.
40°23′00″ N., 73°49′00″ W., 0.6 nautical mile radius	II	Cellar dirt.
40°10′00″ N., 73°42′00″ W., 0.5 nautical mile radius	II	Wrecks.
19°10′00″ N. to 19°20′00″ N., 66°35′00″ W. to 66°50′00″ W	II	Industrial wastes.
38°30′00″ N. to 38°35′00″ N., 74°15′00″ W. to 74°25′00″ W	III	Acid wastes.
38°20′00″ N. to 38°25′00″ N., 74°10′00″ W. to 74°20′00″ W	III	Municipal sewage sludge.
31°46′00″ N., 80°30′00″ W., 31°47′06″ N., 80°29′00″ W., 31°48′00″ N., 80°30′30″ W., 31°46′30″ N., 80°32′00″ W.	IV	Industrial wastes.
27°12′00″ N. to 27°28′00″ N., 94°28′00″ W. to 94°44′00″ W	VI	Do.
28°00′00″ N. to 28°10′00″ N., 89°15′00″ W. to 89°30′00″ W	VI	Do.
40°00′00″ N. to 40°04′20″ N., 73°41′00″ W. to 73°38′10″ W	II	Incineration of wood.

DREDGED MATERIAL SITES

(All dredged material sites will be retained under EPA Headquarters management until formally approved for continuing use or otherwise assigned for Regional management prior to such designation.)

LOCATION (LAT., LONG.)

Newburyport, MA—42°48′50″ N., 70°47′00″ W.; (½ N. Mi. square).

Marblehead, MA—42°25′42″ N., 70°34′00″ W. (2 N. Mi. diameter).

Boston, MA—41°49′00″ N., 70°25′00″ W. (1 N. Mi. diameter).

Cape Arundel, ME—43°17′45″ N., 70°27′12″ W. (500 yds. diameter).

Absecon Inlet—39°21′07″ N., 74°23′40″ W.; 39°21′18″ N., 74°23′53″ W.

Cold Spring Inlet—38°55′41″ N., 74°53′05″ W.; 38°55′33″ N., 74°53′23″ W.

Manasquan Inlet—40°06′22″ N., 74°01′46″ W.; 40°06′38″ N., 74°01′39″ W.

East Rockaway—40°34′36″ N., 73°49′00″ W.; 40°35′06″ N., 73°47′06″ W.; 40°34′10″ N., 73°48′36″ W.; 40°34′12″ N., 73°47′17″ W.

Jones Inlet—40°34′32″ N., 73°39′14″ W.; 40°34′32″ N., 73°37′06″ W.; 40°33′48″ N., 73°37′06″ W.; 40°33′48″ N., 73°39′14″ W.

Fire Island—40°36′49″ N., 73°23′50″ W.; 40°37′12″ N., 73°21′30″ W.; 40°36′41″ N., 73°21′20″ W.; 40°36′10″ N., 73°23′40″ W.

Mud Dump—40°23'48" N., 73°51'28" W.; 40°21'48" N., 73°50'00" W.; 40°21'48" N., 73°51'28" W.; 40°23'48" N., 73°50'00" W.

Shark River—40°12'48" N., 73°59'45" W.; 40°12'44" N., 73°59'06" W.; 40°11'36" N., 73°59'28" W.; 40°11'42" N., 74°00'12" W.

Rockaway Inlet—40°32'30" N., 73°55'00" W.; 40°32'30" N., 73°54'00" W., 40°32'00" N., 73°54'00" W.; 40°32'00" N., 73°55'00" W.

Mayaguez Harbor, PR—18°15'30" N., 67°14'31" W.; 18°15'30" N., 67°13'29" W.; 18°14'30" N., 67°13'29" W.; 18°14'30" N., 67°14'31" W.

Arecibo Harbor, PR—18°30'00" N., 66°42'45" W.; 18°30'00" N., 66°43'47" W.; 18°31'00" N., 66°43'47" W.; 18°31'00" N., 66°42'45" W.

Ponce Harbor, PR—17°55'30" N., 66°38'29" W.; 17°55'30" N., 66°39'31" W.; 17°54'30" N., 66°38'29" W.; 17°54'30" N., 66°39'31" W.

Yabucoa Harbor, PR—18°00'54" N., 65°44'23"W.; 18°01'33" N., 65°45'58" W.; 18°03'12" N., 65°45'42" W.; 18°02'30" N., 65°43'43" W.

Georgetown Harbor—33°11'18" N., 79°07'20" W.; 33°11'18" N., 79°05'23" W.; 33°10'38"N., 79°07'21" W.; 33°10'38" N., 79°07'21" W.

Port Royal Harbor—32°10'11" N., 80°36'00" W.; 32°10'06" N., 80°36'35" W.; 32°08'38" N., 80°36'23" W.; 32°08'41" N., 80°35'49" W.

Port Royal Harbor—32°05'46" N., 80°35'30" W.; 32°05'42" N., 80°36'27" W.; 32°04'22" N., 80°36'16" W.; 32°04'27" N., 80°35'18" W.

Brunswick Harbor—Atlantic outlet, Ga., St. Simons Sound, Brunswick Harbor Bar Channel, maintenance dredging disposal area 1 nautical mile wide by 2 nautical miles long adjacent to the channel located on the south side of the entrance and being 6.6 nautical miles from shore at a point of beginning at 31°02'35" N. and 81°17'40" W., thence due east to 31°02'35" N. and 81°16'30" W., thence due south to 31°00'30" N. and 81°16'30" W., thence due west to 31°00'30" N. and 81°17'40" W., thence due north to the point of beginning.

Canaveral Harbor—28°19'53" N., 80°31'08" W.; 28°18'50" N., 80°29'40" W.; 28°17'35" N., 80°30'52" W.; 28°18'38" N., 80°32'20" W.

Fort Pierce Harbor—27°28'30" N., 80°12'33" W.; 27°28'30" N., 80°11'27" W.; 27°27'30" N., 80°11'27" W.; 27°27'30" N., 80°12'33" W.

Jacksonville Harbor—30°21'30" N., 81°18'34" W.; 30°21'30" N., 81°17'26" W.; 30°20'30" N., 81°17'26" W.; 30°20'30" N., 81°18'34" W.

Miami Beach—25°45'30" N., 80°03'54" W.; 25°45'30" N., 80°02'50" W.; 25°44'30" N., 80°02'50" W.; 25°44'30" N., 80°03'54" W.

Palm Beach Harbor—26°46'10" N., 80°02'00" W.; 26°45'54" N., 80°02'06" W.; 26°45'54" N., 80°02'13" W.; 26°46'10" N., 80°02'07" W.

Port Everglades Harbor—26°07'00" N., 80°04'30" W.; 26°07'00" N., 80°03'30" W.; 26°06'00" N., 80°03'30" W.; 26°06'00" N., 80°04'30" W.

Charlotte Harbor—26°37'36" N., 82°19'55" W.; 26°37'36" N., 82°18'47" W.; 26°36'36" N., 82°18'47" W.; 26°36'36" N., 82°19'55" W.

Tampa Harbor—27°38'08" N., 82°55'06" W.; 27°38'08" N., 82°54'00" W.; 27°37'08" N., 82°54'00" W.; 27°37'08" N., 82°55'06" W.

Tampa Harbor—27°37'28" N., 83°00'09" W.; 27°37'34" N., 82°59'19" W.; 27°36'43" N., 82°59'13" W.; 27°36'37" N., 83°00'03" W.

Palm Beach Harbor—26°46'00" N., 79°58'55" W.; 26°46'00" N., 79°57'47" W.; 26°45'00" N., 79°57'47" W.; 26°45'00" N., 79°58'55" W.

Key West—24°27'24" N., 81°45'38" W.; 24°27'24" N., 81°44'32" W.; 24°26'20" N., 81°44'32" W.; 24°26'20" N., 81°45'38" W.

Pascagoula, MS—30°11.9' N., 88°33.1' W.; 30°11.9' N., 88°32.3' W.; 30°11.6' N., 88°32.4' W.; 30°11.6' N., 88°32.1' W.; 30°10.5' N., 88°33.2' W.; 30°10.6' N., 88°34.0' W.

Panama City, FL—30°07.1' N., 85°45.9' W.; 30°07.2' N., 85°45.5' W.; 30°06.9' N., 85°45.1' W.; 30°06.7' N., 85°45.6' W.

Port St. Joe, FL—29°50.9' N., 85°29.9' W.; 29°51.3' N., 85°29.5' W.; 29°49.2' N., 85°28.2' W.; 29°49.0' N., 85°28.8' W.

Port St. Joe, FL—29°53.9' N., 85°31.8' W.; 29°54.1' N., 85° 31.3' W.; 29°52.2' N., 85°30.1' W.; 29°52.2' N., 85°30.8' W.

Galveston Harbor and Channel, Texas

Disposal Area No. 1—Beginning at lat. 29°18'00", long. 94°39'30"; thence to lat. 29°15'54", long. 94°37'06"; thence to lat. 29°14'24", long. 94°38'42"; thence to lat. 29°16'54", long. 94°41'30"; thence to point of beginning.

Freeport Harbor, Texas

Disposal Area No. 1—Beginning at lat. 28°54'42", long. 95°17'38"; thence to lat. 28°54'-3"; long. 95°16'54"; thence to lat. 28°53'48", long. 95°17'27"; thence to lat. 28°54'21", long. 95°18'03"; thence to point of beginning.

Matagorda Ship Channel

Disposal Area No. 1—Beginning at lat. 28°24'31", long. 96°18'48"; thence to lat. 28°23'27", long. 96°17'38"; thence to lat. 28°23'15", long. 96°17'54"; thence to lat. 28°24'18", long. 96°19'03"; thence to point of beginning.

Corpus Christi Ship Channel

Disposal Area No. 1—Beginning at lat. 27°49'34", long. 97°01'51"; thence to lat. 27°48'28", long. 96°59'49"; thence to lat. 27°48'18", long 96°59'56"; thence to lat. 27°49'23", long. 97°01'58"; thence to point of beginning.

Port Mansfield Channel

Disposal Area No. 1—Beginning at lat. 26°34'09", long. 97°15'52"; thence to lat. 26°34'09", long. 97°15'18"; thence to lat.

26°33'57", long. 97°15'18"; thence to lat. 26°33'57", long. 97°15'52"; thence to point of beginning.

Disposal Area No. 1-A—Beginning at lat. 26°34'17", long. 97°16'12"; thence to lat. 26°34'18", long. 97°15'55"; thence to lat. 26°33'59", long. 97°15'52"; thence to lat. 26°33'58", long. 97°16'11"; thence to point of beginning.

BRAZOS ISLAND HARBOR

Disposal Area No. 1—Beginning at lat. 26°04'38", long. 97°07'52"; thence to lat. 26°04'38", long. 97°07'42"; thence to lat. 26°04'05", long. 97°06'42"; thence to lat. 26°04'05", long. 97°07'52"; thence to point of beginning.

Mississippi River, Gulf Outlet, La.—Breton Sound and Bar Channel. Maintenance dredging disposal area 0.5 mile wide by 12.5 miles long, parallel to the channel and located on the south side. Beginning at 29°32'23" N. and 89°12'20" W., following channel centerline (azimuth 308°47') in Breton Sound to 29°29'15" N. and 89°07'06" W., following centerline (azimuth 300°36') of the gulf entrance channel to 29°25'06" N. and 88°59'54" W., thence to 29°24'45" N. and 89°00'09" W., thence to 29°28'53" N., and 89°08'08" W., thence to 29°31'41" N. and 89°12'09" W., thence to the point of beginning.

Mississippi River, Baton Rouge to the Gulf of Mexico, La.—South Pass. Maintenance dredging disposal area 0.5 mile square, parallel to the channel and located on the west side. Beginning at 28°58'33" N. and 89°07'00" W., following channel centerline (azimuth 295°41') of the gulf entrance channel to 28°58'24" N. and 89°06'30" W., thence to 28°57'54" N. and 89°06'42" W., thence to 28°58'06" N. and 89°07'18" W., thence to the point of beginning.

Mississippi River, Baton Rouge to the Gulf of Mexico, La.—Southwest Pass. Maintenance dredging disposal area 2 miles square, parallel to the channel and located on the west side. Beginning at 28°54'24" N. and 89°26'03" W., following channel centerline (azimuth 0°09') of the gulf entrance channel to 28°52'18" N. and 89°26'03" W., thence to 28°52'18" N. and 89°27'48" W., thence to 28°54'24"N. and 89°27'48"W., thence to the point of beginning.

Mississippi River Outlets, Venice, La.—Tiger Pass. Maintenance dredging disposal area 0.5 mile wide by 2.5 miles long, parallel and adjacent to the channel and located on the south side. Beginning at 29°08'24" W. and 89°25'35" N. following 270° azimuth to 29°08'24" W. and 89°28'05" N., thence to 29°07'54" W. and 89°28'05" N., thence to 29°07'54" W. and 89°25'35" N., thence to the point of beginning.

Waterway from Empire, La. to the Gulf of Mexico—Bar channel. Maintenance dredging disposal area 0.5 mile wide by 1 mile long, parallel to the channel and located on the west side. Beginning at 29°15'06" N. and 89°36'30" W., following channel centerline (azimuth 11°08') of the gulf entrance channel to 29°14'30" N. and 89°36'36" W., thence to 29°14'36" N. and 89°36'48" W., thence to 29°15'12" N. and 89°36'42" W., thence to the point of beginning.

Barataria Bay Waterway, La.—Bar channel. Maintenance dredging disposal area 0.5 miles wide by 2 miles long, parallel to the channel and located on the east side 1,500 feet distance from the channel. Beginning at 29°16'13" N. and 89°55'54" W., following azimuth 312°07' to 29°14'45" N. and 89°54'05" W., thence to 29°14'30.5" N. and 89°53'45" W., thence to 29°15'54" N. and 89°55'34", thence to the point of beginning.

Bayou Lafourche and Lafourche—Jump Waterway, La.—Bell Pass. Maintenance dredging disposal area 2,000 feet wide by 1.5 miles long, parallel to the channel and located on the west side. Beginning at 29°05'00" N. and 90°13'45" W., following Bell Pass centerline (azimuth 12°55') in the gulf entrance channel to 29°03'51" N. and 90°14'06" W., thence to 29°03'57" N. and 90°14'21" W., thence to 29°05'06" N. and 90°14'03" W., thence to the point of beginning.

Houma Navigation Canal, La.—Cat Island Pass. Maintenance dredging disposal area approximately 0.5 miles wide by 5 miles long parallel to the Cat Island Channel and located on the west side 1,000 feet from the channel centerline. Beginning at 29°05'30" N. and 90°34'41" W., following azimuth 358°41' to 29°03'39.5" N. and 90°34'38.5" W., following azimuth 354° to 29°01'10" N. and 90°34'20" W., thence to 29°01'10" N. and 90°34'54" W., thence to 29°03'39.5" N. and 90°35'12" W., thence to 29°05'30" N. and 90°35'14" W., thence to the point of beginning.

Atchafalaya River—Morgan City to the Gulf of Mexico, La. and Atchafalaya River and Bayous Chene, Boeuf and Black, La.—Bar channel. Maintenance dredging disposal area 0.5 mile wide by 12 miles long, parallel to the bar channel and located on the east side. Beginning at 29°20'50" N. and 91°24'03" W., following channel centerline (azimuth 37°57') of the gulf entrance channel to 29°11'35" N. and 91°32'10" W., thence to 29°11'21" N. and 91°31'37" W., thence to 29°20'36" N. and 91°23'27" W., thence to the point of beginning.

Freshwater Bayou, La.—Bar channel. Maintenance dredging disposal area 2,000 feet wide by 3.5 miles long, parallel to the channel and located on the west side. Beginning at 29°32'00" N. and 92°18'48" W.,

following channel centerline (azimuth 09°25') of the gulf entrance to 29°28'24" N. and 92°19'30" W., thence to 29°28'25" N. and 92°19'42" W., thence to 29°32'01" N. and 92°19'00" W., thence to the point of beginning.

Mermentau River, La. Maintenance dredging disposal areas 0.5 mile wide and 1.5 miles long, parallel to the entrance channels in the Lower Mermentau River and in the Lower Mud Lake, both located on the west side:

Disposal Area "A", Mermentau River, La. Beginning at 29°44'48" N. and 93°07'12" W., following channel centerline (azimuth 256°59') of the gulf entrance to 29°43'39" N. and 93°07'36" W., thence to 29°43'42" N. and 93°07'48" W., thence to 29°44'51" N. and 93°07'24" W., thence to the point of beginning.

Disposal Area "B", Mermentau River, La. Beginning at 29°43'24" N. and 93°01'54" W., following channel centerline (azimuth 359°50') of the gulf centerline to 29°42'33" N. and 93°02'12" W., thence to 29°42'36" N. and 93°02'24" W., thence to 29°43'36" N. and 93°02'06" W., thence to the point of beginning.

Crescent City Harbor—41°43'15" N., 124°12'10" W., (1,000 yd. diameter)

Humboldt Bay Harbor—40°45'44" N., 124°15'42" W. (500 yd. diameter)

Noyo River—39°25'45" N., 123°49'42" W. (500 yd. diameter)

Farallon Islands—37°31'45" N., 122°59'00" W. (1,000 yd. radius)

San Francisco Channel Bar—37°45'06" N., 122°35'45" W. (5,000 yds. x 1,000 yds.)

Moss Landing 100 fathom—36°47'53" N., 121°49'04" W. (500 yd. radius)

Moss Landing—36°48'05" N., 121°47'22" W. (50 yds. seaward of pier)

Port Hueneme—34°05'00" N., 119°14'00" W. (1,000 yd. radius)

Los Angeles—33°37'06" N., 118°17'24" W. (1,000 yd. radius)

Newport Beach—33°31'42" N., 117°54'48" W. (1,000 yd. radius)

San Diego—Point Loma—32°35'00" N., 117°17'30" W., (1,000 yd. radius)

San Diego 100 fathom—32°36'50" N., 117°20'40" W. (1,000 yd. radius)

Honolulu Harbor—21°14'30" N., 157°54'30" W. (1,000 yd. radius)

Kauai—Nawiliwili—21°55'30" N., 159°17'00" W. (1,000 yd. radius)

Kauai—Hanapepe—21°50'18" N., 159°35'30" W. (1,000 yd. radius)

Guam—Apra Harbor—13°29'30" N., 144°34'30" E. (1,000 yd. radius)

Mouth of Columbia River—46°14'37" N., 124°10'34" W.; 46°13'53" N., 124°10'01" W.; 46°13'43" N., 124°10'26" W.; 46°14'28" N., 124°10'59" W.

Mouth of Columbia River—46°13'03" N., 124°06'17" W.; 46°12'50" N., 124°05'55" W.; 46°12'13" N., 124°06'43" W.; 46°12'26" N., 124°07'05"W.

Mouth of Columbia River—46°15'43" N., 124°05'21" W.; 46°15'36" N., 124°05'11" W.; 46°15'11" N., 124°05'53" W.; 46°15'18" N., 124°06'03" W.

Mouth of Columbia River—46°12'12" N., 124°09'00" W.; 46°12'00" N., 124°08'42" W.; 46°11'48" N., 124°09'00" W.; 46°12'00" N., 124°09'18" W.

Mouth of Columbia River—46°12'05" N., 124°05'46" W.; 46°11'52" N., 124°05'25" W.; 46°11'15" N., 124°06'14" W.; 46°11'28" N., 124°06'35" W.

Chetco River Entrance—42°01'56" N., 124°16'33" W.; 42°01'56" N., 124°16'09" W.; 42°01'38" N., 124°16'09" W.; 42°01'38" N., 124°16'33" W.

Rogue River Entrance—42°24'16" N., 124°26'48" W.; 42°24'04" N., 124°26'35" W.; 42°23'40" N., 124°27'13" W.; 42°23'52" N., 124°27'26" W.

Coquille River Entrance—43°07'54" N., 124°27'04" W.; 43°07'30" N., 124°26'27" W.; 43°07'20" N., 124°26'40" W.; 43°07'44" N., 124°27'17" W.

Coos Bay Entrance—43°21'59" N., 124°22'45" W.; 43°21'48" N., 124°21'59" W.; 43°21'35" N., 124°22'05" W.; 43°21'46" N., 124°22'51"W.

Coos Bay Entrance—43°22'44" N., 124°22'18" W.; 43°22'29" N., 124°21'34" W.; 43°22'16" N., 124°21'42" W.; 43°22'31" N., 124°22'26" W.

Umpqua River Entrance—43°40'07" N., 124°14'18" W.; 43°40'07" N., 124°13'42" W.; 43°39'53" N., 124°13'42" W.; 43°39'53" N., 124°14'18"W.

Suislaw River Entrance—44°01'32" N., 124°09'37" W.; 44°01'22" N., 124°09'02" W.; 44°01'14" N., 124°09'07" W.; 44°01'24" N., 124°09'42" W.

Tillamook Bay Entrance—45°34'09" N., 123°59'37" W.; 45°34'09" N., 123°58'45" W.; 45°33'55" N., 123°58'45" W.; 45°33'55" N., 123°59'37" W.

Depoe Bay—44°48'33" N., 124°03'53" W.; 44°48'32" N., 124°03'43" W.; 44°48'15" N., 124°03'45" W.; 44°48'16" N., 124°03'55" W.

Depoe Bay—44°48'09" N., 124°05'05" W.; 44°48'09"N., 124°04'55" W.; 44°47'53" N., 124°04'55" W.; 44°47'53" N., 124°05'05" W.

Yaquina Bay and Harbor Entrance—44°36'31" N., 124°06'04" W.; 44°36'31" N., 124°05'16" W.; 44°36'17" N., 124°05'16" W.; 44°36'17" N., 124°06'04" W.

Port Orford—42°44'08" N., 124°29'38" W.; 42°44'08" N., 124°29'28" W.; 42°43'52" N., 124°29'28" W.; 42°43'52"N., 124°29'38" W.

Willapa Bay—46°44'00" N., 124°10'00" W.; 46°39'00" N., 124°09'00" W.

Nome—West Site—64°30'04" N.

Nome—East Site—64°29'54" N., 165°24'41" W., 64°29'45" N., 165°23'27" W., 64°28'57" N., 165°23'29" W., 64°29'07" N., 165°24'25" W.

Anchorage Harbor—61°14'07" N., 149°53'56" W.; 61°14'16" N., 149°54'15" W.; 61°14'45" N., 149°53'36" W.; 61°14'36" N., 149°53'17" W.

Fish Cannery Wastes Site—Region IX.
Location:
Latitude—14d22'S;
Longitude—170d41'W (center point).
Size: 1 nautical mile in diameter.
Depth: 1,200 meters (4,000 feet).
Primary Use: Fish cannery wastes.
Period of Use: Site will expire (36 months after date of publication).
Restriction: Disposal shall be limtied to not more than 130,000 tons per year of fish cannery wastes generated on the island of Tutuila, American Samoa.

(b) The following sites are designated "Approved Ocean Dumping Sites" for continuing use, subject to the listed restrictions:

(1) Gulf Ocean Incineration Site—Headquarters.
Location—Latitude and Longitude—
26°20'00" N. to 27°00'00" N.;
93°20'00" to 94°00'00" W.
Size—(square miles) 1892.
Depth—(feet) 4500.
Primary Use: At sea incineration primarily for organochlorine wastes. Incineration of other wastes will require research studies or equivalent technical documentation to determine acceptability for ocean incineration.
Period of use: Continuing use.
Restriction: Only one ship will be permitted to burn wastes at a time, except under extreme emergencies.
(2) Herbicide Orange Incineration Site—Headquarters.
Location—Latitude and Longitude—
15°45' to 17°45' north latitude;
171°30' to 173°30' west longitude.
Size—14,400 sq. n. mi.
Depth—greater than 15,000 feet.
Use—solely for at sea incineration of Herbicide Orange by the United States Air Force aboard the *M/T Vulcanus*, owned and operated by Ocean Combustion Service.
Period of Use—May 15, 1977, to September 30, 1977. The designation of this site will be withdrawn after this period of use.
(3) Kwajalein Ocean dumping site—Region IX.
Location—Latitude and Longitude—
08° 47' north latitude,
167° 36' east longitude.
Size—1,000 yard radius.
Depth—1,655 fathoms (9,930 feet).
Primary use—waste materials resulting from the operation of the Kwajalein Missile Range.
Period of use—Three years after issuance of an ocean dumping permit for use of this site.
(4) Sewage Sludge Site—Region II.
Location:
Latitude—40°22'30"N to 40°25'00"N;
Longitude: 73°41'30"W to 73° 45' 00"W.
Size: 22.7 square kilometers (6.6 square nautical miles).
Depth: 27 meters (90 feet).
Primary Use: Sewage sludge.
Period of Use: Until December 31, 1981.
Restriction: Disposal shall be limited to sewage sludge generated by those permitees holding ocean dumping permits which were in force on January 1, 1979. Disposal of other wastes at this site is not permitted until adequate studies of the probable impacts of those wastes on the site have been completed.
(5) Alternate Sewage Sludge Site—Region II.
Location:
Latitude—40°10'30"N to 40°13'30"N;
Longitude: 72°40'30"W to 72°43'30"W.
Size: 31 square kilometers (9 square nautical miles).
Depth: 55 meters (180 feet).
Primary Use: Sewage sludge.
Period of Use: Until December 31, 1981.
Restriction: Disposal of sewage sludge at this site shall take place only upon a finding by EPA that the existing site cannot safely accommodate any more sewage sludge without endangering public health or degrading coastal water quality. Disposal of other wastes at this site is not permitted until adequate studies of the probable impacts of those wastes on the site have been completed.
(6) San Nicolas Basin Ocean Dumping Site—Region IX.
Location—Latitude and Longitude (northwest corner)—
32°55' north latitude,
119°17' west longitude.
Size—1 square nautical mile.
Depth—400 fathoms (2,400 feet).
Primary use—disposal of formation cuttings, waste drilling mud, and non-perishable solid waste.
Period of use—three years after issuance of an ocean dumping permit for use of this site.
(7) Acid Waste Site—Region II.
Location:
Latitude—40d 16' N. to 40d 20' N.
Longitude—73d 36' W. to 73d 40' W.
Size: 41 square kilometers.
Depth: Ranges from 22.6 meters to 28.3 meters.
Primary Use: Aqueous acid waste (note restriction below).
Period of Use: Continuing use.
Restriction: Aqueous acid wastes are those that are miscible with seawater and will

not form or include a significant solid phase.
(8) South Oahu Site—Region IX.
Location (center point):
Latitude—21°15'10" N.
Longitude—157°56'50" W.
Size: 2 kilometers wide and 2.6 kilometers long.
Depth: Ranges from 400 to 475 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material.
(9) Nawiliwili Site—Region IX.
Location (center point):
Latitude—21°55'00" N.
Longitude—159°17'00" W.
Size: Circular with a radius of approximately 920 meters.
Depth: Ranges from 840 to 1,120 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material.
(10) Port Allen Site—Region IX.
Location (center point):
Latitude—21°50'00" N.
Longitude—159°35'00" W.
Size: Circular with a radius of approximately 920 meters.
Depth: Ranges from 1,460 to 1,610 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material.
(11) Kahului Site—Region IX.
Location (center point):
Latitude—21°04'42" N.
Longitude—156°29'00" W.
Size: Circular with a radius of approximately 920 meters.
Depth: Ranges from 345 to 365 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material.
(12) Hilo Site—Region IX.
Location (center point):
Latitude—19°48'30" N.
Longitude—154°58'30" W.
Size: Circular with a radius of approximately 920 meters.
Depth: Ranges from 330 to 340 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material.
(13) Cellar Dirt Site—Region II.
Location (center point):
Latitude—40° 23' 00" N.
Longitude—73' 49' 00" W.
Size: 1.1 square nautical miles.
Depth: Ranges from 29 to 38 meters.
Primary Use: Cellar dirt.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to excavation dirt and rock, broken concrete, rubble, tile, and other nonfloatable debris.
(14) Tampa Harbor Site 4—Region IV.
Location:
27°32'27"N., 83°03'46"W.;
27°30'27"N., 83°03'46"W.;
27°30'27"N., 83°06'02"W;
27°32'27"N., 83°06'02"W.
Size: 4 nautical square miles.
Depth: Ranges from 21.8 to 24.1 meters.
Primary Use: Dredged material.
Period of Use: Three years.
Restrictions: Disposal shall be limited to dredged material from the Tampa Harbor Project.
(15) New York Bight Dredged Material Disposal Site—Region II.
Location:
40°23'48" N., 73°51'28" W.;
40°21'48" N., 73°50'00" W.;
40°21'48" N., 73°51'28" W.;
40°23'48" N., 73°50'00" W.
Size: 2.2 square nautical miles.
Depth: Ranges from 16 to 29 meters.
Use Restricted to Disposal of: Dredged materials.
Period of Use: Continuing use, subject to volumetric restriction as noted below.
Restriction: Disposal shall be limited to 100 million cubic yards of dredged materials generated in the Port of New York and New Jersey and nearby harbors. Dumping within the area described by the following coordinates shall be limited to projects determined by the Corps and EPA to demonstrate a specific need, such as research or final capping. 40°23'48" N., 73°51'28" W.; 40°23'23" N., 73°51'28" W.; 40°23'23" N., 73°51'06" W.; 40°23'48" N., 73°51'06" W. Dumping in the southeast quadrant of the site shall not be authorized except as part of a research project on capping.
(16) Gulf of Mexico Platform jacket site—Region VI.
Location:
27d 39'44.665" N, 91d 10'03.059" W;
27d 39'42.304" N, 91d 07'06.927" W;
27d 37'05.471" N, 91d 07'09.610" W;
27d 37'07.828" N, 91d 10'05.672" W.
Size: 3 statute miles on the side (9 square statute miles total area).
Depth: 600 fathoms.
Primary Use: One-time disposal of damaged platform jacket. Period of Use: Until the one-time dump of the damaged jacket is concluded; however, the period of use shall not exceed three years from the date of publication of this Notice.
(17) Deepwater Industrial Wastes Dump Site—Region II.
Location (center point):
Latitude—38°45'00"N.
Longitude—72°20'00"W.
Size: Circular with a radius of 3.0 nautical miles—28.3 square nautical miles.

Depth: Ranges from 2,250 to 2,750 meters.
Use Restricted To: Aqueous industrial materials.
Period of Use: Continuing use.
Definition: Aqueous industrial materials are defined as those wastes generated by a manufacturing or processing plant (i) with solid concentrations sufficiently low so that waste material is dispersed within the upper water column; or (ii) neutrally buoyant or slightly denser than seawater, such that, upon mixing with seawater, the material does not float.

(18) Deepwater Municipal Sludge Dump Site—Region II.
Location:
Latitude—38°40'00" to 39°00'00"N;
Longitude—72°00'00" to 72°05'00"W.
Size: 100 square nautical miles.
Depth: Ranges from 2,250 to 2,750 meters.
Use Restricted To: Municipal sewage treatment sludge.
Period of Use: Five years after commencement of dumping of municipal sewage treatment sludge at the site.
Restriction: Municipal sludges generated at Publicly Owned or Operated Treatment Works (POTW's). Biologically treated industrial waste sludges are to be excluded.

(19) Jacksonville Dredged Material Site—Region IV.
Location:
30°21'30" N., 81°18'34" W.;
30°21'30" N., 81°17'26" W.;
30°20'30" N., 81°17'26" W.;
30°20'30" N., 81°18'34" W.
Size: One square nautical mile.
Depth: Ranges from 12 to 16 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Jacksonville, Florida, area.

(20) Galveston Dredged Material Site—Region VI.
Location:
29°18'00" N., 94°39'30" W.;
29°15'54" N., 94°37'06" W.;
29°14'24" N., 94°38'42" W.;
29°16'54" N., 94°41'30" W.
Size: 6.6. square nautical miles.
Depth: Ranges from 10 to 15.5 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Galveston, Texas, area.

(21) Drilling muds and cuttings site—Region IX.
Center point location: 33°34'30" N latitude, 118°27'30" W longitude.
Size: A circle with a diameter of 3.0 nautical miles.
Depth: Approximately 485 fathoms (2910 feet).
Primary Use: Drilling muds and cuttings.
Period of Use: 3 years from effective date of site designation.
Volumes: To be determined by EPA Regional Administrator, Region IX.
Restriction: Disposal shall be limited to water-based drilling muds and cuttings which meet the requirements of the Ocean Dumping Evaluation Criteria of 40 CFR Part 227. Permittee(s) must implement monitoring program acceptable to EPA Regional Administrator responsible for management of the site.

(22) San Francisco Channel Bar Dredged Material Site—Region IX.
Location:
37°44'55" N, 122°37'18" W;
37°45'45" N, 122°34'24" W;
37°44'24" N, 122°37'06" W;
37°45'15" N, 122°34'12" W.
Size: 4,572 x 914 meters.
Depth: Ranges from 11 to 14.3 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to material from required dredging operations at the entrance of the San Francisco main ship channel which is composed primarily of sand having grain sizes compatible with naturally occurring sediments at the disposal site and containing approximately 5 percent of particles having grain sizes finer than that normally attributed to very fine sand (.075 millimeters). Other dredged materials meeting the requirements of 40 CFR 227.13 but having smaller grain sizes may be dumped at this site only upon completion of an appropriate case-by-case evaluation of the impact of such material on the site which demonstrates that such impact will be acceptable.

(23) Mouth of Columbia River Dredged Material Site A—Region X.
Location:
46d 13' 03" N., 124d 06' 17" W.;
46d 12' 50" N., 124d 05' 55" W.;
46d 12' 13" N., 124d 06' 43" W.;
46d 12' 26" N, 124d 07' 05" W.
Size: 0.27 square nautical miles.
Depth: Ranges from 14–25 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Columbia River entrance channel and adjacent areas.

(24) Mouth of Columbia River Dredged Material Site B—Region X.
Location:
46d 14' 37" N., 124d 10' 34" W.;
46d 13' 53" N., 124d 10' 01" W.;
46d 13' 43" N., 124d 10' 26" W.;
46d 14' 28" N., 124d 10' 59" W.
Size: 0.25 square nautical miles.
Depth: Ranges from 24–39 meters.
Primary Use: Dredged material.

Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Columbia River entrance channel and adjacent areas.

(25) Mouth of Columbia River Dredged Material Site E—Region X.
Location:
46d 15' 43" N., 124d 05' 21" W.;
46d 15' 36" N., 124d 05' 11" W.;
46d 15' 11" N., 124d 05' 53" W.;
46d 15' 18" N., 124d 06' 03" W.
Size: 0.08 square nautical miles.
Depth: Ranges from 16-21 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Columbia River entrance channel and adjacent areas.

(26) Mouth of Columbia River Dredged Material Site F—Region X.
Location:
46d 12' 12" N., 124d 09' 00" W.;
46d 12' 00" N., 124d 08' 42" W.;
46d 11' 48" N., 124d 09' 00" W.;
46d 12' 00" N., 124d 09' 18" W.
Size: 0.08 square nautical miles.
Depth: Ranges from 38-42 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Columbia River entrance channel and adjacent areas.

(27) Coos Bay Dredged Material Site E—Region X.
Location:
43d 21' 59" N., 124d 22' 45" W.;
43d 21' 48" N., 124d 21' 59" W.;
43d 21' 35" N., 124d 22' 05" W.;
43d 21' 46" N, 124d 22' 51" W.
Size: 0.13 square nautical mile.
Depth: Averages 17 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material in the Coos Bay area of type 1, as defined in the site designation final EIS.

(28) Coos Bay Dredged Material Site F—Region X.
Location:
43d 22' 44" N., 124d 22' 18" W.;
43d 22' 29" N., 124d 21' 34" W.;
43d 22' 16" N., 124d 21' 42" W.;
43d 22' 31" N., 124d 22' 26" W.
Size: 0.13 square nautical mile.
Depth: Averages 24 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material in the Coos Bay area of type 1, as defined in the site designation final EIS.

(29) Coos Bay Dredged Material Site H—Region X.
Location:
43d 23' 53" N., 124d 22' 48" W.;
43d 23' 42" N., 124d 23' 01" W.;
43d 24' 16" N., 124d 23' 26" W.;
43d 24' 05" N., 124d 23' 38" W.
Size: 0.13 square nautical mile.
Depth: Averages 55 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material in the Coos Bay area of type 2 and 3, as defined in the site designation final EIS.

(30) Fernandina Beach, Florida Dredged Material Disposal Site—Region IV.
Location:
30°33'00" N.; 81°16'52"W.
30°31'00" N.; 81°16'52" W.
30°31'00" N.; 81°19'08" W.
30°33'00" N.; 81°19'08" W.
Size: 4 square nautical miles
Depth: Average 16 meters
Primary use: Dredged Material
Period of Use: Continuing use
Restrictions: Disposal shall be limited to dredged material which meets the criteria given in the Ocean Dumping Regulations, Part 227.

(31) Morehead City, North Carolina, Dredged Material Disposal Site-Region IV.
Location:
34°38'30" N., 76°45'0" W.;
34°38'30" N., 76°41'42" W.;
34°38'09" N., 76°41'0" W;
34°36'0" N., 76°41'0" W., 34°36'0" N., 76°45'0" W.
Size: 8 square nautical miles.
Depth: Average 12.0 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Morehead City Harbor, North Carolina area. All material disposed must satisfy the requirements of the ocean dumping regulations.

(32) Savannah, GA, Dredged Material Disposal Site—Region IV.
Location:
31d, 55' 53"N., 80d 44' 20"W.;
31d 57' 55"N., 80d 46' 48"W.;
31d 57' 55"N., 80d 44' 20"W.;
31d 55' 53"N., 80d 46' 48"W.
Size: 4.26 square nautical miles.
Depth: Averages 11.4 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Savannah Harbor area.

(33) Charleston, SC, Dredged Material Disposal Site—Region IV.
Location:
32d 40' 27"N., 79d 47' 22"W.;
32d 39' 04"N., 79d 44' 25"W.;
32d 38' 07"N., 79d 45' 03"W.;

32d 39' 30"N., 79d 48' 00"W.
Size: 3 square nautical miles.
Depth: Averages 11 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Charleston Harbor area.

(34) Charleston, SC, Harbor Deepening Project Dredged Material Disposal Site—Region IV.
Location:
32d 38' 06"N., 79d 41' 57"W.;
32d 40' 42"N., 79d 47' 30"W.;
32d 39' 04"N., 79d 49' 21"W.;
32d 36' 28"N., 79d 43' 48"W.
Size: 11.8 square nautical miles.
Depth: Averages 11 meters.
Primary Use: Dredged material from the Charleston Harbor deepening project.
Period of Use: Not to exceed seven years from the initiation of the Charleston Harbor deepening project.
Restriction: Disposal shall be limited to dredged material from the Charleston Harbor deepening project.

(35) Wilmington, NC, Dredged Material Disposal Site—Region IV.
Location:
33d 49' 30"N., 78d 03' 06"W.;
33d 48' 18"N., 78d 01' 39"W.;
33d 47' 19"N., 78d 02' 48"W.;
33d 48' 30"N., 78d 04' 16"W.
Size: 2.3 square nautical miles.
Depth: Averages 13 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from Wilmington Harbor area.

(36)—(41) [Reserved]

(42) Sabine-Neches Dredged Material Site 1—Region VI.
Location:
29°28'03" N., 93°41'14" W.;
29°26'11" N., 93°41' 14" W.;
29°26'11" N., 93°44'11" W.
Size: 2.4 square nautical miles.
Depth: Ranges from 11-13 meters.
Primary Use: Dredged material.
Period of Use: Continuing Use.
Restriction: Disposal shall be limited to dredged material from the Sabine-Neches area.

(43) Sabine-Neches Dredged Material Site 2—Region VI.
Location:
29°30'41" N., 93°43'49" W.;
29°28'42" N., 93°41'33" W.;
29°28'42" N., 93°44'49" W.;
29°30'08" N., 93°46'27" W.
Size: 4.2 square nautical miles.
Depth: Ranges from 9-13 meters.
Primary Use: Dredged material.
Period of Use: Continuing Use.
Restriction: Disposal shall be limited to dredged material from the Sabine-Neches area.

(44) Sabine-Neches Dredged Material Site 3—Region VI.
Location:
29°34'24" N., 93°48'13" W.;
29°32'47" N., 93°46'16" W.;
29°32'06" N., 93°46'29" W.;
29°31'42" N., 93°48'16" W.;
29°32'59" N., 93°49'48" W.
Size: 4.7 square nautical miles.
Depth: 10 meters.
Primary Use: Dredged material.
Period of Use: Continuing Use.
Restriction: Disposal shall be limited to dredged material from the Sabine-Neches area.

(45) Sabine-Neches Dredged Material Site 4—Region VI.
Location:
29°38'09" N., 93°49'23" W.;
29°35'53" N., 93°48'18" W.;
29°35'06" N., 93°50'24" W.;
29°36'37" N., 93°51'09" W.;
29°37'00" N., 93°50'06" W.;
29°37'46" N., 93°50'26" W.
Size: 4.2 square nautical miles.
Depth: Ranges from 5-9 meters.
Primary Use: Dredged material.
Period of Use: Continuing Use.
Restriction: Disposal shall be limited to dredged material from the Sabine-Neches area.

(46) [Reserved]

(47) Portland, Maine, Dredged Material Disposal Site—Region 1
Location:
43°33'36" N, 70°02'42" W;
43°33'36" N, 70°01'18" W;
43°34'36" N, 70°02'42" W;
43°34'36" N, 70°01'18" W;
Size: 1 square nautical mile.
Depth: 50 meters.
Primary Use: Dredged material.
Period of Use: Continuing Use.
Restrictions: Disposal shall be limited to dredged material.

(48) Pensacola, Florida Dredged Material Disposal Site—Region IV.
Location:
30°17'24" N., 87°18'30" W.
30°17'00" N., 87°19'50" W.
30°15'36" N., 87°17'48" W.
30°15'15" N., 87°19'18" W.
Size: 2.48 nmi².
Depth: Average 11 m.
Primary use: Dredged Material.
Period of use: Continuing use.
Restrictions: Disposal shall be limited to dredged materials which are shown to be predominantly sand (defined by median grain size greater than 0.125 mm and a composition of less than 10% fines) and meet the Ocean Dumping Criteria.

(49) Mobile, Alabama Dredged Material Disposal Site—Region IV.
Location:
30°10'00" N., 88°07'42" W.
30°10'24" N., 88°05'12" W.
30°09'24" N., 88°04'42" W.
30°08'30" N., 88°05'12" W.
30°08'30" N., 88°08'12" W.
Size: 4.8 nmi².
Depth: Average 14 m.
Primary use: Dredged materials.
Period of use: Continuing use.
Restrictions: Disposal shall be limited to dredged materials which meet the Ocean Dumping Criteria.

(50) Gulfport, Mississippi Dredged Material Disposal Sites—Region IV.
Location: Eastern Site
30°11'10" N., 88°58'24" W.
30°11'12" N., 88°57'30" W.
30°07'36" N., 88°54'24" W.
30°07'24" N., 88°54'48" W.
Western Site
30°12'00" N., 89°00'30" W.
30°12'00" N., 88°59'30" W.
30°11'00" N., 89°00'00" W.
30°07'00" N., 88°56'30" W.
30°06'36" N., 88°57'00" W.
30°10'30" N., 89°00'36" W.
Size: Eastern—2.47 nmi². Western—5.2 nmi².
Depth: Eastern—9.1 m. Western—8.2 m.
Primary use: Both sites—Dredged material.
Period of use: Both sites—Continuing use.
Restrictions: Disposal shall be limited to dredged materials which meet the Ocean Dumping Criteria.

(51) Calcasieu Dredged Material Site 1—Region VI.
Location:
29d 45' 39" N, 93d 19' 36" W;
29d 42' 42" N, 93d 19' 06" W;
29d 42' 36" N, 93d 19" 48" W;
29d 44' 42" N, 93d 20' 12" W;
29d 44' 42" N, 93d 20' 24" W;
29d 45' 27" N, 93d 20' 33" W.
Size: 1.76 square nautical miles
Depth: Ranges from 2-8 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the vicinity of the Calcasieu River and Pass Project.

(52) Calcasieu Dredged Material Site 2—Region VI.
Location:
29d 44' 31" N, 93d 20' 43" W;
29d 39' 45" N, 93d 19' 56" W;
29d 39' 34" N, 93d 20' 46" W;
29d 44' 25" N, 93d 21' 33" W.
Size: 3.53 square nautical miles.
Depth: Ranges from 2-11 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the vicinity of the Calcasieu River and Pass Project.

(53) Calcasieu Dredged Material Site 3—Region VI.
Location:
29d 37' 50" N, 93d 19' 37" W;
29d 37' 25" N, 93d 19' 33" W;
29d 33' 55" N, 93d 16" 23" W;
29d 33' 49" N, 93d 16" 25" W;
29d 30' 59" N, 93d 13' 51" W;
29d 29' 10" N, 93d 13' 49" W;
29d 29' 05" N, 93d 14' 23" W;
29d 30' 49" N, 93d 14' 25" W;
29d 37' 26" N, 93d 20' 24" W;
29d 37' 44" N, 93d 20' 27" W.
Size: 5.88 square nautical miles.
Depth: Ranges from 11-14 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the vicinity of the Calcasieu River and Pass Project.

(54) San Juan Harbor, PR Dredged Material Site—Region II
Location:
18d 30'10" N°, 66d 09'31" W°;
18d 30'10" N°, 66d 08'29" W°;
18d 31'10" N°, 66d 08'29" W°;
18d 31'10" N°, 66d 09'31" W°.
Size: 0.98 square nautical miles.
Depth: Ranges from 200-400 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredge material from the Port of San Juan, Puerto Rico, and coastal areas within 20 miles of said port entrance.

(55) Dam Neck, Virginia, Dredged Material Disposal Site—Region III.
Location:
36°51'24.1" N., 75°54'41.4" W.;
36°51'24.1" N., 75°53'02.9" W.;
36°50'52.0" N., 75°52'49.0" W.;
36°46'27.4" N., 75°51'39.2" W.;
36°46'27.5" N., 75°54'19.0" W.;
36°50'05.0" N., 75°54'19.0" W.
Size: 8 square nautical miles.
Depth: Averages 11 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the mouth of the Chesapeake Bay.

[42 FR 2482, Jan. 11, 1977]

EDITORIAL NOTES: 1. For FEDERAL REGISTER citations affecting § 228.12, see the List of CFR Sections Affected in the Finding Aids section of this volume.

2. At 53 FR 6990, Mar. 4, 1988, § 228.12 was amended by adding paragraphs (b)(48), (b)(49) and (b)(50) and at 53 FR 8185, Mar. 14, 1988, paragraphs designated (b)(48), (b)(49) and (b)(50) were added again. The paragraphs added in the March 14, 1988 document appear above as newly added paragraphs (b)(51), (b)(52) and (b)(53). The

Enviromental Protection Agency will publish a correction document in the FEDERAL REGISTER at a later date.

3. The following interim dredged material sites became approved ocean dumping sites when EPA published final rules in the FEDERAL REGISTER. These sites, formerly found in paragraph (a), are now found in paragraph (b) of § 228.12:

Interim site	Paragraph
Morehead City, NC	(a)(1)(i)
Portland, ME	(a)(1)(ii), (a)(3)
San Juan, PR	(a)(1)(ii), (a)(3)
Charleston/Savannah/Wilmington	(a)(1)(ii), (a)(3)
Mouth of Columbia River, OR	(a)(1)(ii), (a)(3)
Gulfport, MS/Mobile, AL/Pensacola, FL	(a)(3)
Sabine Neches Waterway, TX	(a)(3)

At a later date, EPA will publish documents in the FEDERAL REGISTER corredtly removing these interim sites from paragraph (a).

§ 228.13 Guidelines for ocean disposal site baseline or trend assessment surveys under section 102 of the Act.

The purpose of a baseline or trend assessment survey is to determine the physical, chemical, geological, and biological structure of a proposed or existing disposal site at the time of the survey. A baseline or trend assessment survey is to be regarded as a comprehensive synoptic and representative picture of existing conditions; each such survey is to be planned as part of a continual monitoring program through which changes in conditions at a disposal site can be documented and assessed. Surveys will be planned in coordination with the ongoing programs of NOAA and other Federal, State, local, or private agencies with missions in the marine environment. The field survey data collection phase of a disposal site evaluation or designation study shall be planned and conducted to obtain a body of information both representative of the site at the time of study and obtained by techniques reproducible in precision and accuracy in future studies. A full plan of study which will provide a record of sampling, analytical, and data reduction procedures must be developed, documented and approved by the EPA management authority. Plans for all surveys which will produce information to be used in the preparation of environmental impact statements will be approved by the Administrator or his designee. This plan of study also shall be incorporated as an appendix into a technical report on the study, together with notations describing deviations from the plan required in actual operations. Relative emphasis on individual aspects of the environment at each site will depend on the type of wastes disposed of at the site and the manner in which such wastes are likely to affect the local environment, but no major feature of the disposal site may be neglected. The observations made and the data obtained are to be based on the information necessary to evaluate the site for ocean dumping. The parameters measured will be those indicative, either directly or indirectly, of the immediate and long-term impact of pollutants on the environment at the disposal site and adjacent land or water areas. An initial disposal site evaluation or designation study should provide an immediate baseline appraisal of a particular site, but it should also be regarded as the first of a series of studies to be continued as long as the site is used for waste disposal.

(a) *Timing.* Baseline or trend assessment surveys will be conducted with due regard for climatic and seasonal impact on stratification and other conditions in the upper layers of the water column. Where a choice of season is feasible, trend assessment surveys should be made during those months when pollutant accumulation within disposal sites is likely to be most severe, or when pollutant impact within disposal sites is likely to be most noticeable.

(1) Where disposal sites are near large riverine inflows to the ocean, surveys will be done with due regard for the seasonal variation in river flow. In some cases several surveys at various river flows may be necessary before a site can be approved.

(2) When initial surveys show that seasonal variation is not significant and surveys at greater than seasonable intervals are adequate for characterizing a site, resurveys shall be carried out in climatic conditions as similar to those of the original surveys as possible, particularly in depths less than 200 meters.

(b) *Duration.* The actual duration of a field survey will depend upon the size and depth of the site, weather conditions during the survey, and the types of data to be collected. For example, for a survey of an area of 100 square miles on the continental shelf, including an average dump site and the region contiguous to it, an on-site operation would be scheduled for completion within one week of weather suitable for on-site operations. More on-site operating time may be scheduled for larger or highly complex sites.

(c) *Numbers and locations of sampling stations.* The numbers and locations of sampling stations will depend in part on the local bathymetry with minimum numbers of stations per site fixed as specified in the following sections. Where the bottom is smooth or evenly sloping, stations for water column measurements and benthic sampling and collections, other than trawls, shall be spaced throughout the survey area in a manner planned to provide maximum coverage of both the disposal site and contiguous control areas, considering known water movement characteristics. Where there are major irregularities in the bottom topography, such as canyons or gullies, or in the nature of the bottom, sampling stations for sediments and benthic communities shall be spaced to provide representative sampling of the major different features.

Sampling shall be done within the dump site itself and in the contiguous area. Sufficient control stations outside a disposal site shall be occupied to characterize the control area environment at least as well as the disposal site itself. Where there are known persistent currents, sampling in contiguous areas shall include at least two stations downcurrent of the dump site, and at least two stations upcurrent of the site.

(d) *Measurements in the water column at and near the dump site*—(1) *Water quality parameters measured.* These shall include the major indicators of water quality, particularly those likely to be affected by the waste proposed to be dumped. Specifically included at all stations are measurements of temperature, dissolved oxygen, salinity, suspended solids, turbidity, total organic carbon, pH, inorganic nutrients, and chlorophyll *a*.

(i) At one station near the center of the disposal site, samples of the water column shall be taken for the analysis of the following parameters: Mercury, cadmium, copper, chromium, zinc, lead, arsenic, selenium, vanadium, beryllium, nickel, pesticides, petroleum hydrocarbons, and persistent organohalogens. These samples shall be preserved for subsequent analysis by or under the direct supervision of EPA laboratories in accordance with the approved plan of study.

(ii) These parameters are the basic requirements for all sites. For the evaluation of any specific disposal site additional measurements may be required, depending on the present or intended use of the site. Additional parameters may be selected based on the materials likely to be in wastes dumped at the site, and on parameters likely to be affected by constituents of such wastes. Analysis for other constituents characteristic of wastes discharged to a particular disposal site, or of the impact of such wastes on water quality, will be included in accordance with the approved plan of study.

(2) *Water quality sampling requirements.* The number of samples collected from the water column should be sufficient to identify representative changes throughout the water column such as to avoid short-term impact due to disposal activities. The following key locations should be considered in selecting water column depths for sampling:

(i) Surface, below interference from surface waves;

(ii) Middle of the surface layer;

(iii) Bottom of the surface layer;

(iv) Middle of the thermocline or halocline, or both if present;

(v) Near the top of the stable layer beneath a thermocline or halocline;

(vi) Near the middle of a stable layer;

(vii) As near the bottom as feasible;

(viii) Near the center of any zone showing pronounced biological activity or lack thereof.

In very shallow waters where only a few of these would be pertinent, as a

minimum, surface, mid-depth and bottom samples shall be taken, with samples at additional depths being added as indicated by local conditions. At disposal sites far enough away from the influence of major river inflows, ocean or coastal currents, or other features which might cause local perturbations in water chemistry, a minimum of 5 water chemistry stations should be occupied within the boundaries of a site. Additional stations should be added when the area to be covered in the survey is more than 20 square miles or when local perturbations in water chemistry may be expected because of the presence of one of the features mentioned above. In zones where such impacts are likely, stations shall be distributed so that at least 3 stations are occupied in the transition from one stable regime to another. Each water column chemistry station shall be replicated a minimum of 2 times during a survey except in waters over 200 meters deep.

(3) *Water column biota.* Sampling stations for the biota in the water column shall be as near as feasible to stations used for water quality; in addition at least two night-time stations in the disposal site and contiguous area are required. At each station vertical or oblique tows with appropriately-meshed nets shall be used to assess the microzooplankton, the nekton, and the macrozooplankton, Towing times and distances shall be sufficient to obtain representative samples of organisms near water quality stations. Organisms shall be sorted and identified to taxonomic levels necessary to identify dominant organisms, sensitive or indicator organisms, and organism diversity. Tissue samples of representative species shall be analyzed for pesticides, persistent organohalogens, and heavy metals. Discrete water samples shall also be used to quantitatively assess the phytoplankton at each station.

These requirements are the minimum necessary in all cases. Where there are discontinuities present, such as thermoclines, haloclines, convergences, or upwelling, additional tows shall be made in each water mass as appropriate.

(e) *Measurements of the benthic region*—(1) *Bottom sampling.* Samples of the bottom shall be taken for both sediment composition and structure, and to determine the nature and numbers of benthic biota.

(i) At each station sampling may consist of core samples, grab samples, dredge samples, trawls, and bottom photography or television, where available and feasible, depending on the nature of the bottom and the type of disposal site. Each type of sampling shall be replicated sufficiently to obtain a representative set of samples. The minimum numbers of replicates of successful samples at each continental shelf station for each type of device mentioned above are as follows:

Cores	3.
Grabs	5.
Dredge	3.
Trawl	20-min. tow.

Lesser numbers of replicates may be allowed in water deeper than 200 meters, at those sites where pollution impacts on the bottom are unlikely in the judgment of the EPA management authority.

(ii) Selection of bottom stations will be based to a large extent on the bottom topography and hydrography as determined by the bathymetric survey. On the continental shelf, where the bottom has no significant discontinuities, a bottom station density of at least three times the water column stations is recommended, depending on the type of site being evaluated. Where there are significant differences in bottom topography, additional stations shall be occupied near the discontinuity and on each side of it. Beyond the continental shelf, lesser densities may be used.

(2) *Bathymetric survey.* Sufficient tracklines shall be run to develop complete bottom coverage of bathymetry with reasonable assurance of accurate coverage of bottom topography, with trackline direction and spacing as close as available control allows. The site itself is to be developed at the greatest density possible, with data to be collected to a suitable distance about the site as is required to identify major changes in bathymetry which might

affect the site. Specifications for each bathymetric survey will vary, depending on control, bottom complexity, depths, equipment, and map scale required. In most cases, a bathymetric map at a scale of 1:25,000 to 1:10,000 will be required, with a minimum of 1-5 meter contour interval except in very flat areas. When the foregoing bathymetric detail is available from recent surveys of the disposal site, bathymetry during a baseline or trend assessment survey may be limited to sonar profiles of bathymetry on transects between sampling stations.

(3) *Nature of bottom.* The size distribution of sediments, mineral character and chemical quality of the bottom will be determined to a depth appropriate for the type of bottom. The following parameters will be measured at all stations: Particle size distribution, major mineral constituents, texture, settling rate, and organic carbon.

(i) At several stations near the center of the disposal site, samples of sediments shall be taken for the analysis of the following parameters: Mercury, cadmium, copper, chromium, zinc, lead, arsenic, selenium, vanadium, beryllium, nickel, pesticides, persistent organohalogens, and petroleum hydrocarbons. These samples shall be preserved for subsequent analysis by or under the direct supervision of EPA laboratories in accordance with the approved plan of study.

(ii) These parameters are the basic requirements for all sites. For the evaluation of any specific disposal site additional measurements may be required, depending on the present or intended use of the site. Additional parameters may be selected based on the materials likely to be in wastes dumped at the site, and on parameters likely to be affected by constituents of such wastes. Such additional parameters will be selected by the EPA management authority.

(4) *Benthic biota.* This shall consist of a quantitative and qualitative evaluation of benthic communities including macroinfauna and macroepifauna, meiobenthos, and microbenthos, and should include an appraisal, based on existing information, of the sensitivity of indigenous species to the waste proposed to be discharged. Organisms, shall be sorted, and identified to taxonomic levels necessary to identify dominant organisms, sensitive or indicator organisms, and organism diversity. Tissue samples of the following types of organisms shall be analyzed for persistent organohalogens, pesticides, and heavy metals:

(i) A predominant species of demersal fish;

(ii) The most abundant macroinfaunal species; and

(iii) A dominant epifaunal species, with particular preference for a species of economic importance.

(f) *Other measurements*—(1) *Hydrodynamic features.* The direction and speed of water movement shall be characterized at levels appropriate for the site and type of waste to be dumped. Where depths and climatic conditions are great enough for a thermocline or halocline to exist, the relationship of water movement to such a feature shall be characterized.

(i) *Current measurements.* When current meters are used as the primary source of hydrodynamic data, at least 4 current meter stations with at least 3 meters at depths appropriate for the observed or expected discontinuities in the water column should be operated for as long as possible during the survey. Where feasible, current meters should be deployed at the initiation of the survey and recovered after its completion. Stations should be at least a mile apart, and should be placed along the long axis of the dumping site. For dumping sites more than 10 miles along the long axis, one current meter station every 5 miles should be operated. Where there are discontinuities in surface layers, e.g., due to land runoff, stations should be operated in each water mass.

(ii) *Water mass movement.* Acceptable methods include: dye, drogues, surface drifters, side scan sonar, bottom drifters, and bottom photography or television. When such techniques are the primary source of hydrodynamic data, coverage should be such that all significant hydrodynamic features likely to affect waste movement are measured.

(2) *Sea state.* Observations of sea state and of standard meteorological

parameters shall be made at 8-hour intervals.

(3) *Surface phenomena.* Observations shall be made of oil slicks, floating materials, and other visible evidence of pollution; and, where possible, collections of floating materials shall be made.

(g) *Survey procedures and techniques.* Techniques and procedures used for sampling and analysis shall represent the state-of-the-art in oceanographic survey and analytical practice. Survey plans shall specify the methods to be used and will be subject to approval by EPA.

(h) *Quality assurance.* The EPA management authority may require that certain samples be submitted on a routine basis to EPA laboratories for analysis as well as being analyzed by the surveyor, and that EPA personnel participate in some field surveys.

APPENDIX B

NUMERICAL MODELS FOR INITIAL MIXING

B1.0 INTRODUCTION

This appendix presents guidance for the use of numerical models for evaluation of mixing as part of the Tier II and Tier III water column evaluations. The versions of the models in this appendix are a part of the Automated Dredging and Disposal Alternatives Management System (ADDAMS) (Schroeder 1988) and can be run on a personal computer (PC). ADDAMS is an interactive computer-based design and analysis system in the field of dredged material management. The general goal of the ADDAMS is to provide state-of-the-art computer-based tools that will increase the accuracy, reliability, and cost-effectiveness of dredged material management activities in a timely manner.

B1.1 MODEL APPLICATIONS

Any evaluation of potential water column effects has to consider the effects of initial mixing. Section 227.29 defines initial mixing as follows:

> Initial mixing is defined to be that dispersion or diffusion of liquid, suspended particulate, and solid phases of a waste which occurs within 4 hr after dumping. The limiting permissible concentration (LPC) shall not be exceeded beyond the boundaries of the disposal site during initial mixing, and shall not be exceeded at any point in the marine environment after initial mixing.

Versions of the models described in this appendix for use on IBM-compatible microcomputers are found on the floppy disk in the pocket inside the back cover of this manual. The disk contains models appropriate for instantaneous discharges, continuous discharges, and hopper dredge discharges. Each of the models described in this appendix has been designed to evaluate initial mixing for each of the following applications, as discussed in the remainder of Section B1.1:

a) determination of the need for additional water column testing under Tier II,

b) evaluation of dissolved contaminant concentrations by comparison with water quality criteria after allowance for initial mixing under Tier II, and

c) evaluation of concentrations of suspended plus dissolved constituents by comparison with bioassay results after allowance for initial mixing under Tier III.

B1.1.1 Determination of Need for Additional Water Column Testing

The evaluation of the potential for water column impacts in Tier II begins with a determination of the necessity of additional water column testing. This determination is based on a standardized calculation comparing contamination of the dredged material with water quality criteria, considering the effects of initial mixing. The models need only be run for the contaminant requiring the greatest dilution to meet its water quality criterion. The key parameter derived from the dispersion models is the maximum concentration of the contaminant in the water column outside the boundary of the disposal site. This concentration is compared with the applicable marine water quality criterion according to the guidance in Section 10.1.1.2 to determine if additional water column testing is necessary. This evaluation cannot be used to predict water column impacts, but only to determine the need for additional water column testing.

B1.1.2 Evaluation of Dissolved Contaminant Concentrations by Comparison with Water Quality Criteria

If additional water column testing is necessary, the potential for water column impacts may be evaluated under Tier II by comparison of predicted dissolved contaminant concentrations with water quality criteria, considering the effects of initial mixing. This approach is used if there are water quality criteria for all contaminants of concern and if synergistic effects are not suspected; if these conditions are not met, the procedure in Section B1.1.3 is used. The models need only be run for the contaminant requiring the greatest dilution to meet its water quality criterion. The key parameters derived from the models are the maximum dissolved concentration of the contaminant outside the boundary of the disposal site during the 4 hr initial mixing period, and the maximum concentration anywhere in the marine environment after the 4 hr initial mixing period. These concentrations are compared to the applicable marine

water quality criterion according to the guidance in Section 10.1.2.3 to determine if the discharge is acceptable.

B1.1.3 Evaluation of Concentrations of Suspended Plus Dissolved Constituents by Comparison with Bioassay Results

If additional water column testing is necessary, the potential for water column impacts may be evaluated under Tier III by comparison of predicted concentrations of the suspended plus dissolved constituents of the dredged material with bioassay results, considering the effects of initial mixing. For this case, the models calculate the dilution of the dredged material expressed as a percent of the initial concentration. The key parameters derived from the model are the maximum concentration of dredged material in the water column outside the boundary of the disposal site during the 4 hr initial mixing period, and the maximum concentration anywhere in the marine environment after the 4 hr initial mixing period. These concentrations are compared to 0.01 of the LC50 as determined by the bioassay tests according to the guidance in Section 10.2.1.6 to determine if the discharge is acceptable.

B1.2 MODEL DESCRIPTIONS AND LIMITATIONS

The models account for the physical processes determining the short-term fate of dredged material disposed at open water sites. The models provide estimates of water column concentrations of dissolved contaminants and suspended sediment, and the initial deposition of material on the bottom.

Two of the models were developed by Brandsma and Divoky (1976) under the Corps of Engineers (CE) Dredged Material Research Program to handle both instantaneous dumps and continuous discharges. The models were based on work by Koh and Chang (1973). A third model which utilized features of the two earlier models was constructed later to handle a semicontinuous disposal operation from a hopper dredge. These models are known as DIFID (DIsposal From an Instantaneous Dump), DIFCD (DIsposal From a Continuous Discharge), and DIFHD (DIsposal From a Hopper Dredge). Collectively, the models are known within ADDAMS as the Open Water Disposal (DUMP) Models.

For evaluation of initial mixing for ocean disposal, the models need only be run for the contaminant requiring the greatest dilution to meet its water quality criterion. A data analysis routine is contained in the models for calculating the required dilutions and determining which contaminant should be modeled.

In all three models the behavior of the material is assumed to be separated into three phases: convective descent, during which the dump cloud or discharge jet falls under the influence of gravity and the initial momentum of the discharge; dynamic collapse, occurring when the descending cloud or jet either impacts the bottom or arrives at a level of neutral buoyancy where descent is retarded and horizontal spreading dominates; and passive transport-dispersion, commencing when the material transport and spreading are determined more by ambient currents and turbulence than by the dynamics of the disposal operation.

These models simulate movement of the disposed material as it falls through the water column, spreads over the bottom and finally is transported and diffused by the ambient current. DIFID is designed to simulate the movement of material from an instantaneous dump which falls as a hemispherical cloud. Thus, the total time required for the material to leave the disposal vessel should not be greater than the time required for the material to reach the bottom. DIFCD is designed to compute the movement of material disposed in a continuous fashion at a constant discharge rate. Thus, it can be applied to pipeline disposal operations in which the discharge jet is below the water surface or perhaps to the discharge of material from a single bin of a hopper dredge. If the initial direction of disposal is vertical, either the disposal source has to be moving or the ambient current has to be strong enough to result in a bending of the jet before the bottom is encountered. DIFHD has been constructed to simulate the fate of materials disposed from stationary hopper dredges. Here, the normal mode of disposal is to open first one pair of doors, then another, etc., until the complete dump is made, which normally takes on the order of a few minutes to complete. DIFHD should not be applied to disposal operations that differ significantly from that described above.

In addition, it should be noted that the disposed material is expected to behave as a dense liquid. This will only be true if the

material is composed of primarily fine-grained solids. Thus, the models should not be applied to the disposal of purely sandy material. A major limitation of these models is the basic assumption that once solid particles are deposited on the bottom, they remain there. Therefore, the models should only be applied over time frames in which erosion of the newly deposited material is unimportant.

The passive transport and diffusion phase in all three models is handled by allowing material settling from the descent and collapse phases to be stored in small Gaussian clouds. These clouds are then diffused and transported at the end of each time step. Computations on the long-term grid are only made at those times when output is desired.

The use and limitations of the models along with theoretical discussions are presented in detail in Johnson (1988). Additional technical references for the models are provided in the bibliography of this appendix and online in the system. Their review is strongly recommended.

B1.4 MODEL INPUT

Input data for the models is grouped into the following general areas: (1) description of the disposal operation, (2) description of the disposal site, (3) description of the dredged materials, (4) model coefficients, and (5) controls for input, execution, and output.

Ambient conditions include current velocity, density stratification, and water depths over a computational grid. The dredged material is assumed to consist of a number of solid fractions, a fluid component, and conservative contaminants. Each solid fraction has to have a volumetric concentration, a specific gravity, a settling velocity, a void ratio for bottom deposition, and information on whether or not the fraction is cohesive. For initial mixing calculations, information on initial concentration, background concentration and water quality criterion for the constituent to be modeled have to be specified. The description of the disposal operations for the DIFID model includes position of the disposal barge on the grid, the barge velocity, and draft, and volume of dredged material to be dumped. Similar descriptions for hopper dredge and pipeline operations are required for the DIFCD and DIFHD models. Coefficients are

required for the models to accurately specify entrainment, settling, drag, dissipation, apparent mass, and density gradient differences. These coefficients have default values which should be used unless other site-specific information is available. Table B1 lists the necessary input parameters with their corresponding units. More detailed descriptions and guidance for selection of values for many of the parameters is provided directly online in the system.

B1.5 MODEL OUTPUT

The output starts by echoing the input data and then optionally presenting the time history of the descent and collapse phases. In descent history for the DIFID model, the location of the cloud centroid, the velocity of the cloud centroid, the radius of the hemispherical cloud, the density difference between the cloud and the ambient water, the conservative constituent concentration and the total volume and concentration of each solid fraction are provided as functions of time since release of the material. Likewise, the location of the leading edge of the momentum jet, the centerline velocity of the jet, the radius of the jet, the density difference between material in the jet and the ambient water, the contaminant concentration, and the flux and concentration of each solid fraction are provided as functions of time at the end of the jet convection phase in DIFCD and DIFHD.

At the conclusion of the collapse phase in DIFID and DIFHD, time-dependent information concerning the size of the collapsing cloud, its density, and its centroid location and velocity as well as contaminant and solids concentrations can be requested. Similar information is provided by DIFCD at the conclusion of the jet collapse phase. These models perform the numerical integrations of the governing conservation equations in the descent and collapse phases with a minimum of user input. Various control parameters that give the user insight into the behavior of these computations are printed before the output discussed above is provided.

At various times, as requested through input data, output concerning suspended sediment concentrations can be obtained from the transport-diffusion computations. With Gaussian cloud transport-diffusion, only

TABLE B1. MODEL INPUT PARAMETERS

Parameter	Models*	Units	Option**
Disposal Site Descriptions			
Descriptive title	I,C,H		
Gridpoints (left to right)	I,C,H		
Gridpoints (top to bottom)	I,C,H		
Distance between gridpoints	I,C,H	ft	
Constant water depth	I,C,H	ft	C
Gridpoints depths	I,C,H	ft	V
Points in density profile	I,C,H		
Depth of density point	I,C,H	ft	
Density at profile point	I,C,H	g/cc	
Bottom slope in x-direction	I,H	degrees	
Bottom slope in z-direction	I,H	degrees	
Site boundary grid locations	I,C,H		
Disposal Operation Descriptions			
Volume of material in barge	I	cu yd	
Discharge flow rate	C,H	ft^3/sec	
Radius of discharge	C,H	ft	
Discharge depth	C,H	ft	
Angle of discharge	C	degrees	
Vessel course	C	degrees	
Vessel speed	C	ft/sec	
Barge velocity in x-direction	I	ft/sec	
Barge velocity in z-direction	I	ft/sec	
Barge length	I	ft	
Barge width	I	ft	
Port-disposal depth	I	ft	
Bottom depression length in x-direction	I,H	ft	Optional
Bottom depression length in z-direction	I,H	ft	Optional
Bottom depression depth	I,H	ft	Optional
X-coordinate of disposal operation	I,C,H	ft	
Z-coordinate of disposal operation	I,C,H	ft	
Disposal duration	I,C,H	sec	
Time from start of tidal cycle	I,C,H	sec	
Number of hopper bins opening together	H		
Distance between bins	H	ft	

* The use of a parameter in the DIFID, DIFCD, and DIFHD models is indicated in the table by an I, C or H, respectively.
** The use of a parameter for the constant depth option or variable depth option is indicated in the table by a C or V, respectively. Other optional uses for parameters are so indicated.

TABLE B1. MODEL INPUT PARAMETERS (Continued)

Parameter	Models*	Units	Option**
Disposal Site Velocity Descriptions			
Type of velocity profile	I,C,H		
Tidal cycle time of velocity if constant profile not used	I,C,H	sec	V
Vertically averaged velocity in x-direction at gridpoints	I,C,H	ft/sec	V
Vertically averaged velocity in z-direction at gridpoints	I,C,H	ft/sec	V
Velocity in x-direction at upper point	I,C,H	ft/sec	C
Depth of upper point for x-direction velocity	I,C,H	ft	C
Velocity in x-direction at lower point	I,C,H	ft/sec	C
Depth of lower point for x-direction velocity	I,C,H	ft	C
Velocity in z-direction at upper point	I,C,H	ft/sec	C
Depth of upper point for z-direction velocity	I,C,H	ft	C
Velocity in z-direction at lower point	I,C,H	ft/sec	C
Depth of lower point for z-direction velocity	I,C,H	ft	C
Material Descriptions			
Water density at dredging site	I,C,H	g/cc	
Number of solid fractions	I,C,H		
Solid fraction descriptions	I,C,H		
Solid fraction specific gravity	I,C,H		
Solid fraction volumetric concentration	I,C,H	ft^3/ft^3	
Solid fraction settling velocity	I,C,H	ft/sec	
Solid fraction deposited void ratio	I,C,H		
Moisture content of material in barge as multiple of liquid limit	I		Cohesive
Bulk density of dredged material	I,C,H	g/cc	
Dissolved contaminant concentration	I,C,H	mg/l	Optional
Background dissolved contaminant concentration	I,C,H	mg/l	Optional
Sediment contaminant concentration	I,C,H	mg/kg	Optional
Contaminant water quality criterion	I,C,H	mg/l	Optional
0.01 of the acutely toxic concentration (LC50)	I,C,H	%	Optional

TABLE B1. MODEL INPUT PARAMETERS (Concluded)

Parameter	Models*	Units	Option**
Model coefficient			
Settling coefficient	I,C,H		
Apparent mass coefficient	I,C,H		
Drag coefficient	I,C,H		
Form drag for collapsing cloud	I,C,H		
Skin friction for collapsing cloud	I,C,H		
Drag for an ellipsoidal wedge	I,C,H		
Drag for a plate	I,C,H		
Friction between cloud and bottom	I,C,H		
Horizontal diffusion coefficient	I,C,H		
Cloud/ambient density gradient ratio	I,C,H		
Turbulent thermal entrainment	I,H		
Entrainment in collapse	I,H		
Jet entrainment	H,C		
Thermal entrainment	H,C		
Entrainment by convection in collapse	C		
Entrainment due collapse of element	C		
Input, Output and Execution Descriptions			
Processes to simulate	I,C,H		
Type of computations to perform for initial mixing	I,C,H		
Number of depths for initial mixing calculations	I,C,H		
Depths for initial mixing calculations	I,C,H	ft	
Duration of simulation	I,C,H	sec	
Time steps for mixing calculations	I,C,H		
Convective descent output option	I,C,H		
Collapse phase output option	I,C,H		
Number of print times for initial mixing output	I,C,H		

concentrations at the water depths requested are provided at each grid point.

For evaluations of initial mixing for ocean disposal, results for water column concentrations can be computer in terms of mg/L of dissolved constituent for Tier II evaluations or in percent of initial concentration of suspended plus dissolved constituents in the dredged material for Tier III evaluations. The maximum concentration within the grid and the maximum concentration at or outside the boundary of the disposal site are tabulated for specified time intervals.

B1.6 GENERAL INSTRUCTIONS FOR RUNNING THE MODELS

B1.6.1 Target Hardware Environment

The system is designed for the IBM PC-AT (including compatibles) class of personal computers. This does not constitute official endorsement or approval of these commercial products. In general, the system requires a mathematics coprocessor, 640 KB of RAM and a hard disk. The models are written primarily in FORTRAN 77 but some of the higher level operations and file management operations are written in BASIC and some of the screen control operations in the FORTRAN 77 programs are performed using an assembly language utility program.

B1.6.2 Installation and Starting

All files contained on the disk in the folder in the back of this manual should be saved in a directory on the hard disk dedicated for the ADDAMS system, e.g. C:\ADDAMS. The files are archived on the disks and have to be de-archived prior to running the models. To de-archive the files, copy the files from each disk onto the hard drive, call README for each disk, and follow the instructions.

B1.6.3 User Interface

The models in the DUMP application of ADDAMS employ a menu-driven environment with a full screen data entry method. In general, single

keystrokes (usually the F1-F10 function keys, the number keys, Esc key or the arrow keys and the Enter key) are required to select menu options in the system. Menus are displayed on the screen. Cursor keys are used to select between highlighted input fields (displayed in inverted video) much like a spreadsheet program. To enter alphanumeric data, the user moves the cursor to the cell of interest using the up and down arrows to move respectively up and down, the Tab and Shift-Tab to move respectively right and left. The Enter key also will move forward through the cells. The left and right arrow keys are used to move the cursor within a selected cell in order to edit the cell's contents. The Backspace key deletes character in a cell. The Delete and Insert keys delete and insert a row of data on a screen of tabular data. The Pg Dn key moves the cursor to the next screen of data entry and the Pg Up key moves the cursor to the previous screen of data entry. The Esc key permits the user to quit data entry on the present operation and to exit to the previous menu. The Home key exits from the current data entry activity screen to the main menu for the application without loss of data. Results from computations are generally displayed in tabular format on the screen and/or written to print files or devices.

B1.7 STEPS IN USING THE MODEL

The menu driven environment for applying the models is illustrated in the menu tree in Figure B1. The model can be applied by performing the desired operations at several levels. The general steps in applying the model for a disposal operation are as follows:

a. Starting. Change directory to make the ADDAMS directory the default directory. Start the program by entering ADDAMS. The program will display the ADDAMS logo and then an Application Selection Menu. An application in the ADDAMS program consists of one or more stand-alone computer programs or numerical models used to perform a specific analysis. The only ADDAMS application provided on diskette with this manual is named DUMP and consists of programs for evaluating open water disposal of dredged material. Select the DUMP application (Option 4). The program will display a File Manager Menu for the DUMP application input data files.

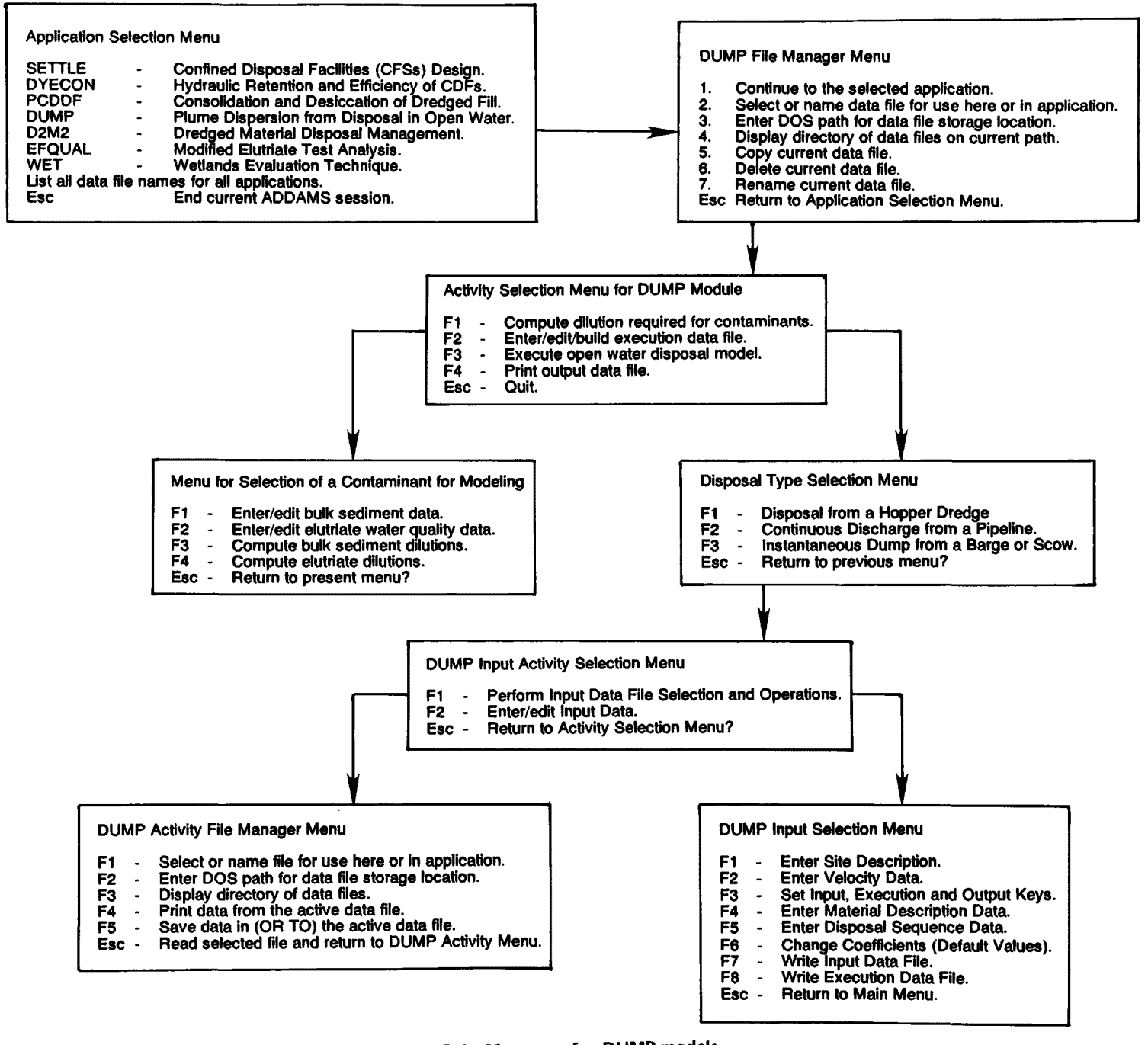

Figure B-1. Menu tree for DUMP models.

b. File manager menu. At this point an input data file or DOS path for data storage may be selected or named. An existing input data file may be selected by displaying a directory of data files (Option 4 on the File Manager Menu) on the specified DOS path. Other file management operations may also be performed on input data files. Input data file names are given an extension of .DUI by the program. After completing all file management operations, if any, select the option to continue (Option 1). The program will display a reference screen with points of contact and then the DUMP Activity Selection Menu.

c. Activity selection menu. The activity selection menu may be considered the main menu for the DUMP application. Option F1 is used to select a specific contaminant for modeling, and a menu for Dilution Requirements by Initial Mixing will be displayed (see step d). Option F2 is used to enter data and build, edit or write input and execution data files. A Disposal Type Selection Menu will be displayed to initiate this process (see step e). Option F3 is used to execute the analysis (see step k). Option F4 is used to print or review output files (see step l).

d. Dilution Requirements for Initial Mixing Menu. A data analysis routine controlled by this menu is used to select a specific contaminant for modeling. Such a selection is necessary under the Tier II analysis both for evaluation of the need for additional testing and for water quality comparisons with criteria. Execution of the open water disposal models for these Tier II analyses allow use of only one contaminant; this option is used to select that contaminant.

Options F1 and F3 are used for the evaluation of the need for additional testing. Bulk sediment contaminant and suspended solids concentrations and water quality criteria are required to compute the required dilutions. The contaminant requiring the largest dilution should be subsequently modeled.

Options F2 and F4 are used for the analysis to compare dissolved contaminant concentrations with water quality criteria. Elutriate and background concentrations and water quality criteria are required to compute the required dilutions. The contaminant requiring the largest dilution should be subsequently modeled.

e. Disposal Type Selection Menu. The selection of a disposal type under this menu controls the input data requests, the type of execution data file that will be built, and the open water disposal model that will be executed. Select the appropriate type of disposal: F1 Disposal from a hopper Dredge, F2 Continuous Discharge from a Pipeline, or F3 Instantaneous Dump from a Barge or Scow. The input data file last used by the program or selected earlier in step b will be read. If the file is new, the input data will be initialized. A DUMP Input Activity Selection Menu will then be displayed.

f. Input Activity Selection Menu. Option F1 may be used to change the input data file or initialize a new data file. This option will call the DUMP Input File Manager Menu to permit file selection (see step g for description). After selecting or initializing an input data file, if needed, select Option F2 to enter or edit input data and write data files. A DUMP Input Selection Menu will be displayed.

g. Activity File Manger Menu. A similar file manager is used for input, execution, and output data file selection and saving. Option F1 is used to specify the name of the file to be saved, read, or printed. The file specified in this option becomes the active data file. Option F2 is used to specify the DOS path to the location where the data file should be read or saved. Option F3 is used to display a directory of DUMP application data files for the current path. An existing data file name may be selected from the list to use as the active data file name for overwriting or reading existing data. Option F4 is used to save the existing data in a file having the active data file name. The input data which are stored in files with an extension of .DUI are displayed in the input data screens displayed under this option. This option is also used to build execution data files. Execution data files are the actual input data files used by the open disposal model to perform the analysis and generate output. These files are unique in structure to the input requirements of a particular open water disposal model, either DIFHD, DIFCD or DIFID. The files are stored with an extension of .DUE.

h. Input Selection Menu. Six types of input data (Options F1 to F6) have to be entered before an execution data file can be written. Default values are included for all of the model coefficients requested in Option F6; therefore, data entry for Option F6 is optional. Values or answers have to be entered for all requests in Options F1 to F5. An input data file may be written at any point to save all the data that has been entered up that point. Enter data for Options F1 through F6 by paging down through the data entry screens and filling in the cells for each option.

i. Write input data file. Write an input data file to save the input data for future editing and use by selecting Option F7 under the DUMP Input Selection Menu. A DUMP Activity File Saving Menu will be displayed (see step g).

j. Write execution data file. Write an execution data file to save the input data in the data structure used by the selected open water disposal model. This is performed by selection Option F8 on the DUMP Input Selection Menu. A DUMP Activity File Saving Menu will be displayed (see step g). All steps required for data entry or editing have been completed and the program is ready to execute the analysis.

k. Execute. Return to the DUMP Activity Selection Menu by repeatedly pressing the Esc key. Select the option to execute the open water disposal model by Selection Option F3. This option uses an execution data file to generate an output file of the same name as the execution data file selected but with an extension of .DUO instead of .DUE. An Execution Data File Selection Menu will be displayed that is similar to the file manager menu described in step g. The only difference is that Option F4 will execute the disposal model instead of saving and writing the data file. The program will then execute the analysis using the selected execution data file and generate an output file. Depending on the structure of the execution data file, either the DIFHD, DIFID, or DIFCD model will be executed. The execution may take a few minutes or several hours depending on the simulation selected and the computer hardware used. For long-term transport diffusion computations the DIFCD program may require about 5 times as long to run as the other disposal models.

l. Print results. Return to the DUMP Activity Selection Menu. Print output by selecting Option F4. A DUMP Output Data File Selection Menu will be displayed that is similar to the file manager menu described in step g. The only difference is that Option F4 will print the output. The output has 132 characters per line and should be printed using compressed print or wide paper. The program will automatically use compressed print on some printers, mainly Epson and IBM printers. It may be necessary to turn on compressed printing on your printer prior to printing the output, or to print the output outside of the AADAMS program using the DOS print command or a word processor. This step completes execution of the DUMP application. In addition, the DUMP Output Data File Selection Menu has an F5 Option to view the output using the LIST.COM utility program.

m. Ending. To exit the program, press Esc repeatedly until you obtain a DOS prompt. During execution of a particular application's program, the user has to wait until the sometimes lengthy computations are computed. The program can also be terminated by a Control-Break or by turning off the computer, but loss of data may occur. These methods of ending are not recommended. Similar methods are available during printing of output.

B1.8 EXAMPLE APPLICATIONS

Three example applications are presented in this appendix. The examples illustrate the use of DIFID to evaluate for the need for additional water column testing (Tier II), DIFCO for a comparison of dissolved contaminant concentrations with water quality criteria (Tier II), and a DIFHD for comparison of water column concentrations of dredged material with bioassay results (Tier III). Descriptions of the examples and a discussion of the model results follow. The input and output files for each of the examples are saved on the disk in the folder in the back of this manual.

B1.8.1 Example Application of DIFID

This example demonstrates the application of the instantaneous dump model DIFID and the evaluation of the need for additional water column testing under Tier II. The input and output files for this example are named DIFID.DUI and DIFID.DUO, respectively.

B1.8.1.1 Operations Information

Disposal from a split hull barge at a disposal site with a constant water depth is modeled. The total volume of the dredged material is 1000 cu yd and is contained in a barge 100 ft long and 50 ft wide. The barge is stationary at the point of release. The unloaded draft of the barge is 5.0 ft, and the time required to empty the barge is 5.0 sec.

B1.8.1.2 Disposal Site Information

The disposal site is 6000 ft by 6000 ft. A 30 x 30 grid with a 1500 ft grid spacing was selected, with the disposal site centered in the grid. The total water depth is 100 ft and no bottom slope exists. The ambient water current is 2.0 ft/sec directed from south to north for the upper 40 ft of the water column. The current then reverses direction over the next 20 ft to become 2.0 ft/sec directed from north to south at a depth of 60 ft below the surface. A linear decrease to a value of zero at the bottom follows. The ambient density profile is a constant 1.018 g/cc from the surface to depth of 40 ft, increasing to 1.022 g/cc at a depth of 60 ft, and a constant of 1.022 g/cc to the bottom.

B1.8.1.3 Dredged Material Information

The dredged material is composed of a sand and a silty clay solid fraction. The sand volumetric concentration is 0.14 ft^3/ft^3 and silty clay volumetric concentration is 0.17 ft^3/ft^3. The remaining 0.69 ft^3/ft^3 is composed of water (both void spaces and entrained water). The settling velocity of the sand is taken to be 0.07 ft/sec, whereas the silty clay fraction is treated as a cohesive fraction with the settling velocity

internally computed. Following deposition on the bottom, a void ratio of 4.0 is specified for the silty clay fraction, whereas a void ratio of 0.8 is specified for the sand. The required dilutions of all contaminants of concern to meet their respective water quality criteria were computed. Cadmium was found to be the contaminant of concern requiring the highest dilution to meet its water quality criterion, and was selected as the parameter to be modeled for evaluation of the need for additional water column testing. The sediment concentration for cadmium is 20 mg/kg and the acute marine water quality criterion for cadmium is 0.043 mg/L.

B1.8.1.4 Coefficients

Default values were used for all coefficients.

B1.8.1.5 Controls for Execution and Output

The total simulation time is specified as 4 hr or 14400 sec, with a 600 sec computational time step. Output is specified for depths of 10, 50, and 99 ft, which correspond to near surface, mid-depth and near bottom, respectively.

B1.8.1.6 Summary of Output

As can be seen from the output, the disposal cloud strikes the bottom in 7.19 sec and grows from an initial radius of 23.44 ft to a final radius at the bottom encounter of 47.58 ft. Collapse on the bottom then occurs with the collapse phase terminated at 58.53 sec after the disposal with the final cloud having a diameter of 364.32 ft. During the initial mixing period of 4 hr, the calculated maximum concentration of cadmium outside the disposal site boundary is 0.00164 mg/L occurring 50 minutes after disposal at a depth of 50 feet. This concentration is less than the acute water quality criterion of 0.043 mg/L, therefore there is no need for additional water column testing according to the guidance in Sections 10.1.1.2 and 4.3.

B1.8.2 Example Application of DIFCD

This example demonstrates the application of the continuous discharge model DIFCD and the comparison of dissolved contaminant concentrations with water quality criteria under Tier II. The input and output files for this example are named DIFCD.DUI and DIFCD.DUO, respectively.

B1.8.2.1 Operations Information

A pipeline disposal operation from a stationary barge at a disposal site with constant water depth is modeled. The pipeline is 1.0 ft in diameter with a discharge rate of 5 ft^3/sec. The end of the pipe is located at a water depth 10 ft below the surface at an angle of 90° with respect to the water surface.

B1.8.2.2 Disposal Site Information

The disposal site is 3000 ft by 3000 ft. A 30 x 30 grid with a 250 ft grid spacing was selected. The disposal site is located within one corner at a distance of 2250 ft from the northern edge of the grid and 500 ft from the western edge of the grid and with the opposite corner 5250 ft from the northern edge of the grid and 3500 ft from the western edge of the grid. The discharge point is located 4000 ft from the northern edge of the grid and 1500 ft from the western edge of the grid. The disposal site is a constant-depth site of 50 ft. The ambient water current is directed from west to east with a magnitude of 0.5 ft/sec over the upper 45 ft of the water column. The velocity then linearly decreases to 0.25 ft/sec at 1 ft above the bottom and finally to zero at the bottom. The ambient density is assumed to vary linearly from 1.0 g/cc at the surface to 1.010 g/cc at the bottom.

B1.8.2.3 Dredged Material Information

The dredged material is a slurry with an average bulk density of 1.32 g/cc and is composed of two solid fractions, sand and silt. The concentration of each is 0.10 ft^3/ft^3. The settling velocity is 0.07 ft/sec

for sand and 0.02 ft/sec for silt. The void ratio after bottom deposition is 3.0 for silt and 0.8 for sand. A previous evaluation indicated a need to conduct additional water column testing. Tests were performed to determine initial dissolved contaminant concentrations in the water column under Tier II. The required dilutions of all contaminants of concern to meet their respective water quality criteria were computed. Cadmium was found to require the highest dilution and was selected as the parameter to be modeled and compared with its water quality criterion. The initial water column concentration of dissolved cadmium was determined to be 0.9 mg/L, the background concentration for cadmium was 0.001 mg/L, and the acute marine water quality criterion for cadmium is 0.043 mg/L.

B1.8.2.4 Coefficients

Default values were used for all coefficients.

B1.8.2.5 Controls for Execution and Output

The total simulation time is specified as 4 hr or 14400 sec, with a 900 sec computational time step. Output is specified for depths of 30 and 49 ft, which correspond to mid-depth and near bottom, respectively.

B1.8.2.6 Summary of Output

As indicated in the output, the momentum jet strikes the bottom after 10.29 sec with a radius of 4.496 ft. Collapse on the bottom terminates after 29.66 sec. The calculated maximum concentration of cadmium after the 4 hr initial mixing period is 0.00914 mg/L above background, and the maximum concentration of cadmium outside the disposal site boundary during the 4 hr initial mixing period is 0.000058 mg/L above background. Both of these values are less than the water quality criterion of 0.043 mg/L, and are acceptable according to the guidance in Sections 10.1.2.3 and 5.1.2.

B1.8.3 Example Application of DIFHD

This example demonstrates the application of the hopper dredge model DIFHD and the comparison of water column concentrations of dredged material with water column bioassay results under Tier III. The input and output files for this example are named DIFHD.DUI and DIFHD.DUO, respectively.

B1.8.3.1 Operations Information

A disposal operation is modeled from a stationary hopper dredge containing eight bins configured in four pairs of two bins, with pairs of bins opened sequentially. Disposal is assumed to occur from pairs of bins with the disposal from one pair essential complete before the disposal from the next pair begins. The total discharge takes 120 sec and occurs through bin doors with a cross-sectional area of 16 ft^2 which yields an equivalent circular geometry with a radius of 2.26 ft. The center-line distance between the bins is 14 ft. The loaded draft is 10 ft. The discharge rate from each bin is taken to be 75 ft^3/sec.

B1.8.3.2 Disposal Site Information

The disposal site is 5250 ft by 5250 ft. A 30 x 30 grid with a 750 ft grid spacing was selected. The disposal site is located within the grid with one corner at a distance of 8250 ft from the northern edge of the grid and 2250 ft from the western edge of the grid and with the opposite corner 13,500 ft from the northern edge of the grid and 7500 ft from the western edge of the grid. The location of the hopper dredge is 4500 ft from the western edge of the grid and 11,250 ft from the northern edge of the grid. The disposal site is a constant depth site with a water depth of 75 ft and no bottom slope. The ambient current is 0.9 ft/sec over the upper 70 ft of the water column and is directed from west to east. The velocity then decreases linearly over the next 4 ft to 0.2 ft/sec, then linearly over the next foot to zero. The ambient density is 1.00 g/cc at the surface and increases linearly to 1.01 g/cc at the bottom.

B1.8.3.3 Dredged Material Information

The dredged material is composed of sand and clay solid fractions, each having a concentration of 0.10 ft^3/ft^3. The setting velocity of the sand is 0.07 ft/sec while the clay is considered cohesive with the settling velocity computed internally. The void ratio on deposition is 4.0 for the clay and 0.8 for the sand. The model is used to estimate the concentrations of dissolved plus suspended dredged material constituents in the water column expressed as a percent of the initial concentration. Water column bioassays indicated that the LC50 was 30 percent of the original dredged material concentration.

B1.8.3.4 Coefficients

Default values were used for all coefficients.

B1.8.3.5 Controls for Execution and Output

The total simulation time is specified as 4 hr or 14400 sec, with a 600 sec computational time step. Output is specified for depths of 50 and 74 ft, which correspond to near mid-depth and near bottom, respectively.

B1.8.3.6 Coefficients

Default values were used for all coefficients.

B1.8.3.7 Summary of Output

As can be seen from the output, the jet of material from a bin reaches the bottom after 9.53 sec and has a radius of 7.21 ft. The resulting bottom collapse continues as long as the bottom cloud is fed by the continuous discharge of material from the remaining bins. The maximum concentration of suspended plus dissolved constituents of the dredged material after 4 hr is 0.0006 percent of the original concentration, and the maximum concentration outside the disposal site boundary during the 4 hr initial mixing period is 0.0125 percent of original occurring 70 minutes

after disposal at a depth of 74 ft. Both of these values are below 0.3 percent (0.01 of the LC50); therefore the discharge is acceptable according to the guidance in Sections 10.2.1.6 and 6.1.

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